SANITATION VALUE CHAIN

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CONTENTS

Original Articles:

Development of Sanitation Toward Sustainable Society

Tetsuya KUSUDA[1]

[1] The Advanced Research Institute, Kyushu University, Japan

Abstract

Hygiene and sanitation are basic human needs to reduce health risk and to increase comfortability in living. Any sanitation system should meet requirements on a sustainable society, which conceptually differ from current systems in developed countries. Requirements on a sustainable society based on strong sustainability are stated in detail. Since the development of sanitation systems should be based on technology, social capitals and economy in the society, these items are discussed in detail. Sanitation systems in developing countries should not directly transferred from those in developed countries. The systems may dynamically change in functions due to social conditions and needs in a region, so that the sanitation systems should be flexible. The sanitation system may create several values. Sanitation value chain is one of them, which brings benefit and incentive for self-operation of sanitation to local societies. This sanitation value chain may be disturbed by global and wide-regional economy systems, so that local currency is recommended to be introduced to the local society.

Keywords: sanitation, sustainability, sustainable society, economy, local currency, social capital, culture

Introduction

Hygiene and sanitation are basic human needs to reduce health risk and to increase comfortability in living. Therefore human beings have been burdened by liquid and solid wastes discharged by themselves, since they had started to live in groups. Then handling and treatment of disposals of liquid and solid wastes as well as water supply have been critical items at anytime and anywhere. Sustainable Development Goals (SDGs) adopted by United Nations General Assembly in 2015[1)], which followed Millennium Development Goals (MDGs) established in 2000[2)], indicate one goal on hygiene and sanitation. Goal 6 of SDGs says "[e]nsure availability and sustainable management of water and sanitation for all."[1)] This means good sanitation is indispensable as same as eradication of hunger for our lives. In SDGs having 17 goals with 169 targets, all targets are expressed in detail on the basis of the concept of sustainable development. Sustainable Development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" in the report "Our Common Future" (commonly called the Brundtland Report) released by United Nations World Commission on Environment and Development in 1987 (WCED 1987). Because of the meaning of the phrase, Sustainable Development, is a sort of political one to reach mutual agreement in the United Nations General Assembly, it is slightly vague, but not inanity. SDGs are ones to strive for and do not state neither how to achieve the goals nor who defrays the expense at all. Furthermore SDGs express that the achievement of them makes human beings get

1) 70/1. Resolution adopted by the General Assembly on 25 September 2015, "Transforming our World: The 2030 Agenda on Sustainable Development," United Nations, 21 October 2015. https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_70_1_E.pdf (Accessed April 8, 2019).
2) 55/2. Resolution adopted by the General Assembly, "United Nations Millennium Declaration," United Nations, 18 September 2000. https://www.un.org/millennium/declaration/ares552e.pdf (Accessed April 4, 2019).

close to the sustainable society, SDGs, however, do not explain the possibility for human beings to definitely reach a sustainable society. Then processes of the transition from the present stage to a sustainable stage are to be created and established based on the idea of Sustainable Development, even in sanitation.

In this paper, in order to develop a methodology on the development of sanitation toward sustainable society for developing countries, basic concept of and requirements in sanitation development, the development of sanitation to sustainable society, and value-added sanitation are discussed.

1. Basic concept of sanitation development

Sanitation in all of the regions has a long history and characteristics reflecting local situations such as culture, climate, geographical features and population. According to Ushijima et al. (2015; 2019), sanitation is divided into three phases in progress; Primitive Sanitation, Modern Sanitation and Postmodern Sanitation. Main points for this classification are simplicity and the cost of the sanitation system, controllability of pollutants and pathogens, safe separation of excreta from living areas, and treatment and disposal methods of wastes. Primitive Sanitation is simple and low in cost such as open defecation without safe separation. Modern Sanitation equips technologies on safe separation and disposal of human excreta from human living environment. Postmodern Sanitation is defined as a system technology with safe separation and recycling of human excreta as resources like fertilizer to construct a value chain in society.

