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Taro Yamauchi
Seiji Nakao
Hidenori Harada *Editors*

The Sanitation Triangle

Socio-Culture, Health and Materials

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Taro Yamauchi • Seiji Nakao • Hidenori Harada
Editors

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Editors
Taro Yamauchi
Research Institute for Humanity and Nature, Kyoto, Japan
Faculty of Health Sciences, Hokkaido University
Sapporo, Japan

Hidenori Harada
Graduate School of Asian and African Area Studies
Kyoto University
Kyoto, Japan

Seiji Nakao
Graduate School of Asian and African Area Studies
Kyoto University
Kyoto, Japan

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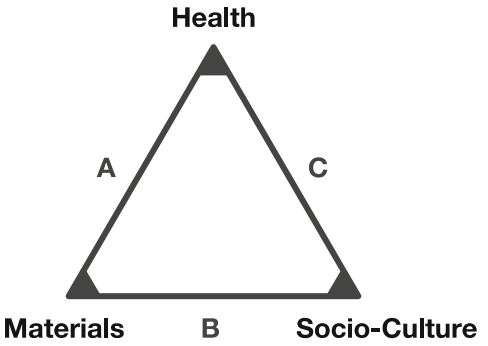

The Sanitation Triangle model

This is a novel theoretical and practical model for global sanitation as proposed in this book. See Chapter 1 for details.

Selection of images by youth members of *Dziko Langa* for Digital Storytelling. See Chapter 9 for details.

Preface

Sanitation refers to a system that hygienically separates humans from harmful excreta and promotes its safe treatment and disposal. The significance of addressing sanitation is encapsulated in the United Nations' Sustainable Development Goal 6: "Ensure availability and sustainable management of water and sanitation for all." We have less than 10 years to meet this daunting goal.

To date, sanitation issues have been focused on infrastructure and facility installation, environmental conservation for alleviation of water and soil contamination, and adverse health outcomes linked to unimproved sanitation. However, sanitation goes beyond technology, encompassing values spawned amidst humans and local communities, which can fall into the nexus of three components: Health, Materials, and Socio-Culture. Our observations of this nexus led to the creation of the *Sanitation Triangle* concept.

Our book brings this novel concept to the world. It is the culmination of our international research addressing global sanitation. The book delivers each component of the *Sanitation Triangle* above, which comprises concepts and case studies. Notably, it showcases interdisciplinary and transdisciplinary research works involving a variety of local actors ranging from children and youth to local governments.

Through this academic contribution, we hope you will be able to visualize how the sanitation themes addressed within are processed through the concept of the *Sanitation Triangle*, and that you will be encouraged to explore and witness a range of sanitation issues emerging in different parts of the world through the triangle lens.

This book is supported by "The Sanitation Value Chain: Designing Sanitation Systems as Eco-Community Value Systems" Project, Research Institute for Humanity and Nature (RIHN, Project No. 14200107). We thank everyone who has been a light on this incredible journey, particularly our project members and the many local actors involved.

Now, it is time to grab the *Sanitation Triangle* and embark on an enlightened quest through global sanitation.

Kyoto/Sapporo, Japan — Taro Yamauchi

Contents

Chapter 1
Introduction

Seiji Nakao, Hidenori Harada, and Taro Yamauchi

Abstract Sustainable Development Goals (SDGs) present a new vision to establish an adequate and equitable sanitation system and require more consideration on the basis of the socio-cultural aspects of global sanitation. Despite these directions, the establishment of global sanitation in low- and middle-income countries has been challenging, and the socio-cultural aspects, especially the interconnections of socio-culture with materials and health, are overlooked. In this context, an interdisciplinary approach including humanities and social sciences is necessary based on the understanding that sanitation is embedded in society. In terms of the interconnection between socio-culture and materials, sanitation requires social relations to function its service chain, and in the interconnections between socio-culture and health, the risk of health by inadequate sanitation is socially allocated unevenly. In other words, an adequate and equitable sanitation system involves appropriate interconnections between the three components of sanitation (social-culture, health, and materials). Therefore, this chapter presents the concept of the "Sanitation Triangle" as an interdisciplinary framework by focusing on the relationship between the three elements.

Keywords Sanitation · Materials · Health · Socio-culture · Sanitation triangle · Sustainable Development Goals

S. Nakao (✉) · H. Harada
Graduate School of Asian and African Area Studies, Kyoto University, Kyoto, Japan
e-mail: nakao.seiji.2i@kyoto-u.ac.jp

T. Yamauchi
Faculty of Health Sciences, Hokkaido University, Sapporo, Hokkaido, Japan

Research Institute for Humanity and Nature, Kyoto, Japan

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1.1 Global Sanitation as a Long-Term Challenge

The establishment of appropriate sanitation has for long been presented as a challenge for global development by international organizations, at least half a century. The League of Nations Health Organization, which became the World Health Organization (WHO), had recognized the importance of sanitation as early as the 1930s, advocating appropriate sanitation in "rural" housing (Borowy 2007: 19–21). The origin of the recent global programs and discourses on sanitation can be traced back to the 1970s—it coincides with the change in the global discourse on international development. From the 1970s, the discourse shifted, from modernization emphasizing growth and industrialization to reducing poverty (Gubser 2012). With this transition from economic development to human development, sanitation became a growing concern (Rosenqvist et al. 2016: 301).

In the 1970s, sanitation became a part of the basic human rights and basic human needs, and the 1980s was designated as the International Drinking Water Supply and Sanitation Decade (1981–1990) (hereafter, "the Decade"). The United Nations Conference on the Human Environment in 1972, known as the Stockholm Conference, proclaimed that the "aspects of man's environment, the natural and the man-made, are essential to his well-being and to the enjoyment of basic human rights" (UN 1973: 3). It also pointed out that people in low- and middle-income countries "continue to live far below the minimum levels required for a decent human existence, deprived of adequate food and clothing, shelter and education, health and *sanitation*" (UN 1973: 3, emphasis added). These perspectives have evolved over the years, and sanitation has become one of the key elements of development. In 1976, the United Nations Conference on Human Settlements—Habitat I recommended that governments consider water and sanitation in rural development planning (UN 1976: 162). To implement this recommendation, the United Nations Water Conference, in Mar Del Plata, in 1977 formulated the action plan for the Decade that "require[s] a concerted effort by countries and the international community to ensure a reliable drinking-water supply and provide[s] basic sanitary facilities to all urban and rural communities based on specific targets to be set up by each country, taking into account its sanitary, social and economic conditions" (UN 1977: 14). It also pointed out that "for providing safe drinking water and sanitation for all human settlements by 1990" (UN 1977: 66). The goal, however, was hardly achieved. The report on the Decade estimated that the global coverage of "urban sanitation" had increased from 69 to 72% and that of "rural sanitation" from 37 to 49% in that period (UN 1990: 20). After the end of the Decade, WHO and others pointed out the necessity to reinforce monitoring at the national level, and WHO and the United Nations Children's Fund (UNICEF) launched the Joint Monitoring Programme (JMP) in 1990 (WHO/UNICEF Joint Monitoring Programme 1992: 1). In the same year, the first issue of the Human Development Report by the United Nations Development Programme (UNDP) was published—it explicitly mentioned that "poor sanitation" is a component of the

"environment" that is created by poverty, and it thus reinforces poverty (UNDP 1990: 7).

From the 1990s, sanitation gained more attention in the realm of the discourse on global development. In 1992, the Earth Summit was held on the 20th anniversary of the first Human Environment Conference and resulted in "Agenda 21," an action plan for sustainable development, which proclaimed to "provide the poor with access to fresh water and sanitation" (UN 1993: 30). The Millennium Development Goals (MDGs), established in 2000, set a more concrete target regarding sanitation—Target 11 of Goal 7 contains the indicator "proportion of people with access to improved sanitation" (UN 2001: 57). The report on the road map of the MDGs stated that "2.4 billion people lack access to basic sanitation," and as "economic development and population growth increase demands, . . .sanitation facilities will become priority areas" (UN 2001: 20). In other words, discussion on sanitation as one of the essential factors for global development has been ongoing for almost half a century.

Yet, the issue of global sanitation still remains unresolved. The JMP for the assessment of the MDGs indicated that, over the MDGs period, the usage of improved sanitation facilities was estimated to have increased from 54 to 68% on a global level. Nearly 2.1 billion people have had access to improved sanitation since 1990. The MDGs target was aimed at reducing the proportion of people lacking sustainable access to basic sanitation by half between 1990 and 2015. Thus, the achieved proportion fell short of the global MDGs target of 77% by nine percentage points, and nearly 700 million people did not have access to basic sanitation facilities; in 2015, 2.4 billion people did not have access to improved sanitation (WHO/UNICEF Joint Monitoring Programme 2015: 12). The improvement has been uneven between urban and rural areas. On a global level, the estimated percentage of the urban population using improved sanitation facilities is 82%, while that of the rural population is 51% (WHO/UNICEF Joint Monitoring Programme 2015: 14).

Furthermore, the pace of improvement in sanitation is markedly slower compared with that of safe drinking water. Over the MDGs period, the global use of improved drinking water sources is estimated to have increased from 76 to 91%. The MDGs target of 88% was exceeded in 2010, and 6.6 billion people had access to an improved drinking water source by 2015 (WHO/UNICEF Joint Monitoring Programme 2015: 6). Although the domain of safe drinking water still faces a challenge, especially in Sub-Saharan Africa (WHO/UNICEF Joint Monitoring Programme 2015: 7), and careful reexamination of the details of its improvement is required (Satterthwaite 2016: 103–106), sanitation has lagged further behind, considering the failure to meet the MDG targets.

The Sustainable Development Goals (SDGs) present a new vision for improving global sanitation. In contrast to the MDGs, which aimed to halve the proportion of the population lacking access to basic sanitation, the SDGs are "sanitation for all" (UN 2015: 14). Though the MDGs emphasized the promotion of sanitation, its quality and effect upon marginalized people were either not mentioned adequately or omitted altogether (UN 2001: 20–21, 24). The SDG 6.2 (sanitation target) is not only "end open defecation" but also "achieve access to adequate and equitable

sanitation and hygiene," "paying special attention to the needs of women and girls and those in vulnerable situations" (UN 2015: 18). To match SDG 6.2, the indicator has also been modified as a "proportion of the population using safely managed sanitation services, including a hand-washing facility with soap and water" (UN 2017: 10). This change in the target on sanitation from the MDGs to the SDGs is fundamental. It is a transformation, so to speak, from building a latrine to establishing an adequate and equitable sanitation system that includes appropriate treatment and disposal of human waste, especially focusing on vulnerable people. Furthermore, for the first time, water, sanitation, and hygiene (WASH) have been targeted under the same global goal (SDG6); the MDG targets did not include hygiene (handwashing).

The transition from the MDGs to the SDGs requires more consideration based on the socio-cultural aspects of global sanitation. Those living in severe situations face structural violence, and vulnerability is a structural product of class-based economic exploitation as well as cultural, gender/sexual, and racialized discrimination (Quesada et al. 2011). In other words, equitable sanitation for those in vulnerable situations can only be based on socio-cultural considerations. Sanitation is a system that comprises not only a latrine but also the works for the treatment and disposal of human waste. Sanitation facilities do not function by themselves, but have significance only through social management. The process of decision-making also largely depends on socio-cultural conditions, and the importance of sanitation needs to be socially acknowledged. The health benefits of sanitation improvement—among the significant contributions of sanitation—also need to be considered in the socio-cultural milieu. In this context, a more holistic approach across disciplines is required.

This book presents a holistic approach to WASH, especially focused on the sanitation of human waste (i.e., human excreta, containing feces and urine), and an analysis of the case studies based on this approach. In this chapter, we present the concept of the Sanitation Triangle as a holistic approach and indicate its scope in comparison with previous research.

1.2 The Sanitation Triangle: An Interdisciplinary Research Field

Recently, several important studies have considered sanitation's socio-cultural aspects. For example, van Vliet et al. (2010, 2011) discussed socio-technical change, multi-level governance, and the role of the citizen-consumer as the social scientific topics relevant to the sanitation challenge. These pioneering works concretely show how the social sciences are involved in sanitation issues. Subsequently, Hyun et al. (2019) reviewed the literature concerning global sanitation, which includes diverse disciplines—not only public health, sanitary engineering, and environmental science but also economics, planning, and social sciences; their review highlights the

growing number of social sciences, humanities, and interdisciplinary studies on sanitation.

Although there is a difference in terms and expressions, these studies share the understanding that sanitation systems are embedded in each society—these systems do not automatically operate by technology and economic interests, but rather, they are "the highly complex interfaces between sanitation technologies, consumers, and providers" (van Vliet et al. 2010: 3). Decentralized sanitation, also known as on-site or off-grid sanitation, commonly employed in low- and middle-income countries barring in the very center of large cities as well as rural areas in high-income countries, also requires the decision-making on sanitation, opened up by actors at multiple levels (van Vliet et al. 2010: 3). More generally, sanitation not only disposes of human waste but also affects the environment and includes the social functions and flows where stakeholders engage in each process (Hyun et al. 2019: 306–307). As discussed in this book, we add the socio-cultural configuration to the sanitation service chain. Cultural cognition on the "pure" and "impure" (Douglas 1966) provides the basis of the practices of sanitary and hygienic activities, creating the stigma and leading to the marginalization of specific groups such as sanitation workers in some cases. In sum, sanitation is a "total social phenomenon," as the eminent French anthropologist Marcel Mauss defined, which is an ensemble of the religious, legal, moral, political, economic, and esthetic matters (Mauss 1923: 32).

Besides these diverse aspects, the difficulties of global sanitation especially in low- and middle-income countries have emerged in the interconnection between health, materials, and socio-culture. In terms of materials, sanitation is a system to transfer human waste and relevant substances and/or transform their state. One of the major difficulties from the viewpoint of materials is that open defecation, use of unsanitary latrines, and unsafe disposal of human waste discharge pollutants and deteriorate the environment, resulting in increased health risks for the people in that neighborhood, but such poor sanitation does not necessarily mean discomfort for those who practice it. This is explained as a negative externality of environmental pollution. Furthermore, sanitation is essentially not a large "income-generating" affair, and is located between economic reasoning and health benefits. Although the economic loss due to poor sanitation has been calculated (e.g., Hutton 2008; Hutton and Haller 2004), it is difficult for low- and middle-income countries or donor countries to direct public investment toward the full implementation of sanitation facilities. Sanitation is a public matter, but sanitation facilities are often private property. Therefore, partial public funding on household sanitation (e.g., Trémolet et al. 2010) and small-scale "income-generating" on-site sanitation (e.g., Ushijima et al. 2015, 2019) are pursued by several groups. These solutions are not operated through the way of "laissez-faire," but they require the social framework for managing the sanitation system. Thus, the interconnection between health, materials, and socio-culture is the key to resolving sanitation affairs.

In terms of health, the problem of sanitation emerges in a misconnection involving the three components. Sanitation reduces health risks, but these are measured at the mass level, and even at this level, the health impact of sanitation is not shown precisely (e.g., Clasen et al. 2014). In contrast to water supply, sanitation's health

benefits can only be understood in terms of the health indicators of the population in each area over a long time. These figures are meaningful for central and local governments, but not for individuals who cannot directly perceive the health benefits. In fact, some reports show that individuals do not place much importance on toilet use for health-related reasons (Jenkins and Curtis 2005; Jenkins and Scott 2007). On the other hand, individuals, rather than governments, are the central actor in the sanitation issues in the rural areas of low- and middle-income countries where on-site sanitation plays a major role; this has made them both users and maintainers of the sanitation service. It is a paradoxical situation that while sanitation's health benefits can be perceived at the public level, the public sector covers only a part of its introduction and maintenance. In other words, the problem emerges in the misconnection involving the three components—health, materials, and socio-culture—derived from the attributes of sanitation itself.

Sanitation is composed of these components. It is intricately linked with the health domain—inadequate sanitation causes excreta-related infections and, in certain contexts, mental suffering. Sanitation is a material flow in terms of the storage of human excreta and their conversion into harmless substances. Material flows are inevitably related to economic activity in that they include the costs of storing and converting human waste and, under certain socio-economic conditions, the benefits of producing compost from that waste. In the Edo era (1600–1867) in Japan, before the introduction of the modern sewerage system, human waste used to be the commodity for economic exchange (e.g., Aratake 2015). Human waste has potential economic value in its materiality. When it comes to socio-culture as a basis for sanitation, norms on defecation, its places, etc. are shaped by cultures, and the technologies and sanitation workers are socially organized. Finally, sanitation does not operate well in the case of misconnection—it is a complex issue encompassing the three components and requires their seamless interconnection. In that regard, sanitation studies are essentially an interdisciplinary research field requiring this interconnection.

To promote and analyze the interconnection, we propose the Sanitation Triangle as an interdisciplinary framework for global sanitation (Fig. 1.1). The triangle represents the three components—health, materials, and socio-culture—and their interconnection, with all three having equal importance vis-à-vis sanitation. The triangle also indicates the connection between each pair of components: A (materials and health), C (health and socio-culture), and B (materials and socio-culture). Conventionally, A has been studied as the calculation of costs and benefits of the (dis)improvement in sanitation-related diseases (Hutton 2008; Hutton and Haller 2004; World Bank 2008). However, despite their importance, few studies have looked into the B and C connections—hence, these are what we focus on in this book.

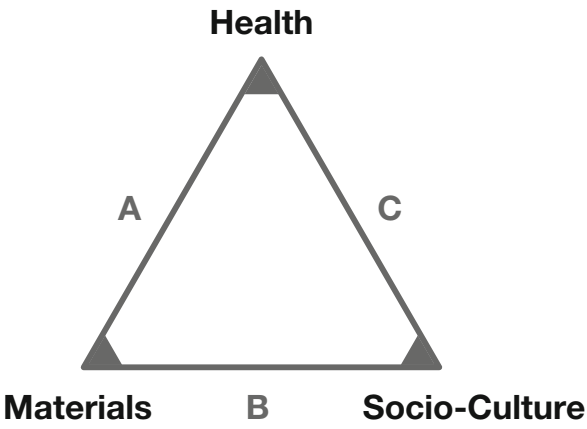

Fig. 1.1 The Sanitation Triangle model

1.3 Organization of the Book

This book is divided into three parts based on the Sanitation Triangle and authors' disciplines. The first part, contributed by the humanities and social sciences, focuses on the connections between health and socio-culture (C) and materials and socio-culture (B). Cultural anthropologists and developmental economists reveal the socio-cultural dimensions of health and material matters. The second part by health sciences, environmental sciences, and science communication focuses on the connection between health and socio-culture (C), highlighting how health issues are fundamentally affected by socio-cultural factors. The third part by sanitary and environmental engineering discusses the connection between materials and socio-culture (B), presenting the relationship between sanitation technology and each society. While the case studies are based on each discipline, their discussions go beyond the disciplines via the focus on the interconnection between the three components.

1.3.1 Part I

In Chap. 2, Nakao presents the outline and scope of the component socio-culture of sanitation, especially indicating its interconnection with health and materials. In Chap. 3, Masuki highlights the injustice and uneven social allocation of sanitation work, and the struggle for remediation of the hygienic, economic, and social working conditions in colonial and post-colonial India. Based on a close reading of Gandhi's works, Masuki reveals the so-called ethics of sanitation; sanitation is at the core of self-rule (*swaraj*) and the social responsibility for human-waste management. In Chap. 4, Ikemi provides the social context of the implementation of new technology in the case of water supply management in rural Senegal. Each

technology requires the social management system and brings forth the people's perception of technology, such as the preference for the type of water. In Chap. 5, Sugita examines the global discourse on and local practices of Menstrual Hygiene Management (MHM). Considering the situation of girls in Uganda's rural areas, Sugita reveals that the actual conditions of "safe" MHM are different from those mentioned in the global discourse. "Safe" MHM requires not only the proper items and facilities but also appropriate treatment of menstrual bleeding to avoid of using it for sorcery.

1.3.2 Part II

In Chap. 6, Yamauchi presents the connection between socio-culture and health in WASH by tracing the studies on the social determinants of health. In Chap. 7, Yamauchi et al. focus on environmental health in school and family in the densely populated area of Bandung, Indonesia, and show that age and gender affect fecal contamination on the hands of children as well as their nutritional and health status. In Chap. 8, Harada depicts the transfer of health risks in sanitation and its allocation in society by citing examples from Vietnam, and offers a perspective on such risks being a social problem in sanitation. In Chap. 9, Nyambe et al. describe a Participatory Action Research (PAR) involving members of youth club in Lusaka, Zambia, and present a case of collaborative examination and intervention through the tools of visualization with the club members, highlighting the health and socio-cultural aspects linked to WASH in their communities.

1.3.3 Part III

In Chap. 10, Harada first describes how sanitation is a system that transforms the quality of materials and generates material flow, and then outlines the connection between materials and socio-culture in sanitation. In Chap. 11, Fujiwara describes the development and implementation process of a new sanitation technology as public infrastructure in Japan, and discusses its diversity of actors and socialization process. In Chap. 12, Harada focuses on a resources-oriented sanitation for the rural areas of Vietnam, Malawi, and Bangladesh, which intend to utilize excreta for agriculture. Three cases of ecological sanitation are compared, and fertilizer values and acceptability of such sanitation discussed. In Chap. 13, Ushijima et al. describe the challenge in creating a sanitation system based on material flow and social network as a case in an urban slum of Indonesia. It depicts an attempt at co-creation of a sanitation system with local actors based on material flows and value flow networks, focusing on the actors' motivation.

The conclusions by Nakao, Harada, and Yamauchi build on the overriding themes appearing in each chapter: the socio-cultural effects of health status and

risks, social embeddedness of technology, and practical implications for interventions in WASH. The chapters are interlinked, providing a vision for the future of interdisciplinary studies and practices of global sanitation through a socio-cultural perspective based on the Sanitation Triangle.

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Part I
Socio-Culture

Chapter 2
Socio-Cultural Aspects of Sanitation

Seiji Nakao

Abstract Although sanitation is embedded in the socio-culture, the socio-cultural aspects of sanitation are not fully discussed. In this context, we focus on the socio-cultural aspects of sanitation, especially the connection between socio-culture with health (C), and with materials (B), as in the Sanitation Triangle model, from the perspective of humanities and social sciences in this part. To introduce this part, we first briefly review previous studies on sanitation by humanities and social sciences, and show the socio-cultural aspects of sanitation. Then, after providing an overview of this part, we discuss the theoretical points of each chapter such as "hard work" or "dirty work," a social configuration of technology, and Menstrual Hygiene Management (MHM) in the local context, and indicate the relevant chapters in this book.

Keywords Sanitation · Sanitation worker · "Hard work" · Social configuration of technology · Menstrual Hygiene Management

2.1 The Studies on Sanitation by Humanities and Social Sciences

In this part, we consider the socio-cultural aspects of sanitation, especially focusing on the connection between socio-culture with health (C), and with materials (B), as in the Sanitation Triangle model (Fig. 1.1 in Chap. 1), from the perspective of the humanities and social sciences. In introducing this part, we briefly discuss the context of studies on the socio-cultural aspects of sanitation and the theoretical points of each chapter.

In sanitary engineering, the socio-cultural aspects of sanitation have either been ignored or perceived as "obstacles" to the resolution of the problem. For example, until the 1990s, studies on social acceptance of wastewater reuse have only assessed

S. Nakao (✉)
Graduate School of Asian and African Area Studies, Kyoto University, Kyoto, Japan
e-mail: nakao.seiji.2i@kyoto-u.ac.jp

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the people's willingness to use recycled water or their usage of the recycled water (e.g., Ahmad 1991; Bruvold 1988; Simpson 1999). Cultural perceptions and differences between social groups were not considered. Since the 2000s, studies have begun to compare the results between different social groups and collect data on the reasons for its disuse (Alhumoud and Madzikanda 2010; Jeffrey 2002; Jeffrey and Jefferson 2003; Marks et al. 2003; Friedler et al. 2006; Nancarrow et al. 2002). Although some reports revealed that there were "religious beliefs" and "psychological reasons" for avoiding recycled water (e.g., Alhumoud and Madzikanda 2010), none examined concretely what those "religious beliefs" and "psychological reasons" were, dismissing them instead by claiming the need for education and campaigns for diffusing scientific knowledge campaigns. In other words, cultural perceptions of recycled water are considered an "obstacle" to the implementation of new technology. The same tendency can be found in the literature toward the improvement of sanitation in low- and middle-income countries. These often treat the customs of open defecation as an "obstacle" (e.g., Mehta and Movik 2011). Though open defecation is heading toward abolishment, it is important to understand the culture surrounding excretion and excreta. Fundamentally, sanitation is included as part of society and culture, and the reverse is not possible. When technological resolution works well, sanitation is embedded in society and culture. In this context, the socio-cultural aspects of sanitation need to be described and analyzed.

The tendency to pay little attention to the socio-cultural aspects is a result of the lack of studies on sanitation from the humanities and social sciences as well as mutual references between them and sanitary engineering. Moreover, sanitation is rarely discussed except in history and archeology. The relevant domains of cultural and social history focus on sanitation-related matters in European history, sometimes including the modern history of North America. The history of cultural cognition on what is "clean" and "dirty" is especially well described, such as the historical development of the consciousness on what is "clean" in modern America (Hoy 1995), and the cultural history of "personal hygiene and purity" in Europe (Smith 2008) as representative works. Although written for a general audience, important literature has emerged on the cultural and social history of waste, including sludge (Lynch 1990), "dirty" workers (Robinson 2004), and the practices around excreta (Dekkers 2018). From the point of view of its technological history, while engineers have summarized it (e.g., Asano and Levine 1996; Lofrano and Brown 2010), historians have rarely focused on this aspect, with one exception being, "The sanitary city: urban infrastructure in America from colonial times to the present" by Melosi (2000), an excellent study on this theme. The literature on toilets in archeology is plentiful; among them, Angelakis and Rose (2014) cover a wide range of global regions. Recently, an interdisciplinary study by historians, archeologists, and paleoparasitologists discussed the relationship between sanitation and human beings through a reconstruction of past diseases (Mitchell 2015). Such studies by historians and archeologists have revealed historical changes regarding the sensitivity over cleanness through the ages, as well as the complex configuration of sanitation in society. These insights suggest that modern thoughts on sanitation are not universal, and sanitation is embedded in each society.

Compared to that of history and archeology, studies on sanitation in other disciplines of the humanities and social sciences are few but have been growing in recent years. As referenced in the Chap. 1 of this book, a few multidisciplinary studies from the 2010s have criticized the technocentric view and tried to challenge and collaborate with the humanities and social sciences. These pioneering works introduced new research topics into sanitation studies, arguing that sanitation governance needs to be consistent with the end-users' needs and decision making (van Vliet et al. 2010, 2011) and power and injustice regarding access to sanitation services (Hyun et al. 2019). They highlighted key socio-cultural issues in sanitation, such as social norms, disparities, regulation, and health impact. However, they do not indicate the interconnection of these issues and why sanitation raises complex problems, and consequently, the whole viewpoint on sanitation remains obscure. The previous studies provide insight into the potential collaboration between sanitary engineering, health sciences, the humanities, and social sciences. However, their perspectives on sanitation are inadequate, especially in terms of integration between the description and analysis of sanitation as a whole. As discussed in Chap. 1, sanitation has three components: socio-culture, health, and materials, and the interconnections between the three components as the Sanitation Triangle.

2.2 Socio-Cultural Matters with Materials and Health

Based on the model, in this part, we clarify how society and culture relate to materials and health problems along with sanitation services.

First, we consider the interconnection between the socio-culture and materials. Along with sanitation services, sanitation entails a social configuration for its operation. Individual excretion, the starting point for sanitation, is a social act because the act has social meanings and requires a place for excretion. In addition, some individuals or groups are also required to operate the functions of sanitation, such as the capture, storage, transportation, processing, reuse, or disposal of excrement. For example, to operate these functions, labor is required to make pit latrines and maintain them and, subsequently, a system for the management of the labor is also required. In this way, the social configuration is constructed along sanitation services to operate its functions smoothly.

Second, we argue that there is a relationship between socio-culture and health problems concerning sanitation. According to the definition by the World Health Organization (WHO), health is "a state of complete physical, mental, and social well-being" (WHO 1946). Sufficient sanitation services are needed for human dignities based on various cultures as a prerequisite for good health in each social and cultural context. We do not assume human dignity as a universally applicable, fixed index; rather, we consider plural human dignities as a person's good state, which is expressed in vernacular formula and roughly corresponds to the concept of "health" given by the WHO. In this sense, sufficient sanitation services, which are based on human dignities, do not have to be "improved latrine" or "toilet," as defined

by the WHO, in all the societies of the world. For example, the latrines would be unnecessary for hunter-gatherers living nomadic lifestyles in forests, and their environment might not be affected by human waste because of the vast area of their activities. What is perceived as the normal way of excretion and the subsequent treatment of human feces and urine, and which approach is better for each individual depends on socio-cultural contexts and material circumstances, which are also allocated socially. Therefore, sanitation-related health problems rely heavily on the socio-cultural context.

2.3 Chapter Overview

This part comprises four chapters that focus on society and culture in sanitation. Chapter 3 highlights the social configuration of the manual scavengers from the Dalit communities (Untouchables) in India. It traces the historical consequences of how certain groups have taken the role of sanitation services and how the ensuing social movement has struggled for the "liberation of manual scavengers." Chapter 4 shows how a rural community in Senegal manages water supplies: how they manage drinking water as materials and allocate labor and tools for its management. Although this case study considers drinking water, it shares an operational issue with the sanitation services in terms of how to operate its functions according to sanitation services. Chapter 5 summarizes the trends of international campaigns on Menstrual Hygiene Management (MHM) and reveals local contexts regarding the learning, knowledge, and experience of young girls on menstrual hygiene in a rural area of Uganda. It uncovers the socio-cultural contexts of menstrual hygiene in the local society and the gaps between the problems discussed in the international discourse and those told by the girls. Based on our theoretical standpoint, we interpret the three chapters of this part to uncover the relationship of socio-culture with materials and problems of health.

The sanitation workers' health and social conditions are yet to be fully studied, and both empirical and theoretical examinations are needed (World Bank et al. 2019). Chapter 3 provides an excellent case study on the history of sanitation workers in India. This historical explore is important, because previous reports on sanitation workers, mostly based on short-term field research, tend to overlook their historical struggles over decades. From a theoretical standpoint, the sanitation works are related to the argument on "hard work," or "dirty work" proposed by the famous political theorist Michael Walzer. Walzer discussed that "hard work" tends to be allocated to marginalized people in society and proposed exchange between the different spheres in these works to decrease the injustice (Walzer 1983). Although "hard work" cannot be completely eliminated in a society, people can share them and partially transfer them to other spheres. "Hard work" usually relates to poverty, discrimination, and power deprivation. Walzer suggested the separation of "hard work" from these containments and the transfer of the marginalized groups, from poverty to money and leisure time, from discrimination to honor, from deprivation to

commitment for decision making regarding their labor. We can consider the "liberation of manual scavengers" in India as a struggle to alter the socio-cultural allocation of sanitation work, as proposed by Walzer. Thus, through the thick description of historical context, Chap. 3 sufficiently presents the ethics of sanitation, which corresponds to the recently proposed idea of sanitation justice (Rusca et al. 2018). It does not present the struggle as a successful case; rather, it emphasizes how the allocation of sanitation work is not only associated with labor but also stigma and health risks. In this sense, society and culture are involved in both the sanitation services and the associated health risks. This point will be discussed again from the perspective of the health sciences in Chap. 8 of Part II, considering other cases.

Chapter 4 addresses the relationship between society and materials through a different lens. It discusses how a social system for water supply management can be created where it did not exist before in society. This case contains the common problem in the challenge of sanitation improvement in low- and middle-income countries; that is, how to create a social system for sanitary services. In sanitary engineering, this topic has been discussed in the sense of social acceptance of new technologies. However, it is better to consider these cases in terms of the formation of a new socio-technological configuration rather than social acceptance. In contrast to the view of "acceptance," classical works in Science and Technology Studies (STS) on large technical systems, such as electricity networks, railroad networks, and telephone systems, etc., show the seamless connection between organization and technology in these technical systems (e.g., Hughes 1986, 1987). Despite differences in the scale and technological characteristics, the basic concept can be applied to any kind of sanitation technology. Technology requires a social system for its operation, and the introduction of technology can be considered as the formation of a new socio-technological configuration (e.g., Hegger 2007; van Vliet et al. 2011). In other words, a new socio-technological configuration is to make a new technology embedded in society. The case study in Chap. 4 provides an original insight into the socio-technological configuration related to sanitation services. Inhabitants' participation in decision making, the transparency of the organization, as well as trust in the quality and safety of drinking water are crucial to a community's autonomous water management. It also relates to the process of social integration of new sanitation technology and the co-creation of the sanitation system in Chaps. 11 and 13 of Part III.

Chapter 5 discusses the relationship between socio-culture and health problems. The narratives of young girls on menstrual hygiene in Uganda reveal their need for not only education but also a social setting that allows for the acquisition and disposal of sanitary pads. This case offers the possibility of broadening the definition of sanitation to include "appropriate management" and "cleanliness." It is locally believed that the menstrual blood can be used for sorcery, so the women carefully dispose of their used sanitary pads. This situation also suggests the MHM difficulties faced by schoolgirls due to the lack of appropriate accommodations for MHM in schools. The girls' concerns indicate the need for hygienic and socio-culturally "appropriate" and "clean" accommodation, including the avoidance of sorcery. Modernization does not eliminate all elements of local culture and, rather it can

work to reinforce some of local culture. Cultural anthropological studies reveal that the culture of sorcery is maintained in the capitalistic economy of African countries (Geschiere 1997; Comaroff and Comaroff 2001). While it is difficult to change the culture of sorcery, it is possible to provide tools and facilities to avoid it. Chapter 5 not only provides a direction for education to promote correct scientific knowledge but also offers solutions adapted to each culture. Also, the hygienic practices in elementary schools in Indonesia are reported from the perspective of health sciences in Chap. 7 of Part II.

As discussed above, this part provides a socio-cultural perspective for sanitation by the focus on the interconnection between socio-culture, health, and materials. It explores materials and health problems related to sanitation through a wider lens considering the local historical and cultural background, and suggests new directions in health sciences and sanitary engineering. More specifically, the topics covered in each chapter—the ethical matters of sanitation in Chap. 3, the socio-technical configuration in Chap. 4, and what is hygienic and culturally "appropriate" in Chap. 5—include new research subjects and ideas, which are refined through the accumulation and comparison of other cases. The socio-cultural aspects of sanitation are too broad to be discussed in these parts, and other important topics such as the actual role of international NGOs, more detailed case studies of sanitation projects, cultural cognition on health, the economic activities of the sanitation industry, and institutional regulations on sanitation are not included. However, these limitations leave new potentials that future sanitation studies in the humanities and social sciences fields can explore.

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Chapter 3
Ideas and Practices for Restoring the Humanity of Sanitation Workers in India

Yui Masuki

Abstract This chapter briefly traces the struggle to restore sanitation workers' humanity in India since the early twentieth century. Sanitation labor has generally been carried out by people from the Dalit community, a group of castes formerly referred to as "untouchables." By paying attention to M. K. Gandhi, B. R. Ambedkar, government authorities, and nongovernmental organizations (NGOs), this chapter examines how humanitarian interventions were made via ideological and practical approaches to address the circumstances of sanitation workers and the limitations thereof. Gandhi's emphasis on the moral aspect of scavenging and Ambedkar's stress on the structural inequalities in the division of sanitation labor informed the mainstream ideas in preindependence India. However, efforts after independence were committed to abolishing the specific task of manual scavenging as a sine qua non for the emancipation of sanitation workers. These endeavors primarily entailed abolishing scavengers' customary rights, the technological invention of low-cost flush toilets, and legal actions taken against the government. However, these attempts have led to dismissing the importance of providing "adequate sanitation" to the bulk of the population (Chaplin, The politics of sanitation in India. Orient Blackswan, New Delhi, 2011: 185, 267), enhancing nonscavenging sanitation workers' conditions, and developing a more mechanized, holistic human waste disposal system. Further, having underlined the unsanitary, inhuman, or moral dimensions of sanitation labor, these interventions did not necessarily consider the complicated context of actual sanitation workers regarding how they perceive the labor on their own terms.

Keywords Sanitation workers · Dalits · Scavengers/scavenging

Y. Masuki (✉)
Japan Society for the Promotion of Science, Daito Bunka University, Saitama, Japan
e-mail: masukiyui@gmail.com

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3.1 Introduction

During my visit to some nongovernmental organizations (NGOs) in India that have worked to boost sanitation workers' status, it was striking to see what they considered to be their achievements. While Gandhian reformers displayed a series of flush toilet models regularly placed as showpieces, Dalit activists provided legal documents that included a judgment of the Supreme Court passed upon their writ petition. These materials, represented in epitome, offer a glimpse into how the path of the struggle to liberate sanitation workers in India, which agents with diverse ideas have walked on for several decades, has been tread thus far. Since 2014, when the central government launched a sanitation campaign, and decades after this matter had already captured national attention, the amount of human capital, thrown into the public domain as municipal sanitation workers, gradually increased. Generally, the country's sanitation labor has been performed by the Dalit[1] community; toilet cleaning has usually been carried out by people from specific castes, such as the *Valmikis*. These individuals have, to varying degrees, found themselves subject to hardship in socio-cultural and politico-economic spheres. By being sensitive to the Indian social context, this chapter chronologically follows the struggle to improve sanitation workers' status from the early twentieth century to the 2010s, in order to understand how activists from different backgrounds have articulated issues affecting sanitation and sanitation workers.

The first section covers the first half of the twentieth century. It describes the discourse and practices of M. K. Gandhi, who aimed to combat social discrimination against sanitation workers, and yet believed that scavengers' "traditional" work was to clean up human waste, an assumption that recent studies have shown to be untrue (e.g., Prashad 2001). The second section delves into the philosophy of B. R. Ambedkar, a social activist and politician from the Dalit community. By exploring his perspectives on sanitation and sanitation workers, some of his claims, in which he assailed Gandhi with vehemence, are clarified. The third section shifts the focus to the latter half of the twentieth century, when both government and nongovernment efforts to enhance sanitation workers' status quo, and manual scavenging[2] in

[1] The term "Dalit" stems from the Sanskrit word *dalita*, meaning "the oppressed." Since the 1970s, when movements under the leadership of those regarded as "untouchables" emerged, it has been used in both academia and activism to denote people from this community. Dalits hail from certain castes. Recent studies have shown that historically, quite a few Dalits did not necessarily engage exclusively in so-called traditional jobs (i.e., tanning and sweeping), or sometimes, they were not even familiar with these professions. In fact, a number of Dalits have historically earned a living through agriculture (Prashad 2001; Rawat 2011). Aside from "Dalit," other terms have been used to describe them—such as *Harijan* (coined by Gandhi)—especially by non-Dalits. They also fall under the administrative category of "Scheduled Castes," which are officially designated to benefit from the government's reservation (affirmative action) system. With these backgrounds attentively taken into account, this chapter primarily uses "Dalit" when referring to people formerly referred to as "untouchables."

[2] According to "The Employment of Manual Scavengers and Construction of Dry Latrines (Prohibition) Act" of 1993, manual scavenging in India involves manual handling of human waste,

particular, was energetically advanced. This chapter specifically deals with attempts to restore the humanity of sanitation workers and centers on interventional approaches by elites and nonsanitation workers. Rather than examining the contemporary union organizations or grassroots labor practices of actual sanitation workers, this chapter tries to unravel how activists have implemented ideological and practical strategies to assist sanitation workers and the constraints thereof.

3.2 M. K. Gandhi and Scavengers[3]

3.2.1 Gandhi's Views on Sanitation

To understand Gandhi's attitude toward sanitation and scavengers, it is helpful to first review his experiences in South Africa since the end of the nineteenth century. He became intensely concerned with the modern idea of sanitation during his stay in South Africa in the early 1890s. He had been plagued by severe racism on the part of Whites, who considered the area where Indians lived to be "insanitary" and related to epidemic outbreaks (Gandhi 1979a: 555–557). Having strongly opposed the authorities' condemnation of Indians, Gandhi claimed that Indian victims of disease were mainly those whom the authorities had employed "to perform the filthiest work" such as cleaning "drains and sewers"; therefore, they tended "to become as filthy in [their] habits as [rightful denizens]" (Gandhi 1960: 363). As Prasad (2015: 53–56) pointed out, Gandhi's experience of racial prejudice heavily impacted his commitment to sanitation matters, both in Indian communities in South Africa and in India itself.

During his stay in South Africa, Gandhi highlighted Indians' sanitation circumstances, wherein he claimed that if Indians were to consider "sanitation and hygiene as part of our [Indians'] being," "the prejudice" would disappear, and for this purpose, "every educated Indian has a unique privilege" to "become a missionary in hygiene and sanitation" (Gandhi 1960: 176, 1961: 101). He believed that improved hygiene among Indians would eventually strike at the root of racial discrimination by Whites. For Gandhi, it was important not only to maintain a state of cleanliness to live a healthy lifestyle and protect oneself against epidemics, but also to aver that discrimination against Indians was entirely unjustified, thus restoring their rights, property, and pride, which assumed a socio-cultural and political significance. Hence, Gandhi was involved in enhancing the cleanliness of Indian localities in South Africa. With respect to the disposal of human waste, for

especially from so-called "dry latrines," which structurally necessitate the services of scavengers (*Appendix D: The Employment of Manual Scavengers and Construction of Dry Latrines (Prohibition) Act, 1993*, Obtained from S*afai Karamchari Andolan*). For historical details on the dry latrine system, see Masuki (2021).

[3] Quite a few parts in this section were previously discussed in Masuki (2018: 7–10).

example, he encouraged Indians "to keep a tin filled with dust in the latrine and cover the feces with dust or ashes" (Gandhi 1961: 84). In his biography, he recalled in a deploring manner that his passion for spreading the idea of sanitation was often met with criticism and indifference by those who opposed it (Gandhi 1927: 503–506).

When he returned to India in 1915, Gandhi frequently connected the notion of sanitation with a high degree of self-control, which he regarded as necessary for India's true independence, or *swaraj* (self-rule) (Masuki 2018: 8). According to Gandhi, "The route leading to *swaraj* is self-control. And self-control means personal cleanliness" (Gandhi 1969: 24). Distinct from others, his perspectives on sanitation had to do with his argument that what a person grows for food, what he eats, and what he defecates are "all equal parts of Gandhi's project" (Alter 1996: 315). Hence, he believed that the work of scavenging "qualifies one for *swaraj*" (Gandhi 1975: 111), and urged citizens to keep their villages clean. Moreover, Gandhi used a variety of methods for human waste disposal and engaged in scavenging himself at his *ashram*[4] (e.g., K. Gandhi 2016).

3.2.2 Untouchability and Scavengers

In reflecting on the problem of untouchability and scavengers in India, Gandhi stressed that scavenging played a crucial role in keeping cities and villages clean, and would lead India to *swaraj*. Gandhi believed that "a scavenger doing his or her duty religiously will not merely bury the night-soil but also observe the stools passed by each and inform each person about the state of his or her health" (Gandhi 1970: 103). Gandhi perceived scavenging as "sacred" and characterized by "dignity," as well as "in no way inferior to a clergyman's" duty (Gandhi 1966b: 391, 1976: 401, 1982: 240). He lamented, however, that the upper castes "have cultivated unfortunately a habit of not looking after" their "own sanitation, because of untouchability," since they regarded it, and in some cases still do, as "the work of untouchables" (Gandhi 1969: 96).

Having associated untouchability with sanitation, Gandhi believed that the former was "in its inception," "a rule of sanitation, and still is in all parts of the world outside India" (Gandhi 1972: 268). That is to say, Gandhi thought that untouchability in India did not exist as it did in other countries; in other countries, in Gandhi's view, untouchability was a rule of sanitation. Yet in practice in India, it was not due to "the sense of high and low" regarding people's class awareness (Gandhi 1978: 379). Therefore, Gandhi thought it was important to spread the view that it is wrong to accept untouchability as "part of [the Hindu] religion" and not to regard scavengers as untouchables "forever" (Gandhi 1966a: 571, 1972: 268). To address the problem of untouchability and to improve India's unsanitary conditions, Gandhi pleaded with the upper castes to actively participate in his scavenging campaign and to be their

[4] An *ashram* is a secluded place where Hindu practitioners of austerity reside.

"own scavenger[s]" (Gandhi 1969: 96). Concerning scavenging work, Gandhi preferred for people to use simple toilets (e.g., shallow pit toilets) and to use human waste as fertilizer, rather than transforming dry latrines into flush ones, and rather than introducing the modern sewerage system. Emphasis was placed on the importance of enhancing scavengers' current "insanitary methods" by providing them with uniforms and proper cleaning equipment, thus ensuring that they collected waste in a clean manner; Gandhi believed that doing so would be "[scientific]" (Gandhi 1979b: 82).

Nonetheless, Gandhi's way of exerting himself in alleviating the practice of untouchability against scavengers was similar to his attempt to redress the unsanitary conditions of some Indians in South Africa. He believed that it is important for the upper castes to "set an example" of being "a perfect sweeper" and to enlighten scavengers how to perform their duties in a professional manner (Gandhi 1966a: 573). Here, Gandhi recognized the scavengers as being ignorant about sanitation matters. Further, although he criticized the sense of class awareness among the upper castes, he did not make much effort to encourage Dalits to change what he considered to be their "traditional" occupation. Indeed, a number of local scavengers did not choose to abandon their toilet-cleaning labor. However, this does not necessarily mean that Gandhi put a great deal of thought into the actual context of these workers, who strategically barely survived with this labor practice. While scavenging work was markedly eulogized by Gandhi and every citizen was urged to become involved in it, at the same time, Gandhi thought that scavengers should, at first, "earn [their] livelihood by being [scavengers]" (Gandhi 1976: 401). Ambedkar furiously took a stand against this attitude.

In Gandhi's view, the upper castes had the chief responsibility of eliminating untouchability, as he deemed it to be directly related not to Dalits, but rather to them. He thus appealed to them to do away with practices of untouchability (e.g., preventing Dalits from entering temples). Notwithstanding, at the same time, he preached that Dalits should live in "cleanliness" and "purify" themselves (Gandhi 1966a: 574). Gandhi's recognition of untouchability against scavengers was therefore influenced by two assumptions: that untouchability should be resolved by appealing to the upper castes to have a change of "hearts" (Gandhi 1982: 240), and that sanitation workers needed to improve their unsanitary methods of scavenging. Hence, he strove to eradicate visible, substantial uncleanliness, especially with the help of the upper castes; this effort and outlook distinguish him from Ambedkar.

3.3 B. R. Ambedkar and the Dalit Movement

3.3.1 Ambedkar's Perspective on Untouchability

One of the most celebrated social activists who broke new ground in the history of the Dalit Movement, which still thrives today, is B. R. Ambedkar. During the course of the Freedom Movement in the first half of the twentieth century, Ambedkar

emerged as a prominent Dalit leader. He severely berated Gandhism as being "nothing short of cruelty" regarding the eradication of untouchability from society (Ambedkar 2019b: 295). He hailed from the *Mahar* caste, a Dalit community in Western India. Throughout his lifetime, he applied himself intently to the issue of untouchability. Unlike other Indian elites of the time, most of whom had studied in the United Kingdom, Ambedkar was educated in the United States in the 1910s. As scholars point out, his experiences there influenced his political thinking in terms of democracy (e.g., Kapoor 2003; Mukherjee 2009), including the introduction of the reservation system for Dalits (Zelliot 2001: 83).

While Ambedkar briefly defined the practice of untouchability in general as "the notion of defilement, pollution, contamination and the ways and means of getting rid of that defilement," he viewed the untouchability in Hindu society as "hereditary" (Ambedkar n.d.: 21–22, 35), thus encompassing religion, the economy, and society. He argued that this idiosyncrasy could not be found outside of the Hindu society. Being a scholar as well, Ambedkar attempted to compare the practice of untouchability among Hindus with that of non-Hindus by taking examples from various communities around the world. He "conclude[d] that there are no people Primitive or Ancient who did not entertain the notion of pollution" (Ambedkar n.d.: 30). For him, the clear difference of untouchability between Hindus and non-Hindus is that while the latter consider it to be "temporary" pollution (that can mostly be observed on occasions such as births and deaths, and that can be accompanied by temporary segregation), Hindus perceive the "impurity" of the untouchables as "permanent" (Ambedkar n.d.: 47). This mode of untouchability, according to Ambedkar, originated from neither racial differences nor profession; therefore, this "hereditary stain" of being impure by birth can never be removed, even if one's occupational background changes (Ambedkar n.d.: 47, 77–107).

As previously explained, Gandhi grappled with the challenges that constantly plagued scavengers. In carefully scrutinizing Gandhi's efforts, however, Ambedkar reproached his preconceptions that untouchability can be eliminated by spreading the idea of cleanliness, as well as Gandhi's proposal of "praising scavenging as the noblest service to society" (Ambedkar 2019b: 292). For a scavenger, he emphasized, it is one's birth that determines who he/she is, whether he/she "does scavenging or not" (Ambedkar 2019b: 292). If a person belonging to a high caste (such as a Brahman) would engage in scavenging, "he would never be subject to the disabilities of one who is a born scavenger" (Ambedkar 2019b: 292).

Therefore, Ambedkar did not simply regard Gandhism as inadequate for improving Dalits' lives, but rather as a "curse," for "under Gandhism," Dalits "must follow their hereditary professions" and "the Untouchables are to be eternal scavengers" (Ambedkar 2019b: 295). Gandhi's enthusiasm for the embodiment of what he called "the ideal *Bhangi*" (Gandhi 1976: 86–88, here, it signifies a scavenger)[5] caused Ambedkar to stiffly accuse him of having "appeal[ed] to the scavenger's pride and

[5] *Bhangi* is caste traditionally considered to be involved in sanitation work, and the cleaning of human waste in particular. Since this term has a derogatory connotation, a number of people

vanity in order to induce him only to keep on to scavenging" (Ambedkar 2019b: 293).

3.3.2 *The Struggle Against Untouchability and Improving the Situation of Sanitation Workers*

The arguments put forward did not prevent Ambedkar from trying to ameliorate the Dalits' working conditions and the unfair practices they experienced in the religious, social, and economic realms. Ambedkar was committed to seeing that the Dalits' conditions, including sanitation workers' social mobility, be substantially improved. In the 1930s, for example, he mobilized Dalits to "make them conscious of their lack of rights" to enter Hindu temples, which was not allowed by the upper castes at the time (Zelliot 2001: 69). The problem of untouchability, according to Ambedkar, revolved around "the idea of pollution by contact" (Ambedkar 2019b: 294) and this was a potent deterrent for high-caste Hindus to share common spaces and substances with Dalits.

In addition, during this period, Ambedkar attempted to cope with the issue of the *watan*[6] system, which he believed "bound them [Dalits] to village rights and village duties" (Zelliot 2001: 58). He submitted a bill to the Legislative Council of the Governor of Bombay in the late 1920s to amend the then-current law called "The Bombay Hereditary Offices Act" (Kotani 2010: 142–143). His primary focus was to ensure that Dalits, and *Mahars* in particular, who possessed their *watan*, would "have their freedom to serve or not to serve" the villagers in a "hereditary" way (Ambedkar 2019a: 79, 83–84). Kotani (2010: 143–144) indicated that this was done for both those who wanted to abandon their obligation to render service to the villagers, as well as those who wanted to serve as in the past; for the latter, the law needed to be revised to enhance their working conditions, including in terms of receiving payment. Underlying this idea was the "modern" notion of "freedom of contract," where Ambedkar expressed overt disapproval of the existing *watan* system wherein "the services of one class of people should be forced upon other classes of people" (Ambedkar 2019a: 84; Kotani 2010: 143). In 1959, more than a decade after India's independence, his effort was eventually brought to fruition when *Mahar watan* was discontinued by passing the "Bombay Inferior Village *Watans* Abolition Act" (Kotani 2010: 147).

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formerly referred to as *Bhangi* abandoned it and have strategically adapted the term *Valmiki* to refer to their community.

[6] According to Kotani (2010: 107), *watan*/*vatan* signifies something "similar to 'share'" in which the "hereditary occupation" is accompanied with a share/portion according to the former. Although the *watan* system as one of "several labor division systems within and between villages" (Shinoda 2005: 53) was prevalent in precolonial Western India, it underwent a significant change from the early nineteenth century under the British rule (Kotani 2010). For further details on historical change in *watan* including *Mahar watan*, see Kotani (2010: 110–174).

Although his plan was supposed to discontinue *Mahar watan*—which did not have a straightforward reference to sanitation or sanitation workers—his initial claim for the improvement of Dalits' occupational mobility and working conditions played a crucial role in helping sanitation workers seek out a better life. While Ambedkar did not make any clear mention of an ideal toilet structure or the specific way scavenging should be performed, he appreciated the importance of sanitation itself. His statements in the Legislative Assembly Debates[7] and on the aims and plans of the Independent Labour Party manifest his zeal for improving village sanitation (Ambedkar 2019c: 419) and developing housing and sanitary environments for the laboring classes, such as coal miners and construction workers. When trying to observe Ambedkar's approach to enhance the status of marginalized communities, his perspectives on community development in India affords a clue; one of the most arresting features is that he considered large-scale mechanization and industrialization to be an indispensable element. Unlike Gandhi, who was not much disposed to the sewerage scheme, as well as Gandhians who riveted their attention on the invention of flush toilets with water-saving technology, Ambedkar directed all his influence to the furtherance of the water resource development project[8] in the country's rivers, such as irrigation, flood control, hydropower generation, and water supply (Abraham 2002; Government of India, Ministry of Water Resources, River Development and Ganga Rejuvenation, Central Water Commission 2016).[9] Based on an approach to benefit the bulk of the population including "the poor and oppressed section of society" (Government of India, Ministry of Water Resources, River Development and Ganga Rejuvenation, Central Water Commission 2016: 49), Ambedkar prioritized efficient water management and its utilization by means of mechanization. This striking contrast of Ambedkar's standpoint on extensive-scale public works with that of Gandhi and Gandhians is partially reflected in the perspectives of the contemporary Dalit-led movements that underline the significance of improving the sewerage system to emancipate scavengers.[10]

When it comes to the direct relationship between Ambedkar and sanitation workers on a practical level, it is not easy to find many scholarly works focusing on this issue. One of the few studies was conducted by Shyamlal (2018), who portrayed quite a few examples to corroborate that in practice, Ambedkar

[7] *The Legislative Assembly Debates Official Report*, Vol. II, 1944, 29th February to 27th March, 1944. p. 719; *The Legislative Assembly Debates Official Report*, Vol. III of 1946, 28th February to 14th March, 1947. pp. 2224–2225.

[8] Ambedkar modeled his water policy (such as the Damodar River Valley project in Eastern India) on the style of "the Tennessee Valley Scheme" implemented in the United States in the 1930s, which was oriented to modernize local communities. *Ambedkar's Contribution to Water Resources Development* (Central Water Commission, Government of India, 2016), Message by Uma Bharti, p. 93 (hereafter cited as *Ambedkar's Contribution*).

[9] See also *Ambedkar's Contribution*.

[10] For example, see "Live chat with Bezwada Wilson, Magsaysay awardee," *The Hindu*, July 28, 2016 (updated September 18, 2016), https://www.thehindu.com/specials/live-chat/Live-Chat-with-Bezwada-Wilson-Magsaysay-awardee/article14513180.ece

contributed directly to the well-being of sanitation workers. Take trade unions, for instance. Shyamlal demonstrated Ambedkar's attempts to call for sanitation workers to organize trade unions "as a weapon" meant "for the removal of discrimination" (Shyamlal 2018: 79). In 1936, Ambedkar first formed a union called "Bombay Municipal *Kamgar Sangh* (Bombay Municipal Workers Organization)".[11] Then, from 1943 to 1944,[12] he held a meeting of Bombay and Delhi's sanitation workers, which eventually led to the establishment of a sanitation workers' union in Delhi in 1944 to address the unfair practices they faced, especially "in the field of education and employment in municipalities" (Shyamlal 2018: 79). In the course of Ambedkar's quest for an egalitarian society for Dalits, the Independent Labour Party and the Scheduled Castes Federation were created in 1936 and 1942, respectively.

As with other Dalits, Ambedkar not only urged sanitation workers to abandon what passed for their "traditional occupation" of "scavenging," but also vigorously underscored the significance of organizing these workers to obtain enhanced working conditions and treatment in society (Shyamlal 2018: 79, 81); this thinking was utterly inharmonious with Gandhi's idea, which aroused little enthusiasm regarding this matter. It is also essential to note that Ambedkar eventually renounced Hinduism and converted to Buddhism in 1956, right before his death; his embrace of Buddhism continues to influence the Dalits' way of living, including that of sanitation workers, to this day.

3.3.3 The Difference Between Ambedkar and Gandhi

As for the problems affecting sanitation workers, Ambedkar's approach contrasts markedly with that of Gandhi. Having exhibited his espousal of the "traditional" division of labor predicated upon one's own caste, Gandhi heightened the value of scavenging work by paying attention to its moral and hygienic aspects. He advocated people to be their "own scavenger[s]" and ended up creating the image of the "ideal *Bhangi*" according to which he encouraged supposedly uneducated sanitation workers to behave in a professional manner (Gandhi 1969: 96, 1976: 86–88). Since the issue of untouchability against scavengers is correlated with sanitation, as Gandhi believed, it was indispensable for sanitation workers to focus on cleanliness and to reform their working environment and methods to become more hygienic, and to stop carrying human waste on their heads in particular.

Ambedkar continued to question the structural inequalities he observed in Hindu society. Hence, he considered Gandhi's idea to be hypocritical and therefore a

[11] Bhagwan Das, *Baba Saheb Bhimrao Ambedkar: Ek Parichaya, Ek Sandesh* (Lucknow: Dalit Tude Prakashan, 1996), p. 56, quoted in Shyamlal (2018: 79).

[12] Naval CM, *Garibo-ke Masiha Dr. Bhimrao Ambedkar* (Jodhpur: Minerva Publications, Bhagwati Colony, 2010), pp. 104–105, quoted in Shyamlal (2018: 79).

fantasy—much less a solution—in that untouchability, according to him, is not merely a matter of sanitation and cleanliness. This is because, according to Ambedkar, in Hindu society, a scavenger is always seen as a scavenger, regardless of his/her current profession, and he/she is stigmatized for having been born into his/her caste (Ambedkar n.d.: 47). Ambedkar viewed scavenging work not as "noble" but as "dirty," which, in general, specific castes belonging to the Dalit community had been constrained to take up as a "hereditary profession" to serve society as a whole (Ambedkar 2019b: 196, 292, 296). Therefore, by highly valuing Dalits' own struggle and agency, his efforts to liberate them revolved around making progress toward their occupational mobility, enhancing their educational opportunities, and establishing a legal framework to secure their rights. Simultaneously, for existing sanitation workers, Ambedkar immersed himself in organizing them to fight against their oppressors for better working conditions and social status.

Gandhi and Ambedkar shared a common conception regarding the significance of sanitation, public health, and sanitation workers in India. They did not, however, agree on how sanitation work or workers should be dealt with; Gandhi treated the moral element with great interest by engaging himself in cleaning work on a daily basis and urging citizens to do the same on an individual level, which for him would be closely associated with the *swaraj*, India's independence. In contrast, Ambedkar devoted himself to restructuring legal and policy frameworks in India's democracy, such as expanding public infrastructure through mechanization to ensure that all citizens—not only certain minorities—could enjoy access to adequate resources (e.g., water), in the same manner as he defended sanitation workers' social and economic rights.

3.4 Movements After Independence: The Abolition of Manual Scavenging

Three elements explain the trends of endeavors, conducted by diverse actors, to restore the humanity of sanitation workers in India after its independence in the late 1940s. One of the most vital is that almost all these efforts—whether by government or nongovernmental activists—considered the elimination of manual scavenging as sine qua non for the emancipation of sanitation workers. This formed a crucial component in the issues affecting sanitation in India, in that this overenthusiasm for eliminating solely manual scavenging partially hindered the development of the country's overall sanitation,[13] including nonscavenging sanitation workers. Activists and reformists had different opinions about whether sanitation workers would be

[13] Chaplin (2011: 267) argues that the efforts to deal with "the problem of manual scavenging" revolved around "a social welfare approach" rather than "[providing] adequate sanitation to all urban residents."

liberated by doing away with manual scavenging, although there was a tacit consensus that it was a prerequisite for their emancipation. This is quite different from Gandhi's approach, which endowed the work itself with dignity and respect; it does not share a complete similarity with Ambedkar's criticism, which questioned the institutionalized category of "sweepers" or sanitation workers, and the power that structurally made them engage in sanitation work, versus merely discontinuing the specific labor of manual scavenging.

While endeavors to restore scavengers' human dignity centered on eradicating the practice of manual scavenging, different activists adopted different approaches to achieve this humanitarian purpose. First, government authorities focused on the so-called traditional system of sanitation work, whereby scavengers cleaned the toilets of their private employers' homes on a daily basis and received food, clothing, and cash as remuneration for their services. This system, which government tried to abolish, was based on the "customary rights" of scavengers; its discontinuance was vigorously and repeatedly suggested. Second, especially since the 1960s, amid the upsurge of celebrating Gandhi's centenary, a few Gandhian organizations have emerged in the country. They strove to eliminate manual scavenging, not by directly abolishing customary rights, but by improving methods of human waste disposal. Thus, they introduced the intermediate technology of low-cost flush toilets and facilitated the conversion of dry toilets, which require manual handling, into flush toilets. Third, Dalits themselves took steps to disestablish manual scavenging, especially starting in the 1990s. After "The Employment of Manual Scavengers and Construction of Dry Latrines (Prohibition) Act" was passed in 1993 that classified manual scavenging as a crime, the legal proceeding was instituted to uphold scavengers' human rights. Dalit activists also mobilized scavengers and trained them how to stand up for their rights in the public sphere. These three features are described chronologically in subsequent sections.

3.4.1 The Discontinuance of the Customary Rights of Scavengers

Between the 1940s and the 1960s, India's state and central governments launched several committees to investigate the conditions of scavengers all over the country. Government approaches strongly associated scavenging/scavengers with the idea of "customary rights" and directed most of their efforts to nullify these rights. "Customary rights" historically, but not legally, guaranteed the stability of certain castes' hereditary occupations by ensuring that they could reap profits of their labor. Scavengers' customary right, according to government authorities, involved the "hereditary" right to clean "latrines in private households," in return for which one is "generally paid in kind (a daily *roti*) and [receives] some perquisites like food or

clothes, etc., on some special occasions like births, marriages, deaths, etc., varying with the status of the householder."[14]

One of the pivotal characteristics of the government's approach to abolishing manual scavenging was its attempt to understand scavengers' customary rights within the framework of the *watan* or "traditional" Hindu *jajamani* system, and how this would be incompatible in a "modern" nation. As mentioned earlier, the term *watan* refers to a set of various "occupations" and a "share/portion," which was prevalent in precolonial Western India, where the vocation of each community member (from the head of the local government to the Dalits) was hereditarily divided and each member was rewarded with the share resulting from his profession (Kotani 2010: 107). The *jajmani* system, however, is a concept described by Wiser in the first half of the twentieth century. Wiser conceptualized this system as "a service interrelationship system" "within the Hindu community" in rural North India, which involved a caste-based division of labor (Wiser 1936: 10, 174). While the *jajmani* system was believed by anthropologists in particular to be a determinantal system that represented a "traditional" Indian village, later studies showed that it was "largely a special kind of invented tradition" and "of relatively recent origin" (Mayer 1993: 362, 387). Having regarded scavengers' customary rights to have operated within the "traditional" *jajmani* system, government officials deemed such rights inappropriate for "modern times" and aimed to eliminate them.

In the latter half of the 1940s, the then-Government of Bombay set up the Scavengers' Living Conditions Enquiry Committee to survey scavengers' socio-economic status in the western half of the country. This committee was influenced by the Gandhian approach to improving scavengers' working and employment conditions.[15] With respect to their customary rights, the disadvantages affecting scavengers and the public, and household members in particular, marked the committee's main recognition (State of Bombay 1952: 32). Having understood that scavengers called "caste *Bhangis*" "have learnt to solely depend upon the scavenging work, in towns and cities," the committee showed interest in considering awarding them compensation for damages caused by the abolition of customary rights and the municipalization of scavenging work (State of Bombay 1952: 33).

In the late 1950s, a national level committee called the Scavengers' Living Conditions Enquiry Committee was formed for the first time under the chairpersonship of N. R. Malkani, a Gandhian politician. The committee published a report in 1961 in which it considered the problem of scavenging to be resolved by

[14] *Report of the Committee on Customary Rights to Scavenging* (Department of Social Welfare, Government of India, 1966), pp. 1–2 (hereafter cited as *Customary Rights Report*).

[15] Like Gandhi, the Committee regarded the carrying of human waste on one's head as "the climax of the whole tragic performance." It therefore suggested the "elimination of the hand-removal method" and the replacement of dry toilets with flush toilets that would "not involve hand-removal" (e.g., septic tank toilet)," as well as the introduction of "mechanical devices" (e.g., "wheel barrows" and "suction pumps") that "would be the only real improvement in the present condition[s] of scavenging work." *Report of the Scavengers' Living Conditions Enquiry Committee* (State of Bombay 1952), p. 58, 60, 62 (hereafter cited in text as *Scavengers' Report*).

revamping the toilet structure and dismantling scavengers' customary rights. As for the content of customary rights, two different labor practices were listed: the "rights for cleaning latrines in certain private households or particular localities" and "rights for the sale and disposal of night-soil collected by private scavengers."[16] According to the committee, scavengers "[working] under the employ of" another scavenger who enjoyed these rights did not discharge their duties properly in terms of everyday toilet cleaning, the disposal of human waste, and their relationship with house owners (Government of India, Ministry of Home Affairs, Central Advisory Board for Harijan Welfare 1961: 80). Having appealed to the "responsibility of the local bodies" to maintain a sanitary environment in towns and cities, the committee emphatically claimed that customary rights should "be abrogated immediately" (Government of India, Ministry of Home Affairs, Central Advisory Board for Harijan Welfare 1961: 80). The report, as illustrated by Sharma (1987), indicated that specific castes in Delhi with ties to scavenging were against the committee's suggestion to abolish their customary rights. They argued that the committee had not sufficiently consulted with "even a single" person where they lived to improve their conditions[17]; thus, the report's observations were not reliable. Further, they expressed that their rights had been in operation since Mughal and British rule as "legal right[s]."[18]

During the first half of the 1960s, while carrying a nationwide census, "several distinguished scholars were invited to write special monographs for the Village Survey series."[19] One of the monographs focused on the "customary rights and living and working conditions of scavengers in two towns" in North India "to find out the nature of [these rights]," and was submitted by "the Social Studies Section of Registrar General's Office" (Government of India, Ministry of Home Affairs, Office of the Registrar General 1966: forward, 1). The monograph detailed scavengers' work practices, with special references to local contexts, such as caste organizations and trade unions. Although the report demonstrated that the abolition of customary rights would not necessarily eliminate the manual handling of human waste by headload, it strongly recommended that scavengers' rights be discontinued from the perspective of humanity, as this system denied their "human dignity" (Government of India, Ministry of Home Affairs, Office of the Registrar General 1966: 9). The monograph not only suggested that scavenging work be municipalized by

[16] *Report of the Scavenging Conditions Enquiry Committee* (Central Advisory Board for Harijan Welfare, Government of India, 1961), p.79 (hereafter cited in text as *Scavenging Report*).

[17] A wall poster, dated September 15, 1966, by the Malkani protest committee of *Bhangi* caste council, para. 3, quoted in Sharma (1987: 166).

[18] A wall poster, dated September 15, 1966, by the Malkani protest committee of *Bhangi* caste council, quoted in Sharma (1987: 167).

[19] *Study of Customary Rights and Living and Working Conditions of Scavengers in Two Towns* (Census of India 1961 Monograph Series Volume I, Part 11-D, Office of the Registrar General, India, Ministry of Home Affairs, 1966), forward (hereafter cited in text as *Study of Customary Rights*).

providing compensation[20] to existing scavengers, and by preparing a legal framework to nullify customary rights, but also stressed the importance of educating scavengers by appealing to "their human dignity," as well as eliminating the "removal of night soil as head load" by introducing sanitary toilets and providing more "mechanized" working conditions (Government of India, Ministry of Home Affairs, Office of the Registrar General 1966: 33).

At the same time, the then-Department of Social Security created the Committee on Customary Rights to Scavenging "to examine the question of abolition of the customary rights to scavenging."[21] Between 1965 and 1966, the committee carried out a survey of scavengers' customary rights in several states, including their rights' "legal aspect[s]," income earned from them, and associated problems; for instance, what they called "intermediaries" (Government of India, Department of Social Welfare 1966: 13–28, 30–31). As was the case with its precedents, the report recognized scavengers' methods of cleaning dry toilets, human waste disposal, and compost as a major source of "urban insanitation" (Government of India, Department of Social Welfare 1966: 34–36). These government efforts to eliminate scavengers' customary rights also involved claim that doing so would enable scavengers to "take [on] other profitable occupations" and that "persons belonging to other communities may also adopt this occupation" (Government of India, Department of Social Welfare 1966: 33–34).

The idea of abrogating scavengers' customary rights exhibits the government's overenthusiasm in modernizing India; there should not be any "traditional" obstruction unsuitable for a clean and sanitary nation. In blaming scavengers, who used to enjoy their customary rights for being marginalized as untouchables, the government forced itself to deal with the question of their humanity by discarding what were thought to be "traditional" and private practices, and incorporating scavengers and the practice of scavenging into the public sphere to befit the country's trajectory of modernization and urbanization. In doing so, scavengers' voices were barely heard, especially when it came to dissenting opinions against abolishing their customary rights (Sharma 1987; Suzuki 2005: 57).

3.4.2 Flush Toilet Installations

In the 1960s, during the celebration of Gandhi's centenary, the movement to enhance the situation of sanitation workers who engaged in scavenging was exalted in India. There were Gandhian social organizations led by activists from upper-caste communities who tried to liberate scavengers. Unlike government authorities, which

[20] As Suzuki (2005: 69) delineated, the subject of appropriate compensation for scavengers was ignored and eventually faded away after the 1960s.

[21] Resolution No. 22/5/65-SCT. III(B), dated April 23, 1965, quoted in *Customary Rights Report* (1966: iv).

focused on abrogating customary rights, a distinguishing feature of these organizations' efforts is that they viewed the installation of flush toilets, which were supposedly suitable for India's local context, as the basis for liberating scavengers from the work of manual scavenging, as well as their marginalized circumstances. Gandhi's followers conducted a number of technological experiments starting in the 1940s; eventually, the twin-pit, low-cost flush toilet was developed as an alternative to dry toilets (Masuki 2018). Gandhian NGOs not only promoted the introduction of low-cost flush toilets, but also facilitated the commercialization of public toilets with flush systems in major cities and towns. Quite a few of these public toilets have a pay-and-use system; the money collected covers their maintenance costs.

An NGO called "*Safai Vidyalaya* (School of Cleaning)" was established in Gujarat, Western India, by Gandhians in the 1960s. This NGO was influenced especially by a Gandhian who considered it more important to liberate scavengers from scavenging than to tackle India's sanitation problem through large-scale mechanization and industrialization, and conducted "experiment[s]" to "eliminate dirty work [of scavenging] from entire community."[22] Based on the "human approach" focusing on sanitation workers, apart from simply building public toilets and low-cost flush toilets, *Safai Vidyalaya* engaged in providing sanitation training to officers and sweepers, installing public toilets with bio-gas plant systems, and providing educational assistance to the children of sweepers.[23] In the 1970s, another Gandhian set up an NGO called the "*Sulabh* International Social Service Organisation (hereafter, *Sulabh*)" in the northern state of Bihar, and promoted low-cost flush toilets. Especially since the 1990s, this NGO has been committed to promoting vocational training and education for what they call ex-scavengers and their children. Similar to *Safai Vidyalaya*, *Sulabh* perceives manual scavenging as "dirty and subhuman" work that should be abolished immediately (Pathak 2006: 13).

The Gandhians' approach to eradicating manual scavenging by transforming toilet technologies differs from Gandhi's notion of scavenging (Masuki 2018: 22–23), wherein he sublimated the work to a "sacred" level and insisted on merely improving its method, and the head-load carriage of human waste in particular (Gandhi 1966b: 391, 1973: 125). It is equally dissimilar to Ambedkar's efforts to mobilize Dalits outside of Hindu society in a socio-democratic manner. To some degree, the Gandhians' initiative has contributed remarkably to a decline in manual scavenging. These attempts, however, demonstrate a limitation in the liberation of scavengers, in that Gandhians bear some resemblance to Gandhi's perspective in how they address the question of eradicating untouchability within the realm of upper-caste leadership, rather than by involving Dalits themselves. This constraint is also reflected in their organizational structure, whereby Dalits have rarely found their place in terms of leadership (Suzuki 2015: 118). In this setting, scavengers have been seen as mere beneficiaries rather than as having "decision-making authority"[24]

[22] Interview with a worker at *Safai Vidyalaya* in Ahmedabad, Gujarat (January 28–29, 2017).
[23] Interview with a worker at *Safai Vidyalaya* in Ahmedabad, Gujarat (January 28–29, 2017).
[24] Interview with a worker at *Safai Vidyalaya* in Ahmedabad, Gujarat (January 28, 2017).

whom the Gandhians believe should receive financial, educational, and religious assistance for the sake of emancipation.

Activists and recent studies have shed light on how the limitations of the reform by Gandhians have heavily impacted sanitation workers in contemporary India. In the past few decades, public toilets have been popularized all over the country, yet there are issues with caste-based structures of toilet cleaning and the mismanagement of workers. Sanitation workers who clean public toilets mostly come from the Dalit community (Suzuki 2015: 118), even though employers have not set any caste-based recruitment policy for this job (Masuki 2018: 21). For the latter, *Sulabh*, for example, mostly provides cleaning jobs as contracts. However, sanitation workers have trouble in terms of working conditions (Singh 2014: 40–41). Workers who clean public toilets in Delhi engage in extremely unhygienic labor conditions and are paid monthly salaries of little more than INR 500–1000 (Singh 2014: 41). The problem of payment for workers occurs not only in the capital, but also in more local areas. In the northwestern state of Punjab, for example, 60 sanitation workers at a hospital that had a contract with *Sulabh* to maintain toilets went on strike in 2015 due to not having been paid for 4 months, and complained about what seemed to others to be a small amount of money.[25] This issue is also prevalent in other *Sulabh* organizational settings. Take a *Sulabh* vocational training center, for instance. Trainees who had formerly engaged in manual scavenging in Rajasthan in Northwest India did not receive their stipend for several months.[26] As for manual scavenging, the promotion of public toilets did not necessarily play a significant role in completely eliminating the practice. Against this background, some Dalit activists clashed with *Sulabh* regarding the management system of the maintenance of a public toilet. In 2016, a municipal corporation in South India filed a lawsuit against *Sulabh*, charging the NGO with having employed manual scavengers to clean "a manhole near the public toilet."[27] A Dalit organization filed the complaint, and accused *Sulabh* of resorting to manual labor instead of utilizing the municipality's "sewage-sucking machine.[28]" Reform thus contains limitations at the ideological level, wherein upper-caste reformers have paid little attention to Dalits' own agency. More importantly, in the practical domain, sanitation workers employed as *Sulabh*'s rank and file are not treated with sufficient dignity and respect in terms of employment conditions.

[25] "Safai Karamcharis Protest Non-Payment of Salaries for Past Four Months," *The Tribune*, August 4, 2015, https://www.tribuneindia.com/news/archive/amritsar/safai-karamcharis-protest-non-payment-of-salaries-for-past-four-months-115235. Accessed May 5, 2021.

[26] From fieldwork at a vocational training center in Tonk, Rajasthan, between 2014 and 2019.

[27] Staff Correspondent, "Case Registered against Sulabh International," *The Hindu*, April 12, 2016, https://www.thehindu.com/news/cities/Mangalore/case-registered-against-sulabh-international/article8464086.ece. Accessed May 5, 2021.

[28] Staff Correspondent, "Action Sought against Manual Scavenging," *The Hindu*, March 28, 2016, https://www.thehindu.com/news/cities/Mangalore/action-sought-against-manual-scavenging/article8404240.ece. Accessed May 5, 2021.

Having transformed the system of human waste disposal by means of flush toilet technology, Gandhians thought to handle the question of untouchability against scavengers from the angle of hygiene. Their repeated emphasis on the modern, scientific, and public notions of sanitation and cleanliness caused them to diverge from the course of Gandhi's efforts to seek change from within Hindu society by attaching moral importance to scavenging and by appealing to the conscience of the upper castes. Ironically, today's movements remain within the confines of reform *within* Hindu society in terms of being under upper-caste leadership (Suzuki 2015: 118), which is liable to dismiss sanitation workers' agency.

3.4.3 The Dalit-Led Movement and the Criminalization of Manual Scavenging

After the 1980s, a policy shift occurred to focus on enhancing scavengers and sweepers' capabilities in the course of abolition of manual scavenging. The government emphasized providing scavengers with vocational training, with the idea of integrating them into the mainstream society from which they were marginalized. These schemes were called "rehabilitation programs." Job training for scavengers was supposed to equip them with "new skills and entrepreneurship capabilities" "[up to] two years while receiving a monthly stipend."[29] This attempt involved identifying scavengers and offering cash assistance and loans for "sanitation-related projects" such as vacuum loaders (Government of India, Department of Social Justice and Empowerment n.d.: 3). Although some so-called ex-scavengers took up alternative occupations through these schemes (e.g., becoming a seamstress or rickshaw driver), studies and activists revealed the inadequate effect of project implementation (e.g., Suzuki 2015: 127–128), as it did not "suit the stakeholders" who were allegedly "women and in the upper age group."[30]

Some movements led by Dalits that emerged in the 1990s[31] constituted one of the most significant changes in the approach to eliminating manual scavenging. In 1990, amid the celebration of Ambedkar's centenary (Suzuki 2015: 214), as Shyamlal (1999: 102) clarified, the "All India S*afai Mazdoor* Congress (All India Sanitation Workers Congress)," a caste association, passed a resolution that included a request

[29] *Central Sector, Self Employment Scheme for Rehabilitation of Manual Scavengers (SRMS),* Department of Social Justice and Empowerment, Government of India, p. 7, Obtained from SKA (hereafter cited in text as *SRMS*).

[30] Ritwika Mitra, "Union Minister Ramdas Athawale's Comment on Manual Scavengers Creates Row in Parliament," *The New Indian Express*, February 5, 2020, https://www.newindianexpress.com/nation/2020/feb/05/union-minister-ramdas-athawales-comment-on-manual-scavengers-creates-row-in-parliament-2099174.html. Accessed May 5, 2021.

[31] Since the 1990s, an increasing number of Dalit-led NGOs all over the country have addressed the question not only of sanitation workers, but also of other issues affecting Dalit human rights and reservation policies in political, economic, educational, and social domains.

that the practice of manually cleaning human waste be legally inhibited, and "modern equipment" for sanitation workers be provided. This entreaty was embodied in 1993 by the passage of the decisive yet highly contentious law, "The Employment of Manual Scavengers and Construction of Dry Latrines (Prohibition) Act (hereafter *the 1993 Act*)," mentioned earlier (Suzuki 2015: 214). This law laid down regulations on the eradication of manual scavenging. The focus of the 1993 Act, however, was confined to "scavengers" engaged in the "manual" handling of human waste from dry toilets, and did not pertain to work conducted manually in cleaning sewers, septic tanks, or manholes.

Seeing this as a stepping stone toward the elimination of manual scavenging, Dalit-led organizations have come to regard scavenging as an irrefutable crime to be deracinated immediately and punished in accordance with the law. This attitude is different from Gandhi's point of view, which appealed to the conscience of the upper-caste citizens and Gandhians, who attempted to change conditions through technology. It is rather similar to Ambedkar's approach; Ambedkar's perspective helped frame India's constitution, which prohibits caste-based discrimination. One of the most well-known Dalit-led NGOs that fights for the rights of sanitation workers is "*Safai Karamchari Andolan* (the Sanitation Workers' Movement, hereafter SKA)," cofounded in the early 1990s by Bezwada Wilson, a Christian social activist, who came from a Dalit community called *Madiga*.[32] As a Dalit NGO, SKA proclaims Ambedkar's notable slogan, "Educate, organize, and agitate,"[33] and attaches importance to ensuring the civil rights of Dalits. Notwithstanding, their mission is not completely aligned with Ambedkar's vision, in that they stress the gravity of citizens' human rights rather than religious conversion.

The perspective of manual scavenging as a crime to be punished immediately led to two distinctive actions: (1) the institution of "public interest litigation"[34] against violations of human rights, and (2) the organization of sanitation workers to join the struggle. SKA's approach views the illegitimacy of manual scavenging and caste-based discrimination against scavengers as stemming from the rule of law in a democratic nation. Unlike Gandhian NGOs that reduced the marginalized position of scavengers to the inadequacy of technology and modern scientific and sanitary discourse, this notion led SKA to attempt to restore the humanity of scavengers in terms of a democratic vision, such as fundamental human and constitutional rights. In 2003, for example, SKA, together with other NGOs, filed a legal petition about violations of the 1993 Act and requested that the Union of India strictly adhere to the law.[35] Approximately a decade after the petition, the Supreme Court ordered the State and Union Territories to take possible measures against violations of the 2013

[32] For a brief explanation of SKA's establishment by Wilson, see Suzuki (2015: 222–223).

[33] From a leaflet on *Bhim Yatra* printed by SKA (hereafter cited as *Bhim Yatra*).

[34] For a few cases of public interest litigation instituted by Dalit activists, including SKA, see Suzuki (2015: 220–226).

[35] *Writ petition* (civil) No. 583 of 2003, Judgment (Supreme Court of India 2014), pp. 1–2, Obtained from SKA (hereafter cited as *WP*).

Act.[36] The court also recommended that the families of the victims who died while cleaning manholes or septic tanks after 1993 be compensated with INR 1,000,000 (Supreme Court of India 2014: 26).

As for the latter, SKA encourages organizing scavengers, as it believes that these legal procedures alone would be incomplete for their liberation, especially in practice.[37] SKA argues that there are still a great number of dry latrines and manual scavengers all over the country, despite the passage of the 1993 Act prohibiting manual scavenging and promoting the spread of available flush-toilet technologies. Having viewed scavenging as a "dehumanizing occupation," SKA has struggled to organize scavengers in the country to claim their fundamental rights in the public domain.[38] Since the 2000s, SKA has committed itself to a campaign to demolish dry latrines that require the daily service of manual cleaning, objecting to government authorities that have not taken any decisive measures to exact penalties on those who have violated the 1993 Act. This demolition of dry toilets, as explained by SKA, is not conducted in a vigilante-like manner. Rather, the owners of the toilets are notified in advance that their current toilets are illegal and that they shall be removed by the organization.[39] Scavengers were also mobilized to burn the baskets in which they carried human waste on their heads.[40]

In the 2010s, SKA's movement against the crime of manual scavenging and for the human dignity of sanitation workers became more consolidated and extensive. In 2010, it organized "*Samajik Parivartan Yatra* (Procession for Social Change)," whereby a bus procession went around various areas of the country and both "women and men" manual scavengers were mobilized.[41] Between 2015 and 2016, it orchestrated another campaign called "*Bhim Yatra* (*Bhim*[42] Procession)" in

[36] The 2013 Act is a revised version of the 1993 Act. Slightly divergent from its antecedent, this act contains new prohibitions (e.g., manual cleaning of septic tanks and sewers). Again, this act is not wholly free of ambiguities. Although the manual handling or cleaning of human waste from "insanitary" toilets is prohibited, the legislation contrarily states that workers with "protective gear" "shall not be deemed to be a 'manual scavenger'" (*The Gazette of India*, Extraordinary Part-2, Section 1, New Delhi, No. 35, September 19, 2013, p. 3–4, Obtained from SKA), and would thus be excluded from punishment (Singh 2014: xxxvii). Aside from the manual scavenging of dry latrines, in 2014, the court criminalized sewer cleaning "without safety gears," even in an emergency (Supreme Court of India 2014: 25).

[37] Harsh Mander, "Barefoot: Burning Baskets of Shame," *The Hindu*, May 8, 2010 (updated November 10, 2016), https://www.thehindu.com/opinion/columns/Harsh_Mander/Barefoot-Burning-baskets-of-shame/article16123459.ece. Accessed May 5, 2021.

[38] *Bhim Yatra*. However, SKA claims that among those SKA has reported having died while cleaning manholes, less than 3% were offered compensation (*Bhim Yatra*).

[39] Information obtained from SKA, New Delhi (February 2017).

[40] Harsh Mader, "Barefoot: Burning Baskets of Shame," *The Hindu*, May 8, 2010 (updated November 10, 2016), https://www.thehindu.com/opinion/columns/Harsh_Mander/Barefoot-Burning-baskets-of-shame/article16123459.ece. Accessed May 5, 2021.

[41] *Bhim Yatra*.

[42] *Bhim* originally comes from Ambedkar's name, *Bhimrao*; this procession was supposed to end one day before Ambedkar's 125th anniversary (*Bhim Yatra*).

500 districts in the nation's 25 states. Under the "Stop killing us" slogan, SKA called out to participants to rise up for the campaign to restore sanitation workers' "constitutional and fundamental rights" and to eradicate the deaths that occur while cleaning "dry latrines, sewers, and septic tanks."[43]

Since SKA's movement against manual scavenging finds legitimacy in the law and basic human rights, it addresses the issue of the caste-based division of labor, not with moral, religious, or technological means, but with the modern, democratic discourse of civil society grounded in the idea of freedom and equality. Hence, SKA can organize scavengers and other sanitation workers together, regardless of religion, gender, or type of scavenging work, thus allowing them to demonstrate their agency. SKA also paved the way for the development of a transnational Dalit network, which could be rather difficult under the Gandhian settings. While it succeeded in mobilizing scavengers in quite a few parts of the country, several scavengers are still engaged in this work, including sewer cleaning by hand. Research is needed to investigate how SKA's future activities may mobilize Dalit communities from a long-term perspective, such that SKA's leadership will be more reflective of Dalits' agency. More significantly, how Dalit leadership could impinge on the upper-caste status quo and transform its relationship with this sector of society should be closely scrutinized.

3.5 Conclusion

Approaches by humanitarian forces to rehumanize sanitation workers in India were buttressed by the postulation that the practice of scavenging and untouchability against scavengers is unsuited to a modern, scientific, and democratic nation. The mainstream idea of restoring their humanity before independence was informed by emphasis on (1) the moral aspect of scavenging by Gandhi, who associated it with India's independence, and (2) Hindu society's structural inequalities questioned by Ambedkar. While Gandhi viewed scavenging itself as dignified and treated its "traditional caste-based" dimension in an exhortative manner, he thought of existing scavengers as ignorant about what he believed to be its moral importance, as well as the scientific notion of cleanliness. Moreover, his commitment to scavenging did not necessarily orient toward the sole issue of liberating scavengers: it was closely associated with his ardor for mobilizing every individual toward *swaraj*, India's independence; toward this goal, scavengers were integrated and represented as an indispensable force. Ambedkar attempted to emancipate Dalits, including sanitation workers, through legal frameworks, labor organizations, and religious conversion. Based on the modern concept of "freedom of contract," Ambedkar's approach aimed to expand Dalits' occupational spectrum, whom he regarded as fettered by the power that structurally made them engage in "hereditary" work, including scavenging.

[43] *Bhim Yatra*.

Having devoted himself to the welfare of all including minorities, he simultaneously attempted to provide public infrastructure in a large-scale mechanized manner, exemplified in the water resource development project. Likewise, he laid the legal groundwork for protecting workers and minorities' rights, and impelled these workers into organizations to enhance their employment conditions and social status.

Efforts after independence approached this issue with the idea of abolishing the specific task of manual scavenging as a sine qua non for sanitation workers' emancipation. Regardless of caste or religion, various actors have exerted themselves to eradicate manual scavenging across the country. Over the two decades after independence, the postcolonial government, partially affected by the ideas of Gandhi and Gandhians, saw scavengers' way of working as "traditional," and tried to incorporate it into public domain by way of municipalization. Within their ideological framework, the manual system of human waste disposal was remodeled as a matter of customary rights. Government-led committees viewed scavengers' customary rights as originating in the *jajmani* system, which they believed was "traditional," and hence antediluvian and inappropriate for building a modern, sanitary nation. Their insistence in discontinuing customary rights involved an assumption that doing so would extricate the public from insanitary conditions, and the scavengers out of insanitary, squalid, and inhuman conditions. In this sense, scavengers' voices were represented in a patronizing attitude; moreover, their objections to the abrogation of their rights have mostly been ignored (Sharma 1987; Suzuki 2005: 57).

Gandhian activists focused on how scavengers' labor was performed, and focused on its unclean aspect, which they believed constituted a good reason for their marginalized status. Unlike Gandhi, Gandhians perceived the work of manual scavenging itself as dirty and inhuman and have repeatedly experimented to technologically alter the toilet system, especially since the 1960s. They eventually popularized the modern notion of sanitation and cleanliness by inventing low-cost flush toilets. Gandhians believed that low-cost flush toilets that use water would be more sanitary and liberate scavengers from manual labor, and this transformation in toilet technology and labor practice would rehabilitate scavengers to the mainstream society from which they were thought to have been segregated. While the introduction of flush toilets in public and private domains has indeed contributed to a decline in manual scavenging to some degree, there has hardly been a significant change in the caste-based division of sanitation labor (Suzuki 2015: 116, 118), which Ambedkar rebuked severely. Further, the Gandhian approach demonstrates reform from above, under the upper-caste leadership (Suzuki 2015: 118); thus, issues such as mismanagement by Gandhians, which affects sanitation workers, in public toilets have surfaced. Within their projects, the laborers' welfare—which Ambedkar devoted himself to protecting—was not prioritized.

Since manual scavenging became enjoined under the law in 1993, Dalit-led liberation movements have revolved around the assertion that it is not merely outdated but also a crime. Instead of resorting to a technology, they have attempted to pave the way for deracinating this practice under the democratic authority and through the idea of modern civic and basic human rights. Therefore, they appealed to the public to adhere to the law by instituting public litigation. As citizens, scavengers

were reconfigured into something whose rights should be protected under the rule of law. Simultaneously, they ensured that those who violated the law should be strictly punished. On a practical level, such movements aim to strengthen the solidarity of scavengers across the country; this has succeeded in foregrounding in the public sphere the matter of manual scavenging, including sewer cleaning by hand. However, there are still quite a few scavengers who reportedly engage in this work. This indicates the other issues require redress, and future research should consider how Dalit leadership in mobilizing Dalit communities may enhance Dalits' agency in the long run. More importantly, how this leadership may impact the upper-caste status quo and transform its relationship with this sector of society should be examined.

In sum, the following two points underscore the limitations of these liberation movements through ideal and practical interventions. First, in attempts made after independence, problems affecting sanitation workers (other than manual scavengers) have not captured as much attention as the issue of manual scavengers. Moreover, these movements have accentuated the importance of scavengers' welfare, but have made little progress in terms of enhancing overall sanitation, including "the adequate provision of sanitation in India's cities" (Chaplin 2011: 17), the development of a more mechanized, holistic human waste disposal system, and active support of nonscavenging sanitation workers. It was only after the mid-2010s that the country witnessed a policy shift to some extent in the entire sanitation system, when a national campaign called "*Swachh Bharat* Mission (Clean India Mission)" was launched, and sanitation infrastructure was gradually equipped.

Second, these interventions underline unclean, inhuman, or sometimes honorable aspects of sanitation workers and their duties, including manual scavenging. In this sense, these interventions have not necessarily explored the details of locally operated sanitation systems and laborers' practices in local communities, nor the transformation of these practices. As for a community in Rajasthan that engaged in sanitation work including scavenging, the labor was of course considered unclean and undesirable, but was simultaneously positively counted in economic, social, moral, and environmental terms embedded within the local context.[44] Sanitation workers' practices need to be understood by being sensitive to how crucially such work informs their daily subsistence, how they interpret it in the context of their way of life, and most importantly, what "humanity" means to them on their own terms, and how their humanity became transformed through these humanitarian interventions.

[44] Findings obtained from fieldwork and interviews focusing on the *Valmiki* community, conducted in Tonk, Rajasthan, from 2014 to 2020.

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Chapter 4
Dissociation Between National Policy and Local Communities in Regard to Water Supply Management

Mayu Ikemi

Abstract Various governments and international organizations have made efforts to expand water supply and sanitation services in rural Africa. This study aimed to evaluate and elucidate the outcomes of national policies on improving water supply management in rural Africa through a case study of Senegal. This case study examined the actual conditions of water supply facilities and residents' water use in villages. I also attempted to identify the remaining challenges for sustainable water management by local communities. In summary, despite improvement in access to safe drinking water resources for rural populations in Senegal, the national policies were not completely successful. My findings highlight that improving water quality is as crucial as expanding water supply facilities in rural Africa. Meanwhile, for the sustainable self-management of water resources in rural Africa, the case study suggested the importance of local people's transparent management, information sharing, and mutual aid. Rural residents in Africa have great potential to improve their current water environment through their own initiatives. This potential should be considered as a key to achieving the goal of sustainable water supply management in local communities.

Keywords Local community · Rural Africa · Senegal · Water management

4.1 Introduction

In 2000, the United Nations (UN) adopted a set of Millennium Development Goals to improve the lives of people in the poorest countries by 2015. As of 2015, the UN reported that 91% of the global population had access to an improved drinking water source. As such, about 663 million people (equivalent to 9% of the global population) were still experiencing a lack of improved drinking water sources. The problem

M. Ikemi (✉)
Sapporo International University, Sapporo, Hokkaido, Japan
e-mail: mayu-ikemi@ts.siu.ac.jp

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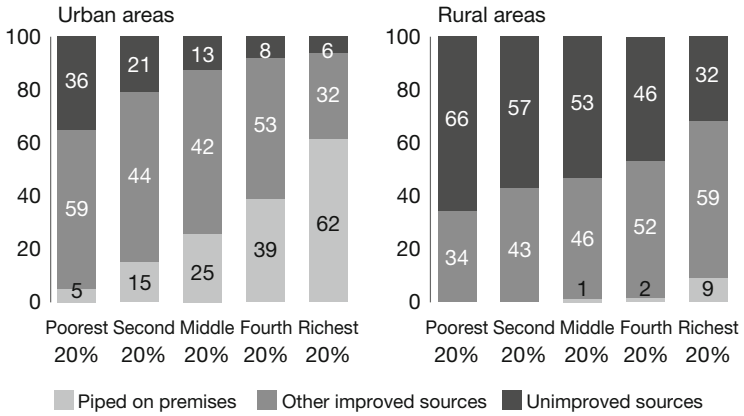

Fig. 4.1 Accessibility to drinking water in sub-Saharan Africa. (© 2012 United Nations. Reprinted from UN (2012: 53) with the permission of the United Nations)

with the lack of improved drinking water sources is severe, particularly in sub-Saharan African countries. Only 25% of the population in these countries have access to improved sources of drinking water (UN 2015).

Limited drinking water supply and poverty are closely related in many African countries. Difficulty in securing safe water entails negative impacts on people's sanitation, health, education, and economic activities. These negative impacts further exacerbate the difficulty in securing safe water. Therefore, low-income people with poor drinking water access in many African countries become trapped in the vicious cycle of poverty and poor drinking water access (Ikemi 2018). The situation is even more dire in rural areas of sub-Saharan Africa.

Figure 4.1 shows the accessibility of drinking water in sub-Saharan Africa reported by the UN in 2012. Most of the people living in rural areas in sub-Saharan Africa did not have piped water on premises. More than half of the population living in rural areas used unimproved water sources, a significantly higher ratio compared with urban areas. Regarding this inequality in access to drinking water between rural and urban areas, the main cause was identified as the lack of capability for the sustainable management of water infrastructure, such as water pipes, wells, and reservoirs. Therefore, water infrastructure management is essential for rural development in many African countries (Ikemi 2018).

Coping with water and sanitation problems, including water infrastructure management, is an urgent development issue in rural Africa that should be addressed by the global community (Ikemi 2017a). Although many projects and studies have been undertaken on sustainable water, sanitation, and hygiene services, only a few could report great achievements (Haq and Cambridge 2012). Ushijima et al. (2015) pointed out the possible reasons for the unsuccessful outcomes of water and sanitation projects as follows: shortage in financial funds, mismatched mechanisms and methods, and lack of understanding of local social and economic conditions. In addition, local residents' active and voluntary participation is necessary to achieving

effective rural development (Chambers 1997). As Chambers (1983) and Ikemi (2017b) emphasized, the success of rural development programs requires professional outsiders, such as researchers and development workers, to seek to understand local residents' knowledge, experience, customs, and values in their daily lives.

The present study aimed to elucidate the actual situation and outcomes of national policies for the management of sustainable water supply in rural Africa through a case study of Senegal. It also sought to clarify the remaining tasks and hidden problems in the outcomes as well as to identify a possible system of effective water management operated by the local community. This study provides the results of field surveys conducted in villages in Senegal. Overall, the rest of this chapter is organized as follows. In the next section, the conditions of the drinking water supply and national policies on water supply management in Senegal are introduced. Section 4.3 describes the outline of the field surveys. Section 4.4 presents the results of the field surveys in detail. In the final section, the findings based on the survey results are summarized, and conclusions are presented.

4.2 Drinking Water Conditions and Water Supply Management Policies in Senegal

With respect to the issue of poor water supply conditions in rural Africa, this research examined the possibilities and challenges related to sustainable water supply management through a case study of Senegal. Senegal is one of the lowest income countries in the world. The global gross domestic product (GDP) per capita in 2018 was 11,381 USD (Statista 2020). In Senegal, the GDP per capita was 1441 USD in the same year (IMF 2019). It was the 155th out of 192 countries in terms of GDP per capita, reporting an even lower value than the average of sub-Saharan Africa countries (1589 USD), which are regarded as the poorest countries in the world (World Bank 2020a). Furthermore, Senegal has significant income inequality between urban and rural areas.

In Senegal, especially in rural areas, the lack of water supply facilities and the heavy burden of water drawing labor have been major concerns for national development. The Senegalese government has taken a number of initiatives to cope with these problems. In 2005, the government launched the program called Millennium Drinking Water and Sanitation Program (Programme d'Eau Potable et d'Assainissement du Millénaire: PEPAM) to improve and expand water production and distribution systems (World Bank 2018). PEPAM had set the specific goal of increasing the access rate of drinking water from 64% (in 2004) to 82% by 2015 (Ministère de l'Agriculture et de l'Hydraulique/Ministère de la Prévention, de l'Hygiène Publique et de l'Assainissement 2005). The Senegalese government also prepared the Poverty Reduction Strategy Paper (PRSP) for 2006–2010 and Economic and Social Policy Document (Document de Politique Economique et Sociale: DPES) for 2011–2015 (IMF 2007; Ministère de l'Economie et des Finances

2011; WFP 2011). The PRSP approach was first suggested at a joint meeting of the International Monetary Fund (IMF) and World Bank in 1999 for poor countries' comprehensive development (Marshall and Walters 2011). For both PRSP and DPES, one of the major goals was to expand access to safe drinking water and sanitation facilities in urban and rural areas. Regarding access to safe drinking water in Senegal, the IMF (2013) reported as follows: "In fact, for the urban populations, the rate rose from 93% in 2006 to 98.797% in 2011. In rural areas, the rate increased from 69.5% in 2006 to 80.1% in 2011." Meanwhile, a more recent joint report by the United Nations Children's Fund (UNICEF) and World Health Organization (WHO) revealed lower access rates to safe drinking water in both urban and rural areas in Senegal, at 93% and 67%, respectively (UNICEF and WHO 2015).

Even the foreign countries that provide official development assistance (ODA) to Senegal have common concerns about these issues. Japan is one of them. The Japan International Cooperation Agency (JICA), which is the Japanese ODA organization, engaged in grant aid cooperation to improve rural water supply in Senegal for over 30 years, from 1979 to 2012. Through this aid, approximately 120 water supply facilities that could provide safe water to approximately 440,000 people in rural areas were constructed (JICA 2015). As for technical cooperation, JICA carried out Project on the Safe Water and the Support on Community Activities (Projet Eau Potable pour Tous et Appui aux Activités Communautaires: PEPTAC). One of the main objectives of PEPTAC was to support the establishment of "water tower users' associations" in Senegal (Association des Usagers du Forage: ASUFOR). Through PEPTAC, JICA has cooperated with many established ASUFORs to provide technical support and allow local residents to maintain and manage water supply facilities by themselves (Japan Techno Co. Ltd. 2015). Generally, one ASUFOR is established in each community to which several villages belong. The main task of the ASUFOR is to engage in the activities of water supply management by maintaining its water tower (see Fig. 4.2). According to Hanatani (2016), the ASUFOR is an institutional mechanism for the rural community in Senegal and has been promoted under the water sector reform since 1996 (Sarr 2008; UNDP 2013). The characteristics of ASUFOR are identified as follows: "i) management body having an independent legal status; ii) use of water meters to enable volumetric water tariff system; and iii) increased private sector involvement in management" (Hanatani 2016: 19).

4.3 Outline of Field Survey

4.3.1 Sites

Senegal (officially, the Republic of Senegal) is a country located in West Africa with a surface area of 196,710 km^2 and a population of about 16 million (World Bank 2020b, c). According to a World Bank report (2020d), in Senegal, the proportion of the population under the international poverty line (defined as living with less than

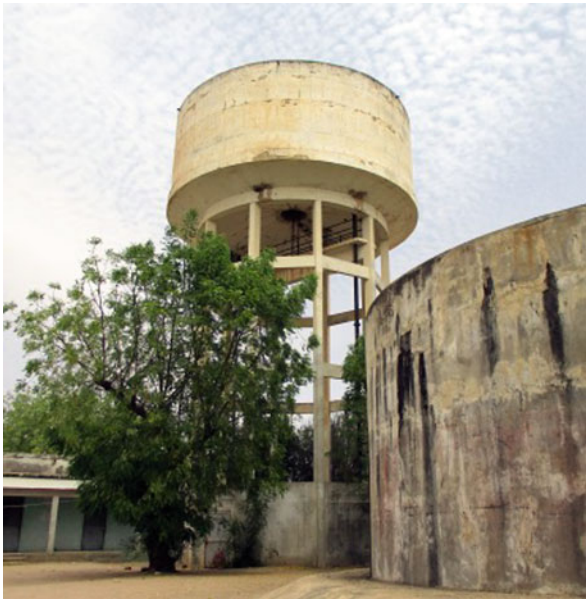

Fig. 4.2 Typical water tower maintained by ASUFORs in rural Senegal. (Photo by Ikemi)

1.9 USD purchasing power parity per day per capita) was 38% in 2011. The report also noted that "460,000 poor people would be added in 2019 to the estimated 5 million poor people in 2011 (63,200 more between 2018 and 2019), due to rapid population growth which has outpaced per capita income growth." Regarding the country's rural areas, the percentage of the rural population to the total population was 77% in 1960, and it decreased to 55.8% in 2011 (World Bank 2020e). Thereafter, it continued to decrease to almost half of the total population (52.3%) in 2019. Among them, 58% lived under the standard of the international poverty line, whereas the rate was 12% in the case of the urban population (World Bank 2020d). The data indicate a significant economic disparity between rural and urban areas. The far more serious poverty problem as well as water supply vulnerability in rural areas compared with urban areas may be one of the causes of the continuous rural population outflow into urban areas.

The research site of this study is the Fatick and Kaolack regions, which are located about 150 km southeast of Dakar, the capital of Senegal. The field research was conducted in six villages in the two regions in March 2017 and October 2018. Figure 4.3 shows the map of Senegal and the locations of the six villages of Tewrou Mbéyéne, Mboudaye, Fissel Deux, Fayil, Ourour Sinthiou, and Fass Koffe. The residents living in these six villages have been facing a severe shortage of infrastructure to use improved water sources, similar to the experience of residents of many other West African rural villages (Nyong and Kanaroglou 1999; Pimentel et al. 2004; Snow 2013; Wijk-Sijbesma 1985).

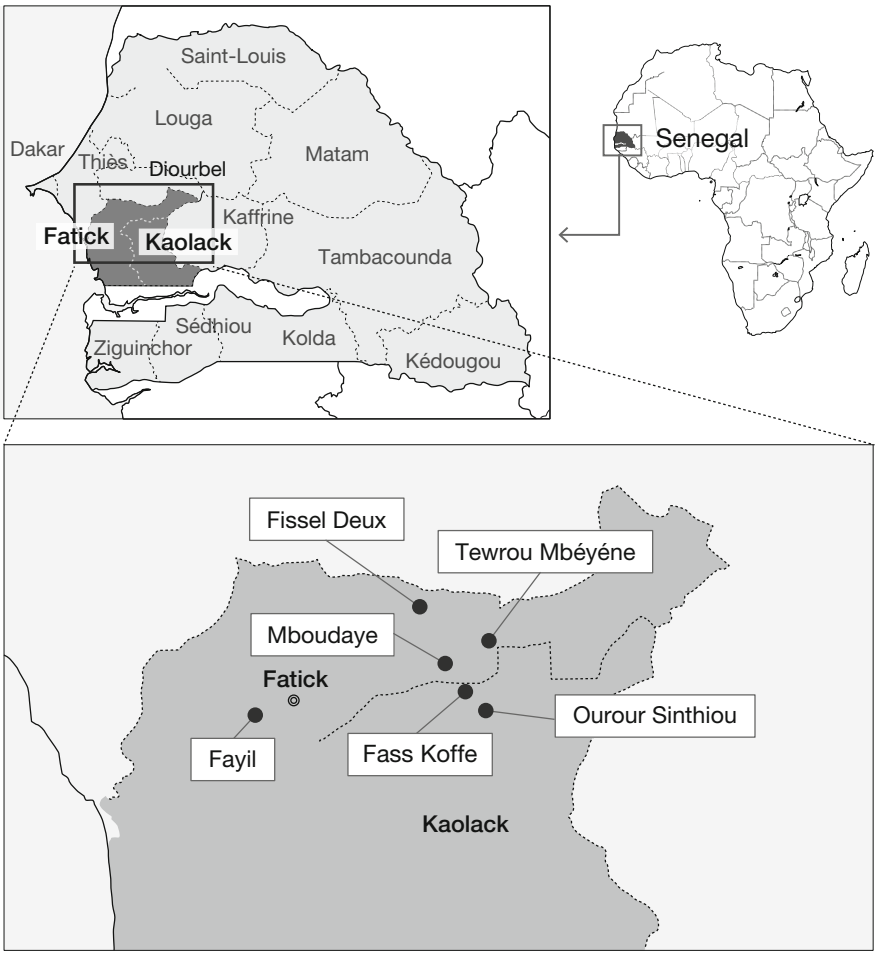

Fig. 4.3 Map of Senegal and location of the six villages included in the field research

4.3.2 Research Methods and Contents

This field research study mainly employed a door-to-door and face-to-face interview survey method. The interview survey was conducted with leaders of each village, representatives of community-based organizations, and other residents. In Senegal, there are generally multiple community-based organizations, including village-level residents' groups and associations. The most common and typical ones are Economic Interest Groups (Groupement d'Intérêt Économique: GIE) and Women's Promotion Groups (Groupement de Promotion Féminine: GPF) that are officially recognized by the government. A GIE is a group of residents working to promote their economic activities and improve their income generation (Ikemi 2017b). A

Table 4.1 Overview of field survey data

Village	Tewrou Mbéyéne	Mboudaye	Fissel Deux	Fayil	Ourour Sinthiou	Fass Koffe
Region	Fatick	Fatick	Fatick	Fatick	Kaolack	Kaolack
Rural community	Ouadiour	Ouadiour	Patar Lia	Diouroup	Ourour	Fass
Population	150	500	166	15,000	537	3000
Availability of electricity	No	No	No	No	Yes	Yes
Number of wells available (No charge)	1	1	2	27	7	0
Fees for filtered water (per 20 L)	200 CFA[a]	200 CFA	400 CFA	300 CFA	150 CFA	150 CFA

[a]100 CFA = 0.17 USD (as of 2018)

GPF is a group organized by women conducting various activities for their income generation, food security, childcare, literacy education, and health and sanitation practices (Ikemi 2011). Participation in these community organizations is a part of their lives, and is often a high priority in their day-to-day efforts. The field surveys targeted the representatives of these community-based organizations as interviewees, because they are well aware of residents' behavior of water use and various water supply-related issues, such as conditions of water supply facilities in their villages.

The survey questionnaire included the following: (1) the number and condition of water supply facilities; (2) the method of maintenance of water supply facilities; (3) the purpose of water use (e.g., drinking, cooking, bathing, washing, and agriculture); (4) the means of drawing and transporting water; (5) the status of activities by the relevant resident organizations and communities; and (6) the problems or needs for general living conditions, such as regional water infrastructure, health, sanitation, economy, and education. The study also observed water supply–related facilities and infrastructure in each village to grasp the situation, including the management by local residents or the community.

Table 4.1 shows an overview of the field survey results from the six villages.[1] The living conditions and current situation of water use differed across the villages. For instance, the number of wells varied from 0 (in Fass Koffe) to 27 (in Fayil), and the fee for filtered water use also varied from 150 CFA (in Fass Koffe and Ourour Sinthiou) to 400 CFA (in Fissel Deux) (100 CFA = 0.17 USD, as of 2018).

[1] All the numbers in Table 4.1 are obtained from the interview survey; no official accurate data are available for most of them.

4.4 Field Survey Results

4.4.1 Piped Water Supply and Water Quality Problem

In terms of the spread of tap water in rural areas, most households in all six villages in this study had a water supply faucet installed. Figure 4.4 shows a typical water supply faucet installed in a household. The residents used tap water by connecting their domestic water faucets to the pipeline connected with a water tower that had been constructed for their community. The water supply tended to be unstable, and the cost of faucet installation was extremely high compared with the average monthly income per capita in rural areas of Senegal. The average cost of domestic faucet installation per household was between 40,000 CFA (about 68 USD) and 65,000 CFA (about 110 USD). Nonetheless, most households had installed domestic faucets to use water at home. This fact indicates a clear achievement of government policy implementation on national development priority issues.

The installation of domestic water faucets for residents in rural areas does not mean that water was always available in their everyday lives. There were two main reasons for this limitation in water use for residents. First, the water supply from the water tower tank in their community was not stable, as mentioned earlier. Second, the faucet water quality was not good enough to be used for drinking or cooking. Faucet water tended to have a high concentration of fluorine, and as such, well water was preferred for drinking in every village. Although preferable for its lower concentration of fluorine, well water also had hygienic safety issues. Generally, before using well water for drinking purposes, the residents had to disinfect it by treating with sodium hypochlorite. During the field research, there were no reports of health problems caused by drinking treated well water. Most of the residents also said that well water tastes good. However, for drinking tap water, some cases of

Fig. 4.4 Water supply faucet installed in a household of rural villages in Senegal (the left photo was taken in the Fissel Deux village chief's yard, and the right photo was taken in the Mboudaye village chief's yard). (Photos by Ikemi)

health problems were reported. According to the Mboudaye village chief, when his daughter returned home after staying outside of the village for a long time, she often drank tap water at home. About 2 days later, she started to have a headache and her legs were hurting so much. Until she stopped drinking tap water, the severe pain lasted such that she could not walk. In Fissel Deux, residents were aware that continuous drinking of tap water would cause adverse health effects, such as dental fluorosis, skin pain, and weakness of the bones and muscles from the excess fluoride in the tap water.

4.4.2 Difficulty in Obtaining Water

Well water is also crucial for the agricultural livelihood of residents in the rural areas of Senegal. Collecting water from a well was reported as troublesome in some villages because of the large depth of some wells. In Tewrou Mbéyéne, there was only one well, and it was 45 m deep. The residents had relied on the well as an important water source for not only drinking but also for crop production. To draw water from this deep well, the residents usually used a donkey and a long rope attached to a bucket (see Fig. 4.5). This traditional method of drawing well water had been practiced in the village for a long time. They had a mechanical water pump that had broken down and never been repaired or replaced owing to budget constraints. The cost of repairing or replacing the pump was simply too much burden to the residents. As shown in Fig. 4.5, the 45 m deep well, the only one in Tewrou Mbéyéne, does not allow the residents to draw water without any support from an animal or a motor engine. It is an urgent task to reduce the burden of drawing well water for the residents in rural areas of Senegal, as the case of Tewrou Mbéyéne highlights. The expansion of water supply facilities, and their sustainable management, will have large impacts for the residents and their communities.

Tewrou Mbéyéne participated in a rural development project supported by a Senegalese institution called National Agency for Agricultural and Rural Council (Agence National de Conseiller Agricole et Rurale: ANCAR) from December 2003

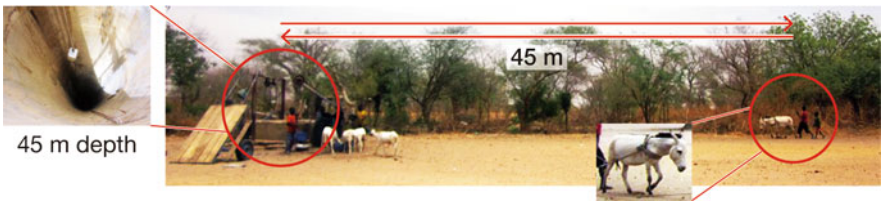

Fig. 4.5 Traditional mechanism of drawing water from a 45-m deep well in Tewrou Mbéyéne. (Photos by Ikemi)

to May 2005.[2] ANCAR carried out a dry-season gardening project to improve the villagers' nutrition and cash income for the community, mainly targeting the village's GIE, which had 40 members (17 men and 23 women) in 2017. At the beginning of the project, the local staff of ANCAR conducted a seminar for the resident participants on basic knowledge and technical guidance relevant to vegetable cultivation. After the seminar, the staff demonstrated how to plant a garden, practically making a pilot field with the participants. The area of the field was gradually expanded, with the type of crops grown being increased as well to include tomato, eggplant, and okra. The management and operation of the field were left up to the participants. The local staff visited the village regularly after the seminar to continue their observation and guidance in the field progress made by the participants themselves. Tools, seeds, and fertilizers were provided by the ANCAR, whereas the other expenses and labor force were provided by the village residents. The project had the following results. First, many of the crops withered even before reaching maturity owing to the insufficient water supply, which itself was because of the undeveloped deep well in the village, as explained above. Second, the residents who positively participated in the activity and worked hard for the project were limited to a few people, such as the family of the village chief and the GIE's president. During the project period, only a few participants put in noticeable efforts, and the group activities of the GIE, a community-based organization, did not seem functional. The necessity of organizational solidarity, and of the role of human resources who possessed leadership skills and influence in the community, was considered to be of great importance. Third, the vegetable crops harvested by the participants were utilized as both food crops and cash crops for the residents of the village. As such, the project implementation could be considered to have led, to some extent, to an improvement in the residents' cash income and nutrition through their participation in the project development.

Thus, the lack of water supply in the village increased the burden of time and labor for the residents to acquire the amount of water they needed. By implication, this situation could be attributed to a lack of water management and may constitute a limiting factor for improvements in income and sanitation. This situation could also hinder their motivation for positive engagement in the activities of their community-based organizations. Meanwhile, the latest field research showed that the president of the GIE installed and started utilizing a new motor pump with a solar-powered engine. This latest finding indicates the possibility of solving the water supply and management problems of the village in the near future (Ikemi 2017b).

[2] ANCAR was established by the government of Senegal in 1999. It is a semiprivate institution co-owned by the government of Senegal, producer organizations, agro-based private actors, and rural governments (USAID and INGENAES 2015).

Fig. 4.6 Water purification device with a reverse osmosis membrane filter and a 20 L plastic container filled with filtered water for sale. (Photos by Ikemi)

4.4.3 Water Supply Management by ASUFOR

As mentioned in Sect. 4.2, several villages come together to form a community in their area, and each community has one ASUFOR. The three main tasks of the ASUFOR are to maintain water supply facilities, collect water usage fees, and manage the association's funds (mostly from the collected water usage fees). Typically, each ASUFOR meets once a month to discuss various issues related to water supply and to collect the water usage fees paid by the residents within the community. During the field research, it was found that not all operations by the ASUFORs lived up to the residents' expectations. As evaluated by the residents, ASUFOR operations had both satisfactory and unsatisfactory cases. The satisfactory case of Fass Koffe (the ASUFOR of Fass community) is introduced first, followed by the unsatisfactory cases of Mboudaye and Tewrou Mbéyéne (the ASUFOR of Ouadiour community).

The ASUFOR of Fass community (hereafter, Fass-ASUFOR), to which Fass Koffe belongs, had regular monthly meetings and collected water charges. The raised funds were used to purchase a water purification device with a reverse osmosis membrane filter, after a transparent discussion and agreement with the residents. Figure 4.6 shows the device and a 20-L plastic container filled with filtered water by the device. The filtered water was sold at 150 CFA (about 0.25 USD) per 20 L. The average daily sales of filtered water reached about 10,000 CFA, equivalent to two tons of purified water produced by the device. The biggest reason for the sale of so much purified water was the residents' strong distrust of the tap water in their homes. Although the residents did not have much financial leeway and the place where they could buy the purified water was a little far from their houses, they were willing to travel and pay for safe drinking water. The residents positively assessed the operation by the Fass-ASUFOR according to the following three perspectives. The first perspective was that the ASUFOR provided safe drinking water, which the residents always needed for their health in everyday life. Second, the ASUFOR's increased funds by selling purified clean water to the residents enabled it to provide a stable

and sustainable clean water supply service. Third, all of the participants (representatives of each village) in the regular monthly meeting held by the Fass-ASUFOR were allowed to take part in the decision-making process.

In contrast, the residents in Mboudaye and Tewrou Mbéyéne reported that the operation by the ASUFOR of Ouadiour community (hereafter, Ouadiour-ASUFOR), to which both villages belong, failed to meet their expectations. Like all other ASUFORs, the Ouadiour-ASUFOR has held a meeting every month since being established. Monthly meetings were the only opportunity for all village representatives to discuss water-related issues in their community and monitor the status of the Ouadiour-ASUFOR's funds. The residents were particularly interested in their ASUFOR's profits from providing faucet water and its expenses for the maintenance of water supply facilities. Without warning and clear reasons, local administration officials decided to ignore the principle of the ASUFOR's transparent decision-making process. The regular monthly meetings were no longer held, which prevented the residents from grasping the operational status of their ASUFOR. The decision resulted in mounting complaints from the Ouadiour community residents, who felt they were not receiving enough services from their ASUFOR relative to the fees they paid for their water use. This case implies the importance of transparent decision making and autonomous management by the community.

4.4.4 Self-Help Efforts for Water Supply Management

The following cases of the residents' voluntary and proactive efforts were obtained through the interview and observation survey conducted in this study. In Fissel Deux, the residents helped one another by allowing the lending of money from the village's mutual credit fund, managed by the microfinance institution of Senegal for the development of rural areas, for the installation of water pipes to use tap water at home. Although the villagers' income level was relatively low, they had been working tirelessly to maintain the funds not only for their village development but also for mutual financial aid among themselves.

The study identified other cases of self-management of water resources in other villages as well. For example, in Fayil, only seven out of 27 wells were used, and most of the seven wells were as shallow as to easily run dry. Moreover, the population of Fayil was the largest among the six villages surveyed in this study (see Table 4.1). As mentioned earlier, residents preferred to use well water for drinking and cooking purposes; however, the amount of available water was too limited to fulfill the demand. The well water shortage problem posed a serious challenge to the village. To confront the challenge, the village enacted the following rules to control the use of well water: (1) limiting each household to only one bucket of water (regardless of size) and (2) restricting the hours for drawing well water (between 7 and 10 am or until the well is empty). The villagers organized a group of seven women living close to each of the seven available wells in the village to ensure compliance with the rules. The group's main role was to manage the wells and

Fig. 4.7 Well covered with an iron grate in Fayil. (Photos by Ikemi)

enforce the rules. Each well was covered by an iron grate and locked all day except for the 3 h for drawing water in the morning (see Fig. 4.7). During the dry season in Senegal, the line of villagers waiting to draw water in front of the well is already long even before 7 am. Drawing water often takes an hour or more during the dry season; in other seasons, it does not take that much time. The village's measures enabled the residents to cope with the problem of well water shortage through their own efforts.

Another example of self-management is that by the residents in Ourour Sintiou. The villagers maintained and repaired nearby wells by themselves. They also shared the cost of purchasing the tools and materials needed for maintaining the wells, such as ropes, cement, and steel slags. Among the total of seven wells in the village, three were closed by the villagers themselves for safety reasons (mainly poor water quality). According to the villagers, there was an instance in which they closed a well after a domestic animal fell into it. The residents in both Fayil and Ourour Sintiou were actively working to manage well water resources for the sake of sustainable and safe water use. These cases are good examples of the residents' self-management of water resources, without relying on the support of local bureaucrats or outside sponsors, in rural areas of Senegal.

4.5 Summary and Conclusions

Various international organizations, including the UN, World Bank, and WHO, have made numerous efforts to expand water supply and sanitation services in rural Africa. They have also published several reports and papers promoting this issue. Governments of African countries have recognized the importance of the issue and have implemented relevant policies. Based on these international efforts, the present study aimed to evaluate and shed light on the outcomes of national policies for improving water supply management in rural Africa. Field surveys were conducted in six villages in rural areas of Senegal. This case study examined the actual conditions of water supply facilities and residents' water use in the six villages.

From the results of the field surveys, this case study also attempted to identify the remaining challenges for sustainable water management by local communities in rural Africa.

In summarizing the findings from the field surveys, the following conclusions can be drawn. First, the Senegalese government has reported significant achievements in expanding water supply facilities and reducing the burden of drawing water from those facilities for rural populations. The government and international organizations have claimed that the implementation of relevant national policies has led to more residents in rural areas being able to access drinking water resources. However, according to the field survey results, the policies for improving access to safe drinking water resources for rural populations in Senegal were not completely successful. Under the national policy of expanding water supply facilities, it is true that most households could have access to tap water. However, a number of villagers reported health issues caused by the unsanitary water from their faucets. Therefore, they still had no choice but to rely on well water for drinking and cooking purposes. As such, the burden of labor from drawing well water was not reduced. The survey results emphasize that improving water quality is as crucial as expanding water supply facilities in rural Africa.

Second, in addition to the water quality problem, many rural residents faced the challenges entailed in the inadequate management of water supply facilities. Despite their poor circumstances, the residents made great efforts to overcome these challenges without relying on the support of local bureaucrats or sponsors outside the village. They helped one another financially through their mutual credit fund for better access to tap water. As for drinking water, they followed their own rules to control the use of well water. They also maintained and repaired nearby wells by themselves, and even shared the cost of maintenance. For the sustainable self-management of water resources in rural Africa, this case study suggests the importance of locals' transparent management, information sharing, mutual trust, and consideration for their neighbors. Moreover, the rural residents showed great potential to improve their current water environment through their own self-help efforts. Such potential should be considered as crucial to achieve the goal of sustainable water supply management in local communities.