Sanitation, however, has not been developing in course of time. It develops depending on social needs, culture, etc. In Japan as an agrarian society, Primitive Sanitation system had been working until around 1955 in local towns. Excreta had been collected by farmers in towns and villages since the Edo era (1600 to 1867) and they were exchanged for grown vegetables such as radish and turnip. This resulted from that excreta were valuable as fertilizer for farmers. After chemical fertilizers were supplied in the commercial base, farmers quit using excreta and started using chemical fertilizers instead, because of cheapness, easy handling and time saving. Then the service of the collection of excreta was transferred from farmers to municipalities, that is, from private business to public service. In Japan, collected excreta in many municipalities except large municipalities like Tokyo, Osaka, and Yokohama which had own wastewater treatment plants until 1950, had been dumped directly to oceans without any treatments until the ratification of Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter in 1980 which was signed by the Japanese Government in 1973. The convention went in effect in 1975 in Japan. In 1980s due to a steep rise of fertilizers and energies in price by “oil shock,” major municipalities started to recycle and reuse treated wastewater and sludge in wastewater treatment plants. In the 21st century, according to lowering the price of phosphate, many municipalities were deeply discouraged to recover it. Some municipalities moved to produce value-added compost and/or solid fuel due to rise in the cost of landfill. This means that active recycling of excreta is controlled under economy. The difference of the costs has been compensated with tax and/or utility charge of sewerage. Since chemical fertilizers are international goods and cheaper than composts made of excreta, this economic phenomenon may happen now and in future even in developing countries. Active recycling of resources supported by social needs differs from the passive one. The active recycling of excreta may produce value-added compost which is suitable for specified local crops and vegetables. Recent rise in motivation of recycling of excreta as compost and solid fuel by municipalities is partly supported with reduction in emission of carbon dioxide and saving fossil fuel.

The development of sanitation in urban areas except for ones close to cultivated fields has been influenced by expansion of urban areas as well as increase in population and population density. In Paris, France, the construction of a covered conduit started in 1374, which transported wastewater including excreta from the castle zone to the

Seine River. Until sewers were constructed, road sweepers had been collecting excreta disposed from verandas of buildings along streets. In 1824, the total length of the sewer in Paris only 37 km. In 1832, on the opportunity of cholera breaking Paris Municipal Government started seriously to tackle the construction of sewers, 7 to 8 km long a year for the reduction in health risk (Chatzis and Coutard 2005; Omori 2014; Kesztenbaum and Rosenthal 2017). Even nowadays the concepts of wastewater treatment in Paris have been unchanged; they are drainage and treatment. In this way, traditional culture rules the concept of wastewater treatment at present.

From the standpoint of sustainable society, developed countries have been trying to get close to it, but they are still far from it. They, having experienced rapid economic growth with deterioration of the nature, have been still consuming plenty of fossil fuels and non-renewable natural resources and discharging plenty of wastes to the nature with pollutants and nutrients. The deterioration has been lasting even if it is not as severe as before. Developing processes and routes which the developed countries took were not a straight way such as the deterioration of nature which was followed by the restoration of nature. Since the goal of the routes had been only abundance in living for individuals and not establishment of a sustainable society for a long time, nowadays they have been trying to convert current societies and individual lifestyle to sustainable ones. This is a sort of detour toward sustainability. The detour, however, does not guarantee the attainment of sustainability. Then developing countries should not trace the ways taken by developed countries. The developing countries should take the shortest and direct way to a sustainable society from now on, instead. The way is not to adopt a lifestyle and a social system in developed countries, but to create a smart lifestyle and a social system with recycling of materials, balanced usage of natural renewable resources and favorable social capital to increase solidarity.

2. Concept of and requirements in sustainable society

In order for a developing country to directly establish a sustainable society, people have to take a different way as mentioned above. In this chapter, requirements in sustainable society are discussed based on the concept of strong sustainability.

The sustainable society is defined as a society sustaining from present generation to future generations, in which all people esteem humanity, have work to realize their own dreams with their own specific character under blessing of the nature, live with healthiness and wellbeing, may have contacts with friends and society with high quality of culture, and have a stable social system.

Sustainability itself ranges from strong to weak. The strong sustainability is for a society to value the nature highly. The weak is to expect the development of technology to compensate the loss or degradation of the nature. Discussion of this paper is based on the strong sustainability.

Sustainable society which meets the above definition has to provide a variety of items for the society and people such as materials, energy, economy, technology, regulations and governance.

Materials such as adequate food, substances for living, spare parts for industrial and agricultural production, etc. have to be supplied.

Energies should come from renewable energies such as solar and geo-thermal energies. The energy with difficulties on risk control and its waste management like atomic energy should not be used in a sustainable society. Regulations of energy usage should be strict to protect sustainable society.

The current economy system in the developed countries is based on capitalism, which approves the private ownership of the means of production and their operation for profit. Major characteristics of capitalism are private property, capital accumulation, wage labor, voluntary exchange, a price system, and competitive markets. In business, decision-making and investment are determined by every owner of wealth, property or production ability

in financial and capital markets, whereas prices and the distribution of goods and services are mainly determined by competition in goods and services markets. Investment of accumulated capital brings interest to the investor except the Islamic world where Islamic religion prohibits earning interest with loan and saving. Market economies exist under many forms of government and organization in many different times, places and cultures. The scale of economies has been expanding in region and in time. Some enterprises expand markets all over the world as globalization of economy. They are rather independent of countries and frequently move their head offices to countries with more profitable regulations including taxation system. Developing countries have much cheaper labor force as well as larger markets, where are attractive places to earn profit and to increase capital for enterprise based on developed countries. To keep local economy sound for local people and to head toward sustainable society, a legally restricted economic system should be adopted. Economy transformed to meet sustainable society is to be sustained over a long run. Since the capitalism essentially pursues benefit, the interest rate is very low in sustainable society. The index of economic growth, GDP, is not appropriate to express the state of economy. GDP is only seen not the index of quantitative increase, but qualitative improvement in sustainable society. The form of consumption is also different from the current one. Since it has been seeing to arrange the goods in such a way as to encourage customers to buy, consumption propensity of individuals should be converted.

Regarding technology, the most rapidly developing one is the artificial intelligence (AI). AI is anticipated to overtake human intelligence around 2045. This is called the technological singularity, which is a hypothetical future point in time at which technological growth becomes uncontrollable and irreversible, resulting in unfathomable changes to human civilization (Eden and Moor 2012: 1-2). In order to avoid to reach the singularity, excess use of AI is to be hesitated. Limits are to be set for the usage of technology even in sanitation. Animal husbandry and agricultural industry in terms of gene technology progress rapidly. Major gene technologies on them are occupied by global enterprises. Even in developed countries, farmers have to buy hybridized seeds every season because the seeds they harvested have not the same characteristics as the hybridized ones. In sustainable society, the hybridized seeds should not be supplied at commercial base.

Governance is especially important. Global regulation, such as no increase in the concentration of carbon dioxide, needs an organization for decision-making under a rule. The rule at this moment is "decision by majority." In order to keep stability of the society, people cannot deny no excess emission of the green-house effect gases (GHGs). This means that the democracy with "decision by majority" has to be improved and sometimes denied due to human nature with desire. Other important requirements for sustainable society are no war, no terrorism, no free-rider for environmental protection, frugal life style, etc.

In the sustainable society, people can not only survive, but can enjoy their lives. The former state is called sustainability with low quality and the latter, one with high quality. Its quality depends on the choice of people in future.

Since sanitation is deeply concerned with natural resources, economy, agricultural and scientific technologies, and local communities, these items are discussed below.

Herman E. Daly, environmental economist, focusing on the utilization of natural resources, indicated following principles on sustainable society (Daly 1991; 2005; Daly and Cobb 1994):

(1) Limit use of all resources to rates that ultimately result in levels of waste that can be absorbed by the ecosystem.

(2) Exploit renewable resources at rates that do not exceed the ability of the ecosystem to regenerate the resources.

(3) Deplete non-renewable resources at rates that, as far as possible, do not exceed the rate of development of renewable substitutes.

The above mentioned principles are based on rates of input and output. Another important item he stated is as follows:

(4) Birth rates must equal death rates, and production rates of commodities must equal depreciation rates.

Kerry Turner, et al. expressed toward sustainable society as follows (Turner et al. 1993: 59-61):

(1) Value resources appropriately and adjust the failure of intervene in the market on the right of ownership.

(2) Keep regenerating capability on renewable natural capitals and avoid excessive pollution to lower purification capability on wastes and to deteriorate biological systems to maintain lives.

(3) Encourage technology development to convert non-renewable natural capitals to renewable ones.

(4) Use renewable natural capitals not to exceed rates of the development of renewable substitutes.

(5) Limit the scale of economic activity not to excess carrying capacity of remaining natural capitals.