Lastly, a remaining challenge is in sustaining the management of technologies related to water supply in rural Africa. This issue cannot be addressed within an administrative framework or national policy. When introducing technology, it is necessary to make policy decisions and provide administrative financial support that are suitable for the actual conditions of rural areas. When new equipment and technologies are introduced, various forms of social organizations that can function practically are needed, as in the cases of the ASUFORs and GIEs in Senegal.

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Chapter 5
Gender and Culture Matters: Considerations for Menstrual Hygiene Management

Elli W. Sugita

Abstract Menstruation hygiene management (MHM) is an important factor in gender-sensitive sanitation promotion. MHM is a concept and an approach in international development that gained greater attention in the last decade. This chapter first reviews the development of MHM (also recently referred to as menstrual health and hygiene: MHH) as an international agenda. The second part focuses on the cultural aspects of menstruation. To illuminate the local reality and cultural context of female students in a secondary school, a case study from the Manafwa district in Uganda will be described. The research results show that seemingly simple behaviors associated with menstrual management pass through the filter of cultural norms and girls' perceptions. Those behaviors include (1) changing menstrual absorbents, (2) using a latrine, (3) discarding used sanitary pads or other sanitary items, (4) washing menstrual items or underwear, and (5) drying them. The chapter will provide some recommendations for MHM interventions.

Keywords Menstrual Hygiene Management (MHM) · Cultural contexts · Taboo · Uganda

5.1 Introduction

When considering sanitation, gender should be an important aspect as men and women share about half the world population and they have different needs for sanitation. The importance of gender issues in sanitation promotion was already recognized in the International Year of Sanitation (IYS) in 2008. One of the five key messages of the IYS, "sanitation contributes to social development," was further elaborated as follows: "Where sanitation facilities and hygienic behavior are present, rates of illness drop, malnutrition in children is reduced, more children, especially girls, attend school and learn better, and women's safety and dignity are improved"

E. W. Sugita (✉)
Faculty of Human Sciences, Osaka University, Suita, Osaka, Japan
e-mail: ellisugita@hus.osaka-u.ac.jp

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(UN Water 2008: 8). Although the privacy, safety, and dignity of girls and women were mentioned, menstruation—a prime factor of privacy, safety, and dignity—was not discussed in detail.

Menstruation is a universal physiological phenomenon experienced by the female body. It refers to the regular monthly bleeding from the endometrium that occurs throughout a female's reproductive lifecycle, apart from the gestational period and the puerperal period. Menstruation plays an important role as a female reproductive function and is closely linked to female health. At the same time, there are various issues for a woman to cope with menstruation.

It was mainly through the discussion process of setting the Sustainable Development Goals (SDGs) that the importance of menstrual hygiene management (MHM) became commonly recognized in international development. It became clear that menstruation-related issues need to be addressed as a development agenda from various aspects, such as achieving gender equality, promoting girls' education, improving women's reproductive health, and improving access to safe water and sanitation. UNICEF and NGOs initiated promotion and interventions of MHM.

On the other hand, menstruation is a domain that is often kept hidden in many societies. Talking about menstruation and disclosing that a woman is menstruating are often considered taboo (Akiho 2019; Mason et al. 2013). In some societies, it may not be a cultural taboo, but their social context makes them uncomfortable or shy to mention menstruation. Since menstruation is a phenomenon unique to women, it is hidden especially from men, and this has led to men not having enough knowledge about menstruation (Ishikawa and Sugiura 2011; Rajak 2015). Some argue that these were the reasons menstrual issues were set aside from the mainstream of international development (Tilley et al. 2013).

It is not just hidden, but there are many taboos surrounding menstruation, and it has various connotations depending on the culture. This makes it even more pertinent to understand local contexts of menstruation when large-scale international development assistance is considered.

In this chapter, the first objective is to review the development of MHM as an international agenda. The second objective is to highlight the cultural aspects of menstruation. A case study will focus on MHM in Uganda and the local reality of female students in a rural high school. I hope these will provide a concrete understanding of why gender, especially menstrual issues, and culture are important in both MHM and sanitation promotion. I will extract recommendations for interventions at the end.

5.2 Menstrual Hygiene Management as a Development Issue

5.2.1 Definitions of MHM

I will start by presenting the definition of "menstrual hygiene management (MHM)," which has now become a common jargon in international development. Later in this section, I will also touch on the newer phrase "menstrual health and hygiene (MHH)" that some organizations have started to use.

The first appearance of the phrase MHM with the acronym in an international meeting was in 2005 at a roundtable meeting hosted by the International Water and Sanitation Centre (IRC) and UNICEF (UNICEF and IRC 2005). However, it took some time for the concept to be recognized and widely understood. The definition of MHM varies depending on the organization and on the documents even within the same organization. One of the earliest and frequently cited definitions would be the following by the WHO and UNICEF Joint Monitoring Programme for Drinking Water, Sanitation and Hygiene (in short, JMP):

> Women and adolescent girls are using a clean menstrual management material to absorb or collect menstrual blood, that can be changed in privacy as often as necessary for the duration of a menstrual period, using soap and water for washing the body as required, and having access to safe and convenient facilities to dispose of used menstrual management materials. (WHO and UNICEF 2012: 16)

WHO and UNICEF (2012) in the same document further identified five preconditions for the above. The first point was about knowledge, suggesting "access to accurate and pragmatic information (for females and males) about menstruation and menstrual hygiene" (ibid). The other four points were materials and physical environment necessary to realize the above. Included were menstrual hygiene materials (such as sanitary pads), facilities that provide privacy for changing menstrual materials and for washing the body, water and soap for washing clothes and drying, and disposal facilities (ibid).

UNESCO (2014) proposed to include broader and systemic issues surrounding girls and women for MHM. They were summarized in the eight points below:

1. Accurate and timely knowledge
2. Available, safe, and affordable materials
3. Sanitation and washing facilities
4. Safe and hygienic disposal
5. Informed and comfortable profession
6. Referral and access to health services
7. Positive social norms
8. Advocacy and policy (UNESCO 2014: 31)

A new concept encompassing both the original definition of MHM by WHO and UNICEF (2012) and the broader systemic factors suggested by UNESCO (2014) is termed "menstrual health and hygiene (MHH)." As the title of the recently issued

Guidance on Menstrual Health and Hygiene (UNICEF 2019) indicates, UNICEF nowadays uses the term MHH rather than MHM. Menstrual health and hygiene, according to UNICEF (2019), is a broader concept linking menstruation with health, well-being, gender equality, education, equity, empowerment, and rights. Some NGOs, such as Save the Children, also started using the label MHH, while some organizations use the term "menstrual health." Although the concept is expanding, in this chapter, I will use the word MHM, since this was the term that drew international attention and the majority of the organizations still uses it.

5.2.2 *Formation of MHM as a Development Agenda and Its Relation with SDGs*

Menstruation was a topic rarely discussed openly as an international agenda. It should be noted, however, that there were development projects and volunteer activities aimed at supporting women and girls with menstrual management. For example, NGOs have developed educational materials, disseminated reusable sanitary pads, or supported constructing incinerators for discarded pads (House et al. 2012). I once visited a Japanese Overseas Cooperation Volunteer in Bangladesh to observe her activities; she was providing local women with technical guidance on how to sew reusable cloth pads.

One of the early large-scale interventions was in 2009 when UNICEF conducted a pilot project producing and disseminating a supplement book titled "Growth and changes" (Sommer 2009) for adolescent schoolgirls in Tanzania. The booklet provided practical information on menstruation, and it was approved by the Ministry of Education in 2010 to be used in the primary school curriculum. This project expanded to other countries as well.

The most significant trigger of the new trend of menstruation becoming a major agenda in international development was when discussions started about post-Millennium Development Goals (MDGs), which later was named Sustainable Development Goals. In 2011, the water, sanitation, and hygiene (WASH) sector held an international conference to discuss the new goals. Here, menstruation was taken up as one of the issues in sanitation and hygiene (WHO and UNICEF 2012). Based on a review of MDGs, the principles of SDGs became disparity reduction and inclusive development. It was agreed that sanitation facilities need to be accessible for girls and women during their menstruation as well. Also, in the examination of the concept of hygiene, menstrual hygiene was identified as a part of improved hygiene (Tilley et al. 2013). The notion that the difficulty of coping with menstruation was a cause for girls' school absenteeism made menstrual management an agenda for the education sector as well (Sommer et al. 2014).

In 2012, the London-based research consortium Sanitation and Hygiene Applied Research for Equity (SHARE) and WaterAid, a major international NGO, published a detailed manual for practitioners to promote menstrual hygiene (House et al. 2012).

Table 5.1 SDG goals and targets related to gender-sensitive sanitation (United Nations 2015: 18; underlined by the author)

Goal 6	Target 6.2: By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations
Goal 4	Target 4.a: Build and upgrade education facilities that are child-, disability-, and gender-sensitive and provide safe, nonviolent, inclusive, and effective learning environments for all

WASH United, a nonprofit organization headquartered in Germany, also played an important role in advocacy; it proposed to designate 28 May as Menstrual Hygiene Day to raise awareness of MHM, and the first Day was commenced in 2014 (WASH United 2020). The date (28th day of the fifth month) was chosen, because the average menstrual cycle is 28 days and blood flow will continue for about 5 days. It was also in 2014 when the above-mentioned guideline on MHM was published by UNESCO (2014). With the slogan "Break the Silence," active discussions and initiatives on menstruation were held internationally (WASHplus Blog 2015). It was around this time that the acronym MHM came to be widely used and became jargon in international development.

The goals of the SDGs were adopted at the general assembly of the United Nations in 2015. The term menstrual management itself was not included in the goals or targets, but MHM is said to be closely related to the following goals (Tiwari 2018; WASH United 2019a, b).

- Goal 3: Ensure healthy lives and promote well-being for all at all ages.
- Goal 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
- Goal 5: Achieve gender equality and empower all women and girls.
- Goal 6: Ensure availability and sustainable management of water and sanitation for all.
- Goal 8: Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all.
- Goal 12: Ensure sustainable consumption and production patterns.

In particular, target 6.2. in Goal 6 explicitly requires sanitation and hygiene to be gender-sensitive (see Table 5.1). The concept of hygiene in target 6.2 further explained by JMP includes menstrual hygiene management (WHO and UNICEF 2017: 2). JMP requires improved sanitation at a health-care facility to have at least one sex-separated toilet with menstrual hygiene facilities. Target 4.a in Goal 4 also implied a school sanitation facility that is gender-sensitive. The SDGs monitoring program guideline on school sanitation and hygiene included menstrual hygiene in their checklist (UNICEF and WHO 2016).

5.2.3 Why MHM Is Important: Research Background

A major reason why menstrual management caught the attention of international development organizations was studies showing that menstruation was causing school absenteeism among female students (Sahin 2015; Sommer and Sahin 2013). For example, research conducted in Malawi showed that one-third of the female students said they were absent from school at least 1 day during their last menstruation (Grant et al. 2013). Another study in northern Ethiopia found that more than half of the girls claimed they had been absent from school due to menstruation, with 39% of the girls saying their academic ability had declined since their menarche (Tegegne and Sisay 2014). About 20% of Ugandan girls in a survey experienced menstrual blood leaking into their uniforms, and this was the major cause for missing school during menstruation due to fear and embarrassment that they may be teased again (Miiro et al. 2018).

For girls at school, sanitation facilities are crucial spaces for changing their absorbents. When girls are able to freely access gender-separated latrines at school, girls were less likely to miss school during their menstruation (Alam et al. 2017). A study on school sanitation (toilets) found that students use of the facility was associated with conditions such as pupil to toilet ratio, toilet type, how new the toilet was, and possibly its cleanliness, especially among girls (Garn et al. 2014). There is also a study reporting that a quarter of the studied girls accidentally dropped their menstrual items at school latrines, and 24% of them brushed/washed the item and reused it (Oduor 2015).

In addition, a lack of knowledge about menstruation especially among adolescent girls was identified by numerous studies. Many girls do not know about menstruation until the first menstruation; for example, 60.3% of the girls surveyed in India said they came to know about menstruation for the first time only at menarche (Shah et al. 2013). They also did not fully understand where menstrual blood came from. Adolescent girls generally lack knowledge of menstruation was the conclusion of a systematic review of 44 studies on menstrual knowledge of girls, aged 10–14 years old, in low- and middle-income countries (Coast et al. 2019).

These results seem to reveal the needs for MHM; with improvements in sanitation facilities in schools leading to an increase in attendance rates among girls (WaterAid and Tearfund 2002). When a teacher or a nurse held classes about MHM, not only did the knowledge about menstruation increase but also the proportion of the students who perceive menstruation as annoying decreased (Hennegan and Montgomery 2016; Su and Lindell 2016). It has also been suggested that the presence or absence of premenstrual education may affect adolescent dysmenorrhea (Chhabra et al. 2017).

However, statistical correlation and causal relationship between school absenteeism and access to menstrual pads or sanitation facilities are up for debate. The impact of MHM interventions is also yielding mixed results. For example, a study found that the distribution of sanitary products in intervention projects did not significantly affect school attendance among female students (Hennegan and Montgomery 2016).

The mixed results could be mainly due to research methodology and measurement issues (Phillips-Howard et al. 2016), while they could be due to the design of the intervention including adaptation to cultural context.

It is important to note that it was not just the recognition of the research on local situations that pushed MHM to an international agenda. Private companies that manufacture female sanitary products also played a role (Sommer et al. 2015). Media also highlighted social entrepreneurs for developing menstrual products with "appropriate technology."

Another aspect that requires further consideration is how the concept of MHM is treating local culture. When UNICEF supported the production of the menstrual education handbook for schoolgirls in 2009, it avoided referring to local cultures and taboos, which led to the approval and dissemination by the Tanzanian government. In 2014, when the broader concept of MHM was proposed, "positive social norms" was one of the eight aspects of MHM (UNESCO 2014). The document explains that taboo, shame, myths, and misconceptions continuing to flourish are obstacles for policy formation as well as health and educational professionals. Those norms and beliefs have their roots in a socio-cultural context, so simply negating them may induce some side effects. The next section further discusses this issue.

5.3 Cultural Issues: Menstruation Embedded in Socio-Cultural Context

Menstruation is not just a bodily but also a socio-cultural occurrence. In other words, a woman experiences menstruation in accordance with the social and cultural values attributed to it locally (Matsuo 2007; Namihira 2009). Each society has its customs and taboos related to menstruation, and the perception and management of menstruation can vary from one culture to another.

For example, a girl's menarche in some societies is perceived not only as a sign that she has joined adulthood but also entering a new stage eligible for marriage. A rite of passage to celebrate the menarche would be conducted in a community (Buckley and Gottlieb 1988). Menstruation is a symbol of fertility and the ability to reproduce.

Contrariwise, menstruation, menstrual blood, or menstruating women are often perceived as dirty, polluted, and dangerous. These seemingly opposite perceptions can coexist in the same culture, which makes menstruation an ambiguous phenomenon. Many cultures, which associate menstruation with pollution, restrict some daily activities of menstruating women as taboo from the fear that those activities may spread the pollution and cause undesirable effects (Briffault 1927; Buckley and Gottlieb 1988; Douglas 1966). Actually, it is said that the word "taboo" originally came from the Polynesian word "*tapu*," which was associated with "menstruation" (Briffault 1927). This shows that menstruation and taboo are closely connected to each other. For example, women in India are forbidden from worshipping at Hindu

temples or performing any rituals while menstruating (Matsuo 2007). In Japan, menstruation, along with childbirth, has been perceived as unclean, and there are reports that the custom of isolating menstruating women in menstrual huts and restricting their daily activities continued in many regions of Japan even after the second world war (Namihira 2009).

Taboos related to menstrual blood influence the handling of used sanitary pads or other absorbents. For example, most female students in Indonesia use manufactured disposable sanitary pads with polymer, yet they do not discard used ones without washing off the blood. Menstrual blood is considered impure and should be washed off (Oguni 2019). The students do not change the pads at school toilets, because the facilities do not allow them to wash and discard the stained pads in an "appropriate" manner. Another research with adolescent girls in Gambia depicts that they are restricted from burning used sanitary pads saying that this can lead to their infertility (Shah et al. 2019).

Local material culture for menstrual blood absorbents also varies. In addition to the rather recent products such as manufactured disposable pads, reusable pads, and menstrual cups, there are different materials utilized for managing the flow. Some are traditional and some are improvised from whatever materials available. Included are used clothes, cottonseed, felt, banana stem fibers, papyrus fibers, plant leaves or ears, the dung of domestic animals, tissue paper, newspaper, notebook scraps, or sponge from bed mattresses. How those materials are used or discarded are shaped by the perceptions on menstruation and menstrual blood, in addition to the economic affordability.

Cultural taboos, materials, and perceptions are not intrinsic to or static in a society, as in the case of Japan (Namihira 2009; Tanaka 2013). Tanaka (2013) argues the development of new menstrual pads and strategic advertisement of the products had changed the perception of menstruation in Japan. In rural Papua New Guinea, the discontinuation of the custom of isolating women in menstrual huts in the early 2000s coincided with the spread of using disposable sanitary pads (Shinmoto 2013, 2019). Until then, everyone in the community knew which woman was menstruating due to the practice of secluding them in menstrual huts, but the use of disposable sanitary pads transformed menstruation into a hidden domain. These cases suggest that culture can change; a shift in material culture may have brought a change in cultural customs and perceptions on menstruation in the society.

Culture can change, yet in dealing with the current condition of women's menstrual management, it is important to understand the local socio-cultural context in which menstruation is embedded (Sato 2019). Taboos surrounding menstruating women and menstrual blood still remain strong in many cultures. There are even cases reported where modern technology and medicalization are used to accommodate cultural taboos and result in reinforcing them. For example, contraceptive pills are used for delaying menstruation so that women can go to a ceremony in a Hindu temple (Matsuo 2007). Cultural taboos, as well as cultural knowledge, shape how women experience menstruation and how they manage it.

5.4 A Case Study from Uganda

5.4.1 Purpose of the Case Study

The purpose of this case study is to understand one of the local realities in a certain area, in this case, rural Uganda. Uganda was one of the earliest countries where political leaders made commitments on MHM for schoolgirls. Nonetheless, the delivery of such a decision takes time to reach the grassroots level, not just in Uganda but in any country or region. Since my focus is to understand how cultural issues shape the behavior related to menstruation, I will present here the situation in 2014 before any intervention reached the research site in Manafwa district, eastern Uganda. I will describe a detailed account of the conditions of menstruation among female students in the target area: how they perceive it, what is considered taboo, how do female students learn about menstruation, and what is their experience of menstruation.

5.4.2 Research Area

The fieldwork of the case study described in this chapter was conducted in Uganda. Uganda is located in eastern Africa and its GNI per capita as of 2019 was USD 789 (World Bank 2021). Its population is 41.6 million with 75.6% residing in rural areas (Uganda Bureau of Statistics 2020), and it consists of about 50 ethnic groups. In terms of basic sanitation coverage, it was 18.49% in 2017 according to the newest available data (WHO and UNICEF 2021).

Uganda was one of the earliest countries where politicians and government officials at the ministerial level recognized the importance of MHM in response to the advocacy of NGOs and international organizations. In August 2014, an international conference on MHM was held where the Minister of Education & Sports (who happened to be a woman) emphasized the importance of tackling menstruation-related problems among girls (NETWAS Uganda 2014). In 2015, "the Menstrual Hygiene Management Charter" was endorsed by the ministries and civil organizations and launched by the speaker of parliament (Ministry of Education, Science, Technology and Sports, Government of Uganda 2015). The ministries that signed the charter included the Ministry of Education, Science, Technology and Sports, Ministry of Gender, Labour and Social Development, Ministry of Water and Environment, Ministry of Health, and Ministry of Local Government. Though there was criticism that these policies lack financial backing and that it will take time for measures to reach schools throughout the country, they are considered to be examples of a national policy (Snel 2015).

The research site is in a rural area of Manafwa District located in eastern Uganda, and it was not affected by such MHM policy by early 2015. No real intervention had reached the school, which was the target of my study. The study site is located in a

Fig. 5.1 Map of the research site in Uganda

hilly area at an altitude of 1450–1600 m near the border with Kenya (see Fig. 5.1). The area is at the foot of Mt. Elgon, which has the fourth highest altitude in Africa (more than 4300-m high). The main occupation of the villagers is farmers, with matoke and maize being their staple foods. The area had no piped water at the time of research and had only boreholes with hand pumps that were shared by the community. The ubiquitous type of sanitation was pit latrines (a basic sanitation facility consisting of a hole in the ground to collect human waste with walls for privacy).

More than 90% of the village population belongs to the Gisu ethnic group (also known as Bamasaba) of the Bantu people. Mt. Elgon is considered to be a holy mountain and the birthplace of the earliest ancestors of their ethnic group. Masaba is the name of their mythical founder, and Mt. Elgon is called Mt. Masaba in the native language.

The secondary school that was the target of this study is the only government school in its subcounty. The school system in Uganda comprises 7 years of primary school, 4 years of secondary school-Ordinary level (O-level), and 2 years of secondary school-Advanced level (A-level). The target school imparts both Ordinary and Advanced level education, with a total of about 1700 students in those 6 years. The school has a rainwater tank that dries up in the dry season. The students also use the community borehole located behind the school.

5.4.3 Research Methods

Data was collected by combining several research methods, namely (1) questionnaire survey ($n = 90$) targeting third- and fourth-year female students in O-level, (2) focus group discussions (three groups) by selecting students ($n = 26$ in total) from among the participants of the questionnaire survey, (3) interviews with female teachers, (4) interviews with local female residents, (5) an interview with the owner of the only store selling sanitary pads in the area (apart from local weekly markets). Information was collected from local residents in order to understand the differences in customs between generations and the traditional way of managing menstruation.

5.4.4 Code Language

In order to understand the perception of menstruation in Gisu culture, I started by asking how menstruation is referred to. In the Gisu language, the phrase generally used for going through the menstrual period is "going to Mt. Masaba" (*khutsa iMasaba*). When asked why they use this expression, the female students could not give an explanation, but only said, "That is what has been said for a long time." Many of the older village women also did not know the reason, but some mentioned that the phrase had its origin in thoughts such as "Menstruation is as difficult as climbing Mt. Masaba" and "Mt. Masaba appears red in color on a moon-lit night." The expression of going to the sacred mountain where the ancestors of the Gisu people were born can be interpreted as indicating awe associated with the sacred mountain and its connection with procreation.

There is another expression commonly used to express menstruation: "monthly illness" (*khuluwara mumwesi*). As the phrase suggests, it literally means an illness that comes every month. It is interesting to note that a negative expression, illness, coexists with the contrasting expression "going to the sacred mountain" for referring to menstruation.

There also exists some code words that can only be understood by the female students; they use these words when in the company of male students and villagers. For example, the abbreviation for a Member of Parliament (MP) is used as a pun to refer to the Menstrual Period (MP). The female students further use the pun to play on words by saying, "I'm in an election campaign right now" when talking about their menstrual period. In another example, a sanitary pad is sometimes called "bread," and going to a kiosk (general store) to buy sanitary pads is called "going to buy bread."

The fact that such code words exist implies the society to which the female students belong is making the students uncomfortable about others knowing that they are in their period. As I will describe later, the reason why they do not want others to know is not only because of embarrassment but also because they fear it will lead to sorcery on them.

5.4.5 Taboos Surrounding Menstruation

In Gisu culture, there are a number of actions that are considered taboo for menstruating women. In the focus group discussions, high school girls mentioned many such actions, although some taboos did not necessarily have a high consensus. For example, after some students mentioned a certain taboo, some other students reacted, "I heard that this is actually okay" or "Really? Is that a taboo?" In other words, there seem to be variations among individuals regarding what is considered taboo.

Table 5.2 lists the main taboos mentioned by the students. The list contains items that either all or a majority of the participants agreed to as being taboo. From the list of taboos, several broad categories emerge, which can be divided into the following:

One category of taboos is related to agricultural production. Forbidden were menstruating women going into groundnut, sweet potato, or pumpkin fields, and doing agricultural work, for example, seed planting, weeding, and harvesting in those fields. Some said just passing those fields should be avoided. It is believed that if a menstruating woman went to the field, the crops will dry or it will lead to a poor harvest. Similarly, climbing mango, avocado, and jackfruit trees will either spoil the fruit or lead to a low harvest. Though these crops are not staples in eastern Uganda, they are still commonly grown in this region.

There are also taboos related to drinking and eating. It is believed that drinking liquids other than water, such as milk, tea, or soda (carbonated drinks such as cola), will cause heavy blood flow and such drinks should be avoided during menstruation. Some said that if soda is offered to them (which is a luxury beverage for a high school student), they take it home on the pretext that, "I want to drink it slowly later," and keep it at home until their period ends. Eating sugarcane is also forbidden during menstruation but that could be because of its high water content, which replenishes body fluids. Some said eating fried beans is also taboo during their period, though they could not give a reason for it. But in most cases, students seem to have their own physiological interpretation of the drinking and eating taboos.

The majority of the population in this area is Christian, and taboos related to the church also exist. It is believed that going to church and participating in activities such as the church choir or touching the Bible during menstruation would desecrate Jesus. Some students said that the church minister taught them that menstruating women should not come to church. However, some students argued that it was not taboo to touch the Bible during menstruation, and a heated debate ensued among the students during the focus group discussions. One counterargument was if you have a pad, you can go to the church. There was also an account that it is not possible to participate in the choir, which entails dancing in Ugandan churches, because of their severe back pain during their period.

Fairly strong taboos were noted regarding objects that had once absorbed menstrual blood. It is said that underwear or cloth used as a menstrual blood absorbent cannot be dried outside even after washing them with soap. Moreover, everyone agreed that discarding used sanitary pads or cloth used as an absorbent within the reach of people (and dogs) is "absolutely unacceptable." In either case, it is believed

Table 5.2 Acts considered taboo during menstruation

Acts	Reason given by the students
Taboos related to agriculture	
Seed planting, weeding, harvesting of groundnuts	Groundnuts will dry or lead to a poor harvest
Crossing groundnuts field	Groundnuts will dry
Planting, weeding, harvesting of sweet potato	Sweet potato will dry or lead to a poor harvest
Seed planting of pumpkin (but harvesting pumpkin is not a taboo)	Pumpkin will dry
Crossing pumpkin fields	Pumpkin will dry
Climbing mango, avocado, and jackfruit trees	Fruit will be spoiled or lead to a low harvest
Taboos related to drinking and eating	
Drinking milk	Heavier blood flow
Drinking straight tea	Heavier blood flow
Drinking soda	Heavier blood flow
Eating sugarcane	Heavier blood flow
Eating fried beans	(No explanation)
Taboos related to church	
Going to church	You are unclean and can desecrate God
Participating in the Communion service	You are unclean
Participating in the church choir	You are unclean
Touching the Bible	Menstrual blood can mix with the blood of Jesus, desecrating him
Taboos related to handling menstrual blood absorbents	
Drying the cloth used as a menstrual blood absorbent outside after washing	A girl who does so is dirty It can be taken and used to cast an evil spell (and the female may become infertile)
Drying the underwear (knickers) used as a menstrual blood absorbent outside after washing	It can be seen by father and uncles It can be taken and used to cast an evil spell (and the female may become infertile)
Discarding used pads or absorbents anywhere other than into a pit latrine	It can be taken and used to cast an evil spell (and the female may become infertile)
Other taboos	
Cooking	You are unclean
Heavy work such as splitting firewood	Heavier blood flow
Playing in rivers	Heavier blood flow
Riding a bicycle	A rat can eat the saddle of the bicycle

that the objects that have (or had) menstrual blood can be taken to a person with malicious intent (mainly witch doctors) and be used to cast an evil spell. According to the students, the worst case is that a woman can become infertile as a result of the spell. It is not just the young students who had this fear, but also older women in the village. During my interview with a housewife with two children, she said:

> One day I happened to leave my underwear on the outdoor drying line and it went missing. This made me very anxious. So, when I became pregnant, I heaved a sigh of relief that my missing underwear had not been used to bewitch me.

This fear of being bewitched is why careful attention is paid to the methods of washing and drying underwear with menstrual blood and cloth used as menstrual blood absorbent, as well as the disposal of used sanitary pads or any other absorbents.

Other taboos that came up during the discussions but with lower consensus were cooking, heavy work such as splitting firewood, playing in rivers, and riding a bicycle. During the focus group discussions, I found that it is difficult to differentiate taboos, which academics would label as a restriction due to the fear of some supernatural power (Sasaki 1994), from inhibited behaviors due to a physiological reason. For the girls themselves, these were all behaviors that they were told not to do and if they violate, a bad consequence would be brought to themselves or their family.

5.4.6 *Imparting Knowledge About Menstruation*

Who imparts knowledge about menstruation to girls and when do they do it? The survey data shows 82% of the girls learn about it from their mothers, while 8% from their paternal aunt (*senge*, in local language), 5% from their elder sisters, followed by 4% from teachers. In Gisu society, the paternal aunt is often responsible for sex education, but as for the knowledge on menstruation, the paternal aunt or older sister would teach about it only if the mother was deceased or had left the home after divorce.

The mother, aunt, or sister teaches the girl who had her first menstruation that starting menstruation means she became mature and she has to be careful with men. How to take care of the menstrual flow and how to keep themselves clean during the period are also among the lessons taught. Taboos related to menstruation are taught mainly by female family members, although some knowledge on taboo was taught by female schoolteachers and church members.

What was surprising was that about half of the female students did not know about menstruation, because they had not learned about menstruation either from their family or at school until their menarche. Out of the 90 high school girls (average age = 17 years), only 47% were told about menstruation before menarche; the average age of menarche among the students was 14.6 years. A student, looking back to her menarche, said "I was shocked and cried when I saw blood on my underwear. I did not know what went wrong with me." This feeling was shared with many other girls who did not have the knowledge of menstruation on the day of menarche. This can be the result of the norm of not talking about menstruation openly even among family members. In Gisu culture, people do not have a rite of passage celebrating menarche, which may be an opportunity for knowing about menstruation before your own.

Menstruation is taught in science/biology during Year Six of primary school and Year Four of high school in Uganda. However, very often it happens that not everything in the textbook can be covered during the actual class periods. Moreover,

in rural areas of Uganda, there are variations in the age at which children start primary education. Some students must repeat the same year even at a primary-school level if their academic performance is not satisfactory. Therefore, it is not uncommon for students in the upper grades of a primary school to be in their mid to late teens.

Not only when they study but also what they study through textbooks was questionable from a practical viewpoint for managing menstruation. In biology textbooks, the contents related to menstruation are covered under the subject of reproduction. It shows male and female organs and explains ovulation, which is important scientific knowledge but not necessarily linked to practical life skills. Female students in the focus group discussions said that they would like to learn more at school about topics such as irregular menstruation, coping with headaches and menstrual cramps, as well as about menstrual hygiene products (such as sanitary pads).

5.4.7 Absorbents for Menstrual Flow

The quality of blood absorbents is a factor that shapes the monthly experience of menstruation. Traditionally in Gisu culture, an absorbent called *Ifungo* as shown in the picture (Fig. 5.2) was used. This is made of fibers obtained from a dried-up stem of a matoke (banana) plant (Fig. 5.3). Since matoke is the staple food in this area, matoke plants are grown throughout the area. When in need, a woman would pull off a handful of the dried stem and crumple it up. Then, it is inserted into the vagina, like

Fig. 5.2 Traditional menstrual absorbents. (Photo by Sugita)

Fig. 5.3 Stem of a matoke plant. (Photo by Sugita)

Table 5.3 Absorbents used for menstruation hygiene management ($n = 90$, multiple choice)

	Have used (%)
Disposable sanitary pads	96
Old clothes	52
Underwear only	49
Reusable sanitary pads	47
Cotton	31
Toilet paper only	12
Tampons	4
"*Ifungo*"	0

a tampon. Older women told me that they used to use it, but the majority of the high school students did not even know about it.

So what kind of absorbents do the high school students use for managing their menstrual flow? Table 5.3 shows the results of a questionnaire on the type of absorbents the students have used. In these multiple-choice questions, 96% of the female students answered that they have used manufactured disposable sanitary pads. It is followed by old cloth, underwear only, and reusable cloth pads. There

are discrepancies between the experience of using them and the students' claim of frequent use.

The high percentage of manufactured sanitary pad use has to be noted with caution. Since the questionnaire allowed for multiple answers, those who answered that they use sanitary pads do not necessarily use them throughout the duration of their menstrual period. It appears that most girls use them only on days of heavy flow, and while they are at school. The reason, I think this, is because when I interviewed the owner of the only general store that sold sanitary pads in the area about his sales, it was not possible for his store alone to supply menstrual pads to most of the female students. There is a weekly market on Wednesdays in the area, but only a few merchants sold sanitary pads. Even in monetary terms, a pack containing seven to ten pads costs between 2000 and 3000 Uganda shillings (approximately USD 0.77–1.15 at the time of research), which is expensive considering that students rarely drank soda, which costs 1000 Uganda shillings. Over 91% of the students ($n = 90$) answered disposable sanitary pads are "very expensive" or "somehow expensive" in the questionnaire. The students also expressed, "sanitary pads are more modern and cooler." The figure for manufactured sanitary pads may be inflated beyond the actual number being used.

"Old cloth" used as absorbents during their period was obtained from old T-shirts, other clothing, or old bedsheets, according to the students. They cut the cloth into squares and fold them before using them to line their underwear. On the other hand, reusable cloth pads have been sewn in advance and are sold in a package (or distributed by NGOs).

Surprisingly, there were students who responded that they only use underwear or toilet paper. The speculation is that they practice this around the fourth and fifth day when menstrual flow is comparatively light. Nonetheless, it is surprising that 49% of the girls have experience taking care of their period with underwear only. In addition, some students use cottonseed that they picked from cotton plants cultivated in fields on the way to the school. There were a few students who said, "I have no choice," but to quietly pick the cottonseed from other people's fields on their way to and from school.

5.4.8 Changing and Disposing of Menstrual Absorbents

How do the students change and dispose of their menstrual absorbents when they are at school? According to the survey, the most frequent answer for the location of changing was inside the school latrine booth (63%) (see Fig. 5.4). Some also used what they called a *sakati* (literal translation would be bathing shelter, but in this case, a space also used for urinating). Boarding students more likely went back to their dormitory room, which is located behind the school for changing. Some students said they would go back home during the break time to change, and 10% of the 90 girls said they don't change while at school. In the focus group discussion, some students said the *sakati* at home is not an appropriate place for changing menstrual

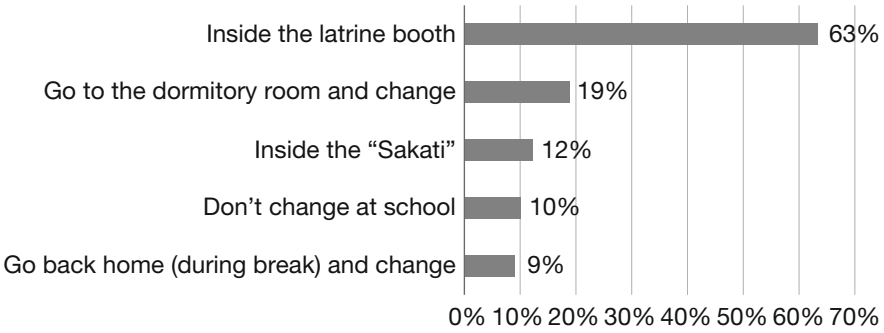

Fig. 5.4 Where students change the menstrual items while at school ($n = 90$, multiple choice)

items, because their father may see the blood on the floor (locally small rocks are spread at the base to allow bathing water to drain into the soil).

Almost everyone responded that they dispose of used sanitary pads, old cloth, cotton, and toilet paper into the pit latrine. The pit is deep and once things are dropped inside, they are out of reach. They throw them into a pit latrine, because otherwise, they fear that the absorbent with menstrual blood can be used for sorcery. A typical explanation given was:

"Even if a trash bin was kept in the cubicle of the latrine, I would never throw sanitary pads in it. My stepmother, who might be watching from behind, could pick it up after I leave and take it to the witch doctor." Relations with the stepmother can be particularly strained in the polygamous Gisu society, and female students feared that their stepmother (or someone who has a grudge on her) might cast a spell on them.

When reusing old cloth, reusable cloth pads, and underwear, everyone said that they wash them with soap and hang them to dry in a place that is not visible to others. Many girls hang them indoors (hang them over the edge of a portable laundry basin and hide it under the bed). When they have to hang them outdoors, they hang them on the wall of a bathing shelter, which is generally located outside their house, and cover them with a thin cloth. This keeps the laundry hidden from the eyes of others, preventing the embarrassment of being seen by the father and from being picked up by someone for bewitching. The girls explain that it is "not good" for underwear or your menstrual blood to be seen by their father or male family members, but this is due to embarrassment and not fear of the spells.

5.5 Discussion and Recommendations

The research results show that seemingly simple behaviors associated with menstrual management pass through the filter of cultural norms and girls` perceptions. (1) Changing menstrual absorbents (2) using a latrine, (3) discarding used sanitary

pads or other sanitary items, (4) washing menstrual items or underwear, and (5) drying them; all these behaviors were not conducted in a cultural vacuum. In this study site, talking about menstruation itself was often refrained from, and strong taboos were connected with the fear of their menstrual blood or items, which once had blood being exposed and used for bewitching. This in turn influenced the above "daily" behaviors.

When an intervention for MHM is to be introduced at schools, cultural context and the voices of female students regarding menstruation must be taken into account. I will discuss four points that emerged from the case study. These points also include my recommendations for implementing international MHM support.

The first is about the disposable sanitary pads and the methods of disposal. Female students said disposable sanitary pads are "modern and cool," and claimed that they often use those pads. After usage, the pads are disposed of by throwing them into pit latrines due to the fear of the pads being used for sorcery. Provision of dustbins in the school latrine booth would not be a solution for this area, as the girls strongly suggested against it for that very reason. These manufactured menstrual pads (at least, currently most of them) do not decompose naturally. If women continue to discard the pads into the earth, it may lead to environmental issues as well as shorten the number of years for a pit latrine to fill up. There are some efforts to produce biodegradable and affordable pads in Uganda, such as EcoSmart pads or MakaPads (College of Engineering, Design, Art and Technology 2020). The appropriateness of installing an incinerator would need further examination reflecting the cultural belief or practice of an area, such as the taboo of burning menstrual blood. It is said that the disposal issue of sanitary products should be further addressed including its impact on the environment and health (Elledge et al. 2018).

Second, in disseminating reusable cloth pads, socio-cultural context and women's practice also should be considered. The instructions of reusable cloth pads, in general, indicate washing them with clean water and soap, then dry them under direct sunlight. In the case of the above research area, clean water and soap were available. Female students were experienced at using old cloth as an absorbent and washed it well and dried it. However, reusable cloth pads, which have the structure to avoid leakage, are much thicker and do not dry easily. Considering the girls' actual practice of drying menstrual absorbents, the thick, slow-drying cloth can become a breeding ground for bacteria. Fast-drying, antibacterial fabric may reduce the problem, but the cost may increase.

Here, I want to make it explicit that I am not supporting one product over the other. Disposable sanitary pads are easy and convenient to handle, while reusable pads are more sustainable. Other products such as menstrual cups have their own benefits. The point is the importance of understanding local context and cultural practices associated with these materials in introducing an intervention and considering the possible negative impact. That may lead to further development of an absorbent or sanitation facility that is appropriate for its culture, environment, and health.

The third issue is about education on menstruation. At the point of research, only 48% of the female students knew about menstruation before reaching menarche. Considering the rate of primary school students having to repeat grades in Uganda (and in many other countries), introducing menstrual education in Year Six might be too late. It is necessary to provide menstrual education for girls at an earlier stage in primary schools. Moreover, the content should focus on providing practical knowledge about how to handle menstrual bleeding, menstrual cramps, irregular menstruation, and other topics closely related to the problems faced by female students, rather than just teaching about ovulation and menstruation as a reproductive function described in current science textbooks.

My last point is about the treatment of cultural beliefs, taboos, and traditional methods of menstrual management. UNESCO (2014) identifies "positive social norms" as one of the essences of MHM. Some MHM educational materials and reports refer to cultural taboos or traditional methods with negative connotations. Although whether each belief or practice is actually harmful or not is up for debate, it is important to notice the hidden curriculum with the interventions. The students from the above case study called disposable sanitary pads "modern and cool" and other traditional methods "backward." Some said it is not taboo to go to the church if you are using those sanitary pads. These notions can marginalize girls who also believe manufactured sanitary pads are cool, yet difficult to afford. During my visit to the same area, I heard some girls have young men with earnings buy pads for them in exchange for sex. These cases suggest that girls who cannot afford new products can get further sidelined with the dissemination of the discourse perceiving negatively of traditional absorbents and the spreading market of menstrual products.

Assistance for MHM is expected to grow in international development. MHM, I believe, is important for girls and women, and it will benefit them with proper consideration. I hope that MHM/MHH interventions and sanitation promotion will reflect the socio-cultural context and the voices of female students.

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Part II
Health

Chapter 6
Interactions Between Health and Socio-Culture in Sanitation

Taro Yamauchi

Abstract This part discusses sanitation from the perspectives of health and well-being. In particular, we focus on the socio-cultural aspects of water, sanitation, and hygiene (WASH) in relation to health. First, we discuss the social determinants of health (SDH) with an in-depth focus on the gender, cultural, and economic disparities that impact access to quality sanitation. We also spotlight sanitation workers, who play a significant part in existing sanitation systems yet unquantified and ostracized. Furthermore, as theoretical underpinnings, we review methodologies to behavioral changes including information dissemination, education approach, and community-based approach. Subsequently, we introduce the three chapters that constitute this part. Chapter 7 examines relationships between child health (e.g., undernutrition and diarrhea) and its associated factors (e.g., water, sanitation, and hand hygiene) in Indonesia. In Chap. 8, we argue the transfer of health risks in sanitation and its social allocation (i.e., genders) in Vietnam. Finally, in Chap. 9, we introduce Participatory Action Research (PAR) involving local children and youth in tackling WASH issues in Sub-Saharan Africa (Zambia). In the end, we reemphasize SDH by mentioning socio-cultural aspects of health and attitudinal and behavioral changes on WASH in society through community-based approach.

Keywords Water, sanitation and hygiene · Socio-culture · Health and well-being · Social determinants of health

T. Yamauchi (✉)
Faculty of Health Sciences, Hokkaido University, Sapporo, Japan

Research Institute for Humanity and Nature, Kyoto, Japan
e-mail: taroy@med.hokudai.ac.jp

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6.1 Introduction

According to the 2017 World Health Organization (WHO) and United Nations Children's Fund (UNICEF) Joint Monitoring Program report, 2.2 billion people (accounting for one-third of the world's population) cannot access safe drinking water; 4.2 billion people are unable to access safely managed toilets, simultaneously resulting in open defecation among 700 million people (WHO and UNCF 2017). Unsafe drinking water has a massive impact on children's health, with 360,000 children under 5 years old dying of diarrhea each year. In addition to biological and medical factors, psychological, social, and environmental factors are important determinants of health. To date, scholars have placed much emphasis on the relationship between health and materials (e.g., infrastructure, technology, economy, resources, etc.), often neglecting the socio-cultural aspects of health. However, our Sanitation Triangle (in Chap. 1) places these socio-cultural aspects as equally, if not even more essential to health. This gap was also highlighted by WHO in 2008 through the issuance of the Social Determinants of Health (SDH) (Marmo et al. 2008). The SDH refers to the conditions in which people are born, grow, live, work, and age and the systems that shape the conditions of daily life. In terms of health, this would include how educational level impacts family planning decisions, income determines whether soap is purchased for handwashing, or residential area determines the ease of access to health centers. These forces and systems include economic and social policies, development agendas, socio-cultural norms, and political systems. This chapter briefly discusses some specific SDH related to sanitation, such as gender differences, culture, education access, employment, and income. Besides, this chapter also discusses solid waste management as well as human excreta as an important part of sanitation to be addressed.

Quality access to safe drinking water and sanitation is the epitome of an environmental determinant of health. There are micro- (individual, household), meso- (school, workplace, community, local government), and macro- (national, international organizations) targets to consider the determinants that affect health. This part presents examples of the micro- (Chap. 7) and meso- (Chap. 8) subjects. Finally, attempts to change people's behavior and transform society (Chap. 9) are discussed. Knowledge about sanitation and hygiene is required to change people's behaviors. Subsequently, through motivation and attitudes, behavior can be changed. The determinants of behavior change differ at the individual, household, and community levels. For example, at the individual level, knowledge about the routes of transmission of pathogens, health effects, proper toilet use, costs and benefits of toilet use, motivation, and adaptation to lifestyle and daily life are necessary for behavior change. At the household level, roles, responsibilities, and division of labor within the household determine behavior. At the community level, social norms and the ability to maintain and manage sanitation facilities define behavior. Determinants of behavior are also related to the context in which the behavior occurs. For example, there are physical determinants, such as climate, geography, and access to resources, economic determinants, such as access to

goods and services, and institutional determinants, such as the availability of subsidies and enforcement of penalties and/or fines. There are also technical determinants, such as ease of use, location, and cost of sanitation facilities. Thus, the determinants of behavior changes related to sanitation are complex.

A more comprehensive list of the possible determinants of open defecation behavior is as follows: (1) no toilet available, (2) distasteful toilet environment (e.g., smells and dirt), (3) convenience, (4) habit, (5) lack of familiarity with toilets, (6) lack of knowledge of health effects, and (7) lack of substances (e.g., toilet paper) for bodily disposal after defecation. The issue of sanitation is linked to physical health through the dangers of unsafe feces disposal; for instance, pathogenic *E. coli* enters the mouth through various routes, known as the F-diagram (WHO 2018). The following is a summary of the health effects of unsafe sanitation. Direct effects cover:

1. Diarrhea is a major public health problem and the primary cause of illness and death among children under five in low- and middle-income countries (Prüss-Ustün et al. 2014), along with cholera, dysentery, polio, typhoid, and other fecal-oral infections.
2. Neglected tropical diseases, such as soil-transmitted helminth infections (e.g., ascites, hookworm, and blood-sucking worms), schistosomiasis, and trachoma, are a major global burden (WHO 2017).
3. Vector-borne diseases, such as the West Nile fever, lymphatic filariasis, and malaria (Curtis et al. 2002; van den Berg et al. 2013), are caused by poor sanitation that fosters mosquito proliferation.

This results in the physical deterioration of children. In the short term, "wasting" (extremely low body weight for height) and "underweight" (extremely low body weight for age) occur, accompanied by "stunting" (extremely short stature for age) in the long term. Cognitive decline, pneumonia, and anemia can also occur. Long-term poor nutrition, disease, and chronic health conditions lead to reduced educational achievement, school absenteeism, and dropout, which result in lower average income and higher unemployment and poverty. This perpetuates a generational cycle that denies improved quality of life and allows minimal improvements to the government economy.

6.2 Sanitation and Gender

In addition, unsafe sanitation can affect broader well-being. Immediate impacts include anxiety, shame, and embarrassment due to open defecation and communal toilets (Sclar et al. 2018). This expands when sanitation does not meet gender-specific requirements, particularly those of women and girls who are at risk of sexual assault. Multiple studies in low- and middle-income countries have shown that women, girls, and even boys report feeling shame, fear, embarrassment, and experiencing nonpartner verbal and physical violence when defecating due to

inadequate and inaccessible sanitation services. Similar to sanitation discrimination against women and girls, recent studies have also documented that denied access to sanitation facilities among transgender and gender nonconforming people leads to higher odds of suicide attempts and inability to provide private household sanitation that offers visitors and/or guests a safe and private setting to defecate, generating shame and embarrassment among hosts. These discriminations subsequently influence the social and educational engagement of these groups, causing loss of dignity. For example, in addition to inaccessible sanitation, which leads to open defecation, users with poor-quality toilet access have to endure (1) toilet design issues (lack of doors, locks, roofs, and walls), (2) non–gender-segregated toilets, and (3) poorly maintained facilities with feces and urine contaminating the environment, which causes users to feel forced to defecate in ways that erode dignity. Eventually, some people choose to openly defecate and/or develop unsafe sanitation behaviors to avoid the above-mentioned issues with sanitation facilities. Studies have shown that these discriminations and limitations negatively impact the socioeconomic status of women and girls due to school and work absenteeism, among other factors.

Some documented and equally unsafe alternatives to open defecation are the use of flying toilets and chambers and disposing of diapers in solid waste, toilet structures, and open spaces (UNICEF and WHO 2018). In the absence of toilets and in instances where toilets were not easily accessible, a survey of Zambian periurban settlements found that several residents attested to the use of "chambers" within their households, characterized as "easily" disposable or cleanable containers for excrement, for example, buckets, bottles, plastic bags, etc. After use, containers could be emptied into the toilet, disposed of with solid waste, or thrown into open spaces and on rooftops, hence being termed "flying toilets" (Nyambe et al. 2018). Results of a bivariate odds ratio on heads of households with toilet access in one of the surveyed settlements further revealed that women had higher odds for chamber use, which was also linked to higher odds of using unimproved sanitation and higher diarrhea prevalence based on a 2-week recall (Nyambe et al. 2020). A study in a Kenyan informal settlement similarly reported that women most frequently suffered respiratory cough/illness, diabetes, and diarrhea, alongside violence, economic, and social impacts, owing to unsafe and unhygienic sanitation access (Corburn and Hildebrand 2015). When compared to discomfort and risks associated with unsafe sanitation use, chambers may benefit users (Bhatt et al. 2019; Cherunya et al. 2020; Kwiringira et al. 2014). In locations where outdoor toilets are the norm, toilets are far from home, or a fee must be paid for toilet use, chambers would be cost-effective, convenient alternatives for child toilet training, during illness, at night, or in poor weather, for example (Corburn and Hildebrand 2015; Nyambe et al. 2020).

6.3 Health and Socio-Culture

Moreover, in situations where sanitation facilities are inadequate, cultural factors can lead marginalized people, such as women, to engage in riskier behaviors. Due to these common difficulties, women may be encouraged to own chambers as part of their wifely duty to cater to the family's sanitation, even when improved sanitation systems are owned. Sadly, whether it is the use of chambers or unsafe, unhygienic, inaccessible sanitation facilities, the costs of health, nutrition, and safety lead to economic burdens experienced through missed work due to illness or caring for the ill, health-care costs, and toilet and transportation fees (Corburn and Hildebrand 2015; Nyambe et al. 2020). Particularly for women and girls, cultural practices may also stipulate that they do not share a toilet with males during menstruation. In some cultures, women and girls cannot share a toilet regardless of menstruation. Nonetheless, in addition to unsafe sanitation, shame, and embarrassment, cultural beliefs and restrictions have been cited as reasons for girls to be absent from school during menstruation (Chinyama et al. 2019), which highlights the requirement to consider the detrimental impacts of cultures on health.

Strong cultural beliefs passed down through generations can perpetuate discrimination, harmful practices, and attitudes and hinder individual and societal development amidst broader societal changes, even when backed with scientific evidence. This emphasizes the requirement to thoroughly consider the culture and education of locals in the development and implementation of health interventions, including sanitation. Studies on child fecal management provide examples of culture and social norms encouraging and/or allowing unsafe sanitation behaviors despite available infrastructure, because caretakers believe that child feces are insignificant and harmless (Aluko et al. 2017; Cronin et al. 2016). Therefore, disposable diapers are not emptied before discarding them into solid waste and open spaces (Bain and Luyendijk 2015; Sahiledengle 2020). This could be seen as a classic example of introducing hardware (diapers) without software to educate users on proper disposal (Preeti et al. 2016; Sahiledengle 2020). In both chambers and diapers, common societal and cultural practices increase the risk of human-fecal contact and allow for unsafe sanitation that risks the health of household members, the community, and the broader environment through unsafe handling and poor disposal.

The situations above provide evidence that safe sanitation is essential for health, from preventing infectious diseases to improving and maintaining mental and social health. Moreover, the success of safe sanitation depends on its ability to consider societies-specific cultural dynamics by either supporting the culture through offering safe and healthy alternatives or educating the culture about healthy behavior change. In addition to the socio-cultural environment, safe sanitation must consider the costs and utility services available to users for them to adequately use and maintain a safe and hygienic process from start to finish. To reduce the negative impact of sanitation on health, "software" approaches are necessary for changing people's hygiene behavior alongside "hardware"— the building of toilets, sewage systems, and sludge treatment facilities. This is important, because appropriate sanitation facilities would

be meaningless if people did not use or maintain them properly. It is also crucial to ensure the continued use and maintenance of sanitation facilities and proper disposal of infant waste to ensure minimal fecal-human contact.

6.4 Tailored Sanitation Services and Behavioral Changes

With behavior change aimed at the use of safe sanitation, safe sanitation infrastructure must be tailored to match the requirements of the society and consider not only the elimination of fecal-human contact but also (1) diverse groups: culturally appropriate, (2) proper fecal disposal, including diapers, (3) environmentally compatible human waste storage, transport, and treatment facilities, and (4) reliable sanitation systems. This also means that sanitation service providers and workers should be considered. According to the WHO, sanitation workers, such as garbage workers, play a significant role in society, because they "bridge the gap between sanitation infrastructure and the provision of sanitation services . . . often at the cost of their dignity, safety, health, and living conditions." Despite this, they are "far too often invisible, unquantified, and ostracized (WHO 2019)."

The situation is worse in low- and middle-income countries, which are characterized by a lack of sophisticated sanitation infrastructure, such that solid waste management has been largely dependent on the informal sector of garbage workers (Sharma et al. 2020). Two problematic scenarios are possible given the direct handling of waste. Sometimes, garbage workers execute their duties without proper personal protective equipment (PPE). However, their duties can involve unsegregated waste, sometimes including infected or hazardous materials (e.g., biomedical waste). Both scenarios predispose these workers to a range of health risks daily, such as cuts, wounds, and respiratory and infectious diseases (Kuijer et al. 2010; Rahman et al. 2020; Sai et al. 2020; Sharma et al. 2020). Given that the current war against COVID-19 has generated a massive amount of biomedical and household waste, improper collection, handling, and sorting practices are quite likely to place these workers in great danger of infection and transmission of pathogens. Furthermore, they may also be exposed to social stigmatization from society because of the nature of their work (Hamilton et al. 2019), which requires daily contact with waste by insulating cleanliness from dirtiness among society. This has created the social category of "dirty workers" (Ashforth and Kreiner 1999).

As methodologies for behavior change, information dissemination, educational approaches, community-based approaches, and commercial marketing approaches have been used. An example of an informational and educational approach is the existing methodology called Participatory Hygiene and Sanitation Transformation (PHAST). This approach is a participatory learning method that aims to empower communities to improve hygiene behavior, reduce diarrheal diseases, and promote effective community management of water and sanitation services (WSSCC 2009). While informational and educational approaches aim at individual behavior change, the community-based approach aims at collective behavior change. Community-led

total sanitation is a well-known initiative of the community-based approach, which consists of a series of community-based activities conducted by trained facilitators. This aims to create a sense of disgust and shame among community members about the impact of open defecation on community health and well-being (Kar and Chambers 2008). Another example of an approach aimed at changing the behavior of a group is the community health club (CHC) (Waterkeyn and Cairncross 2005). CHCs maintain a long-term engagement with the target community and hold a series of meetings to address health, hygiene, and sanitation behaviors. CHCs focus on using local resources and innovations to create change, and group activities can establish a new positive norm for improved hygiene and sanitation behavior. In Chap. 9, Nyambe et al. report on Dziko Langa, a club for periurban children and youth in the capital city of Zambia.

6.5 Chapter Overview

This part comprises three chapters that focus on the relationship between health and socio-culture. This was done in two ways: through understanding the socio-cultural factors, which determine how people and communities relate to the hardware (material) available to them; and by discussing the socio-cultural narratives that shape their health interactions. First, Chap. 7 demonstrates that poor personal hygiene at the individual and household levels places children living in periurban settlements at greater risk of malnutrition and diarrhea. Second, Chap. 8 highlights the social allocation of health risk in sanitation that focuses on female farmers' fecal handling and modern sewerages, resulting in transferring health risks along a river. Finally, Chap. 9 discusses PAR involving local children and youth in (1) water, sanitation, and hygiene (WASH) assessment and intervention, (2) development of a self-assessment methodology for fecal contamination, and (3) a visualization approach for local stakeholders.

Chapter 7 introduces a study that aimed to (1) evaluate child health and nutritional status, (2) demonstrate the factors affecting child health and nutritional status with special attention to WASH, and (3) examine fecal contamination on the hands of children and its factors related to fecal contamination. The study was conducted at a preschool and two elementary schools in the densely populated area of Bandung, targeting 228 pairs of children and their caretakers. Anthropometric measurements, handwashing observation, hand bacteria test, and questionnaires were employed. Based on the multivariate logistic regression analysis, using a towel for handwashing practices was significantly associated with an increased risk of stunting. In household environments, the use of tap water compared to tank water as drinking water by children was a significant predictor of the increased risk of stunting and thinness. In addition, children from households that used open containers for water storage significantly predicted an increased risk of diarrhea. Most children (98.7%) had fecal contamination, and girls had significantly fewer *E. coli* cases than boys. *E. coli* occurrences were negatively correlated with handwashing technique, handwashing

with soap (HWWS), and the study's developed WASH index. This indicates the importance of using the proper handwashing technique and HWWS at appropriate times for the reduction of fecal contamination. The findings also indicate that drinking water management at home and proper personal hygiene practices of children are essential for maintaining and promoting child health in urban slums. Regarding the necessity to pay attention to socio-cultural aspects of health, as discussed above, school sanitation is also discussed in Chap. 5 of Part I in terms of menstrual hygiene management (MHM) among schoolgirls in Uganda.

Sanitation can have an enormous impact on the journey of excreta in the living and surrounding environment, which contributes to the reduction in fecal exposure and subsequent fecal-oral infection risk. However, the fluidity of excreta and its associated health risks should be treated cautiously. Based on examples in Vietnam, Chap. 8 demonstrates the transfer of health risks in sanitation and its allocation in society. Along the river, fecal pollutants and the associated health risks were transferred from urban upstream areas to rural downstream areas, causing a massive impact on livelihoods downstream. Resource-oriented sanitation was enabled at the cost of female farmers' health risks through fecal handling, suggesting a gender-related risk allocation. This chapter also emphasizes the health risk allocation that occurs through modern sewerages, in which flushed excreta reaches those who work in them and on-site sanitation along the sanitation service chain. These findings suggest that sound social allocation and mitigation of health risks are indispensable elements in tackling sanitation-related social issues. As shown here, the allocation of health risk in society is discussed based on the case of sanitation workers in India (Chap. 3 of Part II). It also shows that sanitation work allocates not only health risks but also labor and stigma.

Chapter 9 outlines rich and unique experiences and findings from our WASH participatory action research in two periurban settlements in Lusaka, Zambia. The main participants in the chapter are children and youth, who are key but rare actors in WASH intervention, more so because the sub-Saharan African nation has a young population. This chapter will outline the conceptualization of the Dziko Langa Club as a suitable, engaging means of incorporating and empowering children and youth as coresearchers and participants capable of intervening in the periurban WASH environment. It will then elaborate on three research topics: (1) periurban WASH assessment and intervention through participatory approaches, (2) development of a self-assessment methodology for fecal contamination in the living environment, and (3) visualization approaches for community and stakeholder engagement. These topics can be associated with Chap. 13 of Part III, which refers to using existing social relationships in Indonesia that involve local players (i.e., sanitation workers: garbage collectors).

Based on the above description of the three chapters, we re-emphasize social determinants of health with four important key points: (1) software approaches that are attitudinal and behavioral changes with consideration of socio-cultural aspects related to health as well as hardware approaches (e.g., infrastructures), (2) continued attention from the micro- (e.g., individual) to the macrolevel (e.g., community, society), (3) equitable allocation of health risks in households, regions, and society;

and (4) development and implementation of community-based transformation methodologies of attitudes and behaviors toward sustainable solutions.

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Chapter 7
Influence of Water, Sanitation, and Hygiene (WASH) on Children's Health in an Urban Slum in Indonesia

Taro Yamauchi, Yumiko Otsuka, and Lina Agestika

Abstract Unsafe drinking water, poor sanitation, and inadequate hygiene are key contributors to deteriorating child health in low- and middle-income countries. This chapter focuses on (1) evaluating child health and nutritional status; (2) clarifying the factors contributing to undernutrition and diarrhea prevalence by focusing on water, sanitation, and hygiene (WASH); and (3) evaluating fecal contamination and children's hand hygiene. The study was conducted at a preschool and two elementary schools in densely populated Bandung, Indonesia, targeting children and their caretakers, using anthropometric measurements, handwashing observation, hand bacteria testing, and questionnaires. The results showed that not using a towel after handwashing was significantly associated with increased risk of stunting. Children from households using tap water instead of tank water as drinking water suffered from increased risk of stunting and thinness. Moreover, children from households using open containers for water storage were associated with increased risk of diarrhea. Most children (98.7%) had hand fecal contamination, with girls having significantly less *Escherichia coli* (*E. coli*) than boys. *E. coli* counts were negatively correlated with handwashing technique, handwashing with soap, and a developed WASH index. The findings suggest that successful home drinking water management and proper personal hygiene practices are important for attaining better child health.

Keywords Child health · Water, sanitation and hygiene (WASH) · Fecal contamination · Urban slum

In this chapter, we adopted and reorganized two papers published in the *American Journal of Tropical Medicine and Hygiene* (https://doi.org/10.4269/ajtmh.18-0063) and *Tropical Medicine and International Health* (https://doi.org/10.1111/tmi.13279).