Daly stated principles for sustainability on the usage of natural resources and Turner focused on economy. In addition to the above items, several items have to be added for the nature protection and conservation:

(1) Reduce the amount of accumulated hazardous materials and keep them not to give impact to human beings and other creatures. Keep the cost for surveillances naught.

(2) Quit excess use of natural resources immediately without expecting the development of technology like efficiency rise.

(3) Nurture the nature with redundancy and antagonism.

(4) Be not devastative, but nature-nursing on technology.

(5) Accept self-transition of the nature.

As stated above, requirements in sustainable society are almost understood from a variety of aspects. However, methodologies to proceed to a sustainable society from the present state have not been clear and not established yet. The methodology depends on local conditions. Major basic items on the local conditions for the development of sanitation to sustainable society are, by local people, understanding of importance on hygiene and sanitation, manageable sanitation systems in cost, labor and knowledge, motivation to construct and operate a sanitary system as well as benefit to them. These are to be appropriate for all.

3. Major items for the development of sanitation to sustainable society

Without tracing developing routes taken by developed countries, a developing country should step up the shortest developing route which is determined by back casting from the targets of sustainable society. Crucial points of the design of a developable sanitation system after setting the targets are manageable, operable, maintainable and valuable for local people. These points are discussed below from the standpoint of technology, social capital, and economy system on sanitation. The technology is directly related to planning, construction, operation, control and maintenance of a sanitation system. Social capital is related to management and usage of the system including raising experts. Economy system gives an impact to recycling of wastes.

3.1. Technology

The technology, itself, has a characteristic of self-evolution and its evolution brings unexpected phenomena in multi-aspects to users and societies like AI technology. Martin Heidegger called it as “Gestell” (Heidegger 1957). He stated that a person as an individual loses himself or herself in big organized societies and huge mechanical systems. As he stated, most of modern technologies are big in system, large in scale, highly consumptive in energy, not environmentally sound and difficult or impossible to repair by users. Technologies like those he stated do not fit to sustainable society. Technologies to be contrived should be applicable to sustainable society. The technology

ranges from simple to difficult ones to handle. The former corresponds to sustainability with low quality and the latter does with high quality. The technology has to differ from modern technologies on concept and design. This means that the technology in developed countries should not be transferred directly to developing countries.

Ernest Schumacher proposed appropriate technology (in other words, intermediate technology) which is small-scale, decentralized, labor-intensive, energy-efficient, environmentally sound, and locally autonomous (Schumacher 1973). In the sanitation system, several items are needed additionally such as low cost, low health risk, resource-recycling, and culture friendly. For sanitation systems, construction materials also should be supplied inside the targeted region. Energy for operation is to be renewable ones such as photovoltaic solar panels, small solar power, wind power, micro hydropower and/or human or livestock-powered wheel generators.

There are many types of toilet, ranging from dry toilets including composting toilets urine-diverting dry toilets to constructed wetland and lagoons. An appropriate type of toilet should be chosen to meet needs and demands of the users and other stakeholders. There is no 'one-size-fits-all' sanitation system. Applicability of technology is also under behavioral changes and management as well as political aspects in the society. There are many examples. Simple ones are like SanPlais and Arborloo. The SanPlais is a simple plate that can be used to cover the hole in the ground of pit latrines making them potentially easier to clean and maintain (Brandberg 1991). The Arborloo is a simple type of composting toilet in which feces are collected in a shallow pit to make fertile soil of the full pit (Morgan 2007: ch. 3). Rather complex ones are a urine-diverting dry toilet (UDDT) and a constructed wetland system. UDDT collects feces and urine separately without any flush water (Rieck et al. 2012). The constructed wetland system is a shallow pond, sometimes connected another one. The system receives gray and black waters from housings and industries, in which organic substances are decomposed by bacteria and coarse and fine particles may remove by settling down. Other water quality constituents are also removed by vegetation (Dotro et al. 2017). There are many devices and systems proposed and installed on sanitation. There are, however, few devices and systems which fit for a local condition. Recycling of excreta as fertilizer and/or solid fuel is an ideal way for sustainable society. A better appropriate toilet system fitting for a society has to be contrived depending on local culture and developing stage. An appropriate type of toilet has to be developed according to the development of a society even in sustainable society.

3.2. Social capital

Social capital proposed by Robert Putnam is defined as social functions by social groups with interpersonal relationships, a shared sense of identity, a shared understanding, shared norms, shared values, mutual trust, cooperation, and reciprocity (Putnam 2001: 22-23). The social capital is divided into 3 groups; (a) resources like public spaces, private property, and human capital of people themselves, (b) the relationships among these resources, and (c) the impact that these relationships have on the resources involved in each relationship and larger groups. Social capital has functions such as the improved performance of diverse groups, the superior managerial performance by leaders, improved supply chain relations, sharing the value derived from strategic alliances, the evolution of communities, etc. One of the elements constituting social capital is human relations with trust, cooperation and reciprocity.

The concept by Robert Putnam has both sides on praise and criticism on the lack of awareness of the structural socio-economic conditions of society (Skocpol et al. 2000) and the excessive determinism of the historical analysis because of less data on consideration which came from difficulties to collect data. Quantification of social capital is difficult to estimate, but efficient to make a plan and to operate well.

Sanitation system is usually managed, operated and maintained in a local group, so that the group should be formed by people in terms of social capital. Outsourcing of the system should be avoided because it could be a

target of benefit. Local government and/or leaders are requested to make extraordinary efforts to enhance social capital and collaboration as a part of governance.

3.3. Economy system

On economy, the main idea on sustainability is to shift the path of progress from economic growth which is not sustainable, to stable economy in sustainable society. As stated above, in sustainable society, investment would be mainly for replacement and qualitative improvement, instead of speculation on quantitative expansion, and would occur less often. GDP is not expected to increase considerably, but the qualitative improvement in design of products and services may make GDP increase without increasing the amount of resources used.

Recycling of solid and liquid wastes brings several values to individuals and the society such as conversion of awareness from payer to seller, fertilizers as resources, comfortability in living and pollution control as cleanness. The conversion of awareness from payer to seller means that stopping payment for the treatment of wastes and earning money with self-operated sanitation system, instead. These values are precious and are not converted directory into monetary values. Once a sanitation system is involved in the business world, especially as a part of the global business, the value is appraised as only a resource and the other values may be neglected. Therefore the sanitation system with the recycling of wastes should be partly isolated from the capitalistic economy. One example of the isolation from capitalistic economy is to introduce local currency with a different value unit such as consumed time.

A sanitation system in a region is an infrastructure. Design, construction, operation, maintenance of the system are related to plenty of items, technology, supports by society, economy, governance and so on. These elements are not independent, but internally related each other. For instance, applicable technologies in a region are related to experts in it and the experts as well as rather independent economy are supported by the power of social capital. The social capital forms culture and culture creates new ideas and innovation on technology and social system. Especially technology, social capital and economy stated above are key elements including governance.

4. Development of value added sanitation

4.1. Sanitation system and micro economics

Sanitation is a public infrastructure even if how small the community is. There are many ways to add values to sanitation systems such as sanitation value chain and social capital enhancement in addition to health risk reduction, nature protection intensification, and recycling resources as stated in the previous chapter. These items are included in the concept on smart sanitation.

Sanitation value chain may bring many benefits such as a solution to lessen gender problems with cash income especially for women (Ushijima et al. 2015; 2019). It could be double-edged sword. On installing it, other problems may emerge on micro economics.

The first is local culture on capitalism. If capitalism in the region is a kind of the traditionalism, local people may not want to increase their daily income above which they need for their daily lives. They may not have enthusiasm to earn more money as culture which is sometimes seen in Latin America.

The second is expectation on the market mechanism. Local people involved in the value chain system might be disappointed and lose their own motivation if the value of their products would be cheaper than expected by "invisible hand" in economics.

The third is an economic mechanism over the region. If someone could produce fertilizers more economically and agriproducts at cheaper cost, they could get more benefit in the competitive business world based on capitalism.

In this case, this sanitation value chain could be merged into the more profitable system, in particular, by a global enterprise or a strong national enterprise.

Methods to protect local markets not so as to be merged into other ones and to hold this value chain should be designed at the first stage to reduce risk and to increase economic resilience in the targeted region. In some areas in Africa, excreta collection for agricultural use has already started by private sectors (Tarrow 1996; Otoo 2018). This means excreta collection could be profitable and it is unnecessary for municipal service to do it. The finance to start up and to get hold of technicians could be targets of official supports for privatization.

Local markets for goods and services are protected from the invasion of private business. Based on environmental soundness, local production and local consumption is recommended. Methods to avoid the invasion are firstly to construct an extended value chain within a community including not only sanitation, but also solid waste recovery and secondly local people should use local currency to have the right of decision for these valuables in the region.