T. Yamauchi (✉)
Faculty of Health Sciences, Hokkaido University, Sapporo, Japan

Research Institute for Humanity and Nature, Kyoto, Japan
e-mail: taroy@med.hokudai.ac.jp

Y. Otsuka · L. Agestika
Graduate School of Health Sciences, Hokkaido University, Sapporo, Japan

T. Yamauchi et al. (eds.), *The Sanitation Triangle*, Global Environmental Studies,
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7.1 Introduction

Contaminated drinking water and poor sanitation and hygiene lead to the deterioration of children's health, indirectly causing undernutrition (WHO et al. 2015). According to a report by the World Health Organization (WHO) and United Nations Children's Fund (UNICEF), 89% of the world's population used (at least) basic drinking water services, but only 68% used (at least) basic sanitation services in 2015 (WHO and UNICEF 2017). The United Nations Sustainable Development Goals, therefore, were implemented to achieve universal, equitable access to safe, affordable drinking water and adequate, equitable sanitation, and hygiene for all by 2030 (Targets 6.1 and 6.2) (United Nations 2015).

Although the number of deaths among children under 5 years of age has decreased globally from 12.6 million in 1990 to 5.6 million in 2016, many children still die from preventable diseases (UNICEF et al. 2017). Worldwide, diarrhea is the second-greatest cause of death among children under 5 years of age (UNICEF et al. 2017), and it is a children's health challenge requiring prioritization. According to recent estimates, access to improved water, sanitation, and hygiene (WASH) could prevent 58% of diarrheal deaths among children under the age of five worldwide per year (United Nations 2015). The pathogens that cause diarrhea are transmitted via the fecal-oral route, but their transmission can be prevented by handwashing (Curtis et al. 2000). Handwashing with soap (HWWS) reduces the risk of diarrhea by 48% (Cairncross et al. 2010) and is important in reducing the risk of infectious diseases, as more bacteria of fecal origin can be eliminated by HWWS than handwashing using water alone (Burton et al. 2011). However, in a recent systematic review, it was estimated that only 19% of the world's population performs HWWS after using the toilet or touching children's feces (Freeman et al. 2014), putting the remainder at high risk for fecal contamination. This statistic emphasizes the importance of clean water, sanitary conditions, and proper hygiene (i.e., HWWS) in promoting children's health.

Numerous researchers have investigated the relationship between children's health and WASH in low- and middle-income countries. Previous studies have shown that the level of household sanitation and the household caretaker's personal hygiene practices are strong predictors of child stunting (Jee et al. 2015) and that the use of a high-quality toilet protects against diarrhea and stunting in children (Fink et al. 2011). Urban slums in low- and middle-income countries face several challenges, such as high population density, a lack of durable housing, housing with an insufficient living area, housing insecurity, and poor access to improved water and sanitation (UN-HABITAT 2006), and these challenges can affect children's health. Moreover, although a previous study revealed that children in slums are subject to greater health risks than those in non-slum urban areas, the risk is lower than it is among children living in rural areas (Fink et al. 2014). For example, in Indonesia, untreated drinking water and unimproved sanitation were strong predictors of child

stunting (Torlesse et al. 2016), and the use of piped water reduced the risk of diarrhea in children (Komarulzaman et al. 2017). Nevertheless, the relationship between WASH and children's health in urban slums remains unclear and requires thorough examination.

Therefore, an evaluation of fecal contamination through handwashing practices is important and must be conducted to counteract the problem of poor child health in urban slums. That said, there is no "gold standard." Several researchers have investigated the relationship between fecal contamination of a child's hands and handwashing behaviors (Kyriacou et al. 2009; Padaruth and Biranjia-Hurdoyal 2015) and their level of knowledge and awareness (Grimason et al. 2014), but few studies have been conducted on the relationship between handwashing techniques and fecal contamination levels. Furthermore, targeting the frequency and technique of handwashing simultaneously is effective for changing handwashing behaviors (Friedrich et al. 2018), making an investigation of these practices—especially those of children—necessary. Thus, a comprehensive assessment of the various aspects of behavior, knowledge and awareness, and technique must be conducted.

As already discussed, the assessment of handwashing behaviors requires international attention. A previous study suggested that self-reported data regarding handwashing behaviors were rife with overestimations of actual behaviors (Hirai et al. 2016). Therefore, a comprehensive evaluation of handwashing behaviors requires the simultaneous use of questionnaires and observations of participants' actual handwashing practices. However, such approaches are time- and labor-intensive and can thus be difficult to apply to a large sample. Hence, it is important to consider conceptualizing and developing a more efficient way to mitigate the above-mentioned challenges.

The researchers primarily aimed to evaluate children's nutritional status and the prevalence of fecal contamination on the hands of children living in an urban slum. Regarding the former, we conducted direct observations and administered a questionnaire to clarify the factors contributing to undernutrition and the prevalence of diarrhea by focusing on WASH from three perspectives: the household environment, children's personal hygiene practices, and their level of knowledge and awareness. With respect to the latter, we identified the factors related to fecal contamination on hands and developed an index to comprehensively evaluate handwashing techniques, HWWS compliance, and knowledge and awareness of WASH; we later investigated their relationship with fecal contamination.

7.2 Materials and Methods

7.2.1 Study Area and Participants

This cross-sectional study was conducted in the densely populated area of Bandung, West Java Province, Indonesia, from August to September 2017. The data were collected in cooperation with a preschool facility, Pendidikan Anak Usia Dini

(PAUD), and two elementary schools in the area. All the children and their caretakers at PAUD, as well as the children in grades 2, 4, and 6 and their caretakers in the elementary schools, were enrolled. After explaining the purpose and content of the survey, we have obtained informed consent and assent from 228 pairs of caretakers and their children, respectively. The children who were unable to obtain consent from their caretakers and/or were absent during the investigation period were excluded.

7.2.2 Anthropometric Measurements

The participants' height was measured to the nearest 0.1 cm using a stadiometer (Seca 213; Seca, Hamburg, Germany), and their body weight was measured to the nearest 0.1 kg using a digital scale (BC-754-WH; Tanita, Tokyo, Japan). Their body mass index (BMI; in kg/m^2) was calculated from these measurements. The ages of the children were calculated by software (WHO AnthroPlus version 1.0.3 (WHO 2009a); WHO, Geneva, Switzerland) using their date of birth (as reported by their caretakers) and the research date. Their height-for-age z-scores (HAZ) and BMI-for-age z-scores (BMIAZ) were calculated from the anthropometric measurements using international references (de Onis et al. 2007; WHO Multicentre Growth Reference Study Group 2006) (WHO AnthroPlus version 1.0.3 software). The children with HAZ scores < -2 were categorized as stunted, and those with BMIAZ scores < -2 and $> +2$ were classified as thin and obese, respectively (de Onis et al. 2007; WHO 2009a, 2018).

7.2.3 Handwashing Technique Check

To evaluate the children's handwashing techniques, a checklist was modified based on WHO handwashing procedures (WHO 2009b). The following ten steps were included: (1) wet hands with water; (2) apply enough soap to cover all hand surfaces; (3) rub hands palm-to-palm; (4) rub right palm over left dorsum with interlaced fingers and vice versa; (5) rub hands palm-to-palm with fingers interlaced; (6) rub backs of fingers to opposing palms with fingers interlaced; (7) rub rotationally with left thumb clasped in right palm and vice versa; (8) rub rotationally backward and forward with clasped fingers of right hand in left palm and vice versa; (9) rinse hands with water; and (10) dry hands thoroughly with a single-use towel. The children were also instructed to freely use the water, soap, and towels that were provided and to do what they normally would at home before demonstrating their handwashing practices. A single researcher (Y.O.) noted the children's actions according to the steps.

7.2.4 Fecal Hand Contamination

The level of fecal contamination on children's hands was examined for participants in grades 2, 4, and 6 ($n = 169$). The enumerators used a wiping kit, which contained a cotton swab and 10 mL of sterile phosphate buffered saline (PBS) in a test tube (Swab test ST-25PBS; ELMEX, Tokyo, Japan). Before the children demonstrated their handwashing practices, a cotton swab moistened with sterile PBS was rolled on the surface of the dominant hand of each child (i.e., palm, backside, and fingers). All the samples were kept on ice and transported to a field laboratory within 4 h of sampling. The samples were processed in a laboratory by membrane filtration to detect *Escherichia coli (E. coli)*. Under aseptic conditions, each sample (10 mL) was divided into low and high volumes (1.0 and 9.0 mL or 0.5, 1.0, and 8.5 mL) and passed through a 47-mm-diameter 0.45-μm cellulose filter. After filtration, the filter was placed in XM-G growth media (XM-G; Nissui Pharmaceutical Co., Tokyo, Japan) and incubated at 37 °C for 20 ± 2 h. The bacterial load on each sample of media was assessed in terms of colony-forming unit (CFU) counts per hand. The presence of *E. coli* was determined by size and color of the colony (i.e., a blue and purple colony larger than 1 mm). The purple colony was included in our analysis to prevent overlooking *E. coli* because of the growth media's manual's instructions: *E. coli* may produce a blue to blue-purple reaction. For each sample, both the media (low and high volumes) were used to estimate the concentrations of *E. coli*. When both the media counts included 100 or fewer colonies, the concentrations were added to determine the sample concentration (CFU per hand). If the high-volume media's count exceeded 100 colonies, the low-volume media sample was used to estimate the concentration. In addition, when colonies were not successfully formed or they fused together, we deemed them "uncountable" and excluded them from analysis. A blank test was performed more than once a day to ensure that there was no contamination during the inspection process.

7.2.5 Questionnaires

Structured questionnaires were developed according to the preliminary research and after discussion with local people to ensure their suitability for the local context. They were then administered to the caretakers and elementary-school children. The questions for the caretakers included items related to the following: (1) basic demographics including age, educational background, occupation, household monthly income, and household environment (drinking water source, toilet type, sewerage); (2) level of WASH knowledge and awareness and handwashing behaviors; and (3) reported prevalence of diarrhea and respiratory symptoms during the preceding 2 weeks.

The following questions were focused on assessing levels of sanitation knowledge and awareness: (1) Do you know that boiling water kills germs? (2) Do you

know that water containers need cleaning and covering? (3) Do you know that human feces contain germs? (4) Do you think that drinking water can be contaminated by fecal bacteria? (5) Do you think that unclean drinking water can make you sick? (6) When do you think it is most important to wash one's hands? (7) Do you think that your hands can be contaminated by bacteria if you don't wash them after using the toilet? (8) Do you think that handwashing is important for disease prevention? (9) Do you think that inadequate drainage facilities can cause environmental pollution and health problems? The scores were calculated based on the number of correct answers to the sanitation knowledge and awareness items.

7.2.6 WASH Index

Water, sanitation, and hygiene knowledge and awareness scores were calculated based on the number of correct answers to the items in the WASH knowledge and awareness section. Regarding handwashing behaviors, the participants were asked what their usual procedure for cleaning their hands was on various occasions with reference to the recommendations of the Centers for Disease Control and Prevention (2016). Handwashing behaviors were categorized as "always wash hands with soap" and the converse according to their answers. Diarrhea was indicated in cases of three or more loose or liquid stools per day (WHO 2005). For elementary-school children, a questionnaire regarding WASH knowledge and awareness (only questions 1–8) and handwashing behaviors (only 6 occasions) was selected and modified for children by using easily understood vocabulary. The scores for handwashing techniques, HWWS, and knowledge and awareness of WASH were converted into full scales of ten points each. The total score was obtained by adding the scores of the three items together, and it was set as the WASH index (maximum 30 points).

7.2.7 Statistical Analysis

A bivariate analysis was performed with the data for stunting, thinness, diarrhea prevalence, and each individual variable (i.e., household, caretaker, and child characteristics). The independent variables were chosen from covariate variables: (1) those that had significant differences in stunting, thinness, and diarrhea prevalence on bivariate analysis; (2) children's health status and relevance as pointed out in previous studies; and (3) WASH items of interest in this study. Stepwise forward selection method was applied to these variables in three multivariate logistic regression analyses, where each of stunting, wasting, and diarrhea was dependent variable.

Bivariate analyses were also performed to determine differences in the handwashing techniques, HWWS, levels of knowledge and awareness, and *E. coli* counts based on participants' gender and grade level. All *E. coli* counts were normalized to CFU per hand and log 10 (hereafter referred to as "log") transformed

before analysis. We used Pearson's correlation to assess the relationship between *E. coli* counts (log) and the scores for handwashing techniques, HWWS, level of awareness of WASH, and the WASH index.

A p-value of <0.05 was considered statistically significant. JMP 13.1.0 software (SAS Institute Japan, Tokyo, Japan) was used for all the statistical analyses.

7.3 Results

7.3.1 Child, Caretaker, and Household Characteristics

The household and caretaker characteristics are shown in Table 7.1. More than half of the caretakers had more than a high-school diploma. When dividing household income into low (<2,000,000 rupiah or US $160), middle (2,000,000 to <4,000,000 rupiah or US $160 to < US $320), and high (≧4,000,000 rupiah or ≧US $320) categories, low- and middle-income households comprised the majority. Households using tank water (purchase/refill) as drinking water were the most prevalent, at 65%; the remaining households used tap and ground water, which were boiled before use. Most of the households had installed their own toilets (private). The households using septic tanks for toilet wastewater treatment comprised only a quarter of the total, whereas the remaining three quarters discarded untreated wastewater in the river directly or indirectly. More than half of the participants attained the maximum total score for WASH knowledge and awareness. The proportion of caretakers who said that handwashing before eating was important exceeded 95%; however, the corresponding proportion when asked after using toilet was below 70%.

Table 7.2 shows the characteristics of the children. The prevalence of diarrhea and respiratory symptoms in the preceding 2 weeks was 14.0% and 39.9%, respectively. A significant association was found between the presence of diarrhea and respiratory symptoms ($p < 0.05, \chi^2$ test). The proportion of children who answered that it was important to wash one's hands before eating reached 90%, but the corresponding proportion when asked about toilet use was only 43%. This tendency was like that of the caretakers. Furthermore, the handwashing technique check yielded an average score of 5.0 points, and only 11 children (5%) did not use soap.

The results of the analysis of the children's nutritional status are shown in Table 7.3. The scores for HAZ using the WHO as a reference ranged from -1.27 to -1.04, and the BMIAZ scores ranged from -0.66 to -0.49. The prevalence of stunting, thinness, and obesity according to the WHO's criteria indicated that boys experienced higher prevalence in all categories ($p < 0.05, \chi^2$ test). When comparing the mean BMIAZ score in this study and the SEANUTS study (Sandjaja et al. 2013) with children aged 5–12 years, all the values fell between those of the rural and urban categories (Fig. 7.1).

Table 7.1 Characteristics of households and caretakers ($n = 228$) (Otsuka et al. 2019a)

Characteristics	*n*	Proportion (%)
Educational background		
Completed primary education	112	49.1
Completed secondary education	116	50.9
Occupation		
Working	52	22.8
Nonworking[a]	176	77.2
Monthly income (rupiah)		
<2,000,000	133	58.3
2,000,000 to <4,000,000	74	32.5
≥4,000,000	20	8.8
No response	1	0.4
Household water and sanitation		
Source of drinking water		
Tap water	60	26.3
Tank water	147	64.5
Groundwater	21	9.2
Drinking water storage type		
Closed container	217	95.2
Open container	11	4.8
Toilet type		
Private	206	90.4
Shared	22	9.6
Treatment for toilet sewage		
Septic tank	60	26.3
No treatment	168	73.7
Water, sanitation, and hygiene knowledge and awareness		
Total score (median, range)	9 (6–9)	
Important times for handwashing		
After using the toilet	159	69.7
Before eating	217	95.2
After eating	128	56.1
Handwashing behaviors		
Always wash hands with soap	61	26.8

[a]Unemployed or homemaker

7.3.2 *Factors Contributing to Children's Health and Nutritional Status*

Tables 7.4 and 7.5 present the results of the logistic regression analysis. Being male (adjusted odds ratio [AOR] = 3.96; 95% confidence interval [CI], 1.80–8.88) and not using a towel after handwashing (AOR = 2.37; 95% CI, 1.13–4.96) were associated with an increased risk of stunting. Being from a middle-income household was associated with a reduced risk of thinness compared to being from a

Table 7.2 Characteristics of children ($n = 228$) (Otsuka et al. 2019a)

Characteristics	n	Proportion (%)
Gender		
Boy	117	51.3
Girl	111	48.7
Grade		
Preschool	59	25.9
Grade 2	58	25.4
Grade 4	51	22.4
Grade 6	60	26.3
Disease symptoms[a]		
Diarrhea	32	14.0
Respiratory illness	91	39.9
Water, sanitation, and hygiene knowledge and awareness ($n = 169$)		
Total score (median, range)	7 (2–8)	
Important times for handwashing		
After using the toilet	73	43.2
Before eating	151	89.3
After eating	50	29.6
Handwashing behaviors ($n = 169$)		
Always wash hands with soap	47	27.8
Handwashing skills ($n = 221$)		
Checklist total score (mean ± SD)	5.0 ± 1.8	
With water and soap	210	95.0
With water	11	5.0
Using a towel	158	71.5

[a]Prevalence during a 2-week period

Table 7.3 Children's nutritional status by gender ($n = 228$) (Otsuka et al. 2019a)

	Gender	
	Boy ($n = 117$)	Girl ($n = 111$)
Height-for-age z-scores (mean ± SD)	−1.27 ± 0.99	−1.04 ± 0.78
Boys' mass index-for-age z-scores (mean ± SD)	−0.66 ± 1.39	−0.49 ± 1.15
Stunting (%)	27.4 ($n = 8$)	9.0 ($n = 10$)
Thinness (%)	15.4 ($n = 18$)	8.1 ($n = 9$)
Obesity (%)	7.7 ($n = 9$)	1.8 ($n = 2$)

low-income one (AOR = 0.26; 95% CI, 0.07–0.92). Children from households using tap water instead of tank water as their drinking water source were more likely to suffer from stunting and thinness (AOR = 2.26; 95% CI, 1.03–4.93; and AOR = 2.88; 95% CI, 1.13–7.35, respectively). Regarding diarrhea prevalence, children from households using open containers for water storage suffered from an increased risk (AOR = 5.01; 95% CI, 1.08–23.15), and being from a middle-income

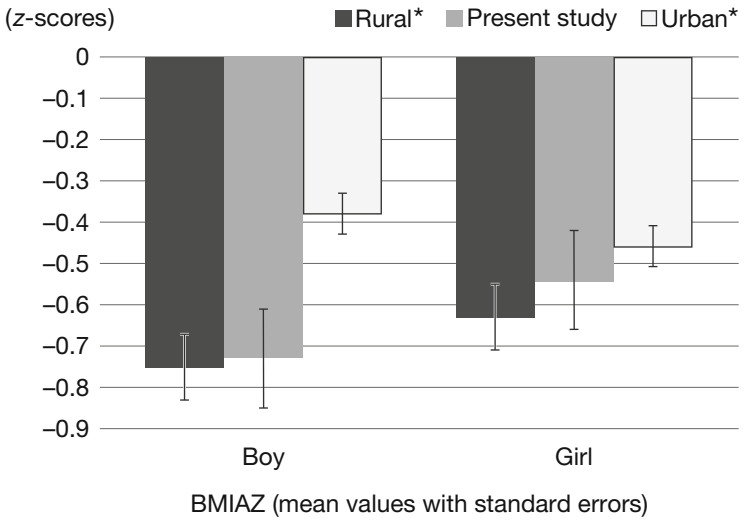

Fig. 7.1 Comparison of children's nutritional status in areas in Indonesia (rural and urban) *South East Asian National Survey; rural: boy ($n = 691$), girl ($n = 729$); urban: boy ($n = 682$), girl ($n = 670$). *BMIAZ* body mass index-for-age *z*-scores (Otsuka et al. 2019a)

household instead of a low-income one was associated with a reduction in risk (AOR = 0.36; 95% CI, 0.13–0.99).

7.3.3 Handwashing Technique Check

The results of the handwashing technique of children by gender and grade level are shown in Table 7.6. The average score for handwashing techniques was only adequate for about half of the ten steps, at 5.5 points. Although over 90% of the children used soap, fewer than 10% performed steps six (backs of fingers to opposing palms with fingers interlaced), seven (rotational rubbing of the left thumb clasped in the right palm and vice versa), and eight (rotational rubbing backward and forward with the fingers of the right hand in the left palm and vice versa). In addition, none of the 166 subjects completed all ten steps. There was no significant difference in the average score by gender, but it was significantly higher among those in grades 4 and 6 than those in grade 2; there was no significant difference between those in grades 4 and 6.

Table 7.4 Factors associated with undernutrition in the multivariate logistic regression analysis (Otsuka et al. 2019a)

Variables		Adjusted odds ratio	95% confidence interval	*P*-value
Stunting				
Gender	Girl	1.00	–	–
	Boy	3.99	1.80–8.88	0.001
Handwashing step ten	Observed	1.00	–	–
	Not observed	2.37	1.13–4.96	0.022
Toilet sewage treatment type	Septic tank	1.00	–	–
	No treatment	2.06	0.81–5.19	0.127
Drinking water source	Tank water	1.00	–	–
	Tap water	2.26	1.03–4.93	0.042
	Ground water	0.55	0.11–2.65	0.453
Thinness				
Monthly income	Low	1.00	–	–
	Middle	0.26	0.07–0.92	0.037
	High	0.39	0.05–3.25	0.381
Water storage type	Closed container	1.00	–	–
	Open container	2.95	0.69–12.60	0.144
Drinking water source	Tank water	1.00	–	–
	Tap water	2.88	1.13–7.35	0.027
	Ground water	1.40	0.34–5.81	0.646
Gender	Boy	1.00	–	–
	Girl	0.51	0.21–1.27	0.148
Age		1.17	0.98–1.40	0.072

Table 7.5 Factors associated with diarrhea prevalence in the multivariate logistic regression analysis (Otsuka et al. 2019a)

Variables		Adjusted odds ratio	95% confidence interval	*P*-value
Monthly income	Low	1.00	–	–
	Middle	0.36	0.13–0.99	0.049
	High	0.32	0.04–2.58	0.284
Drinking water source	Tank water	1.00	–	–
	Tap water	0.40	0.13–1.26	0.118
	Groundwater	0.77	0.19–3.10	0.716
Water storage type	Closed container	1.00	–	–
	Open container	5.01	1.08–23.15	0.039
Water, sanitation, and hygiene knowledge and awareness				
Important times for handwashing	More than two choices	1.00	–	–
	One choice	2.15	0.94–4.93	0.069

Table 7.6 Handwashing techniques by gender and grade (Otsuka et al. 2019b)

Handwashing step	Total ($n = 166$) %	Boy ($n = 85$) %	Girl ($n = 81$) %	*P*-value	Grade 2 ($n = 55$) %	Grade 4 ($n = 51$) %	Grade 6 ($n = 60$) %	*P*-value
1 Wet hands with water	90	87	93	NS	91	92	87	NS
2 Apply enough soap to cover all hand surfaces	92	92	93	NS	80	100	97	<0.05
3 Rub hands palm-to-palm	89	86	91	NS	76	96	93	<0.05
4 Rub right palm over left dorsum with interlaced fingers and vice versa	55	48	62	NS	27	69	68	<0.05
5 Rub hands palm-to-palm with fingers interlaced	42	38	47	NS	24	41	60	<0.05
6 Rub hands with backs of fingers to opposing palms with fingers interlaced	3	5	1	NS	0	8	2	<0.05
7 Rotationally rub hands with the left thumb clasped in the right palm and vice versa	10	11	10	NS	2	24	7	<0.05
8 Rotationally rub hands backward and forward with the fingers of the right hand clasped in the left palm and vice versa	2	2	3	NS	0	4	3	NS
9 Rinse hands with water	95	94	95	NS	84	100	100	<0.05
10 Dry hands thoroughly with a single-use towel	77	74	80	NS	56	98	78	<0.05
Total score (mean ± SD)	5.5 ± 1.7	5.4 ± 1.7	5.7 ± 1.6		4.4^{ab} ± 1.8	6.3^{b} ± 1.2	6.0^{b} ± 1.4	

NS not significant
A value between the same superscript character denotes a significant difference, $p < 0.05$

Table 7.7 Prevalence of handwashing with soap by gender and grade (Otsuka et al. 2019b)

Occasion	Total ($n = 169$) %	Boy ($n = 87$) %	Girl ($n = 82$) %	*P*-value	Grade 2 ($n = 58$) %	Grade 4 ($n = 51$) %	Grade 6 ($n = 60$) %	*P*-value
Before eating	80	77	83	NS	76	76	86	NS
After using the toilet	58	55	61	NS	45	59	70	<0.05
After blowing one's nose, coughing, or sneezing	57	46	69	<0.05	66	45	60	NS
After touching an animal, animal food, or animal waste	81	76	87	MS	66	88	90	<0.05
After touching garbage	73	67	79	NS	64	67	87	<0.05
After playing in the yard	62	52	71	<0.05	45	69	72	<0.05
All occasions	28	23	34	NS	19	20	43	<0.05
Total score (median, range)	4 (0–6)	4^{a} (0–6)	5^{a} (0–6)		3.5^{b} (0–6)	4^{c} (0–6)	5^{bc} (0–6)	

NS not significant
A value between the same superscript character denotes a significant difference, $p < 0.05$

7.3.4 Handwashing with Soap (HWWS)

Table 7.7 shows the prevalence of HWWS among children by gender and grade. The proportion of children who answered that they usually performed HWWS on all occasions was 30%; before eating, 80% did; and under 60% did so after using the toilet. The girls had significantly higher total scores than the boys. Those in grade 6 had a higher total score than those in grades 2 and 4. The girls reported practicing HWWS more often than boys ($p < 0.05$) after blowing their noses, coughing, and sneezing and after playing in the yard.

7.3.5 Knowledge and Awareness of Water, Sanitation, and Hygiene (WASH)

The children's level of knowledge and awareness of WASH by gender and grade level are shown in Table 7.8. About 26% of the children obtained full marks (data not shown). There was no significant difference in the total score by gender. There were, however, significant differences in the total scores between the grades, with those in the higher grades having significantly higher scores. The children who answered that washing their hands before eating was important reached 90%, but only half of those indicated knowledge of its importance after toilet use.

7.3.6 Fecal Hand Contamination

The differences in *E. coli* counts on hands by gender are shown in Fig. 7.2. *E. coli* was detected in 148 of the 150 samples (98.7%). The median CFU counts per hand in sixth graders were significantly lower than in fourth graders (data not shown). According to the median scores, the girls demonstrated significantly fewer *E. coli* bacteria than the boys ($p < 0.05$). Table 7.9 shows the correlation between *E. coli* counts and scores for handwashing techniques, HWWS, knowledge and awareness of WASH, and the WASH index. There were significant negative correlations between *E. coli* counts and handwashing techniques ($r = -0.171$, $p < 0.05$), HWWS ($r = -0.225$, $p < 0.01$), and the WASH index ($r = -0.205$, $p < 0.05$).

7.4 Discussion

The first part of the discussion is focused on the factors contributing to children's health and nutritional status, with a special focus on households' socioeconomic status, caretakers' level of WASH knowledge and awareness, and each household's

Table 7.8 Knowledge and awareness of WASH by gender and grade (Otsuka et al. 2019b)

Question	Total ($n = 169$) %	Boy ($n = 87$) %	Girl ($n = 82$) %	*P*-value	Grade 2 ($n = 58$) %	Grade 4 ($n = 51$) %	Grade 6 ($n = 60$) %	*P*-value
Do you know that boiling water kills germs?	78	82	73	NS	64	84	85	<0.05
Do you know that water containers need cleaning and covering?	92	97	88	<0.05	81	96	100	<0.05
Do you know that human feces contain germs?	91	89	93	NS	83	92	98	<0.05
Do you think that drinking water can be contaminated by fecal bacteria?	72	77	67	NS	41	78	97	<0.05
Do you think that unclean drinking water can make you sick?	88	86	89	NS	76	92	95	<0.05
Which of the following do you think are important times for handwashing?								
After using the toilet	43	47	39	NS	26	33	68	<0.05
Before eating	90	87	91	NS	79	98	92	<0.05
Do you think that you can spread germs if you don't wash your hands after going to the toilet?	92	91	94	NS	79	98	100	<0.05
Do you think that handwashing is important for disease prevention?	93	95	91	NS	88	94	98	NS
Total score (median, range)	7 (2–8)	7 (2–8)	7 (2–8)		5^{ab} (2–7)	7^{ac} (4–8)	8^{bc} (3–8)	

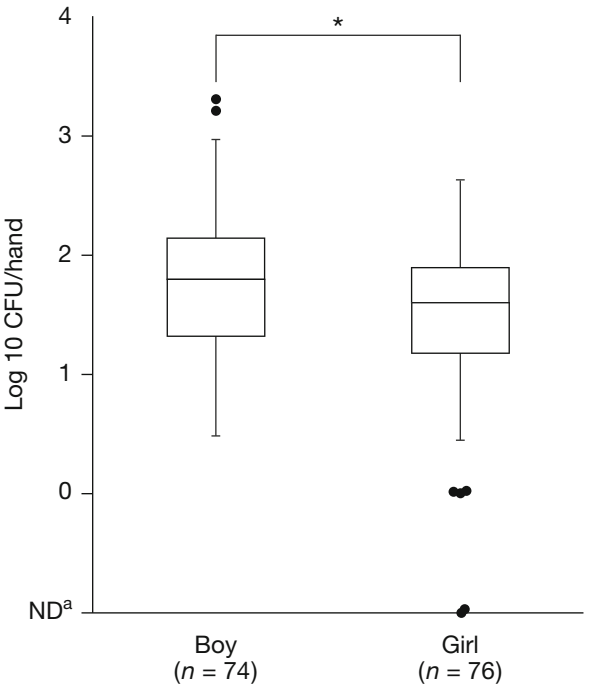

Fig. 7.2 Comparison of *Escherichia coli* counts by gender. It includes box and whisker plots showing the levels of *E. coli* contamination per hand among children. The line in each box represents the median, the tops and bottoms of the boxes represent the 75th (Q3) and 25th (Q1) percentiles, and the top and bottom whiskers extend to the Q3 + 1.5 × IQR and Q1–1.5 × IQR, respectively. [a]Not detected. *Wilcoxon rank sum test, $p < 0.05$ (Otsuka et al. 2019b)

Table 7.9 Correlation with detected *Escherichia coli* amounts (Log10 CFU/hand) (Otsuka et al. 2019b)

Variable (score)	Correlation coefficient
Handwashing technique	−0.171*
Handwashing with soap	−0.225**
Knowledge and awareness of WASH	0.002
WASH index	−0.205*

WASH water, sanitation, and hygiene
* $p < 0.05$, ** $p < 0.01$

WASH status. Then, based on the results obtained from the tests of elementary-school children's levels of fecal hand contamination, in the second part, we delve into a deeper discussion of children's hand hygiene, handwashing with soap (HWWS), levels of WASH knowledge and awareness, fecal hand contamination, and handwashing techniques while noting differences in gender and grade level. Lastly, a WASH index developed to evaluate comprehensive competency in terms of handwashing techniques, HWWS, and knowledge and awareness of WASH is introduced.

7.4.1 Factors Contributing to Children's Health and Nutritional Status

To our knowledge, the research regarding children's nutritional status in urban slums has mostly been carried out in India and low- and middle-income African countries. While there are some studies focused on Indonesian urban slums, most include relatively old data, for example, from the Nutrition and Health Surveillance System. We compared the current study with the SEANUTS study (Sandjaja et al. 2013) conducted in 48 rural and urban districts in Indonesia to evaluate the nutritional status of children in urban slums (Fig. 7.1). The mean BMIAZ score of this study fell between those of the rural and urban areas in the SEANUTS study. In particular, the BMIAZ score of the boys in this study was almost the same as that of those in rural areas in the SEANUTS study. It is possible that children's nutritional status in low- and middle-income countries tends to be poorer in urban slums than in general urban areas. The nutritional status of Indonesian children was generally good (Fig. 7.1). However, we must pay attention to children's nutritional status in low- and middle-income countries, especially in urban slums, because obesity rates might increase as the economic situation improves in the future.

In a multilevel study in low- and middle-income countries including Indonesia, a high level of wealth was reported as a preventive factor for diarrhea in children under 5 years of age (Pinzón-Rondón et al. 2015). The current study shows that the prevalence of diarrhea among children from middle-income households is lower than among those from low-income ones (Table 7.5). Generally, children under 5 years of age are more likely to suffer from infectious diseases than those of other ages; however, this study revealed that the prevalence of diarrhea was higher in children above 5 years of age (14.8%) than among those under 5 years of age (11.4%). This may be the case because PAUD is a supplementary education facility, and, according to the locals, the families of the children who attend PAUD have relatively high socioeconomic status. In fact, the proportion of families with low household incomes was lower for preschool children (36%) than for elementary-school children (67%) (data not shown). Thus, household income should receive higher consideration when examining diarrhea prevalence, regardless of the child's age.

Although it is an important factor to consider, there are few studies investigating the relationship between the prevalence of diarrhea and a caretaker's knowledge and awareness of WASH. However, a previous study in Ethiopia reported the relationship between knowledge regarding diarrhea (i.e., the causes of diarrhea) and the prevalence of diarrhea in children (Nigatu and Tadesse 2015). Even so, no relationship was found between the prevalence of diarrhea and a caretaker's knowledge and awareness of WASH in the current study (Table 7.5), probably because caretakers' levels of knowledge and awareness of WASH were generally high, resulting in a lack of remarkable differences between the caretakers (Table 7.1). Therefore, the small number of caretakers who had relatively low levels of knowledge and awareness may have prevented the observation of true differences. Moreover, the data

regarding diarrhea prevalence were collected based on each caretaker's recall of the previous 2 weeks instead of an official diagnosis, so the data-collection method may have affected the results.

7.4.2 *Children's Health, Nutritional Status, and Household WASH Knowledge*

In addition to assessing the caretakers' levels of WASH knowledge and awareness, the households' WASH facilities were reviewed in relation to the children's health and nutritional status. Previous studies have reported that improved water sources were linked to a lower risk of stunting in parts of Ethiopia and Tanzania (Altare et al. 2016; Gebregyorgis et al. 2016). This study showed that over 85% of families used tank water or tap water for drinking (Table 7.1). Between these two water-source types, tank water reduced the risk of stunting more (Table 7.4). This could be related to the tap water's quality, since, in Bandung, residents purchasing bottled water considered other water sources to be of poorer quality (Anindrya et al. 2017). This study revealed that water sources contributed to both stunting and thinness (Table 7.4), indicating that the use of tank water could improve children's nutritional status.

As in a survey of villages in Bangladesh (Kunii et al. 2002), this one revealed that appropriate water storage is important for reducing the risk of diarrhea. Water stored in covered areas was less likely to be associated with high-level contamination by *E. coli* (Heitzinger et al. 2015). For example, in villages in the slums of Nairobi, the prevalence of soil-transmitted helminths was lower in children whose households used covered storage areas for drinking water than in children whose households did not (Caitlin et al. 2016). Furthermore, in the studied area, even if there were water-supply facilities within the home, the amount of water provided to each household was insufficient. As shortages of water were a daily problem in the area, storing water for extended periods was both common and necessary. Therefore, the availability of appropriate water storage facilities must be ensured to prevent contamination by pathogens in low- and middle-income countries where the water supply is inadequate.

Regarding household sanitation, several studies in India (Jee et al. 2015) and low- and middle-income African countries (Curtis et al. 2000) reported that the quality of sanitation facilities was associated with children's nutritional status; however, there was no relationship between sanitation and children's nutritional status in our findings (Table 7.4), possibly because the quality of the sanitation facilities in the studied area was relatively high compared to those in the areas in the aforementioned studies. Moreover, there was no considerable difference in the quality of sanitation facilities among the households in this study. In fact, 90% of the households had private toilets, and there were no cases of open defecation in the studied area

(Table 7.1). On the other hand, in this study, a lack of treatment for toilet wastewater was not a significant factor in children's nutritional status (Table 7.4). It is unlikely that the availability of septic tanks affected the nutritional status of the children, since sewage eventually flowed into the nearby river regardless of whether a septic tank had been installed. Although sanitation did not directly contribute to the nutritional status of children in this study, it is necessary to clarify how untreated wastewater affects the health of children and the environment in other areas in future studies.

As mentioned previously, diarrhea is caused mainly by the ingestion of pathogens but can be prevented by handwashing (Curtis et al. 2000). An estimated 50% of undernutrition is associated with the repetition of diarrhea and intestinal nematode infections caused by unsafe water, inadequate sanitation, and insufficient hygiene (Prüss-Üstün et al. 2008). We found that the risk of stunting increased in children who did not use towels after handwashing, but not in children who did not use soap (Table 7.4), possibly because almost every child used soap in their handwashing routine (Table 7.2), while 71.5% of children used towels. Another possible reason is that using a towel after handwashing increases the likelihood of eliminating bacteria. A previous study demonstrated the effectiveness of using towels and revealed that using a clean towel after handwashing led to the presence of fewer *E. coli* bacteria on hands than air-drying (Friedrich et al. 2017). Thus, using towels can reduce the risk of infectious diseases, which lead to undernutrition. Moreover, the importance of the towel-use step, which the WHO incorporated into the recommended handwashing procedure, was confirmed in this study.

7.4.3 Hand Hygiene and HWWS

A more in-depth assessment of fecal contamination and hand hygiene showed the presence of *E. coli* on 98.7% (148/150) of children's hands (Fig. 7.1). In an urban area in India, bacterial pathogens were detected in all specimens taken from students' hands (*E. coli* was 20%) (Tambekar and Shirsat 2009), and, in another study, 61% of children had potential pathogens on their hands (*E. coli* was present in 12% of cases) (Ray et al. 2011). In two elementary schools in Malawi, *E. coli* bacteria were detected on the hands of 67 and 75% of pupils (Grimason et al. 2014), and, in Kenya, on the hands of 41% of students (Greene et al. 2012). Thus, the detection rate for bacteria on children's hands is inconsistent, perhaps because of differences in sampling and detection methods. It is thought that there is a high risk of undetected fecal contamination, since the detection rate for *E. coli* on children's hands in this study was overwhelmingly greater than in previous ones; however, it is difficult to compare the rates of detection directly.

The reason for high levels of fecal contamination in this study may have been children's failure to wash their hands with soap after using the toilet at school.

Problems with unavailability of soap for handwashing in schools were pointed out in a previous study, (Lopez-Quintero et al. 2008) and it is a barrier to the effective practice of HWWS. In Greece, the fecal *Streptococci* detection rate on children's hands in 20 elementary schools that provided soap was lower than that of those attending a school that did not provide it (Kyriacou et al. 2009). The handwashing technique check (Table 7.1) in this study revealed that most children normally use soap at home; however, at the schools where the children spend half of the day, there was no soap in the restrooms. Providing soap in schools' restrooms may improve HWWS behaviors and reduce fecal contamination.

HWWS reduces the risk of diarrhea by 48% (Cairncross et al. 2010), since more bacteria potentially of fecal origin can be removed by HWWS than with water alone (Burton et al. 2011). A previous study in Tanzania (Pickering et al. 2010) reported that people who always performed HWWS had significantly less *E. coli* and fecal *Streptococci* contamination than those who did it occasionally or rarely. Thus, it is important to consistently practice HWWS to remove bacteria. This study supported the importance of frequently practicing HWWS, since it was revealed that there was a significant negative correlation between the number of *E. coli* and the practice of HWWS (Table 7.4). Moreover, promoting effective handwashing techniques is important for reducing contamination (Friedrich et al. 2017); hence, there was a significant negative correlation between the number of *E. coli* present and the use of effective handwashing techniques (Table 7.4). Therefore, fecal contamination decreased as the frequency with which children used soap in various situations increased, and the importance of effective handwashing techniques was supported.

The most critical times for handwashing are before preparing food or cooking, before eating or feeding a child, after cleaning a child's bottom, and after defecation (United Nations 2015). In terms of the six occasions investigated in this study, the ones matching these critical times were before eating and after toilet use. Approximately 80% of children indicated that handwashing before eating was important, while only half of this number reported the same for toilet use (Table 7.3). Inadequate handwashing after toilet use can promote the direct transmission of pathogens through interpersonal contact or indirect transmission through food and the environment (Pickering et al. 2010); therefore, effective handwashing after toilet use is important for preventing fecal-oral bacterial transmission. In this study, more than 90% of the children said that they usually washed their hands (with either water alone or soap) after toilet use and that they did so more effectively than elementary-school students in other low- and middle-income countries (Vivas et al. 2010; Xuan and Hoat 2013). However, the rate of children who usually performed HWWS after toilet use was not high, at 58% (Table 7.2), since only 43% thought that it was important to wash one's hands after toilet use (Table 7.3: the children in lower grades had especially low rates of 26 and 33%). Therefore, awareness of the importance of handwashing after toilet use and the practice of HWWS must be increased.

7.4.4 HWWS, WASH Knowledge and Awareness, and Fecal Hand Contamination by Gender and Grade

Pertaining to gender-related differences in fecal contamination levels, previous studies that measured *E. coli* and fecal *Streptococci* on the hands of high school students in Tanzania (Pickering et al. 2010) and elementary school students in Greece (Kyriacou et al. 2009) revealed that boys' hands showed more bacterial contamination than girls', perhaps because boys tend to engage in more outdoor activities and games, making them more prone to contact with the soil and subject to more contamination, as the Greek study suggests (Kyriacou et al. 2009). As in the previous studies, the amount of *E. coli* found on the hands of the children was significantly greater among boys than girls (Fig. 7.2). Furthermore, boys' compliance with HWWS behaviors was significantly lower, and, in terms of the six occasions, boys scored significantly lower on "a person who washes hands with soap" after "playing outside" (Table 7.3). This is considered a reason for the larger number of *E. coli* bacteria on the hands of boys. The risk of fecal contamination from one's surroundings is considered higher for boys than girls, making it necessary to thoroughly impress the importance of practicing good hygiene on boys, especially HWWS. In this study, no distinction was made between urination and defecation. However, handwashing behaviors may differ by gender after urination and defecation; therefore, further research is needed on this point.

It is important to emphasize the importance of education about HWWS practices in the lower grades (Xuan and Hoat 2013). A previous study conducted in Vietnam reported that it was less common for children to practice HWWS in the lower grades (Xuan and Hoat 2013). Likewise, in this study, the children in the lower grades had significantly lower scores for handwashing techniques, HWWS behaviors, and knowledge and awareness of WASH than those in the upper grades (Table 7.6), possibly because children in the higher grades have had more exposure to hygiene education (En and Gan 2011; Xuan and Hoat 2013). On the other hand, there was a significant difference between children in the second and fourth grades in terms of handwashing techniques, but there were none between those in the fourth and sixth grades (Table 7.6). Considering that the handwashing techniques of preschool children (not published) were less effective than those of second graders, this implies that there is a gradual improvement in handwashing techniques between the preschool phase, when children begin learning about handwashing, and the fourth grade, with a plateau at the latter age. Further studies are needed to investigate how such changes in handwashing techniques by grade level occur after the sixth grade and whether this can be reproduced in other regions and populations.

7.4.5 Children's Handwashing Techniques

Although it is important to evaluate children's handwashing techniques, it is difficult to evaluate them accurately. In addition, there are few studies evaluating the

handwashing techniques of children based on observations of participants at each step of the process with the use of universal procedures. A study in Vietnam (Xuan and Hoat 2013), in which the handwashing techniques of children (in grades 1, 4, and 7) were investigated by observation, evaluated the use of the procedure (eight steps) recommended by the country's Ministry of Education and Training and showed that only 3% of the children performed all the steps correctly. However, the data of those performing each step showed a 46–82% rate of completion, and approximately half of the children performed each step. In contrast, in our study, we evaluated the handwashing techniques of children using a modified procedure based on recommendations by the WHO (2009b). None of the children performed all ten steps perfectly, and only two (1.2%) performed nine of the steps (Table 7.6). It seems difficult for elementary-school children to perform all the handwashing steps perfectly according to the WHO's recommended procedure.

Focusing on each step, the procedure was divided into three levels. Most children were relatively capable of doing steps one, two, three, nine, and ten. Steps four and five were done by half the children; 90% of them were unable to do steps six (with the backs of the fingers to the opposing palms with the fingers interlaced), seven (rotationally rubbing with the left thumb clasped in the right palm and vice versa), and eight (rotationally rubbing backward and forward with the fingers of the right hand in the left palm and vice versa; Table 7.6). The elementary-school children were unable to carry out all the steps completely, since the WHO's recommended procedure was designed for use in healthcare centers/facilities like hospitals, and it was too detailed for them to grasp. Still, considering that half of the children successfully performed steps four and five (washing the palms and backsides with fingers crossed), it can be inferred that education on these steps will lead to improvements in children's handwashing techniques. Furthermore, it would be beneficial to develop procedures that could be used universally considering the field conditions surrounding the evaluation and guidance of children's handwashing techniques.

7.4.6 WASH Index

To reduce the fecal contamination level of children and prevent diarrhea, it is important to comprehensively evaluate not only handwashing behaviors and knowledge and awareness of WASH but also handwashing techniques. Although several researchers have investigated the relationship between fecal contamination on children's hands, handwashing behaviors (Kyriacou et al. 2009; Padaruth and Biranjia-Hurdoyal 2015), and knowledge and awareness (Grimason et al. 2014), investigations of the relationship between handwashing techniques and fecal contamination are rare. Equally, few researchers have analyzed the relationship between comprehensive abilities in terms of (1) handwashing behaviors, (2) knowledge and

awareness of WASH, and (3) handwashing techniques and fecal contamination. Nobody appears to have integrated handwashing behaviors, knowledge and awareness of WASH, and handwashing techniques into a single index yet. We, therefore, developed a WASH index to evaluate a comprehensive ability reflecting handwashing techniques, HWWS, and knowledge and awareness of WASH. The results showed a significant negative correlation between the WASH index and number of *E. coli* on a subject's hands. Overall, we uncovered associations between the comprehensive ability composed of handwashing techniques, HWWS, and knowledge and awareness of WASH and fecal contamination (Table 7.4). The validity of the WASH index must be verified in other regions and populations.

7.4.7 Limitations

There are limitations in the current study that must be addressed in future work. The findings may not be generalized to all children in urban slums in low- and middle-income countries, because the sample size was relatively small, and the quality of the sanitation facilities was generally high and consistent in the studied area. In addition, the subjects may have overreported their levels of WASH knowledge and awareness and overestimated their handwashing behaviors on the questionnaire. Considering the participants' educational level and the time required to complete the questionnaire, we prioritized ease of answering to reduce the burden on the participants. However, the simplicity of the questionnaires may have made it easy for them to guess the correct answers. The handwashing observations were conducted by a single researcher to minimize observation bias, although the presence of the researcher may have caused the participants to alter their hand hygiene behaviors, as previously reported (Srigley et al. 2014). Therefore, we investigated hygiene behaviors with a comprehensive approach using both the questionnaire and a direct observation of each child's handwashing technique to compensate for this issue. Our findings revealed that household characteristics, such as monthly income and drinking water management, as well as children's hygiene practices, had an association with children's health. The influence of the school and community environment should also be considered, because most children spend many hours outside their homes.

Moreover, differences in handwashing abilities were found between second and fourth graders (Table 7.6). However, it is unclear when the shift in technique occurred, since we only sampled students in grades 2, 4, and 6. Even so, the study revealed that there was a difference between students in the lower and upper grades. We found a relationship between the number of *E. coli* on a student's hands and their WASH index, which we developed for comprehensive evaluation. However, contrary to expectations, a student's level of knowledge and awareness of WASH was unrelated to the number of *E. coli* on their hands (Table 7.9). This may have been due

to the simplicity of the questionnaire (only simple "yes" or "no" answers were required); it may also have been too easy for children to guess the correct answers. In addition, the evaluation standard for the children's handwashing techniques was relatively high (designed for adults in a healthcare setting). Even so, the evaluation clarified which steps in the handwashing process need to be emphasized more in elementary schools. Lastly, the *E. coli* detection method presented a challenge: since this study was aimed at identifying the contamination risk among children, we decided to focus strictly on *E. coli*, counting the blue and purple colonies. It was, however, possible to overcount the *E. coli* bacteria due to the means of detection (only by the color of the colony reflecting enzymatic activity based on the measurement principle).

7.5 Summary

In conclusion, the nutritional status of the children living in an urban slum in Indonesia was generally good. Not only were household characteristics, like monthly income and drinking water source, significantly associated with the children's nutritional status, but the characteristics of the children themselves, such as gender and handwashing techniques, were as well. On the other hand, the households' monthly income and water storage type were significantly associated with the prevalence of diarrhea in children. Therefore, home drinking water management and proper personal hygiene practices among children are important for maintaining and improving children's health in Indonesian urban slums.

Almost all the children at the study site exhibited fecal contamination on their hands. However, using proper handwashing techniques and practicing HWWS at appropriate times can reduce fecal contamination. The data showed that handwashing techniques, HWWS, and knowledge and awareness of WASH were poor among children in the lower grades and that boys were at especially high risk of fecal contamination. Hence, it is important that grade- and gender-specific elementary school education on handwashing be considered. It is equally important to develop easier handwashing methods and tools for children. The study indicated the presence of a relationship between fecal contamination and the WASH index, which comprehensively captured handwashing techniques, HWWS practices, and knowledge and awareness of WASH. Further verification of the validity of the WASH index and the development of comprehensive indicators are needed.

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Chapter 8
Social Allocation of the Health Risks in Sanitation

Hidenori Harada

Abstract Sanitation can change the fate of excreta and control the emission to the living and ambient environment, leading to the reduction of fecal exposure and the mitigation of fecal–oral infectious risk. The fate of excreta and its associated health risks in sanitation, however, may not be limited within the living boundary of a single person or even within a community. Based on examples in Vietnam, this chapter demonstrates the transfer of health risks in sanitation and its allocation in society. Along a river, fecal pollutants and the associated health risks were transferred from the urban upstream areas to rural downstream areas, resulting in the change of livelihood downstream. Resource-oriented sanitation was enabled at the expense of female farmers' health risks through their handling of fecal matter, indicating a gender-related risk allocation. This chapter also discusses the health risk allocation of modern sewerages between those who flush excreta and those who work in the sewerages, and that of on-site sanitation along the sanitation service chain. Since sanitation possibly causes the transfer of health risks in society, sound social allocation and mitigation of health risks are essential to address social challenges in sanitation.

Keywords Health risk transfer · Health risk allocation · Fecal exposure · F-diagram · Fecal river pollution · Water, sanitation and hygiene (WASH)

8.1 Introduction

Water, sanitation, and hygiene (WASH) is a practice that reduces the chance that people are exposed to pathogens, especially those derived from human excreta. Out of the three components of WASH, sanitation plays a role in treating and disposing excreta for people's health, which makes the living environment free from fecal

H. Harada (✉)
Graduate School of Asian and African Area Studies, Kyoto University, Kyoto, Japan
e-mail: harada.hidenori.8v@kyoto-u.ac.jp

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contamination, and eventually reduce fecal exposure and fecal–oral infection (Fig. 8.1). Sanitation can change the fate of excreta and control the emission of fecal matter to the living and ambient environment. A sanitary toilet is the step to contain fecal matter and is a key part of sanitation. If the fate of excreta after toilets is not properly controlled, fecal matter is emitted to the living environment and sanitation will not achieve its goal.

Unfortunately, a large proportion of the global population cannot successfully change the fate of fecal matter owing to improper sanitation. After excreta is emitted in an unsanitary manner with the amount above the level of an acceptable environmental capacity, the living environment will be contaminated by fecal matter and its associated microorganisms. As illustrated in Fig. 8.1, humans can be exposed to them by different environmental media (water, soil, object surface, etc.) through various pathways in daily activities (drinking, eating, and activities involving contact with fomite).

The media, pathways, and associated daily activities are, by nature, the matter of socio-culture. The fate of excreta may not be limited within the living boundary of a single person, or further even in a community. Excreta are generated in a place and can be transferred to and emitted in another place, by the movement of media carrying excreta, by a vehicle truck, and by passing through water ways and pipelines. Rivers or canals in areas with dense populations but improper sanitation potentially transfer excreta and their diluted matter to downstream areas. More generally, community X may be cleaned out by the transfer of excreta to community Y. This transfer, however, may pollute community Y, where the excreta was transferred, possibly causing the transfer of health risks derived from excreta-related (i.e., sanitation-related) microorganisms from community X. Substantial pollution and the associated health risks in community Y, transferred from community X, may change the livelihood of people in community Y to avoid contact with pollutants and further mitigate the associated health risks.

The transfer of sanitation-related health risks may also occur between people within a community. When excreta are stored, treated, and disposed of where

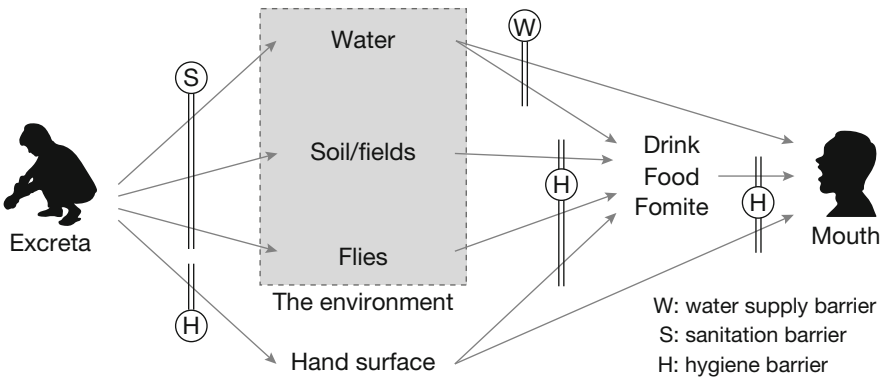

Fig. 8.1 Emission, transmission, and exposure of fecal matter and the role of water supply, sanitation, and hygiene (F-diagram)

generated, the health risks caused by the excreta will be held by the excreter. In reality, there are many types of sanitation, in which the people who excreted differ from the people who handle the excreta generated by the former. Excreta stored in an on-site sanitation facility, called fecal sludge, is often emptied and transported by someone other than the excreter; then, the excreta is transported to another place, where it is hopefully treated and disposed of by someone else. This may allocate the sanitation-related health risk from the excreter to someone who handles excreta later on. Further, even within a single family, the excreter may not be involved in handling excreta. For example, the cleaning duties of sanitation facilities are not equally allocated to each of the users of the facility, and the person responsible for cleaning may be exposed to the sanitation-related health risk more than others who transfer the risk to the cleaning person.

The health issue of sanitation is not only an issue within a certain person, but beyond a person, a family, and even a community. It is transferred and allocated to society as a socio-cultural matter. This section will demonstrate the transfer and allocation of sanitation-related health risks based on cases in Vietnam. Then, we discuss how such a transfer and allocation of health risk will affect and be affected by socio-culture.

8.2 Transfer of Fecal Matter from Urban Upstream Areas to Downstream Areas

8.2.1 Study Area

The Nhue River is a distributary of the Red River, passing through the center of Hanoi, the capital of Vietnam (Fig. 8.2). It flows down through agricultural fields and joins another larger distributary of the Red River—the Day River—nearly 80 km downstream of the intake. Hanoi, located upstream of the Nhue River, has a limited capacity for wastewater treatment. Of the city's population, 96.8% used water flush toilets and 84% was connected to septic systems, most effluent of which was discharged into sewer systems (Brandes et al. 2016; Harada et al. 2011). In contrast, only 33% of the population is covered by wastewater treatment plants in the city (Japan International Cooperation Agency and Nippon Koei 2019), meaning that most of blackwater (toilet wastewater) generated in Hanoi reach at public water only after limited treatment in septic systems.

The upstream area of the Nhue River is characterized by urban land use with high population density but poor wastewater treatment capacity, while the downstream area is characterized by farming areas, including rice cultivation, livestock, and poultry production. Historically, the river has played an important role as an irrigation water source for farming areas as well as a place for river fishing (Pham et al. 2015; Nguyen et al. 2014). However, it has been recently contaminated by

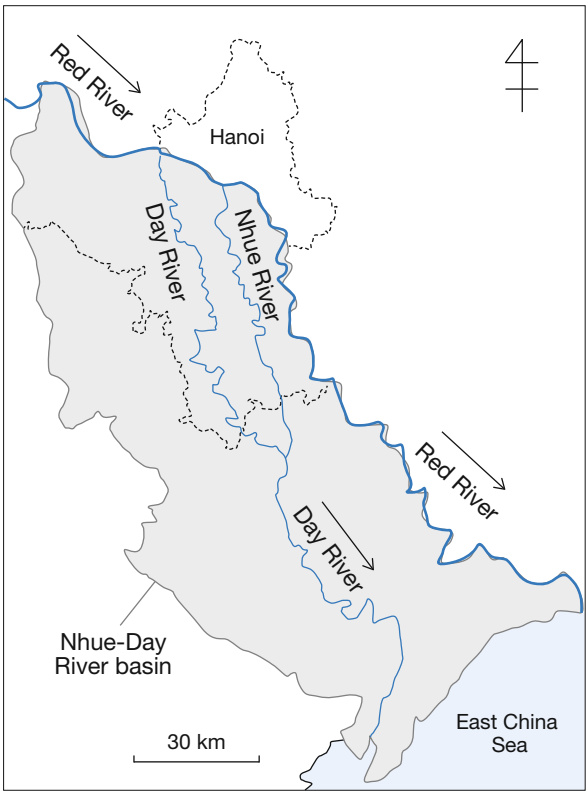

Fig. 8.2 A map of Nhue River

receiving a large amount of polluted water from urban Hanoi in its upstream areas (Fig. 8.3).

8.2.2 Transition of Fecal Pollution Along Nhue River

To characterize the impact of upstream urban water pollution on the downstream area along the Nhue River, we conducted a series of river surveys from 2011 to 2018. Figure 8.4 shows the river water quality along the Nhue River from the intake point (S1) to 1 km downstream of the confluence with the Day River (S9). The low values of total organic carbon (TOC; an indicator of organic pollution) concentration and electrical conductivity (EC; an indicator of ionic substances) at S1 indicate less pollution of the source water of the Nhue River at the intake, which is diverted from the Red River (1.0 mg/L of TOC, 0.18 mS/cm of EC). They, however, gradually increased by passing thorough urban Hanoi and peaked right after passing urban Hanoi (S5; TOC: 134.0 mg/L, EC: 0.76 mS/cm). The concentration of *Escherichia coli*, a microbiological indicator of fecal pollution, was also low at the intake of

Fig. 8.3 Nhue River approximately 20 km downstream from the intake. The river water was heavily polluted with dark gray color. (Photo taken by Harada, September 2017)

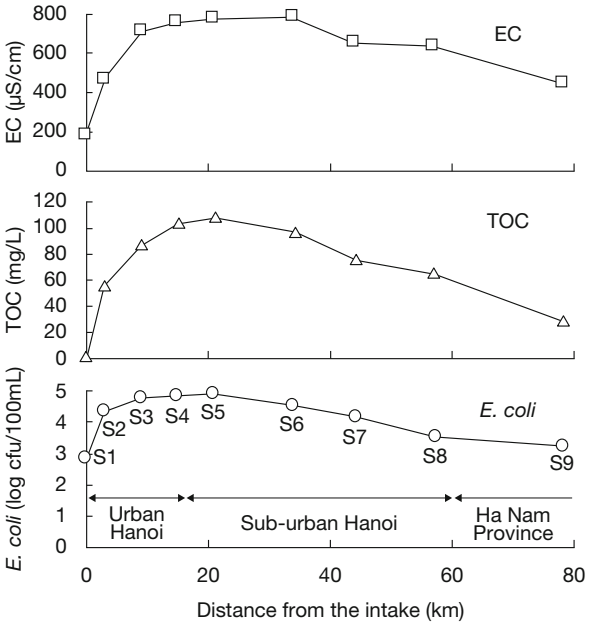

Fig. 8.4 Transition of TOC, EC, and *E. coli* along Nhue River. *TOC* total organic carbon, *EC* electrical conductivity. Data are shown as geometric mean of the results from three surveys on March 9, 12, and 15, 2018 (Tanaka 2019)

Nhue River (S1; 7.0×10^2 cfu/mL). Entering urban Hanoi, it increased more rapidly than TOC and EC, and then reached near 10^5 cfu/100 mL at S3–S5. All these parameters started to decrease after leaving the urban areas. The pollution, however, lasted long distances. The *E. coli* concentration was 5.0 times higher than the intake level at S8, 35 km downstream from the border of urban and suburban areas. Even at S9, where the Nhue River flowed into the Day River, the *E. coli* concentration was 2.3 times higher than the intake of Nhue River, S1.

The aforementioned fecal pollution trend was further characterized by a host-specific *E. coli* genetic marker. *E. coli* can be derived not only from humans but also from warm-blooded animals. A human-associated genetic marker, H8 (Gomi et al. 2014; Harada et al. 2018; Warish et al. 2015), was tested with 120 *E. coli* isolates for each of the nine sampling points to obtain information on the host of each *E. coli* isolate. As illustrated in Fig. 8.5, the proportion of H8-positive *E. coli* continuously increased from the intake (23.3% at S1) and peaked immediately after urban Hanoi (56.7% at S3), and it tended to decrease after leaving the urban areas. As the sensitivity of H8 markers for sewage was 63.3% in Vietnam ($n = 120$), the high positive proportions (52.5–56.7% at S3–S5) indicate that most *E. coli* isolates at S3–S5 are expected to have a human origin. This implies that the fecal pollution strengthened within urban areas was biologically associated with human fecal pollution.