Local currency is called regional currency and community currency. Local currencies are not legal currencies, but have different functions from them. Local currencies are complementary ones and only accepted within the community, which can purchase of locally produced and locally-available goods and services. This means that any key currency is difficult to enter the local community, in other words, more of the benefit accrues to the local community and less drains out to other parts of the country or the world. Local currencies enable the community to more fully utilize its existing productive resources, especially unemployed labor and reciprocity of residents. When legal currencies circulate less than demands, local currencies work well and encourage efficient use of local resources. Local currencies are utilized in many regions with different purposes.

4.2 Sanitation system and local culture

Sanitation system is operated usually by homemaker, in particular by housewives. When they have much free time, they could handle sanitation. Modernization brings free time to homemakers, but in the previous stage of modernization they might not have free time enough to handle sanitation system. How to make free time for them should be in mind. Free time and money is exchangeable in capitalism. Religious and animistic taboos should not be violated for installment of sanitation systems. Abhorrent actions are not to be adopted in the sanitation value chain system. The social capital brought by human relationships in a community is an important factor for success of the sanitation value chain system. Sympathy and identification of people in a community may create innovation on the sanitation value chain system toward sustainable society. Cooperation and collaboration in a community is a key word for success. Religious background is also respected as an important local culture. Therefore the design of toilet should be based on religion, custom, and norms of people.

Conclusion

Hygiene and sanitation are basic human needs to reduce health risk and to increase comfortability in living. Sanitation systems should meet requirements on sustainable society, which conceptually differ from current systems. Detailed requirements on the basis of strong sustainability are stated in this paper. Since the development of sanitation systems should be based on local culture, living standards, lifestyle, technology, norms and so on in the society, the major three items of them; technology, social capital and economy are discussed in detail, including mutual relationships.

Sanitation systems may dynamically change in functions due to social conditions and needs within allowable limits for sustainable society, so that the sanitation systems should be flexible. Sanitation systems in developing countries should not directly transferred from those in developed countries which do not meet conditions for

sustainable society. Sanitation value chain may bring benefit and incentive for self-operation of sanitation to local societies. Sanitation value chain may be disturbed by global and wide-regional economy systems, so that local currency is recommended to be introduced to local societies. This currency system may also bring an economically isolated state to local societies, the societies are, however, able to enhance their social capital. The design of sanitation is also of importance so that sanitation in a region should be designed by desire of local people.

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Handwashing Skills, Hand Bacteria Reduction, and Nutritional Status of Elementary School Children in an Urban Slum of Indonesia

Lina AGESTIKA[1], Yumiko OTSUKA[1], Widyarani[2], Neni SINTAWARDANI[2], Taro YAMAUCHI[1,3]

[1] Graduate School of Health Sciences, Hokkaido University, Japan

[2] Research Unit for Clean Technology (LPTB), Indonesian Institute of Sciences (LIPI), Indonesia

[3] Research Institute for Humanity and Nature, Japan

Abstract

Currently, Indonesia is a developing country with awareness and involvement in a community-based total sanitation program. One pillar of this program is handwashing practice as a prevention from an infectious disease, since many studies revealed a lack of handwashing behavior leads to bacterial contamination from hands. School children are the most vulnerable to bacterial contamination which can lead to nutritional problems. On the other hand, over population and poor-infrastructure also contribute to a lack of sanitation and personal hygiene, and these play important roles in child behavior. Therefore, this study aims to analyze handwashing skills among school children based on World Health Organization (WHO) guidelines regarding hand bacteria reduction and child nutritional status in an urban slum of Indonesia. We conducted a cross-sectional study on elementary school children in the urban slum of Bandung. Participants were the 6th grade children (11 to 14 years old). Forty-one children (24 boys and 17 girls) participated in this study. Our measures were: 1) handwashing skill observation using a checklist, 2) hand bacteria assessment before and after handwashing using a swab, and 3) child anthropometry (height and weight measurement). The association among handwashing skill, handwashing's total time duration, and bacterial assessment were analyzed using Spearman's rank correlation tests, comparison between hand bacteria before and after handwashing, and between handwashing skill and child nutritional status were studied using paired t-tests and t-test, respectively. Results showed that handwashing reduced the *E. coli* count by 0.70 log CFU/hand. Allocating time specifically to pouring water before lathering significantly lowered *E. coli* count after handwashing. Moreover, neglecting hand drying was identified as a potential factor that caused hand contamination and lowered child nutritional status.