Further, helminth eggs were investigated in the water and sediment of the Nhue River, as shown in Fig. 8.6. They were rarely detected in the sample of Nhue River water even though we increased the sample water volume up to 5 L per sample. In contrast, the eggs were detected in 100-g-wet sediment for all samples, of which 77% and 12% were *Ascaris* spp. and *Trichuris* spp., respectively. Possible hosts of *Ascaris* spp. are humans and pigs. Since pig raising was not a common practice in urban Hanoi at S2a–S4, human fecal pollution from urban populations caused the accumulation of helminth eggs in the river sediment. This supports the fecal contamination by human excreta, as indicated by the above results of the human-associated genetic marker of *E. coli*.

The transition of helminth egg concentration in sediment along the river had a different trend from that of *E. coli* concentration in river water. The concentration of helminth eggs in the semibent decreased more quickly after passing urban Hanoi than that of *E. coli*. This could be explained by the fact that helminth eggs, which settle more easily than bacteria (i.e., *E. coli*), accumulated in sediment but were

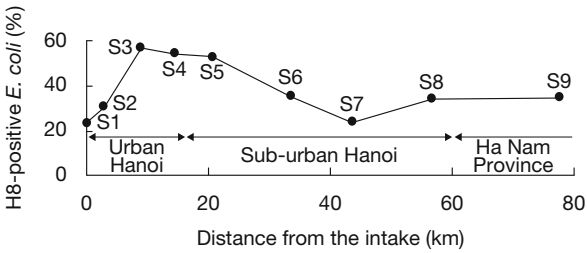

Fig. 8.5 Positive proportion of human-associated genetic marker, H8, for 120 *E. coli* isolates collected at each of the nine sampling points along Nhue River. (Data originated from Tanaka (2019))

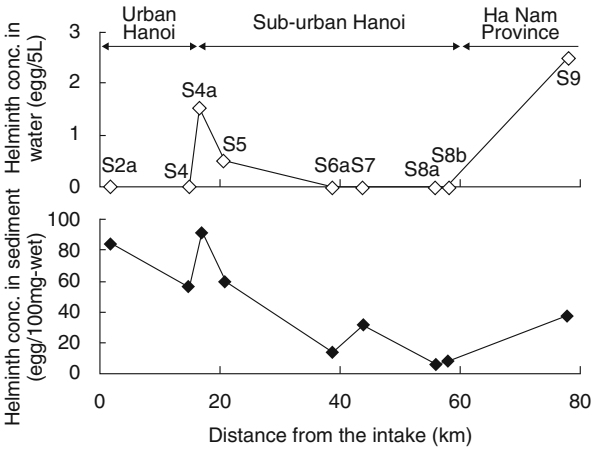

Fig. 8.6 Helminth egg number of Nhue River water (upper) and sediment (lower). The numbers in the figure are the average of viable and nonviable egg numbers from the survey on October 9 and 23, 2015. (Data originated from Sakaguchi (2016))

rarely detected in water (Fig. 8.6). Still, eggs in sediment can be transferred when strong river flows occur (e.g., after heavy rain). The high number of helminth eggs at S9 was possibly caused by the pollution of the Day River, of which the watershed includes ample pig raising.

8.2.3 Allocation of Health Risk Along the Nhue River

The Nhue River was seriously polluted microbiologically, passing through the urban centers of Hanoi. The *E. coli* concentration reached approximately 10^5 cfu/100 mL in urban areas, and helminth eggs accumulated in the river sediment. The rapid deterioration of river water quality within urban areas is explained by the discharge of a large amount of wastewater from urban Hanoi, located upstream of the river. Furthermore, the impact of wastewater discharge in urban Hanoi continued far downstream from the urban areas. In other words, the downstream river water was contaminated by the upstream wastewater, although the downstream areas also discharged their own wastewater (Pham et al. 2017).

Downstream of S5, small-scale agricultural farmers were observed along the river, who utilized river water for irrigation. A health guideline for fecal coliform concentration in wastewater use for irrigation was set as 10^3 count/100 mL by the World Health Organization (Blumenthal et al. 2001; WHO 1989). As fecal coliform is a larger group including *E. coli*, the fecal coliform concentration of a water sample is theoretically equal to or higher than the *E. coli* concentration, indicating that all the sampling points except the intake would not meet the guideline concentration of fecal coliform. Furthermore, despite the gradual decrease in *E. coli* levels, this trend lasted far downstream areas, and the *E. coli* concentration still exceeded 10^3 cfu/100 mL at S9. These results clearly demonstrate that agriculture activities using irrigation water from the Nhue River pose a health risk, as mentioned by Fuhrimann

et al. (2016), who demonstrated the serious microbial pollution of irrigation water near S5. A study also highlighted that farmers along a river in Hanoi in contact with wastewater experienced a significantly higher frequency of diarrhea than those without contact (odds ratio [OR]: 1.98, 95% confidence interval [CI]: 1.18–3.33) (Trang et al. 2007). Of people in the downstream area of the Nhue River, 47% were infected by helminth (*Ascaris lumbricoides*: 24%; *Trichuris trichiura*: 40%; and hookworm: 2%), and people in contact with river water had a higher risk of *A. lumbricoides* (OR: 2.1; 95% CI: 1.4–3.2) in comparison with those without contact (Pham-Duc et al. 2013).

Thus, the case of the Nhue River highlighted the microbiological contamination of the upstream areas, which affected the river water quality and the associated health of people in the downstream areas. This clearly indicates the transfer of fecal pollution and the associated health risks from the urban upstream areas to the downstream areas. In nature, water is possibly polluted after use, and the polluted water flows to another place, posing a health impact there. Sanitation definitely affects this health risk transfer because sanitation is a measure to change the fate of excreta and control the emission to the living and ambient environment. In the following section, we discuss how the livelihood has been affected by pollution with further details of fecal exposure characteristics in a community downstream of the Nhue River.

8.3 Fecal Exposure in Livelihood of the Downstream

8.3.1 Study Area

Trai hamlet is a rural community in the Phu Xuyen suburban district of Hanoi, located downstream of the Nhue River (55 km from the intake of the Nhue River from the Red River). The community had a population of 800 people in a total area of 56.1 ha as of 2010 (Pham et al. 2015). Farming, mainly rice cultivation, is a major occupation. The Nhue River is used as a major irrigation source together with reservoirs, some of which are used as fishponds. Some residents have a side job of river fishing.

A public water supply was not established as of 2010. The people in the community used three types of water for domestic purposes in a mixed manner: well water stored in a tank outside, rainwater stored in a tank outside, and drinking water stored in a pot after boiling. Of the 240 households in the community, 52% employed traditional dry toilets (Fig. 8.7) (Pham et al. 2017). Dry toilets are typically designed as high-floor toilets with a single or double chamber(s), located under the floor slab and above the ground. Excreta or feces separated from urine are stored in the chamber and treated with drying agents such as ash and dry soils. This fecal mixture is used for agriculture after several months of retention in the chamber. The remaining 48% used water flush toilets and discharged their toilet wastewater into

Fig. 8.7 A dry toilet storing excreta in a fecal chamber under the floor slab. (Photo adapted from Harada and Fujii (2020))

the environment directly or after a limited treatment by a septic tank. Water flush toilets have been gradually replacing dry toilets (Pham et al. 2017).

8.3.2 Fecal Contamination in the Community

To investigate the fecal contamination in the community, a variety of environmental media such as drinking water, environmental water, soil, manure, and vegetables were sampled and tested with *E. coli* as a biological fecal indicator in 2014 and 2015 (Fig. 8.8). As mentioned in the previous section, high-level fecal contamination was observed for Nhue River water near the community (median $= 7.4 \times 10^4$ cfu/100 mL). Similar to the discussion in the previous section, the median *E. coli* concentration of the irrigation water (med. $= 1.0 \times 10^4$ cfu/100 mL) indicates substantial fecal contamination, considering the WHO guidelines of wastewater irrigation with a total coliform level of 10^3 count/100 mL (WHO 1989). As the Nhue River is a major irrigation source for the community, this fecal contamination of irrigation water can be associated with Nhue River contamination as well as poor sanitation practices of this community itself, where 48% of households used water flush toilets and discharged toilet wastewater in unsanitary manners to community channels, which is connected to irrigation water reservoirs. Water in paddy fields, where irrigation water was used, was contaminated at a high level (med. $= 6.5 \times 10^2$ cfu/100 mL). Thus, the outside environment in the community was highly contaminated with fecal matter.

Daily water for domestic use was also contaminated. High levels of *E. coli* in stored well water (med. = 60 cfu/100 mL) and stored rainwater (med. = 50 cfu/100 mL) indicate the fecal contamination of their daily water other than drinking water. Although people seemed to keep their drinking water considerably cleaner (med. = 1 cfu/100 mL) than other domestic water, 44% of drinking water was

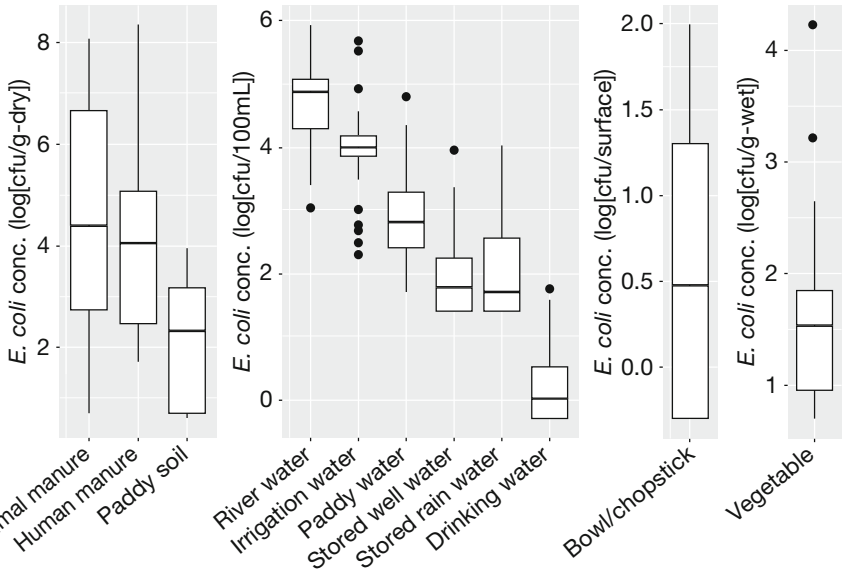

Fig. 8.8 *E. coli* levels of various environmental media. The box indicates quartiles with whiskers extending up to 1.5 times the interquartile range from the hinge. (Figure modified from Harada et al. (2016b))

positive with *E. coli* from 100 mL, which is above the WHO drinking water quality guideline (no detection from 100 mL). Since drinking water is stored after boiling, drinking water contamination is likely caused during storage. As indicated by fecal contamination of rice bowls and chopsticks (62% positive with *E. coli*), their eating/cooking environment was contaminated by fecal matter, supporting potential contamination of boiled water during storage. These contaminations inside houses could be caused by fecal contamination outside.

Animal and human manure mostly originated in the community. Owing to its incomplete treatment, the manure in use was still contaminated at high levels (animal manure: 2.5×10^4 cfu/g-dry; human manure: 1.5×10^4 cfu/g-dry). The community has a custom to eat raw vegetables such as herbs. As contamination of irrigation water and manure implies, *E. coli* was frequently detected in raw vegetables at farms or stores in the community (80% positive, med. = 34 cfu/g-wet), indicating substantial fecal contamination of raw vegetables.

8.3.3 Fecal Exposure in the Community

Fecal contamination potentially causes fecal exposure to humans, leading to the health risk of infection by fecal pathogens. Fecal exposure through their daily life

activities was estimated as *E. coli* exposure. The methodology of stochastic estimation is briefly explained. Exposure was obtained as follows:

$$E_{\text{day},i} = \sum_j F_i \times U_{i,j} \times C_j \tag{8.1}$$

where $E_{\text{day},\ i}$ is the exposure of *E. coli* through activity i (cfu/day) if a person performs the activity; F_i is the frequency or duration of activity i {(count or time duration)/day}; $U_{i,\ j}$ is the unit ingestion amount of media j during activity i {(amount of media j)/(count or unit time duration of activity i)}; and C_j is the concentration of *E. coli* for media j {cfu/(unit amount of media j)}.

For F_i, people's daily activity data were investigated by an interview survey of the people conducted in 2014 and 2015, including activity types, time duration per activity event, and event frequency. $U_{i,\ j}$, called the exposure factor, was collected from the literature. C_j was obtained from the fecal contamination survey in the previous section. Owing to the large variability and uncertainty of the data, the exposure was estimated in a stochastic manner. Probability density functions (PDFs) were defined for variables based on the data obtained. Values of variables were obtained randomly from the PDFs, and the daily exposure of Eq. (8.1) was repeatedly calculated in a stochastic manner by a Monte Carlo simulation with 100,000 trials.

The stochastically estimated exposure is shown in Fig. 8.9 with the probability ranges of the estimates. Although a public water supply had not been established in the community, fecal exposure through drinking (20 cfu/day) and hygiene activities such as bathing and teeth brushing (33 cfu/day) was relatively small. One of the major reasons for these low exposures is the boiling of drinking water before storage. A relatively low contribution of drinking water to exposure in contexts of low- and middle-income countries was also reported in previous studies. For example,

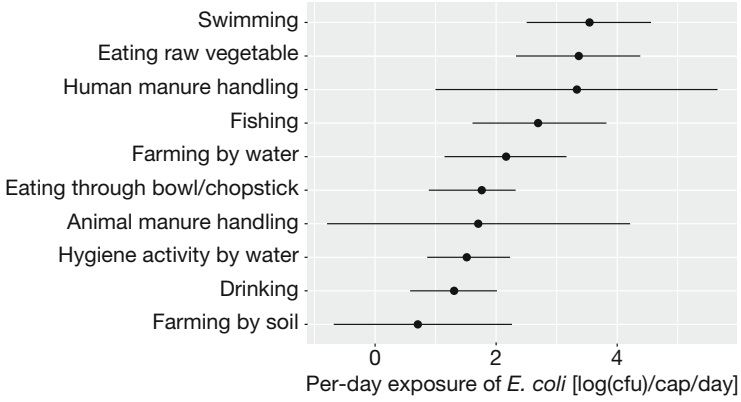

Fig. 8.9 Per-day exposure of *E. coli* from various pathways (12.5, 50, and 87.5 percentiles). (Figure revised from Harada and Fujii (2020))

hand-to-mouth contact was a greater pathway of fecal exposure than drinking in Tanzania (Mattioli et al. 2015); diarrhea in an urban slum in Bangladesh was more attributable to housing and surrounding conditions than the water supply (Khan et al. 2014). However, this result does not indicate the reduced importance of safe domestic water because there is an infection risk of fecal pathogens through drinking and hygiene activities. Further, safe domestic water can greatly contribute to the improvement of sanitary and hygienic conditions in and around houses, potentially reducing exposure through various pathways.

In this community, three major activities causing intensive per-day exposure were swimming [med. $= 3.5 \times 10^3$ cfu/day (1 h/day)], eating raw vegetables [med. $= 2.4 \times 10^3$ cfu/day (med. 58 g-wet eating/day)], and human manure handling [med. $= 2.2 \times 10^3$ cfu/day (1 time/day)]. These high exposures were caused by accidental ingestion of strongly contaminated reservoirs where they swim, eating contaminated raw vegetables, and accidental ingestion of contaminated manure during manure handling. The fourth largest exposure activity was fishing. Fishing was conducted by walking into the water of the Nhue River to catch snails and fishes. This intensive water contact manner of fishing caused the ingestion of contaminated water from the Nhue River, resulting in the great exposure of *E. coli*. Among these activities, swimming and fishing are directly linked to the ingestion of the media of the surrounding environment: reservoirs and Nhue River, respectively. Considering that reservoir contamination was substantially affected by the Nhue River as the original water source, these exposures were associated with Nhue River water pollution, which was strengthened by the pollutants from urban upstream areas, as previously mentioned.

Living on the conditions of the exposure trend mentioned above, people were likely to mitigate health risks through some of the activities with intensive exposure. According to interviews with the chief of the community, people, mainly young men, used to swim almost every day from May to September (the hottest time of the year in the area). The frequency of swimming, however, has recently decreased owing to concerns about contamination of the reservoir and Nhue River. This trend was similar to that of fishing. Fishing was a common side job in the community, and people often fished (except in winter); however, the frequency has decreased. These changing trends of activities could reduce the fecal exposure, leading to less infectious risk of fecal microorganisms. In other words, strengthened by the pollution transfer from the upstream urban areas, the fecal pollution of the Nhue River caused a change in downstream livelihood, such as swimming and fishing.

Exposure through eating raw vegetables is also partly associated with fecal pollution strengthened by pollution transfer from urban areas as the vegetables were irrigated by water in the community, of which quality was affected by Nhue River water quality. Part of the health risks associated with this exposure has been mitigated by people's efforts as people often washed raw vegetables, including washing them with disinfectants. The exposure was calculated based on the fecal contamination of vegetables at farms and stores (before washing for eating), meaning that exposure to eating raw vegetables after washing could be substantially lower than the estimates. According to the WHO (2006), washing in disinfectants and

rinsing in tap water can reduce contamination by 1–2 log units (10–100 times reduction). Assuming a 2 log reduction by their food hygiene behavior, the fecal exposure through eating raw vegetables will be reduced to the same magnitude as relatively small exposure activities such as eating with contaminated bowl/chopsticks, handing animal manure by accidental ingestion, and hygiene activities with contaminated water.

Thus, a significant portion of fecal exposure and the associated health risks was linked to the fecal pollution strengthened by the fecal pollution transfer from urban upstream areas. People's recent change in their livelihood and hygiene behavior mitigated the fecal exposure and the associated health risks to some degree. This demonstrated that the transfer of the fecal-associated health risks from the urban upstream areas contributed to the change in downstream livelihood. However, the remaining major activity causing intensive daily exposure, human manure handling, was not associated with the Nhue River or urban upstream areas. It is a matter within the community. This inner-community exposure is further characterized in the following section.

8.3.4 Fecal Exposure Characterization Through Excreta Use for Agriculture

Although the use of human manure for agriculture could contribute to the development of a sound material cycle, the handling of human manure was one of the major activities causing intensive exposure in the community, possibly leading to infection by fecal microorganisms. The human manure in the community was derived from stored human excreta and dry conditioning agents such as soil and ash after being kept for several months in the toilet chambers. It was removed from the chamber by farmers, and then used for agriculture; for example, soil preparation for rice fields or vegetable farms. If human manure is not completely sanitized, these activities are possible exposure activities owing to accidental contact of contaminated hands with one's face or mouth.

From November 2015 to February 2016, first-person videography captured the human manure handling activities of 25 farmers in the abovementioned community by using small video cameras on their heads (Fig. 8.10). The videography recorded farmers' hand movements. In total, 18.2 h of videography was collected during the period that famers took human manure out from dry toilets and used manure for vegetable farms. Collected video data were translated into a second-by-second time series data of hand contact, known as the micro-level activity time series (MLATS) (Zartarian et al. 1995). By using MLATS data, the hand contamination level and human exposure (dose) were modeled by a stochastic–mechanistic simulation. The details can be found in Julian et al. (2018). Briefly, *E. coli* concentration on hands at a certain time was modeled based on the initial concentration on one's hands, the event of hand-to-object contacts (e.g., hand tool, plastic bag, soil, manure, cloth,

Fig. 8.10 A farmer taking human manure out from a fecal chamber. A mobile video camera was mounted on her head. (Photo taken by Harada)

water), *E. coli* concentration on the object, and a bacterial transfer coefficient from the object to the hand. Then, the dose of *E. coli* was modeled based on the modeled *E. coli* concentration on one's hands, the event of hand-to-mouth contact, surface area of the hand in contact with his/her mouth, and bacterial transfer coefficient from the hand to the mouth. By using field data and literature, *E. coli* concentration on the hands of 14 farmers during the application of human manure for vegetable farms was modeled.

The results indicated widespread *E. coli* contamination with a variety of objects, corresponding to the results in the previous section. The strong contamination of human manure indicates incomplete treatment of human manure in toilet chambers. The farmers contacted 342–848 objects with their left or right hand, per person, every hour. Contacted objects included shovels, plastic bags to keep manure, seeds, the toilet pit, mud, and surface water. In contrast, only four farmers contacted their mouths during the video. This frequency was surprisingly lower than other studies on hand-to-mouth contact: for example, the mean frequency of hand-to-mouth contact among US office workers was 8 times/h, which is adopted in the US Exposure Handbook (Nicas and Best 2008; United States Environmental Protection Agency 2011).

Figure 8.11 shows the simulated *E. coli* concentration on farmers' hands and their *E. coli* dose. As indicated in frequent contact with various objects, the simulation showed strong *E. coli* contamination on farmers' hands after handling human manure. Reflecting the variation of contact objects and contact frequencies by each farmer, the results showed dynamic changes and variation in *E. coli* concentration on the hands and *E. coli* dose. Out of 15 farmers, four farmers (IDs 108, 109, 112, and 117) had a dose of *E. coli* during land application of human manure through hand-to-mouth contact, which rarely occurs in this case. Notably, out of the four farmers, two wore masks. However, they had hand-to-mouth contact, resulting in ingestion. The estimated *E. coli* dose of mean [95% CI] were, for each of the four farmers, 1.2

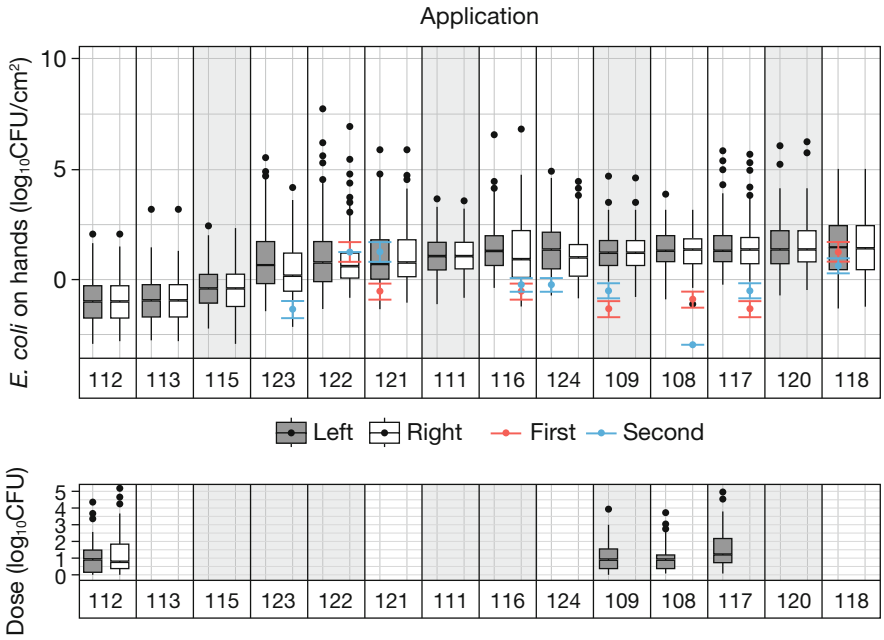

Fig. 8.11 Modeled distributions for final (top) *E. coli* hand concentration and (bottom) *E. coli* dose for farmers ($n = 14$) applying human excreta to land. The simulation was iterated for 100 times. Boxplots indicate median and interquartile range (IQR) with whiskers extending up to 1.5 × IQR from the hinge. *E. coli* concentration on hands was measured for nine farmers before (red) and after (blue) video capturing. The use of personal protective equipment is marked by the gray background for gloves (top) and masks (bottom). The number between 108 and 124 indicates farmers' ID. (Figure adapted from Julian et al. (2018))

[0.7–2], 4.2 [2.7–6.5], 3.0 [1.6–6.1], and 0.6 [0.3–1.3] cfu during each event, corresponding to 0.7 [0.4–1.3], 2.9 [1.8–4.4], 2.2 [1.2–4.4], and 0.7 [0.3–1.5] cfu/h. Assuming a 1-day activity of human manure handling happen for 8 h, the maximum 95% CI of four farmers will be between 2.4 cfu/day (0.3 cfu/h × 8 h) and 35.2 cfu/day (4.4 cfu/h × 8 h). This exposure amount is relatively small compared to the exposures through other activities, as shown in Fig. 8.9.

Thus, farmers' hands were strongly contaminated after handling human manure. This implies that contaminated surrounding conditions caused fecal contamination on their hands. In contrast, their behavior during human manure handling was preventive; substantially less hand-to-mouth contact than other studies. In fact, despite the surrounding contamination, their behavior mitigated a substantial portion of the health risks during human manure handling. However, the simulation demonstrated that accidental and rare hand-to-mouth contacts led to the ingestion of *E. coli*, even though they wore personal preventive equipment such as masks.

Notably, out of the 25 farmers handling human manure in the present study, 24 (95%) were women. The removal of human manure is essential to maintain the function of dry toilets in the community. From the aspect of social allocation of

health risks in sanitation, this resource-oriented sanitation was achieved at the expense of female farmers' health risks, while they partly mitigated the risk by their preventive behavior.

8.4 Allocation of the Responsibility of Sanitation Service and the Associated Societal Health Risks

The above sections indicated that the impact of sanitation spreads in wide parts of society, and even affects the culture. Without sound sanitation, the risks were allocated in an unequitable manner, while people receiving the risks might try to mitigate the risk by different measures such as a change in livelihood and preventive behavior.

The case of pollutant transfer from upstream to downstream areas along the Nhue River suggests the allocation of health risks over geographical boundaries, resulting in the change of livelihood in downstream areas. Although this was severely found in areas where a large part of wastewater was not properly treated, a geographical allocation of risk potentially happens anywhere. For example, household-level polluting behavior in upstream areas generated large health externalities in downstream areas, representing 7.5% of all diarrheal deaths in targeted drainage areas in Indonesia (Garg et al. 2018). In the Citrum River basin of Indonesia, the benefit of investment in river water quality improvement was estimated to be mainly from the development of sanitation and wastewater treatment in its upstream areas, including Bandung City with a population of approximately 2.4 million (Asian Development Bank and World Bank 2013). The overall economic benefit was estimated as 2.3-fold the investment, and 45% of the benefits were derived from health improvements. Such a geographical allocation of health risk potentially occurs also in high-income countries. For example, the Lake Biwa-Yodo River basin in Japan serves water for 17 million people. Owing to water use by people in the upstream areas, it was estimated that 50% of the population in the basin uses water that was consumed equal or more than five times upstream (Sumitomo et al. 1998). Without great effort to establish 43 wastewater treatment plants in the basin, unreasonable health risks in the downstream areas would not be mitigated. A sanitation measure across upstream and downstream areas is challenging. However, it is vital to properly allocate and mitigate the risks associated with sanitation. Mutual discussion between the upstream and downstream areas is required not only for pollution control but also for health risk allocation justified by people in different contexts, leading to the concept of river basin management or watershed management.

Besides the social allocation of health risks from improper sanitation, sanitation technologies have a function in transferring the risk, except those that can completely sanitize human waste on the site of generation without the help of someone else. In the case of the Nhue River, sewerage without sufficient treatment capacity in Hanoi transferred pollutants to the river and posed the associated health

risk to the downstream areas. Originally, sewerage was invented from waterways to transfer human waste to the water body. This technology can remove dirty matter immediately from their living space in the least obtrusive and offensive manner, only by flushing. This convenience was a major socio-economic reason why this system was adopted in most countries (Burian et al. 2000). Instead, nuisance sanitation works (e.g., collecting, transporting, and treating excreta) and the associated health risks, which were originally owned by the people at home, are now allocated to other people. The occupational risk of waterborne diseases by people working in wastewater treatment plants and sewers has been reported. For example, Clark et al. (1976) summarized sewer worker infections such as typhoid fever, Shigellosis, other gastrointestinal bacterial infections, and parasitic infections such as *Entamoeba histolytica* and *Ascaris lumbricoides*. An epidemiological study showed that 65.7% and 32.4% of the wastewater treatment plant workers were, respectively, infected by hepatitis A virus and hepatitis B virus at the timing or prior to the study against 32.6% and 5.8% of the control group, respectively, in Greece (Arvanitidou et al. 2004). Furthermore, the prevalence and risk of respiratory and intestinal diseases are caused by airborne microorganisms among wastewater treatment plant workers (Benami et al. 2016; Heinonen-Tanski et al. 2009; Yang et al. 2019). This evidence suggests that a group of people in the society owns the responsibility to maintain sanitation facilities and the associated health risks, and other people live a healthy life at the expense of sanitation workers' health risks. This can be a form of allocation of health risks to sanitation in society.

Health risk allocation also occurs with on-site sanitation technologies, which accumulate fecal sludge in the facility and therefore require proper fecal sludge management (FSM). Globally, at least 1.8 million people rely on on-site sanitation requiring FSM (Berendes et al. 2017). On-site sanitation and FSM follow the sanitation service chain: excreta containment, emptying, transportation, treatment, and final disposal/reuse (Harada et al. 2016a). The health risks of sanitation are transferred and shared along the service chain. Primarily, emptying work is performed by the expense of the health risks of emptying workers. In the case of Trai hamlet, female farmers were mainly responsible for the service chain between emptying and reuse, potentially owing to health risks, although they substantially mitigated the risk by their protective behavior. However, emptying works are not conducted in a hygienic way in many cases in low- and middle-income countries. For example, in Maputo, Mozambique, 60% of emptying works are estimated to be performed in unhygienic manners (Capone et al. 2020). In addition, the sanitation service chain of FSM often fails in the middle (Peal and Evans 2015). In Mandalay, Myanmar, 67% of fecal sludge from on-site sanitation was emptied as informal business and 64% was illegally dumped (Naing et al. 2019). In other words, the allocation of the responsibility of FSM was released from sanitation workers in the middle of the chain. Although fecal sludge is stored excreta for some years, it also contains fresh excreta from the latest excretion. A variety of pathogens are found in fecal sludge (Yen-Phi et al. 2010). Although the global estimate of the proportion using on-site sanitation with proper FSM was not available owing to insufficient data (WHO and UNICEF 2017), a significant proportion expect to lack proper FSM.

Besides the released responsibility of FSM in the middle of the sanitation service chain, the failure of FSM releases and transfers the associated health risk to the public through environmental fecal pollution by dumping fecal sludge. This could be a major challenge for the social allocation of health risks in on-site sanitation and FSM.

The case of Trai hamlet showed the allocation of health risks related to gender at household levels. This trend can be observed in low- and middle-income countries. Hannan and Andersson (2002) suggested that, in low- and middle-income countries, men typically construct latrines, while women usually clean them. Kwiringira et al. (2014) suggested that both women and men see the cleaning of shared latrines as women's responsibility. Regardless of on-site and off-site sanitation, the handling excreta in households would pose a potential health risk, which is often allocated to women. Further, as suggested in the case of human manure use in Trai hamlet, on-site sanitation with resource recovery often requires additional work with more chances to contact excreta rather than sanitation without resource recovery, and these additional works were mostly done by women. In other words, resource recovery in sanitation in the community is achieved at the expense of women's health risks. In cases of resource recovery in on-site sanitation, resource recovery work is expected to be linked to the persons who are responsible for cleaning toilets, that is, women at household levels in many cases. As the risk of sanitation workers was observed even in modern sewerage, complete mitigation of the additional health risks derived from resource recovery activities is challenging, especially in the context of low- and middle-income countries. In addition to promoting resource recovery in sanitation, it is important to understand the allocation of potential health risks to a group of people behind the resource recovery as well as to minimize the risk along with the resource recovery activities in sanitation.

8.5 Concluding Remarks

This chapter demonstrated the social allocation of health risks in sanitation based on examples in Vietnam. Health risks were clearly transferred among different groups in the society. The increased health risks in sanitation even changed the livelihood. As the complete elimination of the risks is fundamentally difficult owing to the nature of the risks, we should understand who owns the health risks and consider if the risk allocation is reasonable and acceptable in society. Society clearly has a responsibility to allocate health risks equitably among groups in society, and to decrease the risk to a socially acceptable level. Since sanitation possibly causes the transfer of health risks, sound social allocation and mitigation of health risks are essential to address social challenges in sanitation.

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Chapter 9
Participatory Action Research for WASH by Children and Youth in Peri-Urban Communities

Sikopo Nyambe, Yoshimi Kataoka, Hidenori Harada, and Taro Yamauchi

Abstract In the study of water, sanitation, and hygiene (WASH) and its related health impact, it is imperative to understand the people and their respective environments to ensure lasting improvements in their quality of life. To explore this theme, this chapter provides details of a Participatory action research (PAR) conducted with members of Dziko Langa, a children and youth club, based in two peri-urban settlements in Lusaka, Zambia. The study was aimed at collaborative examination and intervention alongside club members, focusing on health and sociocultural aspects relating to WASH within their communities. The chapter is divided into three parts: (1) peri-urban WASH assessment and intervention through participatory approaches, (2) development of a quantitative self-assessment methodology for fecal contamination in their living environment, and (3) visualization approaches for community and stakeholder engagement. Through collaborative studies such as these, we can further explore the abilities of local communities to independently measure the health levels of their environment, identify WASH priorities, engage with stakeholders and policymakers, and share their findings for the betterment of the broader community.

Keywords Participatory action research · Peri-urban · Water, sanitation, and hygiene · Visualization · Fecal contamination · Diarrhea risk

S. Nyambe (✉)
Faculty of Health Sciences, Hokkaido University, Sapporo, Hokkaido, Japan
e-mail: s.p.nyambe@gmail.com

Y. Kataoka
Faculty of Engineering, Hokkaido University, Sapporo, Hokkaido, Japan

H. Harada
Graduate School of Asian and African Area Studies, Kyoto University, Kyoto, Japan

T. Yamauchi
Faculty of Health Sciences, Hokkaido University, Sapporo, Hokkaido, Japan

Research Institute for Humanity and Nature, Kyoto, Japan

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9.1 Health, Social Culture, and Participatory Action Research

A key component of scientific exploration on subjects such as water, sanitation, and hygiene (WASH) and health is the individual—the core recipient of the knowledge and intervention, whose quality of life we are seeking to improve. Failure to recognize the individual and the sociocultural ecosystems that define their way of life has, at times, led to the rejection of inventions and public distrust, even when faced with grave health risks or much needed intervention (Pugliese-Garcia et al. 2018). With regard to personal matters such as health and WASH preferences, the active participation of local people in exploration, discussion, and decision-making offers the possibilities of culturally appropriate, well-rounded, and sustainable input (Jacquez et al. 2013).

Participatory action research (PAR) is a research method that allows stakeholders to determine, assess, evaluate, and address a problem. In PAR, there is exchange of resources and ideas between researchers and participants that is guided by the needs of the participants rather than the researcher (Jason et al. 2019). A consistently developing research method, the process involves repeated cycles of planning, observing, and reflecting, in which individuals and groups engaged in PAR can implement changes required for social improvement. In the recent past, children and young people have been involved in this research method not merely as research subjects, but as active participants and even researchers in their own right (Foster-Fishman et al. 2010; Kim 2016). PAR has thus become more common with regard to such studies because researchers identify children and youth as resources for participatory action and research, gaining ground on preventive and positive developmental movements.

In this chapter, we provide details and findings of PAR conducted with children and youth residents of two peri-urban settlements in Lusaka, Zambia. PAR was conducted through the Dziko Langa Club, which acted as the main vehicle for community engagement with the aim of bottom-up and collaborator approaches. The chapter is divided into three parts: (1) peri-urban WASH assessment and intervention through participatory approaches, (2) development of a quantitative self-assessment methodology for fecal contamination in their living environment, and (3) visualization approaches for community and stakeholder engagement.

9.1.1 Peri-Urban WASH

Globally, over one billion people live in slums (including peri-urban settlements), with poor access to municipal services such as adequate health care and quality WASH facilities. Unfortunately, the number of slum residents continues to rise, particularly in low- and middle-income countries. In Sub-Saharan Africa, peri-urban dwellers account for 59% of the urban population; this is estimated to increase to

1.2 billion people by 2050 (UN Habitat 2016). Very few national surveys on WASH routinely distinguish between slum settlements in rural and urban areas (WHO and UNICEF 2019), making information on peri-urban WASH more often scant and creating a gap in the urban WASH story. WHO and UNICEF (2019) have thus partly credited this gap for uneven peri-urban WASH achievement on a global scale.

9.1.2 The Case of Lusaka, Zambia

Zambia is a low-middle-income nation in Sub-Saharan Africa with a population of approximately 15.5 million, 65% being under the age of 25 years. Only 67.7% and 40% of the population have access to improved drinking water and sanitation, respectively (Central Statistical Office 2016). In comparison to national statistics, peri-urban figures reveal that approximately 56% and as much as 90% of the peri-urban population lack access to safe water and sanitation facilities, respectively (Republic of Zambia 2006). Poor WASH has also been linked to Zambia's annual cholera outbreaks, usually emanating from rural and peri-urban settlements (WHO 2011). In the capital city of Lusaka, 70% of the residents are peri-urban dwellers (Central Statistical Office 2012) distributed across 37 peri-urban settlements (Central Statistical Office 2016). Consequently, Lusaka has experienced regular disease outbreaks due to fecal contamination of food and water caused by poor WASH (Kapata et al. 2018).

Most of Lusaka's unplanned settlements were created during colonial times as "early self-help housing" and "unauthorized housing" as a consequence of the colonial government's African urban employment policies and the rural–urban migration that ensued (Mulenga 2003; Yasini 2007). As of 1974, however, the Zambian government reclassified several illegal settlements to "improvement areas," providing legal settlement status, government municipal provisions, and resident title deeds. Improvement in area development has been slow (Mulenga 2003). Our preliminary research in nine Lusaka peri-urban settlements from August to October 2016 revealed minimal municipal provisions in the upgraded reclassified sites; of the nine assessed settlements, two were selected as research sites (Nyambe et al. 2018).

9.1.3 Dziko Langa Club

In 2017, *Dziko Langa* (DL), meaning "My Community/Country" in the local lingua (Nyanja language), was conceptualized as a suitable, engaging means to include and empower children and youth from our two Lusaka research sites (designated sites A and B) in WASH PAR. Three points should be made at this juncture: (1) children are active participants in WASH, particularly at the household level due to their engagement in domestic chores (Hemson 2007); (2) children are, and can be accurate and

valuable communicators of their experiences, particularly when the right approach/methodology is utilized (Driessnack and Furukawa 2011); and (3) the age group of 18–29 constitutes the largest household head bracket in the country (Central Statistical Office 2016). With the study aimed at participants' peri-urban WASH assessment and intervention as co-researchers and frontrunners rather than mere participants, facilitating their incorporation in WASH research was essential.

The Club, officially registered under the Zambia National Youth Development Council as of December 2019, initially had an age cap of 10–14 years for children and 18–24 years for youth for logistical and planning reasons. Child members were recruited in their fifth grade from two local public schools, while youth participants were recruited through youth centers and vocational schools as students, workers, or unemployed. For research and sustainability purposes, however, older members have been allowed to stay on despite surpassing the age limits in their respective categories, while new members under 25 years of age continue to be added. During the 3 years of study, approximately 80 children and 40 youths were active members of DL.

While children and youth primarily constitute the membership and the executive board of DL, the communal nature of the club requires collaboration and links to WASH and local community stakeholders. In summary, the key actors in the DL story are: (1) DL members who were the main participants as co-researchers and community leaders; (2) peri-urban residents and/or the general public who benefit from DL activities; (3) the research team as aids and co-researchers with DL; and (4) local institutions (e.g., schools, youth centers, health centers) that provide infrastructure, mentorship, and support to DL members and for DL interventions.

9.2 Participatory Approaches: Photovoice and Arts-Informed Research

The initial objective of DL research was for DL members, that is, participating children and youth, to critically assess and find means to intervene in peri-urban WASH. The study used photovoice for youth and arts-informed research for children as participatory approaches, which afforded participants the opportunity to engage in research procedures such as data collection and analysis. DL members were informed of the upcoming activities, and participation was open to DL members who were available at the time of the activities. The entire process for both approaches, including data analysis and the subsequent Sanitation Exhibitions, took place from December 2017 to March 2018. Photovoice, art, and the exhibits worked as a means of community engagement, participant empowerment, information dissemination, and education to both participants and the broader community on peri-urban WASH (Franz 2010; Wang and Burris 1997).

9.2.1 Data Collection

9.2.1.1 Photovoice (Youth)

Photovoice is a visual, participatory method in which cameras are provided to persons often excluded from decision-making processes to capture their perspective of their lives and their community through photographs and accompanying narratives (Wang 2006). Relatively cost-effective and simple to use, photovoice was deemed suitable for data collection for the youth demographic. Moreover, this methodology has been found useful for identifying new, unique priorities in WASH and encouraging community participation in project planning and engagement (Davis et al. 2018). While official research data collection and analysis was only done with the photographs of 12 youths (male = 7, female = 5; age = 17–24) who were available for the initial photovoice exercise (Nyambe and Yamauchi 2021), approximately 30 youths participated in the exercise at both sites. In both cases, prior to data collection, the participants underwent training using digital cameras and research ethics. Thereafter, each of them was given 4 days to take 2–5 pictures in response to the framing question: "What is WASH in your community?" To moderate the number of photographs, each participant was requested to select two pictures for analysis. However, 150 photographs were obtained in total.

9.2.1.2 Arts-Informed Research (Children)

Art is a useful and acceptable tool in health-related research involving children as it helps them to sense, organize, and share their thoughts (Driessnack and Furukawa 2011; Franz 2010). As art is an expressive, thought-provoking, and emotive medium for both the artist and the viewer, its methodology allows for groundbreaking, progressive research that is both socially responsible and useful in addressing social inequalities (Franz 2010). Thus, similar to photovoice, the researchers used art as a means for children to draw their experiences and share them through narration. The arts-informed research was conducted with 50 fifth-grade students (male = 21, female = 29) from two government schools. To ease children's understanding of the framing question, we explained it in both English and Nyanja. Children's framing questions required them to draw "What they wanted to see and what they did not want to see in their communities in relation to WASH." Before answering the framing question, children were provided opportunities to draw, scribble, and familiarize themselves with the art activity. After three free-flow sessions, children were given 15–20 min to draw their answers in response to the WASH framing question. Researchers stressed that the children's artwork would not be assessed based on artistic skills, and that there were no right or wrong answers.

9.2.1.3 Contextualization and Codifying

Contextualization involved participant group discussions centered on the sharing of images and their accompanying stories. This was followed by codifying, which facilitated the placement of key variables into themes (Wang and Burris 1997). The contextualization processes for photovoice and art were similar and first involved the owner of the photograph/artwork: (1) sharing their images and narratives; (2) explaining why photographs were taken or pictures were drawn, citing locations where possible; and (3) highlighting key variables to be noted in the storyline. Participant discussions helped to clarify (1) if participants agreed with the presented subject, (2) why it was a challenge/good thing, and (3) factors responsible for or linked to the aforementioned finding. Additionally, participants were requested to recommend solutions for cited challenges and/or means of sustaining positive behaviors. While codifying was not conducted by children, some basic codifying was done by youth participants. This facilitated their identification of WASH priorities, undergoing further analysis post-exhibition.

9.2.2 Photovoice and Art Results

The results depict the nature of peri-urban WASH in sites A and B as experienced by participants, indicated under the subthemes of peri-urban water, sanitation, hygiene, and WASH confounders. A sample of the results is provided in Fig. 9.1 and Table 9.1 for youth's photovoice, and Fig. 9.2 and Table 9.2 for children's art. Note that narratives have been edited purely for grammatical purposes. Overall, images and narratives depicted open defecation, links between fecal management and water contamination, food management, hand hygiene, WASH facility structures and maintenance, and waste management practices, among other challenges.

Fig. 9.1 Youth photovoice images

Table 9.1 Summary of photovoice narratives (refer to Fig. 9.1)

No.	Narrative
1	The man is living in the dump site as he is trying to make it better. The land was dormant and people began dumping on it
2	The child was defecating outside on a chamber pot [potty] with the mother nearby. There are some fecal remains on the ground
3	This area is not OK. There are a lot of bins around. There is a drainage which goes to the bin when a lot of flooding occurs. The child outside can easily get sick playing there
4	This is an old toilet which collapsed. They do not have a new one. They tried to cover it. It's on a road. They throw their chambers pots [makeshift toilets/potties] in there
5	The road is flooded. They throw garbage here. It is near a number of shops. The child is playing on the wall fence
6	The fresh food is being sold along the roadside. There is garbage along the streets and people are buying the food. There are flies on the fish
7	During the rainy season, residents transform dump sites into gardens
8	These people fetch water from this tap every time. The area around the water source area is unclean and it is not closed. Cleaning the buckets without soap. We do not know if the water is safe or not. It is an old water kiosk. Lusaka Water and Sewerage Company collect money from those who buy water here
9	From the outside, the toilet looks up to standard. Ventilated, clean, tiled. But inside, it was not that clean. The hole is not covered. It can be locked from the inside. No provision is available for handwashing within the toilet, no toilet utensils (tissue, toilet cover)
10	By the dam and the road. This is the industrial area. People use the same water for washing, dumping garbage, urinating, and children swim and play there too

Fig. 9.2 Children's artwork

Table 9.2 Summary of children's art narratives (refer to Fig. 9.2)

No.	Art narrative
1	This house here has no toilet [leading to open defecation; Note: Person on left of the house]
2	This toilet has no door, or cover for the toilet hole, so flies will move from the toilet into the food
3	People are pouring water for each other as they wash hands. This is what I want to see particularly at my house
4	This person came out from the toilet and is washing his hands. The toilet is behind the house and it is clean. The water [tap] is far away from the toilet down there
5	This house is doing very well. The surrounding is clean
6	This is a toilet [black roof], these are flies [left of the toilet] and these are bins [right of the toilet]. The flies are moving from the toilet and the garbage to the house [far left, blue roof]
7	This child here has a mango and she is eating it without washing it; she is eating it near the toilet. The toilet is not clean, flies are flying all over, but the child is still eating
8	Where they draw water from is clean, and the buckets are clean too
9	They are greeting each other [with a fist bump] not knowing whether the friend is from the toilet, or if he washed his hands or not
10	This house has no tap and when they draw [collect] water, they do not add chlorine or boil it. They use the same water to wash dishes, bath, and they still drink from the same water

9.2.2.1 Peri-Urban Water, Sanitation, and Hygiene

Results representing peri-urban water focused on behavioral tendencies related to water sources, and the collection, usage, storage, and treatment of water (particularly treatment of drinking water). Several narratives also incorporated the theme of contamination routes, with fecal disposal, poor waste management, and faulty infrastructure being termed as water pollutants. Refer to Fig. 9.1, Table 9.1 (3, 8, 10), and Fig. 9.2, Table 9.2 (4, 8, 10). Open defecation and public urination were commonly expressed by child participants under the theme of peri-urban sanitation. The results also showcased toilet quality, structure, maintenance, and child fecal management. The condition of public toilet facilities was highlighted by youth participants, and contamination of water and food due to proximity to the toilet was cited by several child participants. Refer to Fig. 9.1, Table 9.1 (2, 4, 9, 10), and Fig. 9.2, Table 9.2 (1, 2, 6, 7). Following the WHO-UNICEF WASH definitions (WHO and UNICEF 2017), hygiene is focused on handwashing. The results indicated important times for handwashing and a close link between handwashing, toilet use, and food consumption. Children's results also highlighted handwashing methods and hand hygiene strategies linked to cultural practices, that is, communal handwashing before a meal, and conservative greeting styles to avoid handshakes [Fig. 9.2, Table 9.2 (3, 9), respectively]. Refer to Fig. 9.1, Table 9.1 (9); and Fig. 9.2, Table 9.2 (3, 4, 5, 9).

9.2.2.2 Peri-Urban WASH Confounders

The results highlighted several often-overlooked factors that, though not covered by formal WASH definitions, play an active role in peri-urban WASH. Poor waste management [see Fig. 9.1, Table 9.1 (1, 3, 5, 6, 7, 8, 10); and Fig. 9.2, Table 9.2 (5, 6, 8)] was indicated as a causal factor for water contamination through flooding due to blocked drainage and pit latrines [Fig. 9.1, Table 9.1 (3, 8)]. It was also cited as a source of food contamination and disease [Fig. 9.1, Table 9.1 (5, 6); and Fig. 9.2, Table 9.2 (6)], canceling out the benefits of water and sanitation access as it attracts flies and microorganisms. Child insights further highlighted the importance of WASH in food hygiene, that is, the washing of fruits and vegetables before consumption [Fig. 9.2, Table 9.2 (7)]. Both child and youth results noted the health implications related to WASH practices and children's play practices [Fig. 9.1, Table 9.1 (3, 5)]. Refer to Fig. 9.1, Table 9.1 (1, 2, 6, 9, 10, 12, 15, 16), and Fig. 9.2, Table 9.2 (3, 4, 9).

9.2.3 A Summary of Peri-Urban WASH

Children and youth alluded to both good and poor knowledge, attitudes, and practices that impacted local WASH. Open defecation and public urination, improper waste disposal, poor food management, and unsafe hygiene practices were attributed to ignorance, force of habit, and a lack of proper facilities (Bhatt et al. 2019; Satterthwaite et al. 2015). Children provided insight into cultural beliefs relating to mothers' management of child feces; that is, that child feces were not harmful and were good for growing vegetables, particularly cabbage. They also provided a few examples of how various habits had changed to accommodate hygiene improvements, such as greeting by fist bumps rather than handshakes, pouring of water rather than communal use of basin water for handwashing, and growing of crops at dumpsites to reduce poor waste disposal practices. The youth, in particular, stressed on household habits and behaviors, and the responsibility of residents to ensure proper WASH (Nyambe and Yamauchi 2021). The need for WASH education was expressed by all participants, with children citing examples of adults who willfully practiced poor WASH despite being informed. This highlighted poor attitudes and behaviors toward new knowledge, particularly when shared by children, emphasizing their marginalized position.

Besides the need for WASH education, local government suppliers were castigated for poor WASH management, ranging from inadequate and delayed service delivery, malpractice, and poor policy implementation. While the cost of WASH facility installation and upgrades should be recognized as impacting governments' ability to facilitate WASH improvements (Satterthwaite et al. 2015), there was a call from participants that authorities should be held accountable for poor service delivery. Participants also lobbied for the incorporation of more public–private

partnerships and/or community-based organizations in local WASH activities. Previous studies have shown how participatory strategies incorporating individual, organizational, and community-level players were used to create awareness and intervention reaching policy levels (Laverack 2017; Postma and Ramon 2016). Children lamented school closures during disease outbreaks and their willingness to participate in preventing such reoccurrences despite lacking the platform. Both children and youth thus mentioned the need for local empowerment and cooperation with other WASH stakeholders for real, consistent improvements in WASH.

9.2.4 Sanitation Exhibition

As a culmination of the photovoice and art exercises, participants held Sanitation Exhibitions at the research sites. The exhibitions were held during the 2017/2018 cholera outbreak that had hit both research sites and required permissions from the local health facilities and police departments to hold the events. The exhibits were open to the public, and a local government representative attended each exhibition as a guest of honor. Media houses were also invited. A total of 223 persons attended the event at both the sites. All DL members' art and photographs were showcased, with the creators giving the narrative of their work to the attendees. The venues for sites A and B were a local school and a local government office, respectively. The venues were designed by children and youth, who also took it upon themselves to incorporate poetry, drama, and song into their WASH information dissemination. Additionally, focus group discussions with community residents in attendance were conducted by the youth at site A (see Fig. 9.3).

The Guest of Honors made a pledge to support DL's work in their communities, citing DL as a proactive group working for disease prevention. Through these events, community residents in attendance sought government assistance and

Fig. 9.3 Sanitation exhibit: (**a**) exhibit setup; (**b**) focus group discussion by youth; (**c**) exhibition hall; (**d**) information dissemination (drama by children)

recognized the need for regular public action through education to help change behavior. There was also recognition of the importance of children and youth involvement in playing an active role in sustainability and change in peri-urban WASH.

9.2.5 Dziko Langa Post-Exhibit

DL members have conducted and/or participated in several community-based interventions. An executive meeting with DL youths registered a total of 22 interventions and training conducted from August 2017 to October 2019, excluding biweekly meetings and/or occasional in-house training. Post-exhibit, DL members held a Sanitation Festival that saw the participation of children and youth from schools and churches alongside local government in community cleanups, waste management, and WASH information dissemination.

Having developed a business idea based on their findings, DL youths through the researchers participated in the 2019 Hult Prize Competition themed "For Us By Us, Youth Unemployment: Can you build the foundations of a venture that will provide meaningful work for 10,000 youth within the next decade?" Their business idea won first place at the Hokkaido University On-Campus competition and reached the semifinals of the regional competition held in Ho Chi Minh City, Vietnam. Examples such as these showcase the possibilities and opportunities offered to communities through the incorporation of local knowledge and collaboration with multidimensional partners.

9.3 An Early Trial of Self-Assessment of Health Risk in WASH

9.3.1 Motivation of Self-Assessment of Health Risk in WASH

PAR is a promising approach to enhance people's motivation to improve WASH, and DL has been effectively exploring and intervening in WASH through PAR, as mentioned above. Still, in many cases WASH interventions such as the introduction of toilets and the treatment and disposal of excrement have not taken root. One of the reasons for this failure is that the health effects of WASH interventions (e.g., reduction in diarrhea frequency) are not apparent in the short term.

As mentioned in Chap. 8, WASH is a system that reduces the likelihood of exposure to pathogens, especially from human excreta, by reducing fecal contamination and exposure in the living environment (Cairncross and Feachem 1993; Wagner and Lanoix 1958). However, fecal contamination is invisible to the naked eye, except in cases of extreme fecal pollution, which is often accidental, complex,

and context-specific (Julian 2016; Julian et al. 2018). While clean water and hand hygiene apparently and immediately contribute to health improvement, the impact of improved sanitation is not quickly realized. Sanitation helps in making the living environment free from fecal contamination (Fig. 9.1 of Chap. 9). Therefore, proper sanitation indirectly improves human health through an improved living environment. Furthermore, although a person may practice proper sanitation, the surrounding living environment cannot be improved if their neighbor still follows improper sanitation. Cronin et al. (2017) indicated that health improvement will occur with at least 60% coverage of sanitation or higher, although the proportion varies in each case. This invisibility, complexity, context-specificity, and indirectness can lead to people's failure to realize the impact on health improvement derived from sanitation.

To tackle this challenge, we conducted a case study to show context-specific quantitative data of fecal contamination, exposure, and health risk to the residents of an urban slum in Bangladesh. It was shown that the residents' interest in WASH could be enhanced, and their behavior partly changed (Goto et al. 2015). If we can take this idea a step further and instead of the external data being given by the outsider, the community quantitatively investigates fecal contamination, exposure, and health risk in WASH by themselves as PAR, they may realize the impact of fecal contamination and exposure in their living environment and the role of WASH. Through this experience, they may become proactive and effective in managing their WASH, which may form the basis for WASH behavior change and improvement. To unify PAR and a quantitative survey on contamination, exposure, and health risk in WASH, we designed a PAR framework for the quantitative self-assessment of fecal contamination, exposure, and health risk in WASH, and conducted a preliminary part of the framework with local DL youth members.

9.3.2 Outline of the Self-Assessment Workshop

In a peri-urban settlement of Lusaka, Zambia, where cholera is sporadic, we implemented an initial workshop model on the quantitative self-assessment of fecal contamination for DL youth members in collaboration with the authors. Exposure and health risk assessment was excluded from the initial trial and the total coliform concentration was used as an indicator of fecal contamination levels. The workshop was held for 2 days (October 26–27, 2019), with five youths aged 17–22 years participating on the first day (approximately 2 h) and seven youths from the same age bracket on the second day (approximately 1 h).

The outline of the 2-day workshop activities is shown in Fig. 9.4. On the first day, the authors gave an overview of WASH and the diverse forms of fecal contamination and exposure to the participants. The participants then listed what they considered important causes of diarrhea and ranked them in order of importance. The participants were divided into two groups: after the instruction on how to collect samples by facilitators, each group moved out to a community and collected samples from six different media types (Fig. 9.5), two were fixed by facilitators, and the remaining

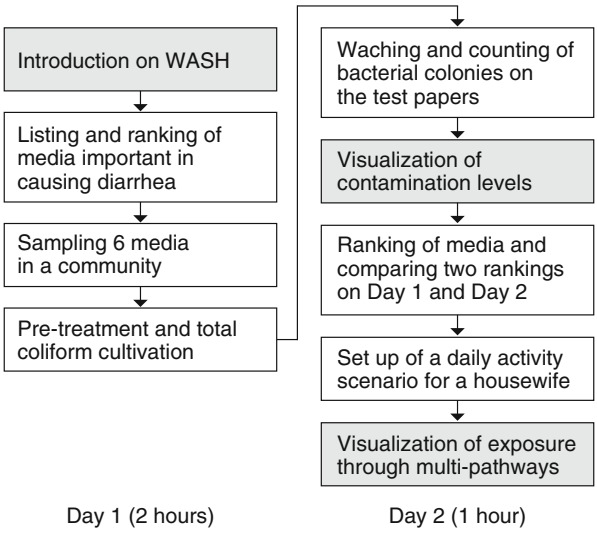

Fig. 9.4 An outline of the 2-day workshop activities. Gray background and white background boxes indicate the processes implemented by facilitators and participants, respectively

Fig. 9.5 Sampling by the workshop participants. (Photo by Kataoka)

four were selected by the participants. After a simple pretreatment, fecal contamination of each sample was tested using the test paper for total coliform (maker of test paper: Shibata, Tokyo). On the second day, after incubating the test papers at 37 °C for approximately 15 h, the participants watched and counted bacterial colonies of total coliforms formed on the test papers with the help of facilitators (Fig. 9.6). After they submitted the colony count data to the facilitators, the data were processed and illustrated as fecal contamination levels of each medium. Participants again ranked the media in a similar manner as on the first day, but this time reflected their own obtained results of fecal contamination levels. They then compared the rankings of the first and the second day with discussions on the differences between the two rankings, and what media they think needs to be tackled to improve their health.

Fig. 9.6 Counting the colony number of total coliforms by the workshop participants. (Photo by Kataoka)

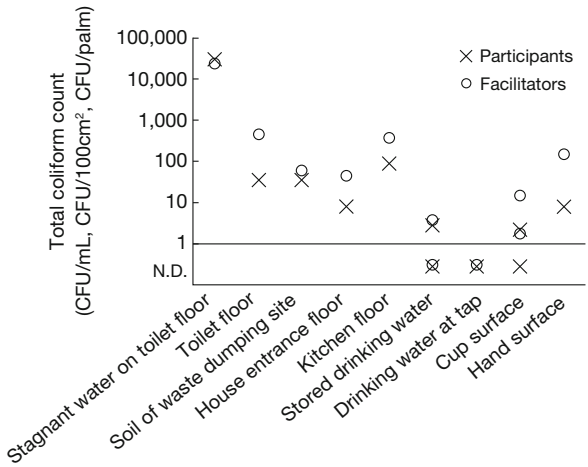

Fig. 9.7 Contamination levels of nine types of media measured by participants and facilitators

Based on a housewife's daily activity scenario, the fecal exposure for each pathway was estimated from the results of the contamination level. However, it was difficult to establish appropriate exposure factors to calculate the exposure for some activities and organize the relationship between contamination and exposure for the participants to understand on site. Therefore, as an initial trial, we limited this methodology to fecal contamination, excluding exposure and health risk aspects.

9.3.3 Learning and Implication from the Early Trial

Comparing the fecal contamination results of the authors' parallel measurements with those of the participants (Fig. 9.7), the correlation between the two

Table 9.3 Media ranking by importance on causing diarrhea (day 1: before fecal contamination survey; day 2: after fecal contamination survey)

Day 1		Day 2	
1st	Drinking water	1st	Kitchen floor
2nd	Uncovered food	2nd	Toilet floor
3rd	Unwashed hand	3rd	Waste dumping site soil
4th	Toilet floor	4th	House entrance floor
5th	Kitchen floor	5th	Cup surface
6th	Domestic water	6th	Hand surface
7th	Waste dumping site soil	7th	Stagnant water on toilet floor

concentrations was moderate ($R^2 = 0.62$), indicating that the measurements by participants were reasonably valid despite their lack of technical knowledge, having merely received brief instructions through the workshop. No total coliform was detected from the source of drinking water, whereas one sample of point-of-use drinking water (stored in a jelly can) was contaminated; this trend of greater contamination of point-of-use drinking water was in line with Harada et al. (2018). Furthermore, the wide contamination of their living environment was indicated in the contamination of various media such as a toilet floor, kitchen, waste dumping site, house entrance, hand and cup surface, and stagnant water on the toilet floor.

Of the 12 types of fecal exposure media listed by participants, the top seven ranked by importance on days 1 and 2 are shown in Table 9.3. On day 1, before the fecal contamination survey, drinking water and uncovered food were ranked as the first and second most important media causing diarrhea, which are typical media directly ingested and apparently associated with exposure. In contrast, on day 2 after the fecal contamination survey, the kitchen floor and toilet floor were listed as the two most important media, which were not directly ingested but indirectly caused fecal exposure through the contamination of the living environment. During the discussion at the end of day 2, the participants highlighted the importance of the media associated with indirect fecal exposure through the contamination of the living environment. This indicates that through the workshop they were able to realize the importance of cleanliness of the living environment rather than the media of direct ingestion, such as drinking and eating.

This early trial showed the potential effectiveness of the individual's quantitative self-assessment of fecal contamination in WASH. Throughout the workshop, participants' enthusiasm was evident through their active participation and dedication. In particular, the change in the ranking of importance of contaminating media, observation of coliform colonies, and knowledge of the extensive contamination of their own community may have led to an improved sense of the role of WASH in controlling fecal contamination in the community living environment and through it, exposure, and health risk potentially. The quantitative self-assessment would therefore help participants understand the importance of sanitation in preventing unhygienic excreta discharge and controlling fecal contamination in the living environment.

However, significant work remains to complete the quantitative self-assessment of fecal contamination, exposure, and health risk in WASH. Due to differences in the types of media, it is not rational to simply compare the contamination levels of all media, such as floor contamination (concentration per area) and water contamination (concentration per volume). To examine the effects of contamination in various media, besides being aware of the contamination level of the media, it is also vital to know the exposure from multiple media and pathways, and the health risks from these exposures with an acceptable level of accuracy to be quantitative for communities' self-learning. This will help participants design countermeasures based on their own measurement of results, taking into account the contamination and exposure trends in the contexts of their community. Due to resource limitation and methodology complexity, this early trial could not cover the exposure and health risk assessment. To achieve these goals, the authors are currently developing a methodology that easily enables the quantitative self-assessment of fecal contamination, exposure, and health risk in WASH using digital software to facilitate its implementation. It is expected that the self-assessment of fecal contamination, exposure, and health risk in WASH through PAR would allow people to realize the effect of WASH, contributing to more effective and sustainable WASH intervention.

9.4 Visualization

9.4.1 Communication in Participatory Action Research

Target 6.2 of the United Nations Sustainable Development Goals, which reads, "By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations (SDGs)," was launched in 2016. However, it is increasingly believed that a top-down approach involving "material and financial assistance" alone may not achieve this goal. Our PAR as described above is practiced with children in the community, in which they themselves conduct research on sanitation issues. It is a practical research method in which community members, consumers, and researchers collaborate to develop specific methods for solving issues and improving the community. We conducted meta-studies to investigate children's research activities with the hope of children identifying problems on their own, changing their attitudes and behaviors through discussions with other children, and having a spillover effect on adults in the community. However, the continuation of activities in the community has been very difficult, especially due to generational change in children and youth groups.

Therefore, it became necessary to focus on "science communication" rather than "education," which is a one-way delivery of knowledge. Science communication is the practice of two-way dialogue that overcomes the differences in science literacy. In many of the children's activities, dialogue among children and between children

and adults brings them into contact with the collective memory of the community and evokes empathy. It also discusses the importance of clarifying how knowledge and skills are exchanged between experts and nonexperts and among nonexperts. This not only encompasses specialized knowledge understood through literacy, but also "indigenous knowledge systems," which are the kind of life knowledge and skills that people transmit from one generation to the next in the community when tackling complex issues of the society (Hoppers 2002). Focusing on the characteristic of "living knowledge" in such dialogues, we attempted to utilize "visual materials" as a tool for PAR, which can directly express emotions and time-related changes that cannot be textually expressed.

9.4.2 What Emerged from the Introduction of Video into PAR

As stated above, DL has been utilizing photovoice and art as part of their regular activities. Typically, participants use these participatory methods to investigate the state of community WASH, demonstrating their findings through photographs, art, and accompanying stories. They also express their findings and messages through theater, poetry, and dance, which they also showcase at public exhibitions held to present their research results. Previous research on children's participation in solving community problems has shown that the easiest way for children to communicate with each other and with adults is through the spoken word, and it is important to create an open space in which children of different ages and abilities can freely express their ideas (Hart 1997). Previous research has also reported on the transformation of WASH-related behavior through photo-based action research and photovoice (Bisung et al. 2015).

We have been collaborating with a video artist in Lusaka with the expectation that the videos created as part of our PAR will be more familiar to the locals and more widely used. As shown in Table 9.4, an introductory video was created from recordings of several activities and interviews with research participants to introduce the activities of March 2018. Afterward, a 30-min documentary video was produced that recorded the 2-month preparatory period (August to September 2018) for the Sanitation Festival that DL held for the local community. Additionally, a workshop

Table 9.4 List of activities related to visualization for March 2018–February 2019

Implementation period	Activity
March 2018	Video production in collaboration with a local video artist 1 (activity video of DL)
August/September 2018	Video production in collaboration with a local video artist 2 (close-up video of the public event)
February 17, 2019	Workshop for information transmission using video (classroom lecture + information transmission group work using SNS)

was held to help DL members use the videos produced for their own publicity and activities and to disseminate information through the videos.

Thus, the PAR activities have been archived on video, and a new look at DL's work reveals that they are constantly creating an "image" of their community's issues and what they have learned through their activities through various visualization methods such as photovoice and art. Both in the place where the "image" is created and in the place where the "image" is exhibited, the research subjects talk about the "image." Moreover, they speak of a single "image" in different words, depending on the occasion. We organized a media team for the members of DL who were particularly keen on communicating their activities to not only the adults in the community, but also persons outside the community through social networking services (SNS), among others, holding workshops to deepen the conversation about the "image" of the team.

9.4.3 Digital Storytelling: Talking About the Image

In collaboration with DL youth members and a local video artist, we held a workshop to experiment with digital storytelling methodology to reflect on past activities while making images. Digital storytelling is a way for ordinary, nonprofessional filmmakers to create short video works by creating "stories" about their own lives and everyday events through dialogue with others in workshops. Alongside the creation of the video, a variety of social activities were organized that encouraged participants' reflection through dialogues and collaboration during the workshop process.

The workshop had five participants aged 18–23 years old, consisting mainly of members of the DL media team who were in charge of dissemination of club activities through social networking, among others. They had participated in almost all DL activities since their inception and were thus also core members of the club. The workshop was held on October 27, 2020, on the campus of the University of

Table 9.5 Structure of the digital storytelling workshop

	Contents	Time	Topic providers/group work
1	Opening	5 min	From researcher
2	Introduction to digital storytelling	10 min	From researcher
3	Discussion to wrap up DL activities (step 1 of the six steps)	40 min	Group work
4	Tips for making video	20 min	From local video artist
5	Digital storytelling from photovoice (steps 2–5 of the six steps)	60 min	Group work
6	Reviewing the video and closing (step 6 of the six steps)	30 min	Group work

Note: The structure of the workshop was based on Hartley and McWilliam (2009)

Fig. 9.8 Selected 13 photos and stories

Table 9.6 The six steps to digital storytelling group work

Step 1	Story circle	Discussing the topic
Step 2	Making story	Writing it as a video script
Step 3	Recording narration	Recorded voiceover
Step 4	Selecting images	Selecting photos for video
Step 5	Editing using PC	Editing video on PC
Step 6	Sharing	Sharing outcomes

Zambia in Lusaka and lasted about 3 h. The structure of the workshop is presented in Table 9.5.

The structure of the workshop consisted of a combination of topic presentations and group work, as shown in Fig. 9.8. The digital storytelling part of the workshop was structured with reference to six standard steps (see Table 9.6) (Hartley and McWilliam 2009). In this trial, workshop time was limited and could, therefore, only be conducted up to step 4. The video was edited by a filmmaker to produce the final product. In terms of the flow of the workshop, we revisited the activities through story circles, summarized them in chronological order, and then selected 13 activities (plus introspection and endings) that made a strong impression on the participants. For each of these, they chose a photo they took and wrote a script. Finally, the order of the scenes was structured as a story in a nonchronological order. The digital storytelling broke down the timeline, and through introspection of the activities, the participants shared the issues they were concerned with in their PAR through story circles. The issues were placed at the beginning of the video, and 5 of the 13 photos selected were about community "issues."

9.4.4 What Visualization Can Bring to PAR

One of the characteristics of PAR is that it is a collaborative practice involving research subjects and researchers who share a target state (Yamori 2018). Yamori states that the research subject and the researcher are "co-participants" in PAR who can both benefit from the process. For the research subjects, visualizing changes during PAR using video allows them to share the changes in the community's perception toward the target state and facilitate the understanding of PAR activities with the community. For the researcher, it is possible to analyze changes in the research subjects that are difficult to observe using conventional methods. Scientific knowledge learned during PAR is connected to local life knowledge through videos produced as part of the research; and by communicating the internalized knowledge, awareness, and understanding of the club members as "stories."

In the early stages of our research, we thought that visualization could help us package and communicate situations and problems that are difficult to be expressed verbally. Digital storytelling was originally approached as a method that emphasized individual narratives, and it was common for each participant to create his or her own story (Ogawa 2016). However, in this trial, all participants created a single story as an exercise of storytelling. Creating "our" story was not intended to be desirable, but as a result, the workshop became a place where the participants were able to see the problem as their own through reflection on the activity, and to share the issue collectively through the process of visualization. Although the visual images themselves are not a short-term solution to change individual behaviors and attitudes, visualization has the potential to become one of the methods to build a common awareness and sustainably tackle various issues in the community.

9.5 Conclusions

This chapter outlines a collaborative research conducted with local children and youth aimed at assessing and improving WASH and health within their households and broader communities. Through PAR, researchers and participants were able to assess the status of their physical environment (ecosystem), understand more precisely, the pathways for fecal contamination within their immediate environment, and visually reflect on, express, and share their findings with the broader community.

Through photovoice and arts-informed research, a full PAR cycle was achieved, moving from data collection to analysis that highlighted participants' recommendations and efforts toward WASH education, community action through exhibitions and public clean-ups, and increased engagement for children and youth as local WASH stakeholders. The sanitation exhibitions, festival, and formal registration of DL were notable, and successful PAR outcomes that were implemented by identifying and acknowledging participants' WASH priorities. They also helped to reveal areas of needed improvement in the current DL model, which we hope to address in

future research: creation of formal long-term WASH partnerships, a narrowed down and simplified peri-urban WASH action plan, and a benefit and continuity plan for the DL club and its members.

Regarding fecal pathways, the methodology of quantitative self-assessment of fecal contamination, exposure, and health risk in WASH was in early-stage development. However, observation of fecal bacteria as a part of PAR made local youth aware of fecal pollution. The initial results, including the ranking of media causing diarrhea, showed a change in their recognition of fecal contamination in their living environment, leading to an improved sense of the role of WASH. However, a significant amount of work remains to complete the quantitative self-assessment of fecal contamination, exposure, and health risk in WASH. An improved methodology with the help of digital software to facilitate workshop implementation and the quantification of fecal contamination, exposure, and health risk is currently under development.

Finally, visualization focused on video, which expresses the spoken language of the participants as it is. With a media group within DL to play a central role in the dissemination of information using the images produced, a system has been established in which club members can be more proactively involved in the visualization. As for the practical results that videos could bring, we expect it would be a tool to promote information dissemination to the local residents and surrounding communities, and that the communication in the process of video production would help DL members reflect on their past activities, deepening their understanding. In addition, the video analysis of the video production to information dissemination process may enable us to examine the function of DL within the local community through its activities from the perspective of science communication.

In all three studies, individual participation aided in a deeper understanding of personal and communal points of view, WASH priorities, and the tools available to the participants. Thus, collaborating with locals through existing community-based organizations such as schools and youth centers may be the first step toward upscaling the activities mentioned in this chapter. As PAR is about partnership and co-research, a successful model should be able to scale-up through participating communities partnering with similar neighboring community organizations in order to interact with locals as co-researchers at an interpersonal level. This requires an environment that bridges the gap between government policies and best practice in WASH, and the individual and their household. It also means ensuring that the local community has a sustainable means of progressing the intervention even after the research is completed, which can be achieved through taking advantage of local resources. While the enforcement of various government policies could benefit successful upscaling and cementing of activities, focus on Dziko Langa as a club in which participatory research methods, fecal contamination measurement, and visualization activities can be conducted within existing community organizations and shared with others offers greater opportunity for sustainability, upscaling, and practical intervention capable of impacting the individual and broader community.

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Part III
Materials

Chapter 10
Interactions Between Materials and Socio-Culture in Sanitation

Hidenori Harada

Abstract The function of sanitation is to control the fate of human waste. A toilet is only the entrance to sanitation, and human waste as materials need to be appropriately handled throughout a sanitation service chain to control the impact of human waste on the environment. While the toilet has a private aspect, post-toilet sanitation has a public aspect. It is unclear how individuals and society should share the impact of post-toilet sanitation. Sanitation enabling the use of human waste may have greater material, socio-cultural, and health impacts in society than sanitation that does not enable the use of human waste. If the impacts caused by sanitation are unreasonable, sanitation will not be sustainable. Designing a sanitation service chain is traditionally an engineering-based business that optimizes these impacts, especially from the material and health aspects. However, in the real world, the system with the maximum benefit and minimum burden as a total for society is not necessarily preferred by all individual stakeholders. Rather than simply adjusting stakeholders' interests, sanitation may actively establish appropriate relationships with each stakeholder, even on an individual level, to be more sustainable. Such a design approach would go beyond the traditional design approaches of sanitation optimization that use conventional engineering tools.

Keywords Sanitation · Material · Socio-culture · The environment · Resource · Stakeholder

H. Harada (✉)
Graduate School of Asian and African Area Studies, Kyoto University, Kyoto, Japan
e-mail: harada.hidenori.8v@kyoto-u.ac.jp

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10.1 Sanitation as a System and a Service Chain to Deal with Material

The definition of the word sanitation is "the protection of public health by removing and treating waste, dirty water, etc." (Pearson (a)) or "the equipment and systems that keep places clean, especially by removing human waste" (Oxford University Press (a)). From a material standpoint, the primary function of sanitation is to handle waste, especially human waste (i.e., human excreta, containing feces and urine). The purpose of sanitation is to clean places and protect public health by adequately handling human waste. Hence, the starting point of the discussion on sanitation should be the quantity and composition of human waste.

Although there are significant individual differences, a study reported that people excrete about 128 g of feces and 1.42 L of urine every day (Rose et al. 2015). At first glance, these numbers may not seem large. However, a simple calculation shows that a community of 1000 people daily produces 128 kg and 1420 L of feces and urine, respectively; similarly, and a city of 1,000,000 people produces 128 tons and 1420 m^3 of feces and urine, respectively. In addition, a person's daily human waste contains 58 g of biochemical oxygen demand (BOD, an indicator of biodegradable organics), 11 g of nitrogen, and 1.0 g of phosphorus (Matsui et al. 2001). Accordingly, a city of 1,000,000 people generates 58 tons of BOD, 11 tons of nitrogen, and 1.0 tons of phosphorus in human waste.

Sanitation aims to tackle a tremendous task when addressing large amounts of human waste generated by people and the materials in it. Sanitation is a complex system of multiple interrelated elements functioning together to achieve this task. The service that realizes sanitation is called sanitation service. A sanitation service chain is a chain of stages in which the service is provided. The sanitation service chain comprises five stages: containment, emptying, transport, treatment, and disposal/end-use (World Bank Water Supply and Sanitation Program 2014) as shown in Fig. 10.1.

As indicated by the sanitation service chain, sanitation involves moving materials and changing its form. For example, sanitation transports human waste and changes it into compost. Sanitation is not just a toilet, and a toilet is only a part of the sanitation system and only the entrance to the sanitation service chain. Correspondingly, the global sanitation indicator of access to sanitation facilities in the Millennium Development Goals (MDGs) (United Nations 2003) has been expanded in the Sustainable Development Goals (SDGs) to include access to safely managed sanitation services (United Nations 2015). In other words, the scope of sanitation in the context of global indicators was enlarged from mere toilets to the fate of human waste in the socio-culture, including what happens after the toilets, to cover the entire area that sanitation needs to tackle fundamentally (World Bank Citywide Inclusive Sanitation (CWIS) Initiative 2021; Harada et al. 2016). Accordingly, the meaning of "sanitation" significantly changed from the toilet in MDGs to sanitation in the SDGs.

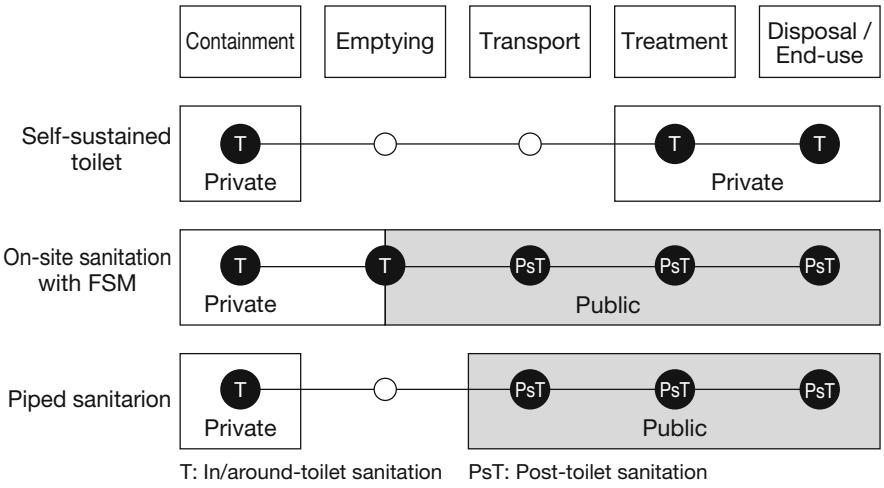

Fig. 10.1 In/around-toilet and post-toilet sanitation with privateness and publicness along the sanitation service chain in three typical sanitation systems

10.2 Toilet and Post-Toilet Sanitation

One of the characteristics of sanitation is that it aims to control the quality of a place or environment. The meaning of hygiene in dictionaries is "the practice of keeping yourself and the things around you clean in order to prevent diseases" (Pearson (b)) or "the practice of keeping yourself and your living and working areas clean in order to prevent illness and disease" (Oxford University Press (b)). Thus, hygiene is the practice of cleaning oneself and one's immediate surroundings. Handwashing, which is a hygiene target of the SDGs, concerns cleaning dirt on the hand surface. Cleanliness of the hand surface can be achieved by handwashing. In contrast, as shown in Fig. 8.1 of Chap. 8, the object that sanitation addresses is human waste. The function of sanitation is to control the fate of human waste, thereby preventing contamination of the place or environment caused by the discharge of human waste. The toilet is directly related to one's act of excretion, and the toilet is often one's private property. Therefore, at the toilet level, sanitation is a private matter. However, sanitation is not something that makes oneself clean. Sanitation control resulting from adequate handling of human waste affects the environment.

Figure 10.1 shows the three typical sanitation systems along sanitation service chains. For self-sustained toilets where human waste can be treated and disposed of/used on-site, the sanitation service chain employs three stages: containment, treatment, and disposal/end-use. All these components stay in/around a toilet. In this case, the sanitation service chain is operated by toilet users, and sanitation has a strong private aspect. In the case of on-site sanitation with fecal sludge management (e.g., a pit latrine and a water flush toilet with a septic tank), emptying is conducted at a toilet and sanitation is a private matter for toilet users until the human waste

accumulated in the sanitation facility (i.e., fecal sludge) is emptied. However, right after emptying at a toilet, transport, treatment, and disposal/end-use are post-toilet sanitation occurrences that extend beyond in/around-toilet sanitation. Similarly, in the case of piped sanitation (e.g., sewerage), the sanitation service chain extends beyond in/around-toilet sanitation after containment (after water flushing). In these two cases, post-toilet sanitation does not directly affect the person using the toilet. It is the business of individuals other than toilet users, and post-toilet sanitation negatively impacts the environment and/or the people involved in post-toilet sanitation. Hence, post-toilet sanitation extends beyond private matters and has a strong public aspect. In many low- and middle-income countries, public systems for the emptying, transport, treatment, and disposal/end-use of human waste are not particularly well developed, often resulting in dumping human waste and negatively impacting the environment and public health (Harada et al. 2016).

Thus, while toilet use is a private matter, post-toilet sanitation use is a public matter. If this is the case, it might not always be rational to cover all post-toilet sanitation with personal expenses. Hence, it is unclear how individuals and society should share the responsibility and burden of sanitation development and operation. Furthermore, while the toilet itself needs to be socio-culturally accepted by the individual, post-toilet sanitation needs to be accepted by society. The sanitation service chain is often established beyond the individual or even the community, and that is where human waste is emptied, transported, treated, and disposed of/used off-site. The location of each stage of the service chain will be different, and thus, the stakeholders involved will be diverse.

It is necessary to ensure that human waste is appropriately managed throughout the sanitation service chain to control the impact of human waste on the environment. For example, human waste needs to be adequately contained in the toilet, transported without dumping, and converted to a safe material for the environment. This series of processes is financially viable; however, due to the relationship between individuals and the public in the society and the multiple stages of the sanitation service chain involving various stakeholders, some stages of the sanitation service chain are not often socio-culturally established and therefore malfunction. Thus, the relationship between sanitation materials handling and socio-culture becomes complex.

10.3 Human Waste Use and Socio-Culture

The object of sanitation, from a material standpoint, is waste material. In reality, it contains organic and nutrient-rich material along with pathogens. The conventional sanitation service chain handles human waste as pollutants, converts it into harmless materials, and returns it to the environment. However, the material value of human waste has been recognized for a long time. For example, in Japan, human waste had historically been used as a valuable fertilizer. The system to use human waste became sophisticated in the Edo era (1603–1868), where farmers paid to collect

human waste and use it for agriculture (Japan Association of Drainage and Environment–Night Soil Research Team 2003). The farmers and human waste collectors bore the financial burden of the post-toilet sanitation service chain in exchange for the fertilizer value, and the sanitation service chain functioned beyond a community without any public financial burden. This relationship worked because the benefits of human waste as fertilizer to the farmer outweighed the farmer's and collector's burden of collecting and transporting human waste.

Unfortunately, this self-sustaining cycle has disappeared in modern Japan. However, today there are several ideas on utilizing the potential resource value of human waste to drive the sanitation service chain and thus contribute to the realization of sound material cycles of human waste. Sanitation, which allows using human waste for agriculture, is particularly considered to have four main advantages: (1) food security and poverty alleviation, (2) cost savings for farmers, (3) preventing nitrogen pollution, and (4) restoring lost topsoil (Winblad and Simpson-Hébert 2004). Various approaches have been proposed to realize these advantages, such as ecological sanitation (Winblad and Simpson-Hébert 2004), resource-oriented sanitation (ROSA 2006), and resource-oriented agro-sanitation (Funamizu 2019).

In a small, closed system where human waste produced by a household is treated at the toilet and used by the household for agricultural purposes, sanitation, including post-toilet sanitation, seems to be a personal matter. In such cases, sanitation might be established socially and culturally, at least at the individual or household level. However, as long as people are members of society, sanitation cannot be completely independent of society. For example, the attitudes of neighboring households to sanitation for agricultural use affect their acceptance of such sanitation (Uddin et al. 2014). Sanitation will always have a social and cultural impact, and thus will never be a truly individual matter.

When sanitation with human excreta has impacts beyond a household or even a community, that is, when human waste is transported, treated, and used by someone else at a different location from the generated place, the location of each stage of the service chain may be different and the stakeholders involved can be diverse. In addition to the essential requirements of the conventional sanitation service chain that does not enable human waste use, sanitation enabling human waste use with impacts beyond a household must convert human waste for use as a valuable material, such as fertilizers and compost. Farmers accept converted human waste as a valuable material. People accept agricultural products made from human excreta. These can be regarded as conditions that affect the sustainability of a sanitation service chain.

Conversely, sanitation enabling the agricultural use of excreta may affect socio-culture. Human waste trading in the Edo era in Japan provides such examples (Aratake 2015). When used for agriculture, human waste was considered goods rather than waste. Farmers and human waste (i.e., night soil) collectors in rural areas collected human waste and purchased it from urban residents (Fig. 10.2). This trading of human waste established a beneficial relationship between the urban and the rural regions as producers and consumers of human waste as fertilizer, respectively. It made the great food consumption in and growth of urban areas more

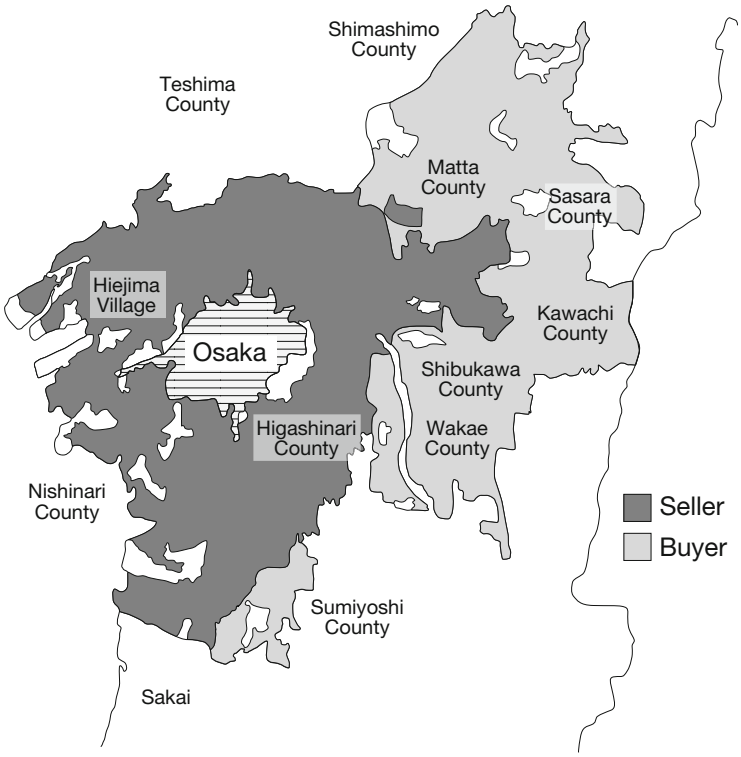

Fig. 10.2 Trading of human waste around Osaka. (Reprinted from Aratake 2015 with the permission of Seibundo Publishing)

sustainable. Around Osaka, which was the largest city center in west Japan, as the scale of human waste use increased, the trade in human waste became more organized. Farmers began to cooperate across villages to form a trading union to effectively negotiate and buy human waste from the urban areas. Accordingly, subcontract business for human waste trading was established, the collection rights of human wastes were transferred between groups. Conflicts among people within a village and across villages happened on the trade, and rulings were made at the magistrate's office. This suggests that sanitation may greatly impact the socio-culture. If the impact caused by sanitation is unreasonable, sanitation will not be sustainable.

10.4 Stakeholders Involved in Sanitation

Various arguments have been made to design sanitation as a sustainable system that is inevitably interrelated with socio-culture. For example, sustainable sanitation (SuSanA 2008), which emphasizes sustainability across the entire sanitation service

chain, calls for the following five sustainability criteria: health, environment and natural resources, technology and operation, finance and economics, and social-cultural and institutional aspects. To satisfy such criteria, stakeholder involvement has often been emphasized in sanitation planning. For example, Kalbermatten et al. (1982) suggested that the feasibility study of a sanitation program should consider users' social preferences and involve the following stakeholders: environmental engineers/public health specialists, economists, behavioral scientists, and the community. However, the role of the community was often limited to advising the above external specialists and selecting a technology from the prepared list of feasible alternatives; this made the sanitation service chain unsustainable.

The Bellagio Principles (Schertenleib 2000), developed by the Water Supply and Sanitation Collaborative Council (WSSCC) in 2000, became a touchstone for subsequent substantial stakeholder involvement. They are composed of the four principles listed in Table 10.1. With human dignity, quality of life, and environmental security at the household level as the main issues, the Bellagio Principles state that all stakeholders, from consumers to service providers, should be involved in decision-making. This idea became the basis of several sanitation planning methodologies, such as household-centered environmental sanitation (Schertenleib 2000), sanitation 21 (IWA 2005), community-led urban environmental sanitation planning (Lüthi et al. 2011), and city-wide inclusive sanitation, CWIS (Schrecongost et al. 2020). Through these methodologies, socio-cultural considerations are now essential in establishing a sanitation system.

While it is essential for the sanitation service chain to be socially and culturally acceptable, the sanitation service chain itself impacts the socio-culture, as discussed above, especially when the service chain involves multiple stakeholders and places. From the material aspect, sanitation affects the local material cycle; for example, dumping without adequate treatment burdens the environment, while using human waste for agriculture promotes resource recycling. The material impact of sanitation on society can be expressed as indices of pollutants, nutrients, money, etc., either maximizing the benefit or minimizing the burden. Engineering tools such as material flow analysis and life-cycle assessment are used to analyze such impacts (e.g., Buathong et al. 2013; Tran-Nguyen et al. 2015; Pham et al. 2017). Such maximization and minimization are called optimization of the system. Designing a sanitation

Table 10.1 The Bellagio principles

Human dignity, quality of life, and environmental security at household level should be at the center of the new approach, which should be responsive and accountable to needs and demands in the local and national setting.
In line with good governance principles, decision-making should involve participation of all stakeholders, especially the consumers and providers of services.
Waste should be considered a resource, and its management should be holistic and form part of integrated water resources, nutrient flows, and waste management processes.
The domain in which environmental sanitation problems are resolved should be kept to the minimum practicable size (household, community, town, district, catchment, and city) and wastes diluted as little as possible.

service chain is traditionally an engineering issue aimed at optimizing the impacts while ensuring the feasibility of the technology.

However, in the real world, because of the varied interests of different stakeholders, the system with the greatest benefit and the least burden is not necessarily selected. In addition, total optimality is not necessarily equal to the sum of partial optimality. The system with the maximum benefit and minimum burden for society is not necessarily a system that an individual stakeholder prefers. If sanitation planning and design exclude individuals' benefits or preferences, the sanitation system would not function appropriately at the ground level. If sanitation is operated beyond the household level, its service chain involves different stakeholders, and some processes may cause a significant burden on a specific social group. The topic of sanitation workers in Chap. 3 of Part I was about the social and cultural burdens that a particular group had to bear to make the sanitation service chain work on a societal level. Another topic, the social allocation of sanitation-derived health risks discussed in Chap. 8 of Part II is an example of how health burdens of sanitation are not always shared equally in society.

To make sanitation sustainable, it is essential to increase overall benefits. Still, it is also necessary to establish an appropriate relationship between the sanitation system and each of the various stakeholders, even on an individual level. We may standardize stakeholders, quantify the impact on standardized stakeholders and the environment, and increase the overall benefits of the system. However, members of a stakeholder group are not homogeneous. There may be marginalized people in a group. Accordingly, we must also understand the sanitation system's impact on each person who uses or works in the sanitation system and the impact each person has on the sanitation system. Moreover, the design of the sanitation service chain should consider the relationships between sanitation and an individual and reasonably and equitably share socio-cultural impacts throughout society. Such a design approach would go beyond the traditional design of sanitation optimization that followed conventional engineering approaches.

10.5 Chapter Overview

In Part III, the authors, who have a background in engineering, examine how sanitation as a material handling system relates to socio-culture and its socio-cultural impacts when introduced in a new place. First, in Chap. 11, as a case study of the relationship between sanitation technology as a public infrastructure in a city and the city's socio-cultural environment, this chapter focuses on the development and implementation history of a new operation and control method for sewage treatment, the dual dissolved oxygen control system. The author, who is a university researcher of sewerage technology in Japan, worked on this system's development and implementation for the past 20 years and reviewed its dynamic relationships with various stakeholders during fundamental research, technology development, and its adoption by a local government to its social acceptance. As mentioned above, recent

sanitation planning has already emphasized stakeholder involvement, but it mainly concerns stakeholder involvement when introducing a sanitation technology that has already been established. This chapter shows that stakeholder involvement is not limited to the coordination of interests among stakeholders when introducing an existing technology; it shows that the dynamic relationships with various stakeholders significantly impact the development of new technology and subsequent social implementation.

Chapter 12 focuses on the cases of self-sustained, resource-oriented dry sanitation, in which human excreta are used by households that use the toilet. In contrast to Chap. 11, sanitation could be a more personal matter in these cases. The chapter considers three rural cases from Vietnam, Malawi, and Bangladesh, where many urine-diverting dry toilets were introduced on a large scale several years ago. While health is not necessarily the primary motivation for individuals to adopt sanitation (Cairncross 2004; Jenkins and Scott 2007), the resource value of human excreta can be a potential motivator. This chapter examines the relations among toilet use, excreta use for agriculture, perception of excreta values, and reasons for users' usage decisions. The results show that the agricultural resource value of human waste alone was not always a motivator to use the resource-oriented dry sanitation facilities but was a motivator when sanitation project was linked to an organic farming project. Further, this chapter examines the socio-cultural barriers to using human waste. It shows their dynamics, potentially impacted by the physical and other socio-cultural conditions, implying that adequate physical and social conditions need to be established to promote the long-term acceptance of the use of toilets as well as human waste.

Chapter 13 also addresses resource-oriented dry sanitation. Unlike Chap. 12, it targets an urban slum and aims to establish a sanitation service chain at the community level. This chapter is based on the authors' ongoing research and implementation project to develop a sanitation service chain in an urban slum in Indonesia, which has not yet been fully implemented. First, the authors conducted a material flow analysis in the targeted slum and clarified the significance of introducing sanitation from a material aspect. Second, employing the methodology of material flow analysis, the authors depict the motivations of the various actors involved in the sanitation service chain and develop it into a value flow network for expressing social relationships. Based on the value flow network, a sanitation service chain is co-created with various actors involved in the network so that the motivations of each are matched, rather than simply optimizing the total impact of sanitation by conventional engineering approaches. In this case, sanitation is used to connect the motivations of different groups, creating a new social network.

As described above, sanitation is not established by merely searching for the optimal conditions of materials, but it is done considering adequate embedding into socio-culture. The perspective of socio-culture is essential to establish a sanitation system and realize a sanitation service chain. It is vital to consider socio-culture dynamically and heterogeneously for developing and introducing sanitation, unlike the old approach of introducing existing sanitation technologies with socio-culture as static and standardized constraints. Understanding the relationship between

materials and the socio-culture in the Sanitation Triangle and the active use of the relationship can be the key to the development, introduction, further co-creation, and proper socio-cultural embedding of sanitation, in order to address global sanitation issues.

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Chapter 11
Social Integration and Acceptance of Emerging Sanitation Infrastructure in Japan

Taku Fujiwara

Abstract Availability and sustainable management of the sewerage system are extremely important as sanitation infrastructure to achieve Sustainable Development Goal 6. Japan has become a depopulated society since 2010, and therefore sewerage systems in Japan will face difficulties because of the decrease in human resources, deterioration of the facilities, and limited budgets. Although innovative sanitation technologies to overcome these issues are strongly required, various barriers inhibit the development, implementation, and technology diffusion. The author and his research group have developed "dual dissolved oxygen control system in oxidation ditch process" through three-way university–industry–government partnerships. This chapter summarizes the history of the development, social acceptance, and expansion to other cities of the technology and analyzes the social integration and acceptance process. The key elements behind the success of this project are as follows: (1) enthusiasm of all stakeholders toward the shared goal, (2) win-win relationships among stakeholders and respect for each other, (3) research and development considering future applications and technology diffusion, (4) participation of local governments as important stakeholders, (5) agreement of the municipal parliament of Konan City, and (6) registration of the technology to "JS Innovation Program," by Japan Sewage Works Agency.

Keywords Dual dissolved oxygen control system · Emerging sanitation infrastructure · Social integration and acceptance · Technology diffusion · Three-way university–industry–government partnerships

T. Fujiwara (✉)
Department of Environmental Engineering, Graduate School of Engineering, Kyoto University, Kyoto, Japan
e-mail: fujiwara.taku.3v@kyoto-u.ac.jp

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11.1 Introduction

The United Nations announced 17 Sustainable Development Goals (SDGs) and 169 Targets as part of its 2030 Agenda for Sustainable Development, a plan of action seeking to strengthen universal peace and human prosperity (UN 2015). Goal 6 aims to "ensure availability and sustainable management of water and sanitation for all." The COVID-19 pandemic has highlighted the critical importance of water, sanitation, and good hygiene practices for protecting human health (UN 2020). Safe management of the sanitation infrastructure is crucial for protecting the health of individuals and drinking water sources, as indicated by Target 6.2 (UN-Water 2017). Target 6.3 aims to "improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally" (UN-Water 2017). The sewerage system is an important sanitation infrastructure from the viewpoints of Targets 6.2 and 6.3, and the availability and sustainable management of the system are of great importance.

Japan became classified as a depopulated society in 2010 (Statics Bureau of Japan 2015), despite the fact that the global population is projected to increase until 2100 according to the World Population Prospects 2019 (median value) (UN 2019). It is expected that sewerage systems in Japan will encounter difficulties due to the decrease in human resources, deterioration of the facilities, and limited budgets. Considering likely future situations in Japan, the simple replacement of sewerage systems is not acceptable, and innovative technologies that allow for sustainable management should be developed. However, various barriers may inhibit such innovation. Through a content analysis of 195 articles, Galvão et al. (2018) identified the following main barriers to the implementation of a circular economy: (a) technological, (b) social, (c) policy and regulatory, (d) managerial, (e) financial and economic, (f) customer, and (g) performance indicator (Galvão et al. 2018).

The author and his research group have developed an innovative sanitation technology, a dual dissolved oxygen (DO) control system in the oxidation ditch (OD) process, through three-way university–industry–government partnerships. Fundamental research was initiated at Kochi University with undergraduate students using lab-scale reactors and synthetic wastewater. The research was then upscaled to bench-scale experiments using real wastewater, and finally applied to full-scale demonstrations at the Noichi wastewater treatment plant (WWTP) in Konan City, in Kochi Prefecture, Japan. After a successful full-scale demonstration, Konan Municipal Government modified the overall sewerage system plan by integrating the 10 WWTPs into two WWTPs in which the developed technology was installed. This modification is expected to save about 400 million JPY and contribute to the sustainable management of the sewerage system in the city (Editorial Department of Journal of Sewerage, Monthly 2020). This system was expanded to nine WWTPs in Japan (as of July 2021) and awarded by the Ministry of Land, Infrastructure, Transport and Tourism, Japan (MLIT), Japan Society on Water Environment

(JSWE), Japan Science and Technology Agency (JST), and the Japan Society of Industrial Machinery Manufacturers (JSIM).

The objective of this chapter is to examine the history of the technological development, social acceptance, and expansion to other cities of the "dual dissolved oxygen control system in oxidation ditch process" and to analyze the social integration and acceptance process of this emerging sanitation infrastructure.

11.2 Development of an Emerging Sanitation Technology Through Three-Way University–Industry–Government Partnerships

11.2.1 The OD Process

The OD process is an extended aeration-activated sludge system that treats sewage from small- and medium-sized communities. The typical OD process consists of an oval- or horseshoe-shaped channel with mechanical aerators that simultaneously provides circulation and oxygen supply to the ditch and a final clarifier that returns activated sludge to the ditch. The primary clarifier is not typical of the system. Figure 11.1 presents a photo of the horseshoe-shaped channel of an OD process in Japan. The United States Environmental Protection Agency published the "Wastewater Technology Fact Sheet for Oxidation Ditches" and showed a common influent biochemical oxygen demand (BOD) loading rate of 0.24 (kgBOD/m^3 day) and hydraulic retention time (HRT) ranging from 6 to 30 h (United States Environmental Protection Agency 2000a). The OD process was designed and operated at a longer HRT from 24 to 36 h in Japan (Japan Sewage Works Association 2019). Japan

Fig. 11.1 Oxidation ditch at Yasu WWTP, Konan, Japan. (Photo: provided by Maezawa Industries, Inc.)

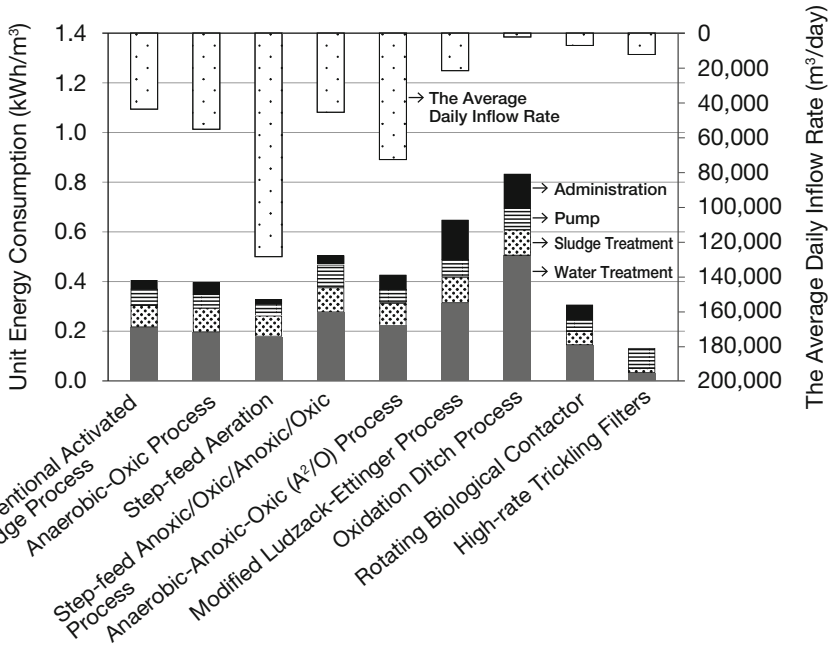

Fig. 11.2 Unit energy consumption for various wastewater treatment processes in Japan. (Reprinted with modification from the Japan Institute of Wastewater Engineering and Technology 2014 with the permission of JIWET)

Sewage Works Agency (JS) reported that average effluent concentrations of BOD and suspended solids were less than 4 and 5 mg/L, respectively, while average total nitrogen (T-N) removal efficiency was about 75% for the OD process (Japan Sewage Works Agency 2000). It also proposed appropriate aerobic sludge retention time and the aerobic/anoxic time ratio for obtaining more than 85% of T-N removal (Japan Sewage Works Agency 2000). Figure 11.2 illustrates the average values of unit energy consumption for various wastewater treatment processes in Japan (Japan Institute of Wastewater Engineering and Technology 2014). The unit energy consumption for water treatment of an OD process is about 0.5 kWh/m^3, which is 2.5 times higher than that for a conventional activated sludge system. Indeed, the OD process is an extended aeration-activated sludge system for small- and medium-sized communities with easy operation and maintenance and good effluent water quality. However, high energy consumption should be brought under control for reducing the cost and mitigating greenhouse gas emissions.

11.2.2 *Outline of the Dual DO Control System in the OD Process*

The dual DO control system in the oxidation ditch process is depicted in Fig. 11.3. Flow boosters with 16 vertical blades are installed at the bends in the OD and are rotated slowly to generate an ideal plug flow. Compressed air from the root blowers is introduced from the membrane diffusers at the straight segment of the ditch to supply oxygen to the activated sludge. Two DO sensors are installed to control the DO gradient in the ditch. The first DO sensor (DO sensor 1) is placed immediately downstream of the aeration units to control the aeration intensity, while the second DO sensor (DO sensor 2) is set at the end of the aerobic zone to control the flow rate in the ditch by changing the rotation speed of the flow boosters. As a result, the dual DO control system automatically regulates the aerobic/anoxic zone ratio in the ditch under large fluctuations in influent loading. Organic compounds in the influent wastewater are decomposed by aerobic respiration in the aerobic zone and denitrification in the anoxic zone. Ammonia in the influent is oxidized to nitrite and nitrate in the aerobic zone; thereafter, oxidized nitrogen is denitrified to nitrogen gas in the anoxic zone. Hence, the balance of aerobic and anoxic zones in OD systems is of great importance for the simultaneous removal of organics and nitrogen from influent wastewater. In addition, energy savings are achieved through the optimization of the aeration and rotation speed of the flow boosters. The JS registered the dual DO control system in the OD process in the JS Innovation Program. The benefits of this technology are summarized as follows (Japan Sewage Works Agency 2014):

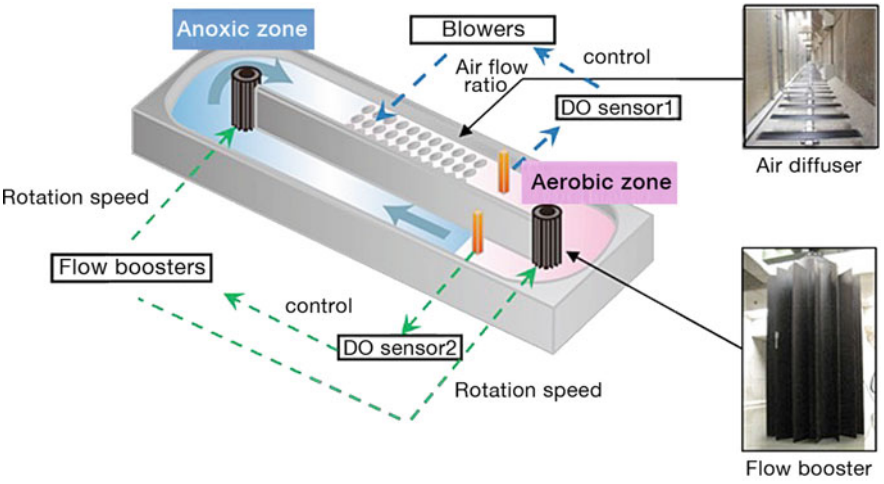

Fig. 11.3 Schematic diagram of dual dissolved oxygen control system in the oxidation ditch process. (Provided by Maezawa Industries, Inc.)

- Stable effluent quality of biochemical oxygen demand (BOD) and nitrogen.
- Reduction in power consumption by 30% compared to conventional OD equipped with vertical shaft aerators.
- Adaptable to high-load operation, such as a temporal excess inflow or high concentration of BOD and nitrogen in influent sewage.

11.2.3 History of Technological Development: From the Origin to the Full-Scale Demonstration

The history of the research, development, and dissemination of the dual DO control system in the OD process is summarized in Table 11.1. The origin of this research is the author's doctoral thesis entitled "Application study of a draft-tube-type reactor to nitrification-denitrification process" published in 1999. The draft-tube-type reactor realized simultaneous nitrification and denitrification by creating both aerobic and anoxic zones in a single reaction tank, and the design and operational parameters were presented in several publications (Fujiwara 1999; Fujiwara et al. 1998). After earning a doctoral degree at Kyoto University, he moved to Kochi University and started lab-scale experiments for the OD process in 2000. He considered that operation at a shorter HRT increases the oxygen consumption rate of activated sludge and enables the control of the DO gradient more easily based on research experience during his doctoral course. He also conducted a theoretical analysis and clarified that the DO recirculation rate is an important operational parameter. The author and his research group experimentally proved that the DO recirculation rate is

Table 11.1 History of research, development, and dissemination for dual dissolved oxygen control system in the oxidation ditch process

FY	Remarks
2000–2004	Lab-scale experiments at Kochi University
2004–2009	Bench-scale experiments at Takasu WWTP, Kochi Prefecture, and Noichi WWTP, Konan
2009–2011	Full-scale demonstration at Noichi WWTP, Konan
2011	Operation commencement at Noichi WWTP, Konan
2012	Revision of master plan for sewerage system in Konan
2014	Registered in the JS Innovation Program
2015	Awarded by MLIT
2016	Awarded by JSWE (the JSWE New Technology Award)
2016	Operation commencement at Yasu WWTP, Konan
2018	Operation commencement at Oomi WWTP, Itoigawa
2019	Awarded by JST (Excellent Practice Awards for the STI for SDGs Award)
2020	Operation commencement at Takanosu WWTP, Kita-Akita
2021	Awarded by JSIM
At present	Determination of introduction in nine WWTPs in Japan (As of July 2021)

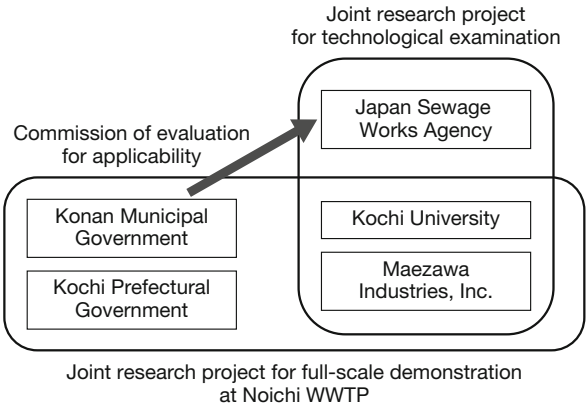

Fig. 11.4 The three-way university–industry–government partnership

an effective parameter for nitrogen removal in the OD process. They also acquired a Japanese patent for a dual DO control system in the OD process, which can automatically control the DO recirculation rate. Detailed information on the DO recirculation rate is available in Sect. 11.2.4.

Thereafter, Kochi University and Maezawa Industries, Inc. jointly launched bench-scale experiments using grid chamber effluent at the Takasu WWTP in Kochi Prefecture in 2004. The core reactor replicated the flow dynamics of typical ODs, and a dual DO control system was installed in the bench-scale plant. The experimental results demonstrated that the dual DO control system achieved considerable nitrogen removal through the stabilization of the ratio between aerobic and anoxic zones, even under the condition of large fluctuation of influent loadings (Chen et al. 2010). Kochi Prefectural Government evaluated the results as successful and introduced the technology to Konan Municipal Government for full-scale demonstrations.

Konan Municipal Government, Kochi Prefectural Government, Kochi University, and Maezawa Industries, Inc. concluded a joint research agreement to construct a full-scale demonstration at Noichi WWTP in 2008. JS, Kochi University, and Maezawa Industries, Inc. also launched a joint research program entitled "Development of energy saving process of wastewater treatment—development of an efficient high-rate OD using dual DO control technology" in 2008 to conduct technological examinations such as project management, conducting a full-scale demonstration, examination of the appropriate design and operational method, and applicability. Konan Municipal Government commissioned JS to evaluate its applicability at Noichi WWTP. The three-way university–industry–government partnership is summarized in Fig. 11.4**.**

There existed two oxidation ditches at the Noichi WWTP: the first OD (first line) was operated using screw-type aerators, and the second OD (second line) was newly constructed and utilized for a full-scale demonstration of a dual dissolved oxygen control system in the OD process. After conducting clean water tests to evaluate flow dynamics and oxygen transfer in FY 2009, a full-scale demonstration was conducted

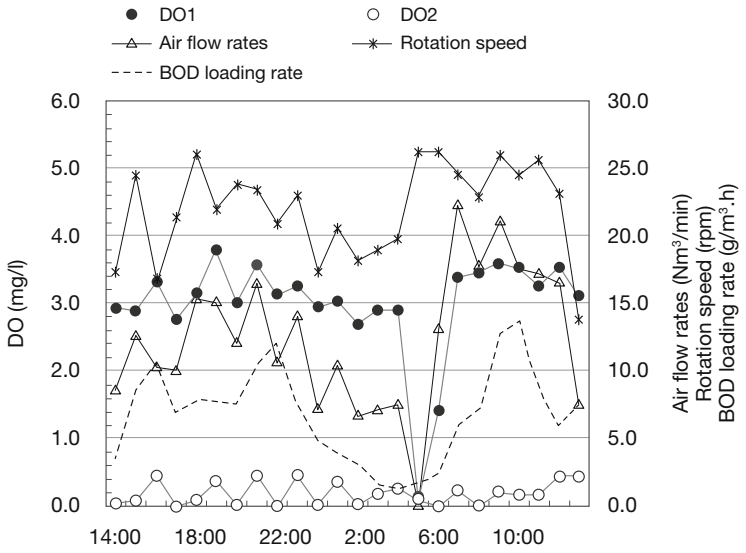

Fig. 11.5 An example of dual DO controls during an intensive survey (February 23–24, 2011). (Reprinted from Fujiwara et al. 2011)

under high loading conditions in FY 2010. All influent sewage to Noichi WWTP was introduced to the second line and water depth was set at 1.5 m. Mean HRT was 16.5 h during the operation in FY 2010 (between May 2010 and March 2011). Detailed information on the operational conditions is available in a previous publication (Nakamachi et al. 2012).

Figure 11.5 presents the profiles of 1-h average DO concentrations, air flow rate of blowers, rotation speed of flow boosters, and BOD volumetric loading rate during an intensive survey between February 23 and 24, 2011. This figure also demonstrates an example of dual DO controls in response to the large fluctuation in influent loading. As shown with the dotted line in Fig. 11.5, BOD volumetric loading rate reached 12.1 g/(m^3 h) at 22:00, then suddenly dropped to a minimum value of 1.29 g/(m^3 h) at 4:00, and finally increased to a maximum value of 13.9 g/(m^3 h) at 10:00. The dual DO controls automatically adjusted the air flow rate and the rotation speed independently to such large fluctuation of influent loading. The values of DO sensor 1 and DO sensor 2 were consequently maintained almost constant. Aeration was stopped by preset timer to adjust extremely low influent loading early in the morning (between 5:00 and 6:00) and only mixing was performed by the flow boosters. Hence, the values of DO sensor 1 and DO sensor 2 at 5:00 became nearly 0 (mg/L) (1-h average between 5:00 and 6:00). Thereafter, the system returned to the dual DO control mode and the DO values also returned to the setpoint immediately. These results clearly demonstrate that dual DO control system is effective for a full-scale OD equipped with blowers, aeration units, and flow boosters.

Figure 11.6 depicts time courses of chemical oxygen demand (COD) and BOD concentration in the effluent. Effluent BOD concentration was 4 ± 3 mg/L

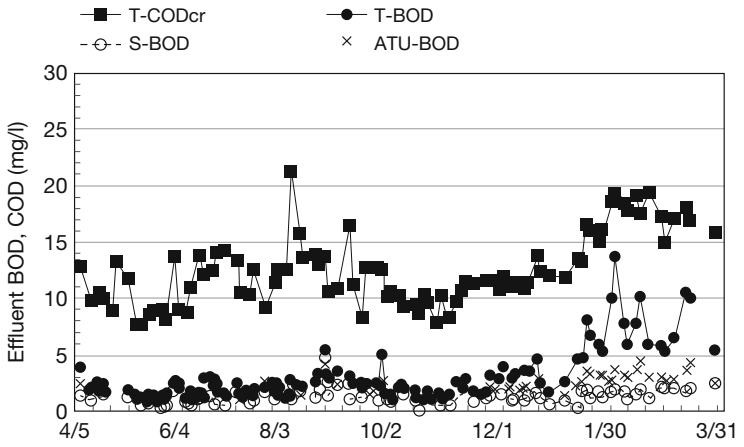

Fig. 11.6 Time courses of effluent BOD and COD concentrations. (Reprinted from Fujiwara et al. 2011)

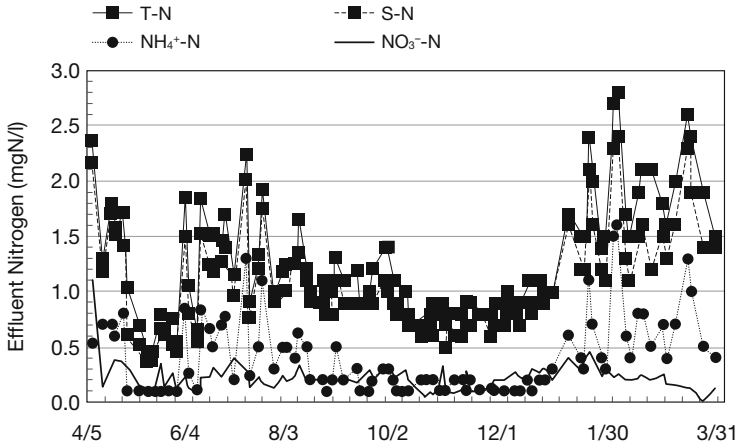

Fig. 11.7 Time courses of effluent nitrogen concentrations. (Reprinted from Fujiwara et al. 2011)

(average ± standard deviation) and 97% of the total BOD was removed on average. Figure 11.7 demonstrates time courses of effluent T-N, soluble nitrogen (S-N), ammonium nitrogen (NH_4^+–N), and nitrate nitrogen (NO_3^-–N) concentrations. Effluent T-N concentration was 1.3 ± 0.5 mg/L, and average T-N removal efficiency was as high as 94% (Fujiwara et al. 2011). These results demonstrated that a dual DO control system realized similar BOD removal and better T-N removal compared to previously reported average values for the OD process (Japan Sewage Works Agency 2000). Figure 11.8 illustrates the relationship between the influent flow rate and unit power consumption for the first line in FY 2009 and the second line in FY 2010. The results demonstrate that the unit power consumption for the

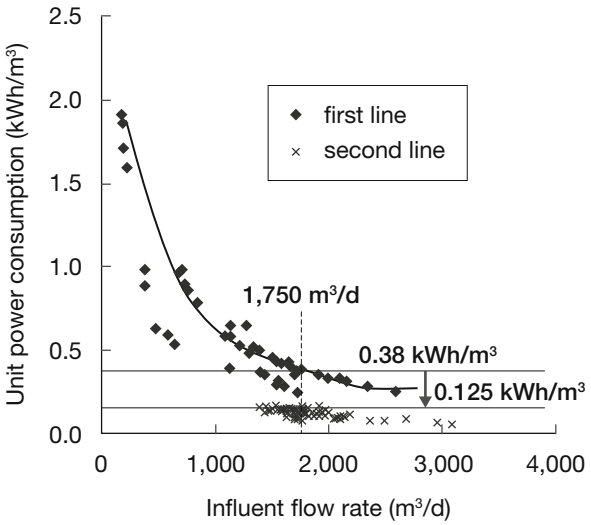

Fig. 11.8 Relationship between influent flow rate and the unit power consumption for the first line in FY 2009 and the second line in FY 2010. (Reprinted from Nakamachi et al. 2012) with the permission of Japan Society on Water Environment)

second line (0.125 kWh/m^3) was only 34% of that for the first line (0.38 kWh/m^3) at the designed influent flow rate of 1750 m^3/day. Rough estimation indicated that the reduction of endogenous respiration by high loading operation, improvement of standard aeration efficiency, and dual DO control contributed to the reduction of unit power consumption by 15%, 28%, and 23%, respectively. The unit energy consumption of 0.125 kWh/m^3 during the full-scale demonstration is much lower than that of a conventional OD process (ca. 0.5 kWh/m^3) and lower than that of a conventional activated sludge system (ca. 0.2 kWh/m^3) in Japan. The drawback of the OD process, high energy consumption, was successfully overcome by introducing the dual DO control system. As shown in Fig. 11.2, unit energy consumption of high-rate trickling filters (TFs) is lower than that of the dual DO control system in the OD process. However, BOD removal rates of trickling filters were inferior to the OD process (low-rate TFs: 80–90%; high-rate TFs: 65–85%) (United States Environmental Protection Agency 2000b), and an additional anoxic process for denitrification is required for T-N removal. As a developing sanitation infrastructure to meet stringent discharge standards, the dual DO control system in the OD process successfully achieved both good effluent water quality and energy efficiency. Additional operation of the second line in FY 2011 under low loading conditions demonstrated that the dual DO control system is effective under both high and low loading operations. Easy maintenance and operation were also confirmed through the full-scale demonstration for 2 years. This advantage will be beneficial for both developing countries and depopulated societies in developed countries to introduce the dual DO control system in the OD process and achieve SDGs.

11.2.4 How Did the Three-Way Partnerships Among University–Industry–Government Overcome Technological Barriers for Innovation?

As mentioned in the introduction, there are several main barriers to the implementation of the circular economy: technological, social, policy and regulatory, managerial, financial and economic, customer, and performance indicators. In this section, the author discusses why the three-way partnerships among university–industry–government were able to overcome technological barriers to implementing a dual DO control system in the OD process.

The first reason is the theoretical analysis of the operational parameters for the OD process. The retention of nitrifying bacteria in the system, appropriate balance of aerobic and anoxic zones, and hydrogen donors for denitrification are extremely important in the process to achieve the simultaneous removal of organics and nitrogen. Of all these conditions, an appropriate balance between the aerobic and anoxic zones is especially difficult to realize because the oxygen utilization rate by activated sludge temporally changes depending on the time variation of influent loading. The author theoretically demonstrated that the DO recirculation rate (R_{DO}) should be adjusted in accordance with changes in the oxygen utilization rate to appropriately manage aerobic/anoxic zone ratio (Fujiwara et al. 2004).

$$R_{DO} = DO_a(Q_R/V) \tag{11.1}$$

where R_{DO} is the DO recirculation rate (g/m^3 h), DO_a is the DO concentration at the aeration point, Q_R is the recirculation flow rate in the OD (m^3/h), and V is the total volume of the ditch (m^3). The index indicates that both DO concentration at the aeration point and the recirculation flow rate are important factors for achieving an appropriate balance between aerobic and anoxic zones. Based on this analysis, the author conceived the idea of a dual DO control system in the OD process, in which aeration intensity and recirculation flow rate are independently controlled by the DO values at two points. The author and his co-investigators acquired patents for the technology (Tsuno et al. 2009), which was the basis of the three-way university–industry–government partnership.

The second reason is to set the experimental conditions under consideration for scaling up the reactor in the future. The author initially started lab-scale experiments using six completely mixed tanks in series with huge recirculation, which can replicate the typical flow dynamics of ODs. As a result, the experimental results obtained from lab-scale reactors were applicable to bench-scale experiments. Thereafter, the bench-scale reactor was placed in the Takasu WWTP, Kochi, Japan, to treat real wastewater with fluctuations in influent flow rate to replicate actual treatment conditions in future applications. A dual DO control system was also installed in the bench-scale reactor, and the effectiveness of the control system was evaluated. The obtained results were therefore effective for the design and operation of a full-scale plant at the Noichi WWTP.

The third reason is the invention of a new type of DO probe and the introduction of appropriate flow boosters for a dual DO control system. The oxidation ditch process is widely applied in small- and medium-sized communities in Japan, and no operation manager is stationed, and patrol monitoring is carried out; hence, easy maintenance and operation is of great importance. From this viewpoint, DO probes utilizing conventional membrane-electrode methods are not appropriate for such WWTPs because of the requirement of periodical calibration, biofilm attachment on the membrane surface, and the need for sufficient sample flow across the membrane surface. Fortunately, novel optical DO probes, the sensor caps of which should be replaced only around once per year, were developed just before the full-scale demonstration at the Noichi WWTP. This invention made the dual DO control system feasible for ODs in Japan. In addition, Maezawa Industries, Inc. introduced flow boosters with 16 vertical blades for the full-scale demonstration. The vertically uniform shape of the boosters can create an ideal plug flow without shortcuts in the ditch, which makes the dual DO control system stable.

11.3 Social Integration and Acceptance Process of the Technology as an Infrastructure in Depopulating Cities in Japan

11.3.1 Social Integration of the Emerging Technology Contributing to Achieving SDGs in Konan City

In this section, the author summarizes the social integration process of the technology in Konan City and discusses how the following barriers were overcome: (b) social, (c) policy and regulatory, (d) managerial, (e) financial and economic, (f) customer, and (g) performance indicator.

Figure 11.9 summarizes the life cycle of the technology and the various barriers at each phase of the cycle. During the research and development phase, the authors overcame many technological barriers to developing the technology, as mentioned in Sect. 11.2.4. Maezawa Industries, Inc. financially supported fundamental and applied research and installed machinery and electrical facilities for full-scale demonstrations. Therefore, they overcame managerial barriers and achieved performance indicators of the technology during the research and development phase. In addition, permission from Konan City parliament was required to conduct a full-scale demonstration at the Noichi WWTP. All members of the three-way partnerships believed that this technology was sufficiently effective to be disseminated and considered that it would be easily accepted by the parliament members by simply explaining its benefits. However, obtaining their consent was difficult because they were representatives of the citizens and were not technical experts. Therefore, they carefully explained the significance, benefits, and limitations of the technology to the city parliament members elected by the citizens for about half a year. They successfully

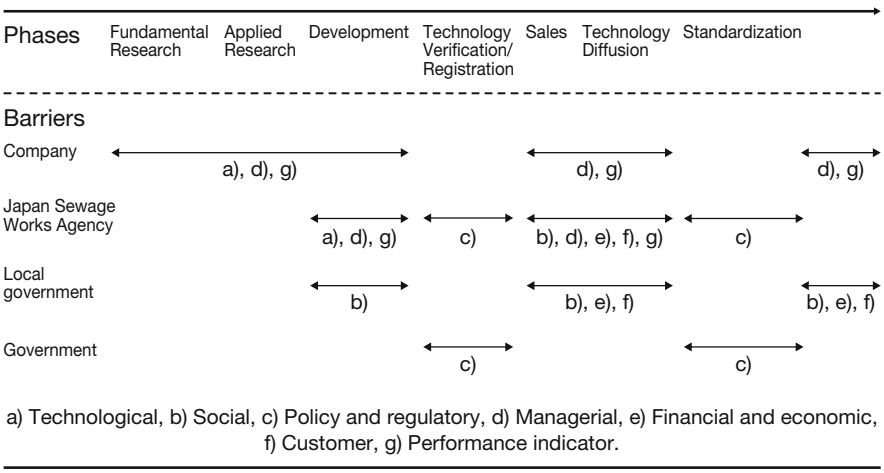

Fig. 11.9 Life cycle of sanitation technology and the various barriers at each phase of the cycle

gained their understanding and were able to start full-scale demonstrations in FY 2009. They thus overcame social barriers to the demonstration.

Sewerage systems were introduced to local municipalities with financial support from the Japanese government. Therefore, the reliability and equity of the employed technology are especially emphasized in Japan as a public service. From this viewpoint, technology verification and/or registration was essential to diffuse new technology after the success of the development. JS has been running the "JS Innovation Program" since 2011, aiming to enhance the development of new wastewater treatment technologies. It also encourages the adoption of registered technologies in contract projects. Kochi Prefectural Government, Konan Municipal Government, Kochi University, and Maezawa Industries, Inc. requested that JS join the three-way partnerships before starting the full-scale demonstration. As mentioned in Sect. 11.2.3, JS accepted the invitation and evaluated its applicability to the Noichi WWTP. JS also registered the new technology in its Innovation Program in 2014, a dual DO control system in the OD process. Konan Municipal Government revised the master plan for the sewerage system in 2012, in which the future integration of 10 WWTPs into two WWTPs is stated for the sustainable management of sewerage systems in future depopulated cities. The developed technology plays a key role in increasing the treatment capacity and realizes the integration of WWTPs in Konan City. Konan Municipal Government continued to utilize the technology at Noichi WWTP after the full-scale demonstration and introduced it to Yasu WWTP after its registration to the JS Innovation Program. They thus overcame policy and regulatory barriers through registration to the JS Innovation Program, and the registration became the basis of sales and technology diffusion thereafter. JST highly evaluated and awarded the three-way partnerships as Excellent Practice Awards for the STI for SDGs Award from the viewpoints of SDGs 6, 7, 11, and 13. This energy-saving sanitation technology directly contributes to both SDGs 6 and 7. Lower unit

power consumption of the technology mitigates climate change through reduction of carbon dioxide emission and contributes to SDG 13. Integration of the 10 WWTPs into two WWTPs in Konan City by introducing the technology is expected to save about 400 million JPY, making Konan City inclusive, safe, resilient, and sustainable (SDG 11). Indeed, development and social integration of a dual DO control system in the OD process contribute to achieving SDGs in Konan City.

11.3.2 Contribution of Three-Way Partnerships to the Horizontal Development of the Technology

As of July 2021, nine WWTPs in Japan had introduced a dual DO control system in the OD process. JS designed and constructed facilities introducing the novel system at eight WWTPs based on commissions by local governments. Itoigawa City ordered Maezawa Industries, Inc. to design and construct another facility utilizing the system. Figure 11.10 illustrates the concept of capacity enhancement by introducing a dual DO control system. The influent flow rate of specific WWTPs increases with the dissemination of sewerage systems and the integration of facilities, including other WWTPs and night soil treatment plants. However, it will decrease depending on future depopulation in the area. Considering long-term influent flow rate trends, it is not cost-effective to expand facilities utilizing conventional systems to adopt the peak flow rate because additional facilities will become too excessive during the depopulated phase. Instead, the introduction of a dual DO control system realizes a temporal high-loading operation and enhances the treatment capacity without the

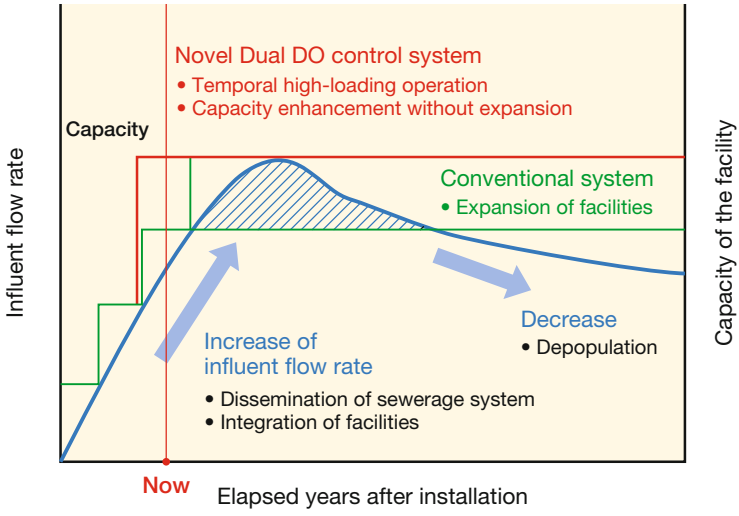

Fig. 11.10 Capacity enhancement through the introduction of dual DO control system

expansion of facilities. Dr. Hashimoto summarized the objectives of installing this system as follows (through multiple responses from each facility): (1) seven WWTPs: avoid expansion of facilities by enhancing the treatment capacity; (2) four WWTPs: increase treatment capacity to integrate other facilities; (3) two WWTPs: increase treatment capacity to receive night soil, etc.; and (4) two WWTPs: reduce installation area and construction cost after process modification to ODs (Hashimoto 2020). In summary, cost reductions due to the enhancement of treatment capacity was the main reason for introducing the system.

Companies generally encounter managerial barriers and performance indicators that must be overcome in the sales and technology diffusion phases, as shown in Fig. 11.9. Maezawa Industries, Inc. and JS are now crossing barriers, and technology diffusion is underway across Japan and globally. The benefits of the dual DO control system mentioned above attract local governments that face social, financial, economic, and customer barriers. Konan Municipal Government welcomes visitors from other local governments and provides them with tours of the Noichi WWTP and Yasu WWTP to explain the system in detail. As mentioned above, the reliability and equity of the employed technology are especially emphasized in Japan as a public service. Therefore, local governments are generally nervous about introducing new technologies into their WWTPs. The frank opinions from Konan Municipal Government could assure them and indirectly support technology diffusion. In addition, Kochi University and Kochi Prefectural Government have annually organized Kochi symposiums on sewerage systems since January 2018, in which various new technologies and initiatives in local governments in Kochi Prefecture have been presented. Many participants from the national government, local governments, and private companies have attended technical tours in the symposium and visited WWTPs employing new technologies, including a dual DO control system in the OD process. Kochi University and Kochi Prefectural Government have indirectly supported technology diffusion by enhancing other local governments' understanding of the system through symposiums.

11.3.3 Stakeholders' Motivations for Joining Three-Way Partnerships

A commemorative round-table talk was held by the *Journal of Sewerage, Monthly* after the reception of the STI for SDGs award. Prof. Taku Fujiwara from Kochi University, Mr. Kenichi Miyata from Konan Municipal Government, Mr. Tsuyoshi Tanaka from Kochi Prefectural Government, Dr. Toshikazu Hashimoto from JS, and Dr. Kazuo Nakamachi from Maezawa Industries, Inc. participated in the round-table discussion; the author served as the moderator. Table 11.2 summarizes the motivations of stakeholders expressed for joining the three-way partnerships (Editorial Department of Journal of Sewerage, Monthly 2020). The member at Kochi University stated that they had been motivated by academic interests, the potential

Table 11.2 Stakeholders' motivations to join the three-way partnerships

	Fundamental research	Applied research	Full-scale demonstration	Technology diffusion
Kochi University	• Academic interests • Publication of research papers • Human resource development	• Academic interests • Publication of research papers • Human resource development • Growth as a researcher	• Academic interests • Publication of research papers • Human resource development • Growth as a researcher • Completion of research and development (R&D)	• Social contribution • Growth as a researcher • Happiness for spread of the developed technology
Maezawa Industries, Inc.		• Growth as an engineer • Publication of research papers	• Growth as an engineer • Publication of research papers • Completion of R&D	• Spread of developed technology to local governments • Spread of developed technology abroad • Deepening of the technology • Contribution to SDGs
Japan Sewage Works Agency (JS)			• JS's history of R&D and standardization and introduction for oxidation ditch (OD) process • Requirement to enhance treatment capacity of OD process • R&D for reconstruction and renewal of existing ODs	• Request for introduction of the developed technology from local governments (integration of WWTPs, temporal increase of influent flow rate, etc.) • Energy saving of OD process • Future standardization
Kochi Prefectural Government		• Desire for inexpensive and high-quality wastewater treatment system • Dissemination of sewerage system in Kochi Prefecture	• Dissemination of sewerage system in Kochi Prefecture • Realization of sustainable sewage works	• Reconstruction and renewal of existing ODs in Kochi Prefecture • Integration of sewerage system and rural sewerage facilities

(continued)

Table 11.2 (continued)

	Fundamental research	Applied research	Full-scale demonstration	Technology diffusion
Konan Municipal Government			• Enhancement of treatment capacity • Cost reduction	• Enhancement of treatment capacity • Reduction of cost and electric consumption • Easy maintenance • Integration of WWTPs • Expansion of sewerage area

publication of research papers, and human resource development throughout the project. As the main tasks of academia are education and research, these members' motivations are natural. Interestingly, their motivations expanded to growing as researchers and feeling happy about the spread of the developed technology during the phases of applied research, full-scale demonstration, and technology diffusion. Discussions in the three-way partnership broadened their minds and visions and increased their motivations. The members from Maezawa Industries, Inc. joined the project from an applied research perspective. Their main motivations were growth as an engineer, completion of R&D, and the spread of developed technology. As members of a private company, their motivations for the completion of R&D, sales, and spread of developed technology are essential, and Dr. Nakamachi was satisfied with the project because of his growth as an engineer. In addition, winning the Excellent Practice Awards for the STI for SDGs Award highly motivated them from the viewpoint of their contributions to the SDGs. The motivations of JS were based on the history and recent situations of the OD process. JS has enabled the research and development, standardization, and introduction to most local governments of the OD process. The deadline of reconstruction and renewal of existing ODs is approaching for many WWTPs, and innovative technologies that can enhance the treatment capacity of OD processes are now required by local governments for various reasons such as integration of WWTPs, temporal increase of influent flow rate, and energy saving, among others. JS is now considering the future standardization of the "dual DO control system in oxidation ditch process" and its further diffusion. Kochi Prefectural Government desired an inexpensive and high-quality wastewater treatment system for the dissemination of its sewerage systems. They strongly supported conducting full-scale demonstrations at Noichi WWTP in Konan City and indirectly supported technology diffusion after the development by organizing the Kochi symposium on the sewerage system. The motivations of Konan Municipal Government were the enhancement of treatment capacity and cost reduction. The developed system is effectively utilized both at Noichi WWTP and Yasu WWTP, and the enhancement of treatment capacity, reduction of cost and electric consumption, and easy maintenance are realized. Future integration of WWTPs and expansion of sewerage areas is expected based on the revision of the master plan for the sewerage system in Konan City in 2012.

11.4 Summary

In this chapter, the author examined the history of the R&D and technology diffusion of the "dual DO control system in oxidation ditch process" and discussed the social integration and acceptance of emerging sanitation infrastructure. Three-way university–industry–government partnerships supported the completion of the project in a satisfactory manner. The following elements made the project successful:

1. Enthusiasm of all stakeholders toward the shared goal of the project.
2. Win-win relationships among stakeholders based on their motivations and respect for each other.
3. Research and development considering future applications and technology diffusion.
4. Participation of local governments in the joint project as important stakeholders.
5. Agreement of the municipal parliament of Konan City based on a careful explanation of the significance, benefits, and limitations of the system.
6. Registration of the "JS Innovation Program," which encourages the adoption of registered technologies in JS's contract projects.

The sustainable management of sanitation systems is essential for protecting the health of individuals and drinking water sources in both developing countries and future depopulated societies in developed countries. The author hopes that the information provided here will be useful for realizing sustainable sanitation systems through the introduction of innovative technologies.

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Chapter 12
Acceptability of Urine-Diversion Dry Toilets and Resource Values of Excreta in Rural Societies

Hidenori Harada

Abstract Global challenges of water scarcity and food insecurity justify sanitation approaches that utilize dry sanitation with the agricultural use of excreta. One such approach is urine-diverting dry toilets (UDDTs) that separate urine and feces at the source at the time of excretion, thereby efficiently sanitizing the feces without liquid by separating the urine. However, in practice, some people have an aversion to the agricultural use of human excreta. Although the resource value of human excreta can potentially drive the spread of sanitation, this can only be achieved when a sanitation system utilizing human excreta for agriculture is accepted and rooted in society. This chapter studies the long-term acceptability of UDDTs that were installed several years ago in Vietnam, Malawi, and Bangladesh, focusing on the fertilizer value of human excreta. The majority of UDDTs were continuously used in all cases. Physical conditions and usability were the primary reasons to use UDDTs. Proportions of the continuous use of urine were low in all cases, and the perceived fertilizer values of urine by UDDT users were significantly lower than those of feces in Malawi. The fertilizer values of feces and urine alone were not always a motivation to use UDDTs although that of feces possibly contributed to the continuous use of UDDTs in Malawi. Religious impurity was a major barrier to use of urine and feces in Bangladesh, although it could be overcome with clean conditions of UDDTs and appropriate socio-cultural context.

Keywords Ecological sanitation · Resources-oriented sanitation · Fertilizer value · Human excreta · Urine-diverting dry toilets · Acceptance

In this chapter, we adopted and re-organized the contents of Harada and Fujii (2020) and re-organized them with additional data in Bangladesh.

H. Harada (✉)
Graduate School of Asian and African Area Studies, Kyoto University, Kyoto, Japan
e-mail: harada.hidenori.8v@kyoto-u.ac.jp

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12.1 Introduction

Ensuring sanitation is essential for human health and dignity. Unfortunately, 2.0 billion people still do not have access to basic sanitation services (WHO and UNICEF 2020). Although the Sustainable Development Goals set a target to ensure sanitation access for all by 2030 (United Nations 2015), no ideal solution is currently available to ensure global sanitation.

Given the critical issues facing the world in the future, sanitation solutions must be compatible with solutions to global challenges such as water scarcity and food insecurity. These conditions justify sanitation approaches that utilize dry sanitation with agricultural use of human excreta. Furthermore, agricultural use of human excreta adds value to sanitation based on the resource value of human excreta. This value can potentially speed up the slow pace of sanitation adoption worldwide. There are many approaches to sanitation that employ agricultural use in a dry manner. One such approach is urine-diverting dry toilets (UDDTs), aiming at the sanitization of human excreta and agricultural use. UDDTs typically used in low- and middle-income countries are waterless toilets that separate urine and feces at the source at the time of excretion, thereby efficiently sanitizing the feces without liquid by separating the urine. Based on the concept of ecological sanitation (Ecosan), UDDTs have been used in many countries (e.g., Harada and Fujii 2020; Jackson 2005; Werner et al. 2009; Winblad and Simpson-Hébert 2004).

On the other hand, in practice, some people have an aversion to agricultural use of human excreta; such an attitude is called fecophobia (Winblad and Simpson-Hébert 2004). Establishment of latrines employing excreta use is, therefore, sometimes difficult because of fecophobic attitudes; for example, some face challenges in the initial acceptance of UDDT installation and ongoing management after installation (Drangert 2004; Jackson 2005; Uddin et al. 2014). Regardless of whether the type of latrine employs human excreta for agriculture or not, there are two essential requirements for latrines: to provide a comfortable defecation space that can be used continuously and to improve human health through their use. Although the type of latrines that take advantage of the resource value of human excreta and use it for agriculture can potentially drive the spread of sanitation, it is essential that the agricultural use of human excreta and latrines employing mechanisms to use excreta are socio-culturally acceptable and established in the field for the long term.

This chapter focuses on UDDTs in rural areas to examine the socio-cultural acceptability of sanitation employing excreta use for agriculture. Based on three cases of UDDT introduced in rural areas of Vietnam, Malawi, and Bangladesh, and used for some years, we examined the factors that influenced the establishment of UDDTs, and the impact of the fertilizer value of feces and urine on the socio-cultural establishment of UDDTs on a long-term basis. Furthermore, we discuss the relationship between long-term establishment of sanitation and the fertilizer value of human excreta.

12.2 Methodology

12.2.1 Case A: UDDT Introduction in Rural Vietnam

Vietnam is a country in South East Asia, surrounded by China, Laos, Thailand, Cambodia, and the East China Sea. The project site was in a hamlet of the Dan Phuong Commune, located in Lam Dong Province in the central highlands of Vietnam (Fig. 12.1). The total population of the project site was 491. At the time of project implementation, most households did not own any toilets in the project site, although some households had unsanitary simple pit latrines without slabs, meaning unimproved sanitation. Most households earned their livelihoods from agriculture. Although some areas of Vietnam have traditions of using human excreta for agriculture, people in the target areas had no such tradition.

In this project, 85 UDDTs with double fecal chambers were installed in each household by an international NGO (Nippon International Cooperation for Community Development) in 2012–2013. Figures 12.2 and 12.3 show the appearance and interior view of the UDDT. The design of the toilet is a partial modification of the UDDTs previously designed in Vietnam (Nha Trang Pasteur Institute VinaSanres Project 2002). This UDDT has a squatting pan with two covered holes at each end, leading to two separated fecal chambers under the slab, and a urinal in the center of the pan for draining and collecting urine. The urine is stored in a urine container behind the toilet building and can be used as a liquid fertilizer for agriculture after dilution. Ashes fall into the fecal chamber, where they are held for at least 10 months.

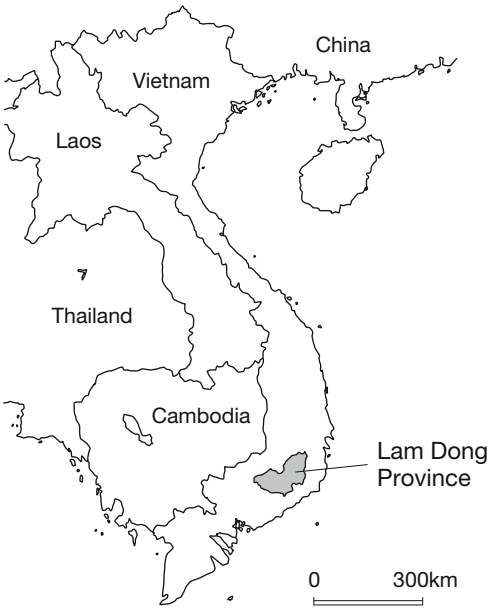

Fig. 12.1 Area of the UDDT project in Vietnam

Fig. 12.2 A UDDT in the case of Vietnam: (left) outside views of a UDDT; (right) inner view of a UDDT. (Adapted from Harada and Fujii 2020)

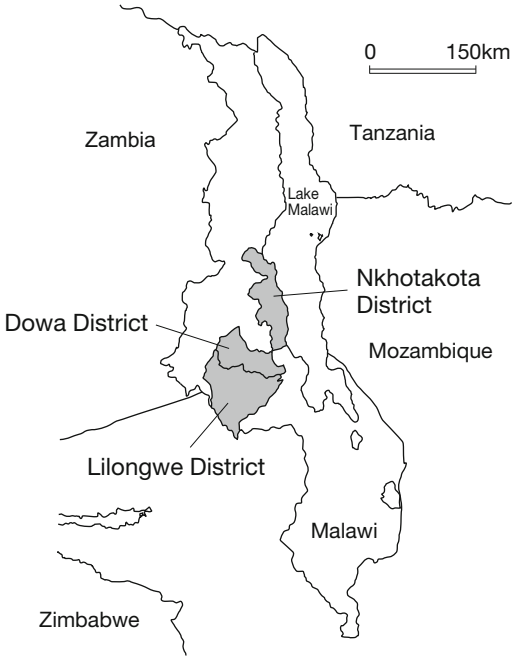

Fig. 12.3 Area of the UDDT project in Malawi. (Adapted from Harada and Fujii 2020)

The fecal matter mixed with ash is then removed through a small door behind the toilet building and can be used for agriculture.

The UDDTs were built by local contractors trained and supervised by the NGO after orientation and lectures on the significance of UDDTs. The beneficiaries contributed to the construction in part by providing labor. Once in use, a local female health worker, who was one of the beneficiaries, visited each household every 2–3 weeks for 4 months. See Harada et al. (2004) and Harada and Fujii (2020) for more information on the project.

After the UDDTs were installed, door-to-door monitoring on the use of UDDTs was repeated for 4 months by using a checklist composed of 17 items (Harada et al. 2004). No monitoring or intervention activities were conducted for political reasons from 7 to 38 months after the installation. Approximately 3 years later, specifically, 39 months after installation, a postintervention monitoring survey, consisting of structured interviews and observations of construction conditions, toilet management, and usage, was conducted (Harada et al. 2009).

12.2.2 Case B: UDDT Introduction in Rural Malawi

Malawi is located in southeastern Africa and is separated from Tanzania and Mozambique by Lake Malawi (Fig. 12.3). As of 2017, 65.9% of Malawi's rural population did not have at least basic sanitation services (WHO and UNICEF 2020). The abovementioned NGO that introduced UDDTs in Vietnam implemented a comprehensive rural development project in three districts in Malawi (Nkhotakota, Dowa, and Lilongwe, Fig. 12.3) between 2007 and 2014. A total of 1052 UDDTs with double fecal chambers, including public units, were introduced as part of the project, with a slightly modified design of the UDDTs introduced in Vietnam (Fig. 12.4). The total number of beneficiaries reported by the NGO was 26,100, most of which did not have access to basic sanitation facilities before the project and

Fig. 12.4 A UDDT in Malawi: (left) outside views of a UDDT; (right) inner view of a UDDT. (The left figure was adapted from Harada and Fujii 2020)

had no experience with the use of human excreta for agriculture. UDDTs were built by local contractors trained and supervised by the NGO, and beneficiaries contributed to the construction in part by collecting bricks and providing labor. Workshops were held on the usage of UDDTs, their cleaning, and use of the collected feces and urine for agriculture.

In 2017, a postintervention monitoring survey consisting of structured interviews and observations of construction status, toilet management, and usage was conducted on 277 UDDTs over 5 years after their introduction. In conjunction, an investigation was conducted on demographic status, perceptions of the effect of UDDT use on diarrhea reduction, and perceptions of the effect of feces and urine use on yield increase, as briefly summarized in Harada et al. (2018) and Harada and Fujii (2020).

12.2.3 Case C: UDDT Introduction in Rural Bangladesh

The project site was a rural area, located at Keshabpur Upazila and Sharsha Upazila in Jessore district, Khulna division, Bangladesh (Upazila is an administrative unit under a district) (Fig. 12.5). Of the populations in Keshabpur and Sharsha, 98% and 96% used well water at the time of the survey, respectively. Sanitary latrines with water sealing, sanitary latrines without water sealing, nonsanitary latrines, and others were, respectively, used by 29%, 29%, 37%, and 5% in Keshabpur, and 27%, 33%, 33%, and 7% in Sharsha.

Since 2004, the introduction of UDDTs with double fecal chambers and an anal cleaning space has been attempted in Bangladesh (Fig. 12.6). A postintervention monitoring study of 300 UDDTs introduced in Keshabpur and Sharsha between 2007 and 2016 by an international NGO (Japan Association of Drainage and Environment) different from that in cases A and B was conducted in 2018. In this study, structured interviews and observations were used to investigate, similarly to case B. In addition, structured interviews were conducted on the main reasons for continued use and cessation of UDDTs, and of feces and urine for agriculture.

12.3 Results and Discussion

12.3.1 The Case of Rural Vietnam

12.3.1.1 Use of UDDTs

At 39 months after the introduction of UDDTs, 65.8% of the UDDTs were in use. More than 80% of UDDTs without serious physical damage were used. Considering the 3-year nonintervention period, these percentages were evaluated as high, and the use of UDDTs can be assessed as having a certain degree of long-term acceptance.

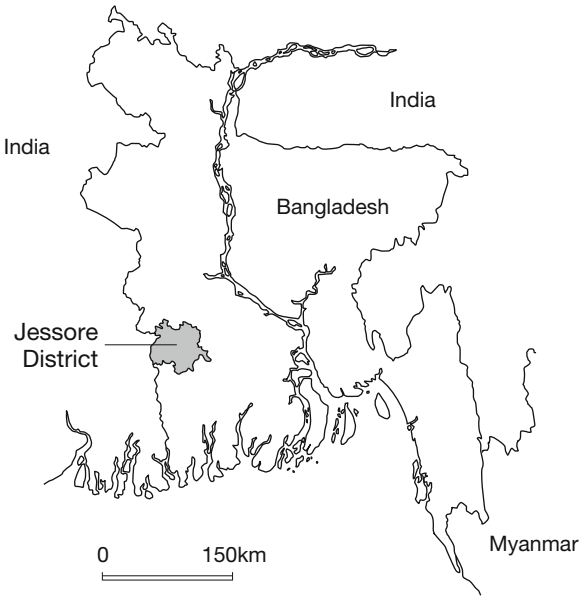

Fig. 12.5 Area of the UDDT project in Bangladesh

Fig. 12.6 A UDDT with double fecal chambers and anal cleaning space in Bangladesh. The fecal hole cover can be observed in the upper middle, and the urinal is in its lower-right part. The anal cleaning space is located at the leftmost middle in this picture

The main reason for lack of use was physical damage caused by strong winds at the highland. For continued use, robust construction and active self-repair by the users remain major challenges to achieving sustainable use of UDDTs.

The long-term acceptability of UDDTs may be related to the condition of the fecal chamber. Table 12.1 summarizes the use of UDDTs by fecal chamber conditions after their introduction. The percentages of UDDTs with a foul odor, maggots, and more than ten flies in the fecal chamber were 14.0%, 12.0%, and 0.0%, respectively. Prior to the installation, users were particularly concerned about the fecal odor of UDDTs, but minimal odor or no fly problems were observed in most of

Table 12.1 Proportion of UDDTs with improperly operated fecal chambers

Check item	Months 0–4 % of UDDTs in use	Month 39 % of UDDTs in use
Offensive fecal smell inside toilet rooms	1.3	14.0
Maggots inside fecal chambers	0.0	12.0
Many flies (>10) inside fecal chambers	0.0	0.0

Adapted from Harada and Fujii (2020)

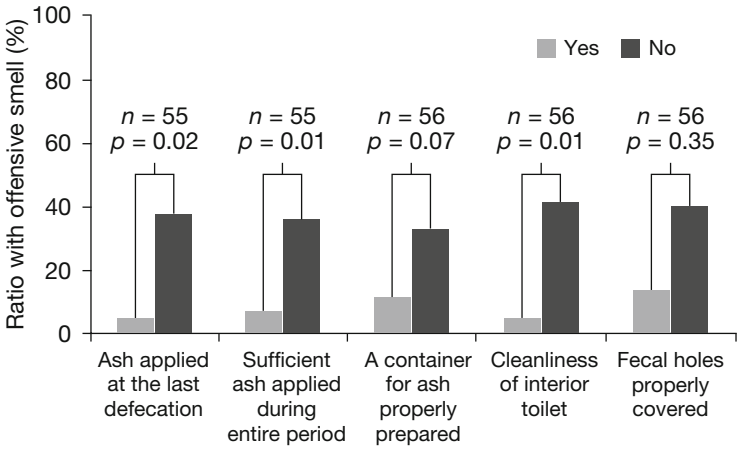

Fig. 12.7 Proportion of UDDTs with offensive fecal smell by conditions. Significant differences were tested by the Mann–Whitney *U*-test. (Adapted from Harada and Fujii 2020)

the UDDTs. Furthermore, as shown in Fig. 12.7, there was a significant difference in the ratio of UDDTs with foul odor depending on the inside condition of the fecal chambers, and the ratio was significantly lower in fecal chambers in good condition. The absence of foul odor and fly problems could be prerequisites for long-term acceptance of latrines, including UDDTs, and most of the UDDTs introduced in this case were in good condition and met these prerequisites even after a 3-year period with no intervention.

One of the reasons why the proper operation of UDDTs was sustained in the long term would be continuous guidance on UDDT management through household visits by a local health worker who herself used a UDDT. As reported by Harada et al. (2004), a typical error in the use of UDDTs in the early stages of their introduction was lack of dispersion of ashes in the fecal chamber; ash is essential in keeping the inside of the chamber in good condition. The conditions of most UDDTs were improved through regular visits by the health worker for the first 5 months. The household visit by the health worker was continued on an irregular basis from month 6 when the project team withdrawal occurred to month 39 when this survey was conducted. Regular visits at the early stage and irregular visits

afterward would have contributed to the relatively good condition of the fecal chamber at month 39.

12.3.1.2 Use of Fecal Matter and Urine

At 39 months after the introduction of UDDTs, 27.1% and 17.3% of the UDDTs were using fecal matter and urine, respectively, for agriculture. As mentioned above, 65.8% of households continued to use the UDDTs in the long term, while many households did not use feces (27.1% in use) or urine (17.3% in use). In the project, acceptability of agricultural use of feces and urine seems to be low, and a major part of the agricultural resource value of human excreta was not effectively utilized. Although some ethnic groups, including the majority of Vietnam, the Kinh, have a history of agricultural use of human excreta, the K'ho, who are the main ethnic group in the study area, had no tradition of using human excreta for agriculture before the UDDT project. This cultural background of the beneficiaries might have affected the acceptance of human excreta use. Although use of UDDTs themselves was accepted to some degree on a long-term basis, the use of human feces and urine as resources is a major unresolved issue in this case.

12.3.2 The Case of Rural Malawi

12.3.2.1 Use of UDDTs

The period after the introduction of UDDTs in rural Malawi varied between 5 and 9 years when the survey was implemented. Of the UDDTs introduced, 79.7% were in use at the timing of the survey. Physical damage to the toilets due to heavy rains and strong winds was identified as the main reason for discontinuing their use, similar to the case of Vietnam. This ratio of UDDTs in continuous use was higher than the 65.8% usage ratio of UDDTs in Vietnam ($p = 0.014$). Furthermore, considering that the case of Vietnam was based on the results of UDDTs 39 months after their introduction and that the results in Malawi were based on the results more than 5 years after their introduction, the long-term acceptability of the use of UDDTs in Malawi was estimated to be higher than that in Vietnam. The factors contributing to this long-term use are discussed in the following sections.

12.3.2.2 Use of Fecal Matter and Urine

At 5–9 years after the introduction of UDDTs, the utilization ratios of fecal matter and urine were 78.0% and 28.5%, respectively, in the case of Malawi. In particular, the ratio of fecal matter was significantly higher than that in Vietnam (27.1%, $p < 0.001$). Only for the UDDTs in use the utilization ratio of fecal matter reached

up to 97.7%. Despite the lack of customary use of human excreta for agriculture in Malawi, those who continued to use UDDTs used their fecal matter almost entirely for agricultural purposes. On the other hand, the utilization ratio of urine was much lower than that of feces ($p < 0.001$); and only for UDDTs in use the ratio of urine use was 35.7%; urine was not used in many households. Underlying this difference in the ratios between fecal matter and urine was that feces was perceived to have a stronger fertilizer effect than urine. When asked about their perceptions of the fertilizer effect of fecal matter and urine at the time of the survey, 98% of UDDT users perceived an increase in yield due to the use of fecal matter in agriculture, whereas only 44% perceived an increase in yield due to urine use ($p < 0.001$, unpublished data). In this region, there was no custom of using human excreta for agriculture, but UDDT users were highly aware of the value of fecal matter for agriculture. This higher perception of the material value of fecal matter possibly contributed to the long-term acceptance of not only the agricultural use of fecal matter but also the use of UDDTs themselves.

Although the agricultural use of feces is effective, a large proportion of nitrogen, phosphorus, and potassium, which are the three major elements of fertilizer, are contained in urine rather than feces; human urine is reported to have a good fertilizing effect when used properly (Jönsson et al. 2004). Accordingly, use of urine is desirable, and from the viewpoint of the material cycle of nutrients, it is rather preferable than the use of fecal matter. In fact, the utilization ratio of urine was as low as 28.5%, although the agricultural value of urine was explained to the local people during the UDDT introduction, according to an interview with a representative of the NGO implementing the project. One of the reasons for this low acceptability of use of urine is that urine was perceived to have a much lower fertilizer effect than fecal matter, as mentioned above. Yet another possible reason is that there is a tradition of agricultural use of animal manure, which is in the form of solids. Similar to animal manure to some degree, fecal matter treated in the fecal chambers of UDDTs was in the form of solids containing ash. It has a suppressed odor and is dry and less unpleasant. These conditions of fecal matter itself and the familiarity of solid animal manure may give users a positive attitude to using fecal matter. In contrast, urine does not change significantly in morphology from the time of excretion through UDDT use. Users may consider using urine in its liquid and foul-smelling state to be a significant psychological barrier, and it may be one of the reasons for its low utilization ratio.

In addition to these perceptions of feces and urine, another possible reason for the marked difference in fecal matter use between Malawi and Vietnam is the way the project to introduce UDDTs was structured in these two cases. In Vietnam, the UDDT introduction project was implemented on its own, whereas the Malawi UDDT introduction project was implemented as a component of an integrated community development program with seven other components (Table 12.2). In this integrated configuration, the installation of UDDTs was not conducted as a stand-alone practice but was directly linked to agricultural technology transfer efforts to promote effective use of human excreta in agriculture. For example, a demonstration farm was used to instruct UDDT users in the use of fecal matter and

Table 12.2 Eight components of the integrated community development program in Malawi

Eight components	Activities
Ecological sanitation	UDDT introduction
Reforestation	Moringa and Jatropha planted; 5520 fruit trees planted; useful trees introduced; improved oven stoves introduced
Agricultural technology transfer	Organic farming; permaculture; distribution of local seeds; use of feces and urine
Human resource development	Fostering of local leaders; development of project, agriculture, women's, and health committees; workshop for local people
Infectious disease control	Malaria control; HIV prevention; infectious disease control
Water supply	Construction of wells; workshop for village level operation and maintenance
Maternal and child health	Education activities for maternal and child health; introduction of bicycle ambulance
Income creation	Product development using local agricultural product

Note: Information from Nippon International Cooperation for Community Development (2015)

urine in agriculture for them to recognize the benefits of their use. Although the effectiveness of these efforts was limited with respect to urine, these efforts may have increased awareness of the agricultural value of fecal matter, potentially associated with the experiences of the use of animal manure, contributing to its higher utilization ratio. Other agricultural, health, and human resource components of the integrated community development program may have also been indirectly linked to UDDTs. Thus, integration of UDDTs with other related components may have contributed to the increased acceptability of agricultural use of fecal matter, as well as the acceptability of UDDT use itself.

12.3.3 The Case of Rural Bangladesh

12.3.3.1 The Use of UDDTs

The period after the introduction of UDDTs in rural Bangladesh varied by households between 2 and 11 years. Of the UDDTs introduced, 45.3% were in use at the timing of the survey. This utilization ratio was significantly lower than the 79.7% utilization ratio in Malawi ($p < 0.001$). Based on the results of the structured interview survey of households with UDDTs in use, the three most frequent answers to the primary reasons for continuously using UDDTs were, in order of percentage, robustness against flooding and rain compared to pit latrines (21.3%), ease of use compared to pit latrines (19.1%), and longer physical life than pit latrines (15.4%). These reasons were related to the physical characteristics of their construction as toilets. It is notable that neighbors' use of UDDTs (13.2%) and health improvement effect of UDDTs (13.2%) were other major reasons for using them, implying that health aspects and social relations in the community also contributed to their use. On

the other hand, only 5.1% of households indicated the fertilizer effect of human excreta as the primary reason for using UDDTs. The agricultural value of human excreta was not the main reason for most households to use UDDTs, although 88.7% of the surveyed households had farmland.

Based on the structured interview survey of the households with UDDTs not in use, the three most frequent answers to the primary reasons to stop using UDDTs were, in order of percentage, discomfort compared to pit latrines (32.3%), no use of fecal matter and urine for agriculture (25.8%), and difficulty in using UDDTs compared to pit latrines (21.9%). Discomfort and difficulty in use, summarized as usability, accounted for more than 50% of the primary reasons for stopping using UDDTs. In contrast, easiness (19.1%), comfort (12.5%), and positive usability were the primary reasons for the continuous use of UDDTs. This discrepancy implies that there was significant variability in usability even when the same technology was introduced.

12.3.3.2 Use of Fecal Matter and Urine

At 2–11 years after the introduction of UDDTs, agricultural use of fecal matter and urine was 37.0% and 7.3%, respectively, in Bangladesh. Similar to the case of Vietnam, the utilization ratio of fecal matter was significantly lower than that of Malawi (78.0%, $p < 0.001$), and the utilization ratio of urine was significantly lower than that of feces ($p < 0.001$). For UDDTs in use only, the utilization ratio of feces was 81.6%; most UDDT users used fecal matter. Of the three cases, the utilization ratio of urine was the lowest, at 16.2%.

Based on the structured interview survey of UDDT users, the two most frequent answers to the primary reasons for using fecal matter were increased yield (65.9%) and improvement in quality of harvest (24.7%). On the other hand, the primary reasons for stopping using fecal matter were religious impurity (33.3%) and lack of collected amount of ash (29.4%). All the respondents in the case of Bangladesh were Muslim, and the religious characteristics of the survey area potentially affected the acceptability of using fecal matter.

It should be noted that the lack of ash was the main reason for stopping using UDDTs. Although the use of UDDTs itself is possible without spreading ashes in sufficient quantities, as shown in the case of Vietnam, the proper spreading of ash in the fecal chamber after defecation keeps it in good condition and prevents foul odor and flies, increasing usability (Winblad and Simpson-Hébert 2004). The main reason for stopping using the UDDTs mentioned above was poor usability. Our results imply that inability to obtain sufficient ashes worsened the condition of the fecal chamber, possibly resulting in unpleasant fecal matter under inappropriate treatment and hindering its agricultural use, as well as the use of UDDTs themselves in this case.

As for urine, the two most frequent answers to the primary reasons to use urine were increase in yield (81.8%) and improvement in quality of harvest (13.6%), while the three most frequent answers to the primary reason for not using urine were

religious impurity (44%), bothersomeness in collecting, transporting, and using urine (28.1%), and foul odor (10.1%). Similar to fecal matter, religious characteristics had a major impact on use of urine. On the other hand, labor and odor at the time of urine use were also reasons for not using it to some extent.

In the Bangladeshi case, religious impurity was the main reason for stopping the use of both feces and urine. Difficulties in using human excreta in the Muslim community have been reported (Nawab et al. 2006). Interestingly, the degree of religious impurity was associated with conditions of UDDTs as well as social relations in the community in the case of Bangladesh. Focusing on the use of urine, which had a particularly low utilization ratio, the degree of religious impurity was found to be significantly and positively correlated with the occurrence of insects (mainly cockroaches) in the fecal chamber ($R = 0.17$, $p = 0.004$), while the degree was found to be significantly and negatively correlated with the frequency of participation in community-based organization (CBO) activities ($R = -0.25$, $p < 0.001$), frequency of monitoring UDDTs ($R = -0.25$, $p < 0.001$), and frequency of cleaning UDDTs ($R = -0.15$, $p = 0.015$). Although the correlations were weak, they imply that improving the condition of the fecal chamber and strengthening social relations could have some effect in overcoming religious impurity issues, which are the biggest challenge in the case of Bangladesh.

12.3.4 Comparison of Three Cases

12.3.4.1 Overall Use of UDDTs, Fecal Matter, and Urine in the Three Cases

The use of UDDTs, fecal matter, and urine in the three projects is summarized in Table 12.3. The proportion of households using UDDTs at the time of the survey

Table 12.3 Summary of the conditions of UDDTs and the use of fecal matter and urine in the three cases

Project site	No. of UDDTs introduced in the target project (N)	No. of toilets surveyed (n)	Time after installation (years)	UDDTs in use (%)	Fecal matter in use (%)	Urine in use (%)
Vietnam	85	76	3.5	65.8	27.1	17.3
Malawi	1052	277	5–9	79.7	78.0	28.5
Bangladesh	679	300	2–11	45.3	37.0	7.3

Note: The use of urine and feces was confirmed in only a part of the surveyed population in Vietnam. The proportion of UDDTs using fecal matter was estimated as follows. Out of 17 UDDTs in use, 7 were using feces (41.2%). Assuming that the same proportion of UDDTs were using feces, 20.6 UDDTs were using feces out of the total UDDTs in use (50). This number (20.6 UDDTs) corresponds to 27.1% of the total UDDTs surveyed (76). The proportion of UDDTs using urine was also estimated in the same manner as the survey results that 9 out of 26 UDDTs (34.6%) were using urine

ranged from 45.3 to 79.7%, while the use of fecal matter and urine ranged from 27.1 to 78.0% and 7.3% to 28.5%, respectively. Fecal matter was widely used in the case of Malawi by 78.0% of surveyed UDDTs, corresponding to 97.7% of the UDDTs in use. Compared with fecal matter, urine was used in limited proportions in all three cases. In the case of Bangladesh, it was used by only 7.3% of the surveyed UDDTs, corresponding to 16.2% of UDDTs in use.

12.3.4.2 Acceptability of UDDTs

The resource value of feces and urine from UDDTs has been confirmed (Andersson et al. 2011; Hu et al. 2016; Winker et al. 2009). Across the three cases in Vietnam, Malawi, and Bangladesh in the present study, the proportion of UDDTs continuously used was 65.8%, 79.7%, and 45.3%, respectively, which varied from case to case. Commonly, the main reason for discontinuation of the UDDTs was severe physical damage to their structure. As the quality of building material was reported as one of the main concerns regarding their use (Mkhize et al. 2017), it can be suggested that one of the main issues for the long-term acceptability of UDDTs is sustainability of the buildings. On the other hand, in Bangladesh, the physical characteristics and usability of UDDTs, such as their robustness to floods and storms, ease of use, and usable life, were the main reasons for their continued use. Primarily, the sustainability and usability of the buildings are the most important reasons for their long-term acceptability. It would be essential to construct robust buildings with high usability as well as to have a mechanism to repair broken buildings by local users.

In Vietnam, where the condition of the fecal chambers was investigated after long-term use, most of the fecal chambers of continuously used UDDTs showed a less unpleasant odor and fewer maggots and flies. In addition, poor fecal chamber management conditions were shown to have a significant impact on odor and fly outbreaks. Interestingly, in Bangladesh, the usability of UDDTs was not only the main reason for continued use, but also the main reason for cessation of use. The case of Vietnam implies that poor fecal chamber management conditions may have contributed to poor usability in Bangladesh. As suggested by the main reason for the cessation of use of UDDTs in Bangladesh, the comfort of the UDDTs as a place of defecation would be a prerequisite for long-term acceptability. In Vietnam, regular household visits by a local health worker during the first 4 months after the introduction of UDDTs and irregular household visits thereafter likely contributed to good fecal chamber management for the establishment of the comfort of the UDDTs. The need for community involvement in the maintenance of UDDTs was also pointed out by Mkhize et al. (2017). A certain level of continuous intervention may play an important role in the comfort of UDDTs and their long-term acceptability, especially as the way that UDDTs are used differs from the widely used pit latrines and flush toilets, requiring behavior change by users.

12.3.4.3 Acceptability of Fecal Matter Use

Utilization of fecal matter differed greatly in the three cases, and urine use was rarely realized in any of them. Among the continuous users of UDDTs in Vietnam, the utilization ratios of feces and urine were 41.2% and 34.6%, respectively. Although UDDTs were introduced with the objectives of promoting resource recovery from human excreta along with improving sanitary conditions, both feces and urine were not fully utilized, meaning that the objectives could not be fully achieved. The continued use of UDDTs despite the lack of widespread use of human excreta suggests that the resource value of human excreta was not the main motivation for the continued use of UDDTs. In fact, in Bangladesh, where the main reason for continuing to use UDDTs was investigated, the physical characteristics of the UDDTs' structure and usability were the main reasons for their continuing use, whereas agricultural use of human excreta was not the main reason for most of the UDDT users. Moreover, some households (25.8%) stopped using UDDTs because of the lack of fecal matter and urine use for agriculture.

On the other hand, in Malawi, most of the continuously used UDDTs also used fecal matter for agricultural purposes, and utilization of fecal matter was widely accepted and practiced by most UDDT users. This demonstrates that agricultural use of feces can be accepted and established at a high level in the long term. It has been pointed out that awareness of the fertilizer value of human excreta does not always result in actual use (e.g., Ignacio et al. 2018; Sharda et al. 2020; Mariwah and Drangert 2011). In Malawi, most of the continuous users of UDDTs perceived the fertilizer value of feces to be high and, in fact, used it. One of the enabling conditions for this successful acceptance of feces use is that UDDTs in Malawi were introduced as part of an integrated community development effort, especially in conjunction with organic farming promotion. Although it is not clear whether use of UDDTs was motivated as a result of the perceived value of fecal matter, organic farming promotion may have contributed to its perceived high value, resulting in its continued use. Furthermore, even in Bangladesh, where use of feces was not found to be a major reason for continued use of UDDTs, fecal matter was still used by the majority of UDDT users (81.6%). These findings suggest that even if the fertilizer value of fecal matter is not the main motivation for using UDDTs, use of fecal matter itself can still be acceptable if one uses UDDTs properly.

12.3.4.4 Acceptability of Urine Use

Even in Malawi, where fecal matter use was highly accepted in the long term, the majority of UDDT users did not use urine and did not perceive its fertilizer value. Lack of widespread use of urine was also reported by Okem et al. (2013). In fact, urine contains many nutrients in terms of nitrogen, phosphorus, and potassium compared to feces (Jönsson et al. 2004). However, in each of the three cases in the present study, urine use was limited. As mentioned in the case of Malawi, higher acceptance of fecal matter than urine is possibly associated with the tradition of

animal manure use. Because animal manure is nearly solid, the experience of using animal manure may have positively influenced the perceived fertilizer value of solid feces, but not of liquid urine. In Bangladesh, where the main reasons for not using urine were discussed in interviews, the following main reasons were found: religious impurity, cumbersome collection, transportation, and use of urine, and its smell. Except for religious impurity, usability of urine was the reason for not using it. Challenges remain in increasing the usability of urine so that it can be used in a manner involving easy collection, transportation, and use without foul odor. Various technologies, targeting to increase the usability of urine, might solve these challenges if such technologies were made affordable in rural areas of low- and middle-income countries.

Religious impurity was also found to be a major obstacle to urine use, as observed in Bangladesh. Nawab et al. (2006) reported the difficulty of introducing human excreta into Muslim communities. Despite this, in the present case of Bangladesh, 37% and 7.3% of households adopting UDDTs used feces and urine, respectively, although religious impurity was the main reason for not using human excreta. It has been reported that religion alone does not create a significant barrier to the use of urine and feces (WSP 2010). Uddin et al. (2014) also found that the agricultural use of human excreta was acceptable to some extent to Muslims; gossip in the community, neighborhood opinions, and involvement in CBO activities could influence its acceptability. In the present case of Bangladesh, although the correlations were weak, UDDTs with higher levels of cockroaches and other insects occurrences were associated with a stronger sense of religious impurity, while UDDTs with higher frequency of cleaning and participation in CBO activities were associated with a weaker sense of religious impurity. This suggests a certain degree of effectiveness in overcoming religious impurity with better management conditions of UDDTs, which results in improved usability, along with enabling appropriate social involvement.

12.4 Conclusions

This chapter focuses on UDDTs in rural areas to examine the socio-cultural acceptability of sanitation employing excreta use for agriculture. Based on three cases of UDDTs introduced in rural areas of Vietnam, Malawi, and Bangladesh, and used for some years, we examined the factors that influenced the establishment of UDDTs, and the impact of the fertilizer value of feces and urine on the socio-cultural establishment of UDDTs on a long-term basis. Furthermore, we discussed the relationship between the long-term establishment of sanitation and the fertilizer value of human excreta.

To examine the socio-cultural acceptability of sanitation employing excreta use for agriculture on a long-term basis, this study focused on the fertilizer value of human excreta, and UDDTs were taken up as such sanitation systems. The findings suggested that although the use of UDDTs was well accepted in all cases, even after a long period of time after their introduction, the value of the use of feces and urine

was not always a motivation to use UDDTs, and the driving force of the fertilizer value of human excreta for the social diffusion of sanitation was not clearly observed. Physical conditions and usability, such as architectural sustainability and comfort, were of foremost importance for their acceptability, which would be a common prerequisite for toilets, regardless of resource recovery. On the other hand, the use of feces itself was shown to be widely acceptable under the continued use of UDDTs if they were introduced in an appropriate socio-cultural context, potentially contributing to the continuous use of UDDTs. The use of urine was more challenging than that of fecal matter. While the fertilizer value of fecal matter was perceived to be high, that of urine was not. The low usability of urine, for example, because of its odor and laborious use, was the main reason for its lack of widespread use. Religious impurity was observed as one of the barriers to agricultural use of urine and feces in some socio-cultural backgrounds, but our findings also suggested that the barrier of religious impurity was not unchangeable but might be overcome with appropriate physical and socio-cultural conditions. The proper establishment of physical and socio-cultural conditions in local contexts would be essential to realize resource-oriented sanitation, which can potentially drive the social diffusion of sanitation in rural areas.

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Chapter 13
Social Relationships and Material Flow in the Co-Creation of Sanitation Systems

Ken Ushijima, Neni Sintawardani, and Mayu Ikemi

Abstract This chapter describes the challenges of co-creating sanitation system design based on material flow and social network with value flow in urban slums in Indonesia. The challenges are described in three phases: first, to understand and describe the current material flow of sanitation and environment; second, to extend our understanding of the wider meaning of material flow and value flow network; and, third, to evolve the solution through a co-creation process with local players. Through the first phase, we could understand the overall problem of sanitation in the research field by applying material flow analysis; the strength was the ability to catch all the related processes based on a logical mass balance point of view. However, its weakness was too strict rule and it is difficult to describe each player's motivation; in other words, "driving force" of the system. Therefore, in the second phase, we applied social relationship analysis and could draw reasonable picture of sanitation value flow network. Based on that picture, we had started co-creation approach in order to create new sanitation system with local players, and it is still ongoing. We found that the combination of material flow and social relationship provides reasonable and effective picture of wholistic sanitation system; also, that it is important to validate and update the picture through co-creation process among a team consisting of not only various researchers but also local players.

Keywords Co-creation · Material flow · Value flow · Indonesia · Urban slum

K. Ushijima (✉)
Hokkaido Research Organization, Asahikawa, Hokkaido, Japan
e-mail: ushijima-ken@hro.or.jp

N. Sintawardani
National Research and Innovation Agency, Bandung, Indonesia

M. Ikemi
Sapporo International University, Sapporo, Hokkaido, Japan

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13.1 Introduction

When examining materials or substances, material flow analysis becomes a helpful way to understand and explain the sanitation system (Aramaki and Thuy 2010; Harada et al. 2010). However, the sanitation system cannot be explained only by material flow. One of the most important elements to be added to the discussion is the driving force behind the system. In primitive sanitation, the driving force for sanitation material flow is mainly nature. For example, in open defecation in rivers, excreta flows downstream and is degraded by fish, benthos, bacteria, and so on. However, the modern sanitation system was designed based on simplified material flow and the driving force is usually set in a public service system (Ushijima et al. 2015). Therefore, modern sanitation systems work in public service schemes. Generally, it does not work well outside of public service, such as in slums or in low- and middle-income countries where public service is immature. To achieve the Sustainable Development Goals (SDGs), stating "no one left behind," a new approach for sanitation system design is necessary.

This chapter describes the challenges faced in co-creating sanitation system design based on material flow and social network with value flow in an urban slum in Indonesia. Co-creating new sanitation system is not easy to complete because material flow, social network, and our concerning would be very dynamic. So our challenges are also continuing in this moment. Until now, our challenges can be described in three phases: first, understanding and describing the current material flow of sanitation and the environment; second, extending our understanding to the wider meaning of material flow and value flow network from a solution-oriented viewpoint; third, to evolve the solution through a co-creation process with local players.

13.2 Background

13.2.1 Related Project

The trials described in this chapter were conducted from 2004 to 2019 in several projects: Core Research for Evolutional Science and Technology (CREST) headed by Prof. Funamizu and supported by the Japan Science and Technology Agency (JST; 2004–2007); KAKEN type S headed by Prof. Funamizu and supported by the Japan Society for the Promotion of Science (JSPS; 2009–2013), the Toyota Foundation project (2015–2016) headed by Dr. Ushijima, the first author of this chapter; and the full research project in the Research Institute for Humanity and Nature (RIHN; 2016–2022) headed by Prof. Funamizu (2016–2017) and Prof. Yamauchi (2018–2022). The first project, CREST, was a science and technology project; therefore, project members were mainly engineering and agro-science researchers. In the second project, JSPS-KAKEN Type S, there were two fields—Burkina Faso

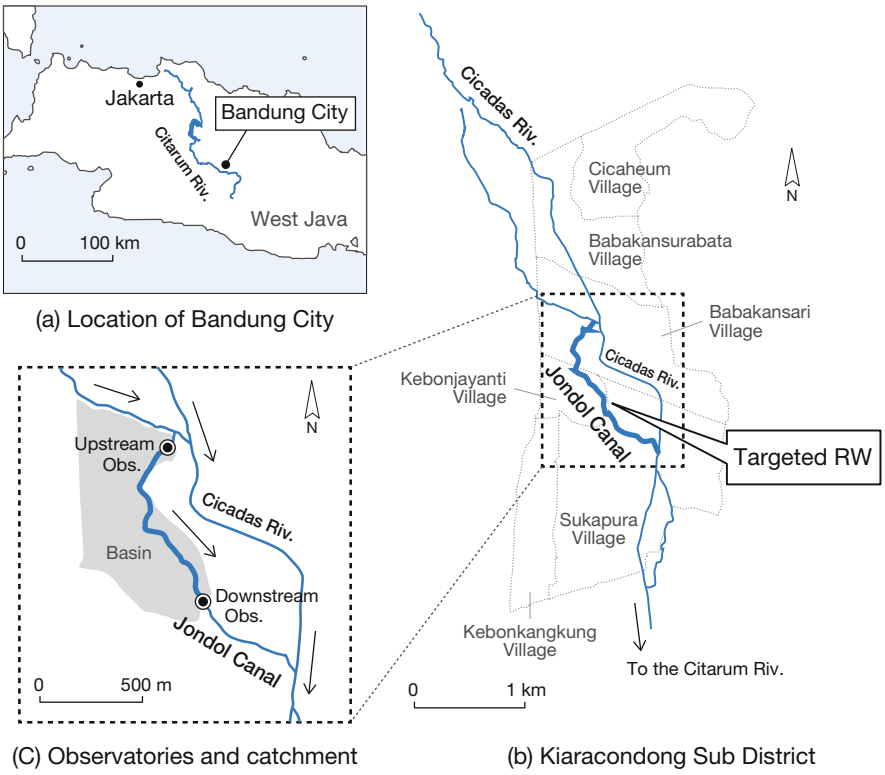

Fig. 13.1 Location of studied area (Ushijima et al. 2008a)

and Indonesia—and various specialists, not only of engineering and agriculture but also social science. In the RIHN project, there were a variety of specialties including human ecologists, health scientists, anthropologists, economists, and engineers.

13.2.2 Overview of Research Field

Our various field activities since 2004 have been implemented mostly in one specific Rukung Warga (hereafter, "targeted RW")[1] in Kiaracondong subdistrict of Bandung City, Indonesia. Bandung City is located in the inland part of west Java Island and upstream of the Citarum River, a major water source for the capital, Jakarta flows through (Fig. 13.1a, b). Bandung City and surrounding cities form the Bandung metropolitan, the second largest metropolitan in Indonesia. The population of Bandung City is 2.48 million (Badan Pusat Statistik [BPS] Kota Bandung 2020:

[1] Rukung Warga (RW) is the smallest administrative unit in Indonesia.

Fig. 13.2 Crowded housing in the targeted RW. (Photo by Ushijima)

51) and that of Kiaracondong subdistrict with the area of 6.1 km^2 is 130,080 (BPS Kota Bandung 2020: 9, 51). Kiaracondong is known as one of the biggest urban slums in Bandung City, and the major problems in this area are crowded housing (Fig. 13.2), a high population density, and poor water and sanitation infrastructure; however, the area of informal settlements is limited and most residences are owned or rented legally.

Our field activities introduced in this chapter were implemented from 2004 to 2019. During these 15 years, the population in Kiaracondong increased by 3.6%, while the population of Bandung City and Indonesia increased by 5.5% and 23.9%, respectively (BPS Kota Bandung 2005: 116–119, 2020: 51). According to local statistics,[2] the population of targeted RW was 1477 with 410 households in 2004 and 1291 with 385 households in 2016.

[2]This is not officially published statistics but displayed on the wall of RW office.

13.3 First Phase: Identifying Sanitation Issue by Simplified and Partial Material Flow

In the first phase corresponding to the CREST project (2004–2007), we focused mainly on water pollution caused by inappropriate sanitation system. Therefore, a field survey was conducted in and around the Jondol Canal, which flows just beside the targeted RW (Fig. 13.1b). The canal flows into the Cicadas River, a tributary of the Citarum River, which is one of the water sources of capital Jakarta. No houses in Kiaracondong were connected to sewerage systems with treatment plants as of 2019, and the water through the Jondol Canal was apparently polluted by wastewater. The project members, including the authors, tried to quantitatively estimate the effect of pollutant load from the slum by measuring the volume and water quality of daily water use in the catchment area, of wastewater discharge from households in the catchment area, and of water flowing the Jondol Canal.

13.3.1 Survey on Sanitation Condition in Catchment Area

13.3.1.1 Overview of Sanitation Condition

According to the local statistics of targeted RW in 2004, the water supply coverage is 21%. Families without water supply obtained water from shared water tap called "CORSEN." This shared water tap is managed by individual owners, and people pay him/her and take water into a plastic tank or bucket by themselves. People also can buy water from water vendors who carry around ten plastic tanks in a cart (Fig. 13.3). The water vendors buy water from CORSEN and carry it to sell to the aged or families who reside far away from CORSEN. Many wells also exist, which people use for water; however, they do not use them for drinking and cooking due to too much iron contain and contamination by *E. coli* (Sintawardani et al. 2005).

Regarding toilets, 87% of the households had private toilets and the others used shared toilets, according to local statistics[3] in 2004. A typical type of Indonesian toilet is a pour-flush-type squatting toilet (Kurasawa 2001: 107–108). The observed domestic toilets were basically the same; however, some had only steps without a bowl and some toilets only had a hole (Fig. 13.4). Other than household toilets, there were some shared toilets located beside the Jondol Canal or ditch and their wastewater was directly discharged (Fig. 13.5). Some of these toilets were constructed by the residents and some by the local government. The quality of construction is rather low compared to private toilets; however, they are sufficiently clean inside because the users pour water after use. Our observation and interview results indicated that people in targeted RW usually clean their anus or urethral opening with water after defecation or urination. They use a 1- to 2-L pail to pick up water from bucket or

[3] This is not officially published statistics but displayed on the wall of RW office.

Fig. 13.3 Water vendor. (Photo by Ushijima)

Fig. 13.4 Toilet in targeted RW. (Photo by Ushijima)

tank. This pail is used for flushing the toilet as well as bathing. The toilet and bathroom were not separate in most homes.

13.3.1.2 Interview Survey

Sixty-two families in targeted RW were interviewed in 2005 in order to know about water use, wastewater disposal, and other related matters (Ushijima 2007). Income

Fig. 13.5 Shared toilet along Jondol Canal. (Photo by Ushijima)

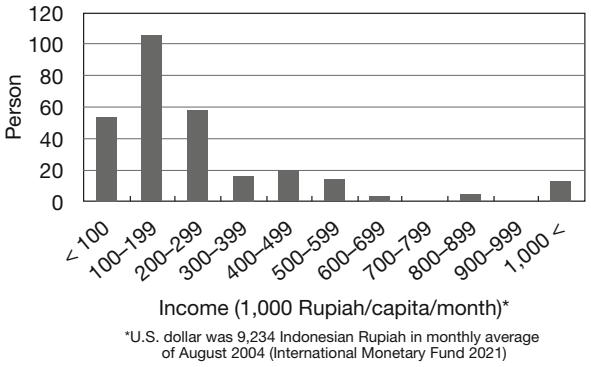

Fig. 13.6 Income range distribution of study area ($N = 62$ families; Ushijima et al. 2008b)

levels of those respondents were rather low, the average per capita income was approximately 300,000 Rupiah/month, and the mode was 100,000–199,000 Rupiah/month (Fig. 13.6) (Ushijima et al. 2008a, b).

Figure 13.7 shows the summary regarding water use time for three purposes: "defecation," "bath," and "wash." Large peak was observed in the morning on all three water uses, and small peak was observed in the early evening on "bath" and "wash." The total volume of these waters corresponds to 55% of the total water usage (Fig. 13.8). Water use for other purposes than the above three was not showing apparent peak.

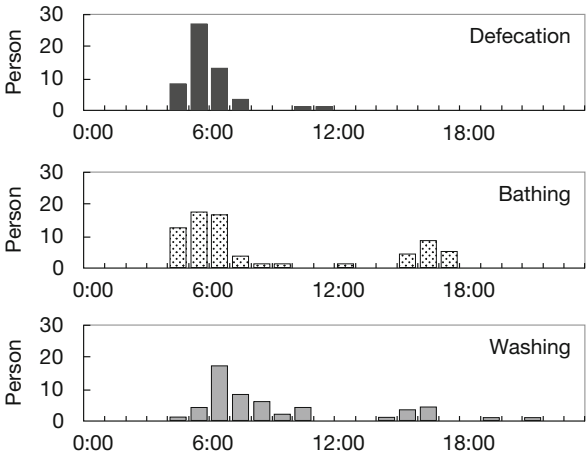

Fig. 13.7 Time distribution of defecation, bathing, and washing (Ushijima et al. 2008a)

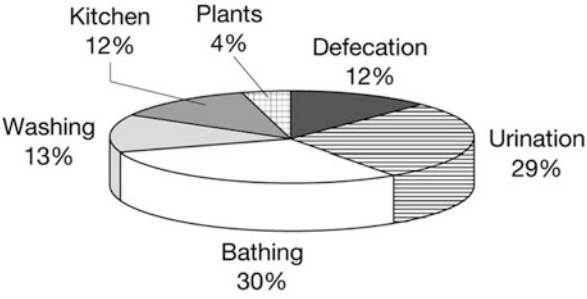

Fig. 13.8 Water usage for each purpose (Ushijima et al. 2008a)

In 53% of the responding families' homes, wastewater from the toilet or bathing activities was directly discharged into the Jondol Canal and finally flow into the Citarum River. In the remaining 47%, the wastewater was treated using a septic tank. The treatment efficiency of septic tanks is generally low (United States Environmental Protection Agency 2002); furthermore, periodical sludge removal was not conducted in many cases. In this study, we interviewed a worker involved in sludge removal in this area and found that all the removed sludge was thrown into the canals. Wastewater, except that from toilet usage and bathing, was directly discharged from all respondent houses.

13.3.2 Field Measurement and Mass Balance Analysis

13.3.2.1 Measurement in the Jondol Canal

Figure 13.1c shows the measurement locations and catchment of the studied section of the Jondol Canal, with a distance of 960 m between the two observation sites. This

area of the catchment was 0.41 km^2 and estimated to have a population of 16,240 and 3585 households. The catchment area is occupied by houses and small farms; factories or other large facilities are not included in this area. Therefore, the side inflow to the canal appears to contain only domestic wastewater and natural components such as rainfall. Our objective was to discuss the effect of domestic wastewater on river water. Hence, our observations were conducted at the end of the dry season to avoid the unsteady effect of rainfall. Regarding other components, there is considerable water usage before prayers in Islamic society. We will discuss this "religious component" in the next section. Feces and urine are the key sources of pollutants; hence, we measured them independently.

13.3.2.2 Domestic Wastewater Measurement

Regarding households, we observed three cases, as shown in Table 13.1. All the houses were facing the Jondol Canal and the outlet pipes directly protruded from the canal wall. We placed a large bucket just below the pipe (Fig. 13.9). The measurement and sampling were conducted using this bucket at 1-h intervals for 24 h. The sampled water was analyzed using a portable water quality analyzer (Lambda 8022; Kyoritsu Chemical-Check Lab. Corp.). These samples were analyzed as composite sample weighted by amount, except for "single household." The analyzed items were NH_4–N, NO_2–N, NO_3–N, PO_4–P and chemical oxygen demand (COD) by the indophenol method, naphthylethylenediamine method, naphthylethylenediamine method with deoxidization, molybdenum blue method, and alkaline potassium permanganate method, respectively.

Figure 13.10 shows the per capita domestic wastewater measurement results. A common trend of increased water usage was observed in the mornings and evenings, same as the result of Fig. 13.6. However, several peaks other than morning and evening were also observed, for example, around noon in the "single household" and the "four-person household" and late evening in the "four-person household." Those peaks seemed due to uniqueness of water use in each household or irregular use, such as because water was used for washing the motorcycle in the late night.

Table 13.1 Wastewater observed families

Household type	Number of household members	Water supply	Toilet	Measurement period
Four-person household	4	Private	Private/water flush/ no treatment	24 h from 11:00 a.m. August 11, 2004
Single household	1	Shared	Private/water flush/ no treatment	24 h from 10:00 a.m. September 1, 2005
Complex houses	11	Shared	Private/water flush/ no treatment	24 h from 10:00 a.m. August 24, 2006

Fig. 13.9 Domestic wastewater measurement (Ushijima et al. 2008a)

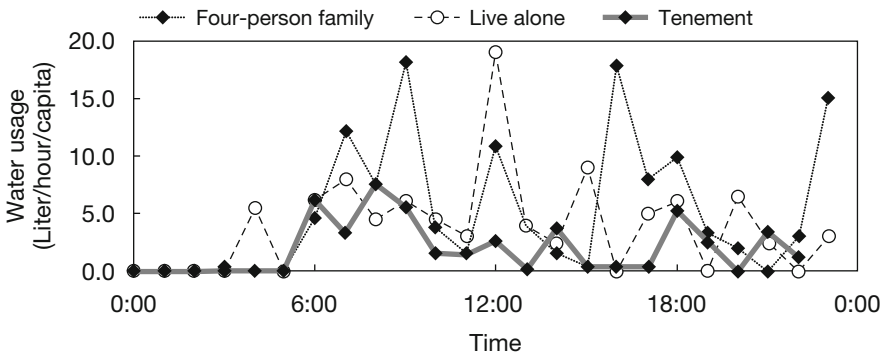

Fig. 13.10 Time series of water usage per capita (Ushijima et al. 2008a)

13.3.2.3 Mass Balance Analysis Between Domestic Wastewater and Jondol Canal

Mass balance analysis provides basic information about water flow in the targeted area and becomes validation to check if there is missing component to be observed. Table 13.2 shows the integrated results of the water balance, which (a) is the per day

Table 13.2 Integrated results of the water balance (Ushijima et al. 2008a)

	m^3/day	Ratio to (a) (%)
(a) Increment in the canal	2581	–
(b) Domestic wastewater discharge × population		
(i) Interview result (average of 62 respondents)	1445	56
(ii) Four-person household	1804	70
(iii) Live-alone household	1543	60
(iv) Vomplex houses	750	29
(c) Natural component (minimum flow)	725	28
(d) (b)-i + (c) + water for wudu	2540	98

flow increment between two observatories and (b) is the estimated total generation of domestic wastewater. The latter was estimated by multiplying each result of the measurement or interview survey with the catchment population. The value of (b)-i to (b)-iv ranges 750–1804 m^3/day and those correspond to 29–70% of (a). River system, even if small channel like Jondol Canal, must have natural inflow component, but it is generally difficult to estimate precisely. We assumed that the minimum flow rate in our observation period was the nearest value to the natural component. It was 725 m^3/day, 28% of (a). Thus, household water discharge (29–70%) and natural inflow (28%) were apparently major components, and those two occupied in total 57–98% of (a). It means that there might be a missing component with 2–43% of (a).

As a probable another component, we focused on water for Wudu.[4] In Kiaracondong, where 97% of the population (15,753) believe in Islam, water for Wudu could not be ignored. We measured water at one mosque after installing a flow meter on the pipe for water supply, and the water usage was estimated to be 4.7 L/prayer/capita. The total amount of water for Wudu in the catchment was estimated to be 370 m^3/day. This activity must be held both at home and in the mosque; therefore, it seemed to be partially included in (b)-ii, (b)-iii, and (b)-iv. Only (c)-i excludes this activity since "water for Wudu" was not an item in the interview survey. When we add Wudu component to (b)-i and (c), total amount reaches 98% of (a). Thus, the water balance estimated above seemed reasonable to explain the situation of study site.

13.3.2.4 Pollutant Load Balance

Figure 13.11b shows the time series of the net pollutant flux, which was derived as follows: the concentration and flow rate are multiplied with each other and are integrated over an hour; finally, the upstream flux is deducted from the downstream flux for each hour. The results show a pattern similar to that of the concentration (Fig. 13.11a).

[4]Wudu is the Islamic procedure to washing parts of the body, a type of ritual purification, or ablution.

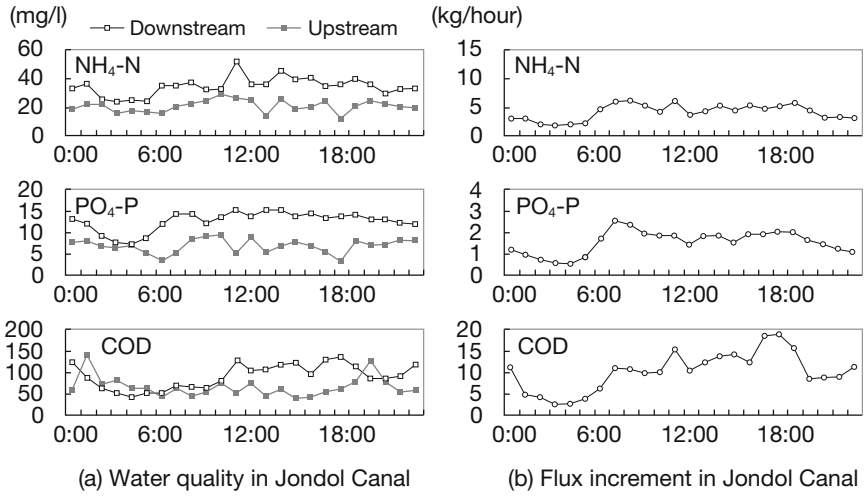

Fig. 13.11 Water quality and flux increment in Jondol Canal (Ushijima et al. 2008a)

Table 13.2(b) shows the pollutant load of the domestic wastewater per capita per day estimated from the results of domestic wastewater measurement. As reference data, the reported values of the case in England (Almeida et al. 1999) and Japan (Nakanishi and Domestic Wastewater Treatment Guidebook Editorial Committee 1986: 31) are shown. The values obtained by the different methods are presented in parentheses. The estimated values for the three families varied greatly. Therefore, we focused on the "single household," which was the closest to the typical condition based on the discussion of water volume. Although the pollutant load from the "single household" was larger than the other two families regarding every item, they were roughly the same as that of the reference data with the exception of NH_4–N. Regarding the amount of NH_4–N, it was probable that NH_4 was generated by the degradation of urea. We should have measured it along with the total nitrogen content; however, we could not do it because of the limitations of our research resources (equipment, time, and workforce).

Table 13.3(a) shows the estimated pollutant flux in the canal; this value was converted to per capita per day. By utilizing the data of the "single household," the runoff rate was estimated to be 0.7, 0.4, and 0.4 for NH_4–N, PO_4–P, and COD, respectively.

13.3.2.5 Contribution of Human Excrements

Table 13.3(c) shows the pollutant load by excrement per capita per day. This was estimated from the excrement analysis. Regarding the feces, almost all respondents (96%) reported the frequency of defecation to be once a day in the abovementioned interview survey. Therefore, we regarded the average weight of the feces sample

Table 13.3 Estimated pollutant flux per capita per day (Ushijima et al. 2008a)

	NH_4–N (g/capita/day)	PO_4–P (g/capita/day)	COD (g/capita/day)
(a) Flux increase in the canal	5.90	2.18	14.86
(b) Domestic wastewater flux			
(i) Four-person household	1.55	2.17	25.32
(ii) Live-alone household	7.89	6.13	35.86
(iii) Complex houses	1.18	0.77	2.88
Almeida et al. (1999)	2.38	6.68	(111.88)[a]
Nakanishi and Domestic Wastewater Treatment Guidebook Editorial Committee (1986)	(11–14)[b]	(1.5–2.1)[c]	26–37
(c) Urine and feces flux			
(i) Urine	1.27	2.70	11.02
(ii) Feces	0.07	0.22	4.01
Almeida et al. (1999) (urine + feces)	2.27	5.24	(48.33)[a]
Nakanishi and Domestic Wastewater Treatment Guidebook Editorial Committee (1986) (urine + feces)	(9–11)[b]	(0.9–1.2)[c]	10–15

[a]Potassium dichromate method
[b]Total nitrogen
[c]Total phosphorus

(90.3 g) as the daily amount of defecation. As for urine, there were no actual data on the urine amount in the area. We considered 1.2 L/day/capita as a reasonable average, as reported by Franceys et al. (1992: 32). In comparison to the reference data, as shown in Table 13.3(b), the estimated values were in a range similar to that of the reference data.

Based on our analysis of the canal water that included only the dissolved part, we estimated the contribution rate of pollutant load by urine in domestic wastewater. The contributions of NH_4–N, PO_4–P, and COD were estimated at 16%, 44%, and 31%, respectively. As for NH_4–N, the actual contribution was larger because of the additional NH_4–N from the degradation of urea in urine, as mentioned above. Furthermore, in the actual situation, the feces also seemed to release soluble pollutants while flowing. This part is not included the estimation above. Thus, the contribution of excrement to domestic wastewater was considerable and it considerably affected the water quality of the Jondol Canal. The improvement of the sanitation system appears to be a high-priority issue concerning the water environment and hygiene.

13.3.3 Identified Sanitation Issues

According to our field measurement and analysis, we found that a large portion of the pollutant load comes from domestic wastewater. Pollutants from excreta were a measurable part of the domestic wastewater and were assumed to have considerable influence on the river environment. Through this first phase, we found that the improvement of sanitation systems in slums is of vital importance to the water environment; however, we also found structural issue that slum residents are difficult to have motivation to improve their sanitation system. As seen in the field, the private toilet itself is comfortable because people frequently flush and wash the floor; therefore, most of the toilets we saw in the field looked sufficiently clean. People are motivated to flush and wash to keep their toilet; but there is little motivation to prevent discharging their excreta to the river because their efforts to prevent may not feedback them directly.

Although the current sanitation system is apparently problematic for environment, it seems to be a reasonable choice for individual user. Therefore, a more attractive alternative should be provided; otherwise, it is difficult to request people to stop discharging their wastewater. In most urban areas in low- and middle-income countries, public services have been supplementing the rest of the material flow, such as the sewerage system. However, sewerage management cost is now a serious issue in many countries. Furthermore, concerning sustainability, low-cost or value-generating sanitation systems, such as resource-oriented sanitation systems, have become prospective alternatives. The critical weakness of those low-cost resource-oriented sanitation system seems immatureness of the reasonable social system design. In other words, it is desired to create that well-designed material and value flow, which enable better material flow and motivate each actor to join and work for it.

13.4 Second Phase: Composing Solution Framework by Material Flow and Social Relationship Network

The second phase of our trial took a very long time. It covers the project of late CREST (2004–2007), JSPS-KAKEN (2009–2013), and Toyota Foundation (2015–2016). In this phase, we hypothesized about material and value flow on the basis of the current material and value flow analysis. Then, field research was conducted on candidate players of new material flows and value flows; in other words, sanitation value networks or social relationship networks.

13.4.1 Crude Picture of Sanitation-Related Material and Value Flow

It is difficult to judge whether a resource-oriented sanitation system with a composting toilet is the best choice or not; however, we had started considering and designing sanitation material flow using the composting toilet system as one of the promising systems. As a first step, a crude picture was drawn (Fig. 13.12). Through this drawing process, we understood that compost collection, transportation systems, and collaborative farmers and their market become essential factors for driving the system. Concurrently, we had already worked in the field (the first phase); therefore, we were exploring available or adaptable material flow that already exists, because creating new material flow seemed much more difficult than adopting currently existing similar material flow.

13.4.2 Possibly Adaptable Material and Value Flow

13.4.2.1 Garbage Collection System

Regarding compost collection and transportation systems, we focused on the garbage collection system since the early stage of the second phase, around 2006. Indonesia has a unique garbage collection system; each neighbor association (RW) employs a garbage collector by collecting small amounts of money from residents (Unisuga and Watanabe 2004). The garbage collector uses a handcart (Fig. 13.13) to collect garbage from each house and brings it to the middle station

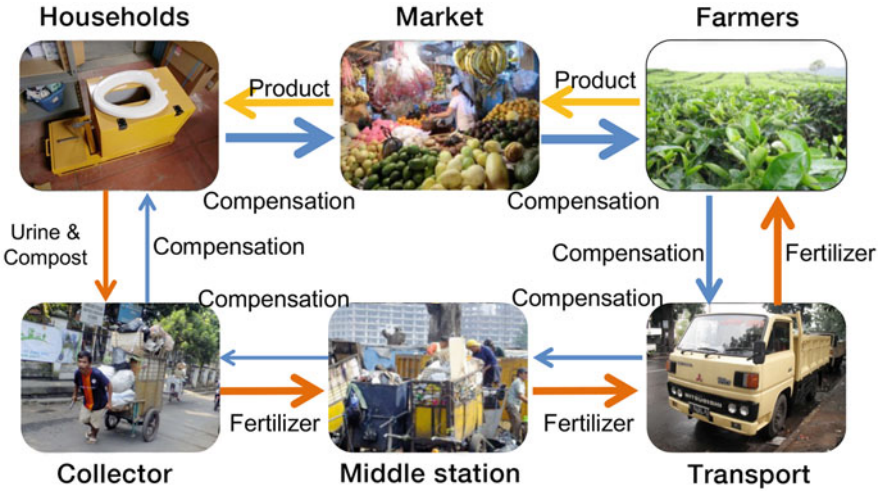

Fig. 13.12 Crude concept for the new sanitation system

Fig. 13.13 Handcart for garbage collection (Ushijima et al. 2008a)

(Tempat Penampungan Sampah; TPS), where municipality prepared for garbage transship from handcart to truck. Garbage is loaded on the truck and transported to the dump site (Fig. 13.14). Thus, the garbage collection process from each house to the TPS was managed in a self-help system by residents, and we regarded it applicable to compost collection.

We conducted a survey on the material and value flow of solid waste management in 2006 and 2012. Interview surveys and measurements were combined to understand the reality of the system.

The targeted RW in Kiaracondong employed one worker for garbage collection. People directly hand garbage to the collector or put it in front of their house. The shape of the collector's handcart (700 × 1150 × 1550 mm) is well-designed as it is suitable for narrow streets in the slum, with a capacity of 1.3 m^3. Collection was performed three times per week, and the collected amount per collection day always corresponded to two handcarts. Collection commenced in the morning and sometimes continued into the afternoon. The garbage collector of this community was paid 400,000 Rupiah/month.[5] Money for garbage collectors, including maintenance costs for handcarts, etc., was collected by the community from each household. The

[5] 1 Rupiah = 0.000109 USD as of 2006.

Fig. 13.14 Garbage transportation by truck. (Photo by Ushijima)

Table 13.4 Summary of field survey on garbage in targeted RW (Ushijima et al. 2008b)

	Results	Reference data	Note
Total amount	0.9 L/day/capita (0.184 kg/day/capita)	1.8 L/day/capita (0.36 kg/day/capita)	Estimated from statistics of Bandung City (BPS Kota Bandung 2004) Weight was estimated by JICA data (JICA 2005) reporting the density of 0.2 kg/L
Organic waste	75%	73.98%	Statistics of Bandung City (BPS Kota Bandung 2004)
Collection capacity of collector	1.1 m^3/day	3 m^3/day	Yamamura (1987) reported on the case of Jakarta
Collection fee	556 Rupiah/month/capita	800–2500 Rupiah/month/capita	Estimated cost on Asia and Latin America (Bartone 2000)
Percentage of collection fee in income	0.3–0.6%[a]	2%	Estimated value of ATP (JICA 2002)

[a]Estimated for mode value in the study site. *JICA* Japan International Cooperation Agency

basic price was 2000 Rupiah/month/household, and some extra charge depends on income; however, the extra charging rule was not clear and was not applied strictly.

Garbage amounts from 62 households in the targeted RW were measured in 2006. The total amount was 184 g/day/capita in which 75% was organic waste on average. Table 13.4 summarizes the results of garbage material flow and value flow. Statistical data for Bandung City and other reported values are also shown as a reference. The total amount per capita was estimated by dividing the collecting amount in volume. The total amount is almost half of reference value. The difference may

reflect the gap of income level. The reference value is the average of Bandung City, while our target was slum residents' generally income level was lower. The percentage of organic waste was as well as that of the reference data. The collection capacity of garbage collector was smaller than that of the reference. Because the collector in the area works only 3 days per week and only in the morning, it could be assumed that he had a potential to collect more in a day. The collection fee was smaller than the reference data reported in Asia and Latin America, and the percentage of collection fee in income is much smaller than the reference data reported as general affordability to pay (ATP; Japan International Cooperation Agency [JICA] 2002). Of course, ATP can change by country, community, income level, and so on; however, at least, the present fee seems not to be too expensive for people.

13.4.2.2 Water Vendors

Among several types of toilets for resource-oriented sanitation system, we assumed urine-diverted composting toilet because the size of this toilet unit is smaller than other types and it will be suitable for slum residents. In terms of material flow, the urine-diverted toilets require collection of solid compost and liquid urine. When we design sanitation material and value flow based on current garbage material and value flow, only a liquid material flow has been lacking. For collecting liquid, we focused on "20L plastic tank" and "handcart" to transport drinking water that residents use in their daily life and water vender, described in Sect. 13.3. The handcart can bring 8–12 tanks. Regarding the salary of liquid collector, we have not yet obtained reasonable value; therefore, we assumed that liquid collector also works for the same salary as the garbage collector, in the cost estimation described later.

13.4.2.3 Truck Transportation

Referring to the garbage collection system, we assumed that the collected compost and liquid would be transported by a truck. Near the big market in Indonesia, there are truck-waiting areas, where people can find and hire the truck to transport their goods bought in the market. We had interviewed those truck drivers to obtain basic information of their business and cost. Some truck drivers are employed by the company and some are self-employed. The trucks waiting for customers had a wide variety of capacities. They were usually transporting food such as vegetables or fruits, but one of the interviewed drivers had experience in transporting livestock manure compost.

13.4.2.4 Linkage to Agriculture

To explore linkage to agriculture, we interviewed managers of tea plantations, rubber plantations, and organic vegetable farms and farmers of pineapple farms, flower farms, and rice farms. We tried to understand the material and value flow of those farmers. This research activity was conducted from 2010 to 2019. Results of those research did not provide definite findings nor conclusions; however, they helped researchers to explore possible linkage of sanitation and agriculture via both qualitative and quantitative evaluation. Furthermore, those field research activities provided us a human network and took an important role in the co-creating process, described in Sect. 13.5.

13.4.3 Feasibility Assessment

At that point of phase 2, researchers have not yet shifted to the idea of co-creation with local people and considered that researchers should propose attractive and affordable sanitation system that gives sufficient incentive for people. Therefore, researchers considered that visualized picture of sanitation value network became useful tool for designing the sanitation system into an attractive and affordable one for people. However, this approach forced researchers to tackle with the issue of assessing the people's possible acceptance. In order to measure how attractive and affordable the new system is, acceptance by people was usually evaluated somehow; however, it was difficult for local people to imagine and evaluate if the system was completely new and not yet existed. Therefore, as a preliminary step, researchers tried to check the objective feasibility of their concept of new sanitation value flow by utilizing the results of field researches provided in Sect. 13.4.2. In this process, researchers focused on physical feasibility in terms of capacity of collection and transportation, potential demand–supply balance, and economic feasibility.

By separating the evaluation of objective feasibility, researchers found that field trial of the sanitation system with local players would be necessary to evaluate people's acceptance. This idea had led them to the co-creation concept.

13.4.3.1 Feasibility of Collection and Transportation Capacity

If we consider a new sanitation system based on crude concept shown in Fig. 13.12, collection and transportation design of compost from toilet and stored urine become necessary. Here, we assume composting toilet that uses sawdust as a composting matrix and needs to add new sawdust after compost removal; therefore, supply and deliver design of new sawdust to replace with compost also becomes necessary. We assumed the frequency and volume of removing compost and adding new sawdust as twice in a year and 0.025 m^3 at one time, following the specifications of the

commercial composting toilet. The average household size was assumed to be four persons/household based on the real average household size of 3.6 person/household in local statistics of the targeted RW. In this case, replacing the amount of compost with new sawdust will be 0.1 m^3/household/time. If all 410 households in the targeted RW use composting toilets and replace compost with new sawdust matrix twice per year, the total amount will be 82 m^3/year. If collection frequency was assumed to be three times/week, the required collection capacity will be 0.52 m^3 per collection day; this is less than half of observed garbage collection capacity (see Table 13.3). The working condition of the garbage collector we interviewed was that he was working 2 days a week and working time is usually only in the morning; therefore, it seems possible to collect compost in terms of collection capacity. As a related issue, we have to consider the required time for compost removal from composting chamber; it greatly depends on the design of mixing device in composting chamber. If we assume composting chamber with removable screw or removable chamber (see Sect. 13.5.2), additional working time for collection would be only a few minutes per one toilet. However, if the composting chamber equips unremovable screw, from our experience, compost removal takes more than 30 min per one toilet; it may become bottleneck of the system.

Regarding urine collection, in a four-person household, one 20-L tank becomes full after about 5 days. Therefore, 410 households in the target RW will produce 102 tanks per day in total. If we assume that the urine collector can collect three carts per day and that one cart carries ten tanks, 3–4 workers are required.

Regarding the collection cost, it corresponds to the salary of compost collectors; there is no assurance that the community can employ compost collectors with the same salary as the garbage collector. However, according to interview results with three garbage collectors, they gave their consent to work as compost collectors and receive the same salary since there was a need for more jobs. Further, one of them mentioned that compost collection seems to have a lower risk of injury (e.g., glass or needles) than garbage collection.

13.4.3.2 Feasibility of Demand and Supply Balance

The balance of fertilizer demand and supply is fundamental to evaluate the feasibility of the resource-oriented sanitation system. From the point of view to complement nitrogen on the field, we regarded total nitrogen contained in annual human excreta production in each area for confirming the potential of its supply. This was estimated by multiplying the population and unit value of nitrogen excretion from the human body (Ushijima et al. 2013). We also regarded the annual total consumption of nitrogen in fertilizer as the potential demand. This was estimated by multiplying standard fertilizer use (FAO 2005) and cultivation area (data sources are listed in Table 13.5) for each product. These were analyzed at the district level in the Indonesian language.

Figure 13.15 shows the potential balance of demand and supply of excreta fertilizer in each district. Bandung City and some surrounding districts showed

Table 13.5 List of agricultural data sources

BPS-Bandung Barat (2010): Bandung Barat Dalam Angka
BPS-Bandung (2009): Bandung Dalam Angka
BPS-Cianjur (2010): Cianjur Dalam Angka
BPS-Galu (2010): Galu Dalam Angka
BPS-Subang (2010): Subang Dalam Angka
BPS-Purwakarta (2010): Purwakarta Dalam Angka
BPS-Cimahi (2010): Cimahi Dalam Angka
BPS-Bandung (2010): Panyleukan Dalam Angka
BPS-Bandung (2010): Panyleukan Dalam Angka
BPS-Bandung (2010): Arcamanik Dalam Angka
BPS-Bandung (2010): Cidapap Dalam Angka
BPS-Bandung (2010): Coblong Dalam Angka
BPS-Bandung (2010): Antapani Dalam Angka
BPS-Bandung (2010): Cinambo Dalam Angka
BPS-Bandung (2010): Gedebage Dalam Angka
BPS-Bandung (2010): Regol Dalam Angka
BPS-Bandung (2010): Bandung Wetan Dalam Angka
BPS-Bandung (2010): Lengkong Dalam Angka
BPS-Bandung (2010): Astanaanyar Dalam Angka
BPS-Bandung (2010): Cibeunying Dalam Angka
BPS-Bandung (2010): Sumur Bandung Dalam Angka
BPS-Bandung (2010): Kiaracondong Dalam Angka
BPS-Bandung (2010): Cibiru Dalam Angka
BPS-Bandung (2010): Andir Dalam Angka
BPS-Bandung (2010): Bojongloa Kaler Dalam Angka
BPS-Bandung (2010): Babakan Ciparay Dalam Angka
BPS-Bandung (2010): Bandung Kulon Dalam Angka
BPS-Bandung (2010): Sukasari Dalam Angka
BPS-Bandung (2010): Rancasari Dalam Angka
BPS-Bandung (2010): Cibeunying Kaler Dalam Angka
BPS-Bandung (2010): Sukajadi Dalam Angka
BPS-Bandung (2010): Bandung Kidul Dalam Angka
BPS-Bandung (2010): Mandalajati Dalam Angka
BPS-Bandung (2010): Batununggal Dalam Angka
BPS-Bandung (2010): BojongloaKidul Dalam Angka
BPS-Bandung (2010): Buah Baatu Dalam Angka

supply excess; in contrast, other districts showed demand excess. It is clear that human excreta generated in Bandung City cannot be consumed all in Bandung City and transportation from inside of Bandung City to outside is necessary. Figure 13.16 shows the accumulated demand and supply by distance from Kiaracondong district. This result indicates that the 32 km circle is an indicative area scale that potential demand and supply are balanced.

Fig. 13.15 Potential balance between nitrogen supply and demand in each district. (Reprinted from Sintawardani et al. 2019 with the permission of Springer Nature)

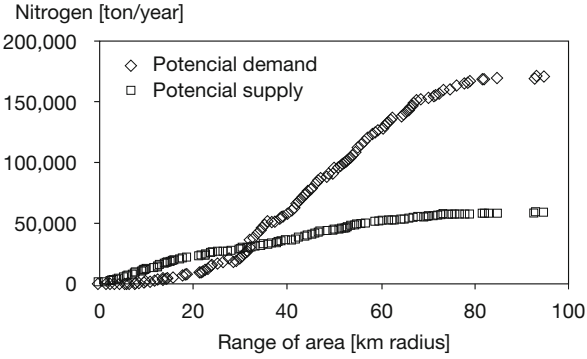

Fig. 13.16 Nitrogen supply potential and demand potential in circle area by its diameter. (Reprinted from Sintawardani et al. 2019 with the permission of Springer Nature)

13.4.3.3 Feasibility of Economic Aspect

Based on the abovementioned physical and demand–supply assessment, we estimated the basic cost to provide fertilizer from human feces and urine to the farmers in our concept of sanitation system as a baseline of possible lowest price. The assumed cost factors were collection cost from each house, transportation cost from local station to farmland, and a cost for adjusting element balance of fertilizer, mainly adjusting nitrogen phosphorus ratio from the original ratio of excreta to the ratio plants require. The running cost to maintain composting toilet was supposed to be paid by reach household and compost supposed to be given to collector without payment; therefore, those two were not included in the estimation.

We chose one existing tea plantation site as the case site. It is located 47 km from Kiaracondong, which is farther than 32 km that is the threshold distance reversing

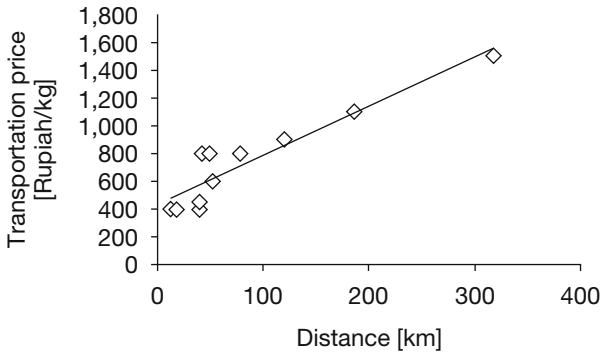

Fig. 13.17 Price–distance curve of truck transportation. (Reprinted from Sintawardani et al. 2019 with the permission of Springer Nature)

the balance of potential nitrogen supply and demand. Unit collection costs for urine and feces were estimated by following the scheme described in Sect. 13.4.2. In current garbage collection in the targeted RW, the community collects 820,000 Rupiah/month from households for one collection worker. This cost includes the maintenance cost for their handcart. The assumed concept of sanitation system requires eight collectors for urine collection and one collector for compost collection. Based on this information and assumption, the unit costs for urine and compost collection were estimated at 130 Rupiah/kg for urine and 308 Rupiah/kg for compost.

Unit transportation cost for compost and urine fertilizer was estimated at 154 Rupiah/kg, by price–distance curve (Fig. 13.17), which was obtained by interviews with truck drivers. According to the results of interviews with a tea plantation company, the required amounts of urine and compost were estimated as 7236 kg/ha and 380.7 kg/ha, respectively. These are estimations based on phosphorus demand; an additional 271 kg/ha of urea fertilizer is required to adjust the N/P ratio appropriately.

Therefore, the total cost of fertilizer provision in our concept of sanitation system was estimated at 3,318,000 Rupiah/ha. This cost is the same level as the price of synthetic fertilizer: 3,193,000 Rupiah/ha (Fig. 13.18). Thus, the cost for fertilizers produced in our concept seemed to be feasible. However, considering low-income Indonesian farmers can buy synthetic fertilizers at subsidized prices, the price of synthetic fertilizer is less than half, which is impossible to compete for fertilizer from our concept of sanitation systems.

Thus, the fertilizer provided by our concept has the potential to become competitive in price; however, further cost down is also necessary. According to Fig. 13.18, urine collection and urine transportation costs are a large portion of the cost; therefore, the cost down of this part is desired. From a technical point of view, urine consists of more than 99% of water contents; if we concentrate urine on-site (e.g., evapotranspiration), costs can be decreased.

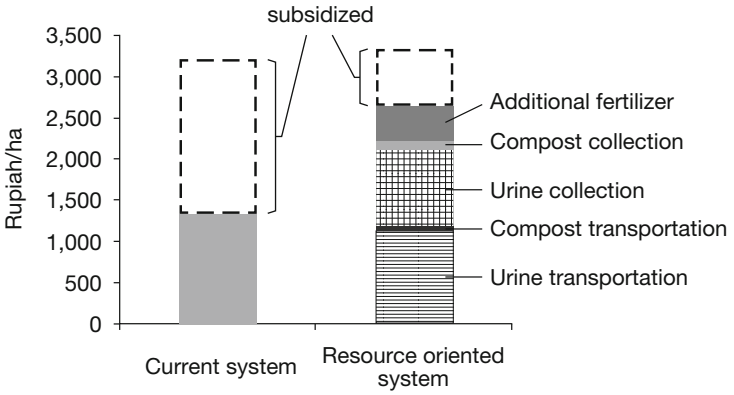

Fig. 13.18 Cost evaluation in the required amount for 1 ha of tea plantation. (Reprinted from Sintawardani et al. 2019 with the permission of Springer Nature)

13.4.4 The New Sanitation System

Although our feasibility assessment did not completely address all material and value flows, it was surly feasible that compost and urine collection system aligned current garbage collection system. The results are sufficiently convincing to proceed with the next step—a trial of a new sanitation system based on co-creation with players.

We also found that the collection and transportation cost for liquid may become a bottleneck for the system due to their volume and weight. Thus, technological innovation concerning the volume reduction of urine is necessary. Another component of the second-phase trial was to develop a comprehensive picture of material and value flow for the new sanitation system (Figs. 13.19 and 13.20). This picture makes it easy to imagine the new sanitation system; it suggests that it may increase employment opportunities and enhance the local economy.

13.5 Third Phase: Co-Creating the Sanitation System Considering People's Social Network

It is difficult to identify exactly when we enter the third phase because the idea of co-creating sanitation system had been gradually practiced in the field of our project, and the concept had been recognized and shared by researchers later. In terms of the period of our project, the RIHN project (2017–2022) was the first project that clearly stated the concept of co-creation. Regarding the co-creation process in our project, we have conducted several trials of co-creation among various researchers and also with local players; some of the trials are still ongoing. In this section, we introduce three of our co-creation trials: authorization from a religious aspect because over

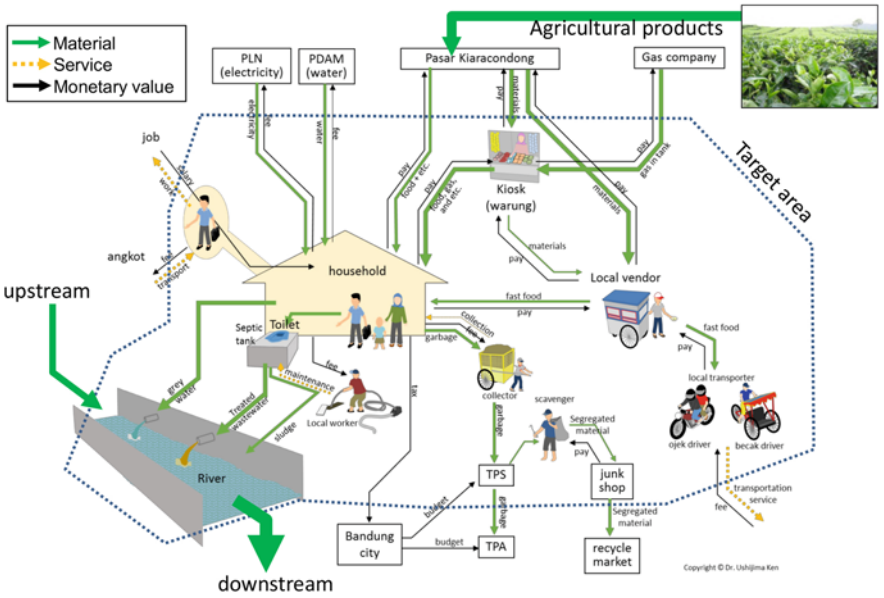

Fig. 13.19 Current material and value flow in and around the targeted area (Ushijima 2017)

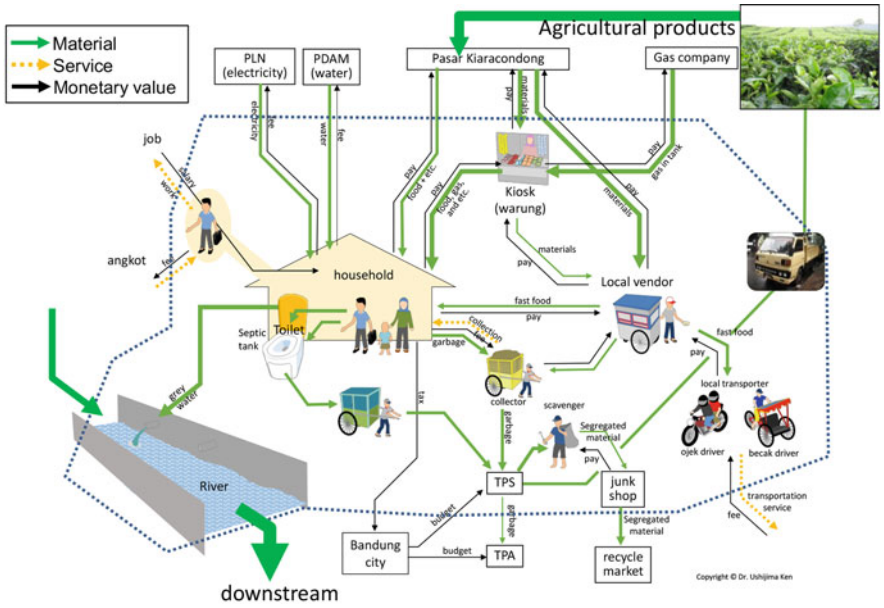

Fig. 13.20 Improved method of material and value flow in and around the targeted area

90% of Indonesian people are Muslims; designing an attractive composting toilet for users because the general public's interests concerned the toilet itself, not the sanitation system; and field test of new sanitation system by organizing field test team with various researchers and local players.

13.5.1 Authorization from Religious Aspect

Winblad and Simpson-Hébert (2004) proposed to apply faecophobic and faecophilic concepts as personal or cultural response to handling human feces. They said that there are continuum and most cultures are somewhere in-between the extremes. In practical use of this concepts, however, it seems difficult to evaluate the degree of faecophobic or faecophilic, and some studies just mention that Muslim and Hindu cultures are generally faecophobic (Khalid 2018; Nawab et al. 2006). In fact, Islamic rule defines human excreta as dirty material called "Najis," which must be completely removed from their bodies before praying. Hinduism also defines human excreta as ritually unclean material and needs to be removed. However, we are still not sure it makes sense to evaluate faecophobic and faecophilic, especially in terms of solution.

From the solution-oriented point of view, the important thing is to find and provide good sanitation solution for targeted people, and therefore if there are some religious barriers, how to remove the barriers is the main topic for us. In our research site in Indonesia, in fact, more than 90% were Muslims, and how to commit to Islamic rule is of course a critically important issue, no matter how they are faecophobic or faecophilic. Conversely, we thought that if we obtain religious certification, it will be a big advantage for diffusing the new system.

Thus, we researchers had chosen a way to collaborate with Islamic authorities and co-create the design of new sanitation system with them. As a first step, researchers had approached several major Islamic groups in Indonesia and asked collaboration to check each process of our sanitation concept in the context of Islam, referring to the basic method of building production line for Halal certificated products.

Checking work was done with four religious authorities in Indonesia, Central Majelis Ulama Indonesia (Central MUI), Majelis Ulama Indonesia Jawa Barat (MUI Jawa Barat), Persatuan Islam (PERSIS), and Pesantren Al Quran Babussalam. Majelis Ulama Indonesia (MUI) was established to organize a committee covering all major Islamic groups and key persons in Indonesian Islamic societies (Hosen 2004). This committee discusses and judges the rightness of the habit, which is difficult to judge only by Qur'an and Sunna. The other two, PERSIS and Pesantren Al Quran Babussalam, are two of the major groups in Indonesia and belong to Hanbali school and Shafi'iyah school, respectively.

Researchers had prepared a paper explaining our new sanitation concept and process, and then visited each group's leader; after explaining the concept and process, they gave a question from below to the leaders and asked to check the system in terms of Islamic rule.

1. If some process lets toilet users, collection workers, transportation workers, and other related workers touch feces or urine, is it a problem?
2. Is it a problem to store urine and compost in a house?
3. Is it a problem to provide compensations for workers who collect urine and feces to users?
4. Is it a problem to eat food grown by human feces and urine?
5. In this sanitation process, at which point and how the feces and urine change into non-Najis, or never change?

As a result, all Islamic leaders answered they have no problem to questions (1)–(4). Although the reason why they answered so had minor differences: the common points were (1) if the system let someone touch feces or urine, it is not a problem because the washing process is enough to remove the Najis; (2) storage is not a problem; (3) the trade of Najis is prohibited, but paying compensation for collectors' work is not problem; and (4) eating food grown by human excreta is acceptable. Regarding question (5), all the Islamic leaders finally concluded that our sanitation process is not a problem; however, identifying the exact point when the Najis changed into non-Najis seemed difficult even for them. Two of the four leaders answered that they cannot identify, lest of two mentioned that mixing with soil or biological process make the Najis to non-Najis.

13.5.2 Designing Attractive Toilet

Although there exist several models of commercial-based composting toilets since more than 20 years, these have not yet been widely used. There are some possible reasons, such as lack of collection and transportation system and lack of market for produced compost, as already described in this chapter. In reality, however, a critically important element for toilet users must be the interface design of composting toilet. To achieve autonomous diffusion of new sanitation systems based on composting toilet, we consider it necessary that we change toilet interfaces and composting systems to be attractive and reasonable. Therefore, we collaborated with product designers in Japan (TAKT PROJECT Inc.) and also with a researcher whose major product design in the Indonesian Institute for Science is to design a composting toilet.

In 2014, our team, consisting of engineering researchers and researchers of product design and product designers, conducted several trials to design a composting toilet. First of all, we asked four Indonesian students who are studying in Japan to simulate their toileting behavior, checked their action, and asked the detail to those students. Based on these results, we designed several trial models and made full-scale mockups of them. Those models are assuming to accept feces, urine, and cleansing water after excretion. By using those mockups, we asked Indonesian people to simulate using those models (Fig. 13.21) and checked in which operation they frequently make misoperation.

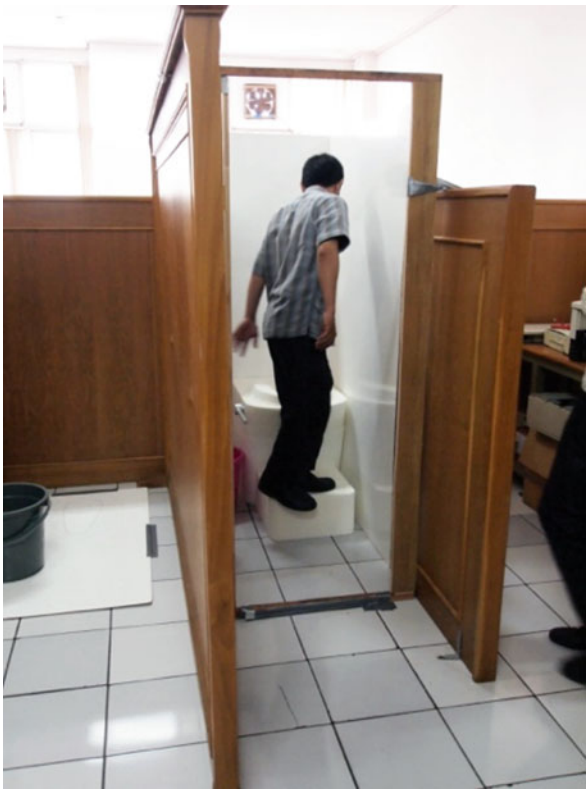

Fig. 13.21 Simulated toileting behavior in a mock bathroom. (Photo by Ushijima)

At the same time, we developed a cartridge composting reactor that can collect compost without digging but just by detaching the cartridge (Fig. 13.22) and also developed automatic urine/feces/water separation system. Then we built the first model of composting toilet and again asked Indonesian people, in this case including residents of targeted RW (Fig. 13.23), to simulate using this toilet, then confirmed that most could use it correctly without instructions.

The above-described designing process had been conducted mainly by engineering researchers and researchers of product design, but Indonesian researchers also concerned; furthermore, the team discussed with Indonesian people. This process itself also included co-creation aspect.

13.5.3 Collaboration Among Players in the Field Test

In the RIHN project, the research team named "co-creation team" had been set up and we started consciously taking co-creation approach in Indonesia from 2016 and it is still ongoing. This team is composed of various researchers including

Fig. 13.22 Detachable composting reactor. (Drawn by TAKT PROJECT Inc.)

Fig. 13.23 User test of the first model of composting toilet in Kiaracondong. (Photos provided by Hokkaido University)

engineering, development economy, social psychology, and so on, and aims to co-create sanitation system in the field with local players and to describe the process of co-creation. Through the experience of phase 2, we had known that we need to make a real-scale field trial with local players, which means co-creation approach, in order to proceed to the next step. Therefore, the team planned to (1) organize a field test team with local players, (2) brake down our concept of new sanitation system into practical field test plan, (3) conduct a field test of new sanitation system,

Fig. 13.24 Discussion with players using visuals. (Photos by Ushijima)

(4) draw the revised picture and action plan of new sanitation system and (5) involving further players for new sanitation system.

At that point, we had already developed a relationship with some of the players. Therefore, we started by enhancing our existing relationship with players: Babakan Synar Elementary School in Kiaracondong; garbage-collection-related workers in Kiaracondong; Eco-pesantren, which is an Islamic school, and so on. In addition, we contacted several foliage plant farmers in Lembang village, which has vast agricultural field next to Bandung City for trial of new sanitation system with non-food-producing agriculture. We introduced our new sanitation concept to farmers and farm owners by using visual materials, such as short movie and illustrated toilet tissue (Fig. 13.24). Through this exploration, finally we got three collaborative farmers. We visited the players several times and discussed the new sanitation system with them.

Among several collaborative schools, Babakan Synar Elementary School had too few toilets compared to the number of students and desired to increase toilets. Teachers in this school also had a high interest in our project in terms of WASH education. Through the discussions between researchers and school teachers, they agreed to install two composting toilets for our field test in this school and allow students to use those toilets. Through those discussions, researchers found that the person who opens small kiosk in this school was also in charge of cleaning current toilet in this school. Researchers also interviewed and discussed with her, and she agreed to join our field test as a player for cleaning and maintaining composting toilet.

Regarding compost and urine collection, researchers discussed with garbage collector of targeted RW. He had been working as a garbage collector of the RW, and therefore he had already known our research activities from 2004, and he agreed to join the field test as a compost and urine collector. Among three collaborative farmers, one young farmer had especially a strong interest in compost and urine use for his cultivation. He asked many questions to researchers about expected

performance of compost and urine fertilizers, and trial plan in his farmland was discussed with researchers.

Through these discussions, researchers and local players drew the field test plan using composting toilet in Babakan Synar Elementary School, collecting compost and urine by present garbage collector, hiring truck to transport compost and urine, and utilizing compost and urine by foliage plants farmers in Lembang. Those discussion processes also enabled researchers to organize a field test team including local players (Fig. 13.25). In August 2019, all the field test team members gathered and a kickoff workshop at Babakan Synar Elementary School was held (Fig. 13.26).

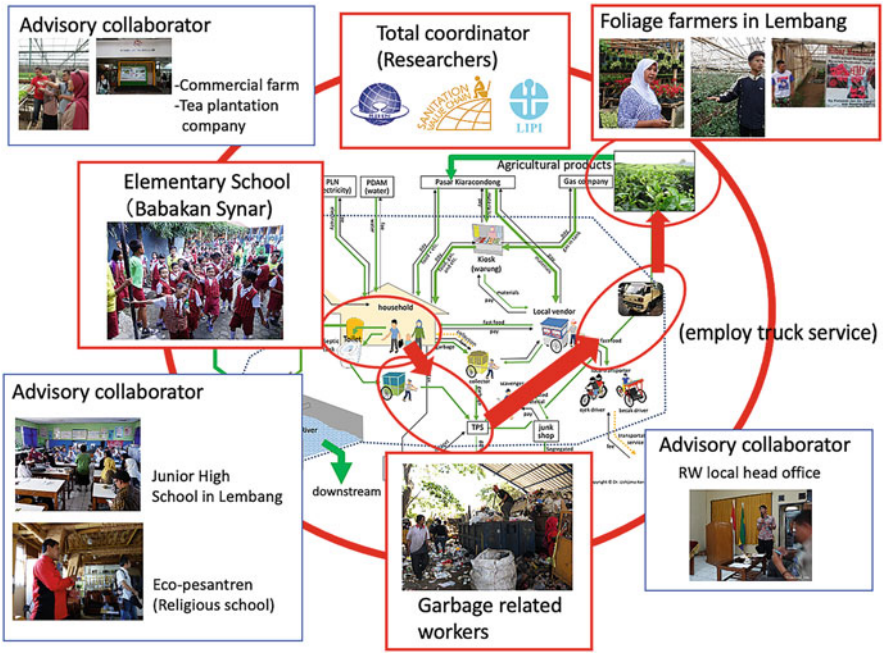

Fig. 13.25 Field test team

Fig. 13.26 Kickoff workshop for the field test team. (Photos by Ikemi)

After that, two composting toilets were installed in Babakan Synar Elementary School and a pretest by limited students was conducted in September 2019. The field test team planned to start field test from the 2020 summer; however, the team could not continue it owing to the COVID-19 pandemic.

13.5.4 Future Plan for the Third Phase and the Post-Third Phase

The third phase is still ongoing. Although researchers still cannot visit the site owing to the COVID-19 pandemic, Indonesian and Japanese researchers set monthly webinar since June 2020, and keep discussing and exploring the way to restart the field test of new sanitation system. Regarding local players in the field test team, researchers also keep in touch with them via web meeting system or SNS. Thus, we have been trying to keep connection among the team and also been making trial to do co-creation via web connection.

13.6 Conclusions

This chapter described our challenge of the co-creation, which was conducted through expanding the material flow approach to social relationship networks and developing effective solutions. Through our 15-year process, we found that material flow and social relationships affinitized strongly each other. Through the first phase, we could understand the overall problem of sanitation in the research field by applying material flow analysis; the strength was the ability to catch all the related processes based on a logical mass balance point of view. However, its weakness was too strict rule and it was difficult to describe each player's motivation; in other words, "driving force" of the system. On the other hand, the strength of social relationship analysis is that it can describe each player's motivation, and its weakness is that it is difficult to list all related processes or players. Therefore, in the second phase, we applied social relationship analysis based on the result of material flow analysis obtained in the first phase and could draw a reasonable picture of sanitation value flow network. Based on that picture, we had started co-creation approach in order to realize the concept of the new sanitation system with local players, and it is still ongoing.

We found that the combination of material flow and social relationship provides a reasonable and effective picture of wholistic sanitation system, and also that it is important to validate and update the picture through co-creation process among a team consisting of not only various researchers but also local players. Although we have not yet sufficiently performed co-creation of sanitation systems, we found one promising approach. In our case, it took 16 years owing to our trial-and-error

process; however, this approach can be adopted at different sites and it will not take a long time to reach co-creation.

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Conclusion

Seiji Nakao, Hidenori Harada, and Taro Yamauchi

The Sanitation Triangle as an Interdisciplinary Approach for the SDGs

For the achievement of the SDG 6.2 (sanitation target), more consideration is required regarding the socio-cultural aspects of global sanitation. As mentioned in Chap. 1, one of the reasons for the failure of the MDG 7-C (sanitation target) is technocentric views and relative socio-cultural ignorance; unlike the MDGs, the SDGs emphasize equity in the realm of sanitation for people in vulnerable situations that have been caused by socio-cultural factors. In addition, health and technology are indispensable for addressing the problem of sanitation. Poor sanitation harms health, and technology is crucial for the formation of sanitation systems. In other words, the SDGs demand a new approach that considers not only health and technology but also socio-culture. Within this background, this book introduces the Sanitation Triangle, an interdisciplinary approach of WASH, especially focusing on global sanitation, including humanities and the social sciences. The Sanitation Triangle is based on the concept that sanitation is composed of three components: health, material, and socio-culture. It also indicates interconnections between them. Through its simple definition, the Sanitation Triangle provides new ways of thinking about sanitation.

First, the Sanitation Triangle proposes the problems of sanitation as a misconnection between the realms of health, materials, and socio-culture. As indicated in Chaps. 3 and 8, which show the uneven allocation of health risks in a particular society, such problems of sanitation are the cause of health risks not being considered as social problems in each society. This point also provides the key to the solution, as seen in the case study of Chap. 9: researchers and youth groups can share

S. Nakao (✉) · H. Harada
Graduate School of Asian and African Area Studies, Kyoto University, Kyoto, Japan
e-mail: nakao.seiji.2i@kyoto-u.ac.jp

T. Yamauchi
Faculty of Health Sciences, Hokkaido University, Sapporo, Hokkaido, Japan

Research Institute for Humanity and Nature, Kyoto, Japan

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the local problems of sanitation using photo-voice and its exhibition. This represents a trial to "socialize" the sanitation problem through Participatory Action Research (PAR) and to connect two components (health and socio-culture). The misconnections between materials and socio-culture are also found in Chap. 5, which shows that the materials for Menstrual Hygiene Management (MHM) are not matched in the socio-culture, such as can be seen with relatively expensive sanitary pads and inadequate settings for their disposal. Chapter 5 proposes "safe" and "clean" sanitary pads for the local socio-cultural context, so the key to the solution is also found in the interconnection of materials and socio-culture. Chapter 11 provides a good example of such an interconnection; new technological configures, new networks of engineers, private companies, and local administrations to make it embedded in society. Furthermore, Chaps. 4 and 13 show the attempts to connect materials and socio-culture by the creation of chains among local actors along with the flow of material; Chap. 13 shows a case of co-creation in which the researchers themselves join the networks of the actors. The Sanitation Triangle detects problems and provides clues to approach them.

Second, the Sanitation Triangle promotes an interdisciplinary approach. Even though the above chapters were written and analyzed by researchers from different disciplines, they discuss common themes. As a typical example, the history of sanitation works in India, written by a cultural anthropologist (Chap. 3), reveals a common problem with the uneven health risk allocation in Vietnam shown by an environmental engineer (Chap. 8). The uneven health risks and conditions between schoolboys and girls in Indonesia (Chap. 7) also demonstrate social allocation. Equity of health risks has also been discussed in ethics and communication between different disciplines. The material matters, including technology, are discussed in different disciplines in Chap. 4 (development studies), Chap. 5 (cultural anthropology), and Chaps. 11 and 12 (sanitary and environmental engineering). All of these chapters take the theme ordinary labeled as "social acceptance of technology," which covers the relationships and the interactions between technology and society. Interestingly, Chaps. 4 and 11 both focus on the process of how new technology has been embedded in a society, and the process itself is the interconnection between technology and society. By presenting the interconnections between the three components, the Sanitation Triangle requires researchers to consider another component on which they do not focus, and, consequently, the interdisciplinary themes have emerged naturally in each study.

Direction for the Future

Sanitation encompasses different spheres of social life. In Chap. 1, we write that sanitation is a "total social phenomenon" that is an ensemble of religious, legal, moral, political, economic, and esthetic matters. Although we do not fully discuss all of these topics, several chapters indicate some of the potentials derived from this idea.

Sanitation inevitably requires an ethical attitude toward sanitation. Chapter 3 addresses the morality and politics of the burden of sanitation workers and shows the ethics of M. K. Gandhi, which is crystallized in the word "*swaraj*" (self-rule), poses one of the critical questions on sanitation: Who should conduct sanitation work for society? Certain members of society engage in sanitation work in a way that entails health risks and may even be stigmatized, while others shoulder their burdens. Gandhi answers that everyone does their sanitation work on their own, which reflects an ethical attitude of "*swaraj*." His answer might be one of the solutions for the ethical matter on the burden of sanitation works, and the answer to his question may differ in each society and depending on sanitation system. How can equity be achieved regarding sanitation work in society and what should others do for such workers? These questions are the starting point of the ethics of Gandhi, and to conceive a more equitable and fair sanitation system in a society and adapt to the age of the SDGs, the ethics of sanitation is necessary. Some related works, such as Walzer, referred to in Chap. 2, will be a source of further development.

The ethics of sanitation resonates with the insight of Chap. 10 that "post-toilet sanitation use is a public matter." The sanitation service chain is socially constituted beyond one household or small community and is maintained by the stakeholders of remote places and those in different social positions. In this context, the setup of the sanitation system requires the networking of different stakeholders, the coordination of their interests, and the establishment of appropriate decision-making; such a trial is shown in Chap. 13. As discussed in Chap. 10, the impact of introducing a sanitation system is not equally beneficial (and can even be detrimental) for individuals or specific groups, especially those who are in vulnerable situations, and the optimal solution as a system is not always the most advantageous for everyone. This point also requires the consideration of sanitation as a public matter. Such an uneven allocation of benefits (or worse) from sanitation could be socially componentized by the legal or communal framework. In other words, to create a sustainable sanitation system, sanitation should be considered a public matter.

Just as the famous feminist slogan noting that private is political, sanitation as a private matter is not limited to individuals. As discussed in Chap. 6, individual health conditions are determined by the socio-cultural situations related to sanitation, and the safety and dignity of an individual in a sanitation service are or should be considered social problems. Chapter 9 describes the trial of the "socialization" of private matters on sanitation through PAR, and it provides the potential of the visualization of sanitation problems to share personal recognition of the problems and develop common concerns about them. Visualization is a tool that attracts people's attention, and it can be a means to make up the starting point of discussion for collectively building consensuses and better solutions. At the same time, it can also be said that visualization is a tool for recognizing social problems as one's own problems. The recognition and sharing of the problems make them "our" problems in society. Therefore, the "socialization" of a private matter includes two sides of the same coin: someone's private matter becomes that of society and other people consider that matter as their own. Visualization promotes both sides through PAR. The aim of visualization is not to directly change the behavior and attitude of

individuals, but to make a private matter of concern about sanitation more visible to build social recognition of the problems and reach toward a solution. Visualization is not a method for quick resolution, but it also has the potential to find an alternative approach to global sanitation with regard to the sustainability of the sanitation system.

Rather than suggesting hasty solutions, the Sanitation Triangle and these potentials provide a perspective for a better understanding of the problem, identify the conditions required for a sustainable sanitation system, and present approaches to achieving those conditions, such as PAR, visualization, and co-creation, by networking the different stakeholders. These ideas and approaches are elaborated through the long-term and intensive discussion among different disciplines, and this book is the result of this interdisciplinary cooperative work. However, this book does not represent an end; the discussion and trial will continue, and we hope that this book evokes other discussions and trials at other times and places regarding global sanitation.