Keywords: child handwashing skill, E. coli, pouring water, drying hands, child nutritional status

Introduction

Child mortality rates due to malnutrition are approximately 860,000 children per year and of those cases 50% feature unsafe water, inadequate sanitation, or insufficient hygiene as a cause of death (Prüss-Ustün et al. 2008). Having insufficient sanitation facilities with poor hygiene behavior will likely result in diarrhea and other related illnesses. In other words, sanitation and hygiene are inseparable in terms of their impact on human health (Cairncross et al. 2010). Even where sanitation facilities are accessible, bacterial contamination on children's hands occurs when handwashing practices are neglected (Greene et al. 2012). Therefore, the Sustainable Development Goals (SDGs) set Water Sanitation and Hygiene (WASH) as a key driver of progress on many SDGs, especially

child health and nutrition (IFPRI 2016).

Handwashing is one of ways to lower the risk of diarrhea and acute respiratory infection (Rabie and Curtis 2006; Luby et al. 2010). Unfortunately, only 19% of all people worldwide practice handwashing after contact with feces (Freeman et al. 2014). It was estimated that 297,000 deaths from diseases could be prevented by the promotion of hand hygiene (Prüss-Ustün et al. 2014). Recent studies have found that adult handwashing skill and duration relates to total bacteria reduction (Lucet et al. 2002; Jensen et al. 2015). However, there are limited studies of this nature conducted in children which investigate potential contamination processes in the context of actual living conditions (Pickering et al. 2010). Our latest study revealed that inadequate handwashing skills among children was a contributing factor towards impaired growth (Otsuka et al. 2018b).

Indonesia is one of developing countries dealing with water, sanitation, hygiene, and malnutrition problems (NIHRD 2013). Recently, urbanization has led to a proliferation of slum areas which suffer from insufficient sanitation infrastructure and poor access to clean water, bringing challenges to the practice of good hygiene behavior (Tarigan et al. 2015). It was shown by the National Survey from Indonesian Ministry of Health (NIHRD 2013) that proper handwashing rates at critical times in Indonesia only reached 47% even though handwashing facilities were found to cover more than 90% of the population. School is a crucial institution for encouraging the development of healthy and hygienic behaviors using the bottom-up approach, through children (UNICEF 2012). Therefore, having insufficient sanitation and hygiene infrastructure at school can lead to a failure in the wider development of good hygiene practices and behaviors.

This study aimed to evaluate elementary school children's awareness of handwashing skills based on WHO hand hygiene guidelines and their effectiveness in reducing total hand bacteria. We also aimed to analyze the relationship between handwashing skills and child nutritional status in an urban slum of Indonesia.

1. Method

1.1. Study area

The study area was selected purposively as one of the urban slum areas in Bandung city. Bandung city is the capital of West Java, Indonesia, with a total population of 2,490,622 registered residents (Badan Pusat Statistik Kota Bandung [BPS-Statistics of Bandung Municipality] 2017). We selected Bandung city because Bandung is currently facing issues related to environment and health. Bandung has challenges as a result from spatial and urban development. This is presenting problems including the proliferation of slum areas which suffer from limited sanitation, poor drinking water, inadequate solid waste management, and a lack of access to clean water (Tarigan et al. 2015). Kiaracondong, as the 3rd highest populated district area (*Kecamatan*) in Bandung city with total population of 132,135 (Badan Pusat Statistik Kota Bandung 2017), was selected as the study area. This area has one elementary school located within the slums, with improper sanitation facilities and handwashing station; this became the research site. Detailed information on this research location are provided elsewhere (Otsuka et al. 2018a). The location of Kiaracondong, Bandung City, is indicated in Figure 1.

1.2. Study design and participants

This study collected data on children's handwashing skills, total hand bacteria (before and after handwashing) and child anthropometry (weight and height). This was a cross-sectional study with a purposive sampling method. Participants were elementary school children in the 6th grade, ranging from 11 to 14 years of age. The 6th grade students in elementary schools were selected because of their ability to follow the study procedure. A total of 41 elementary school children (24 boys and 17 girls) took part in this study. Their handwashing skills were observed

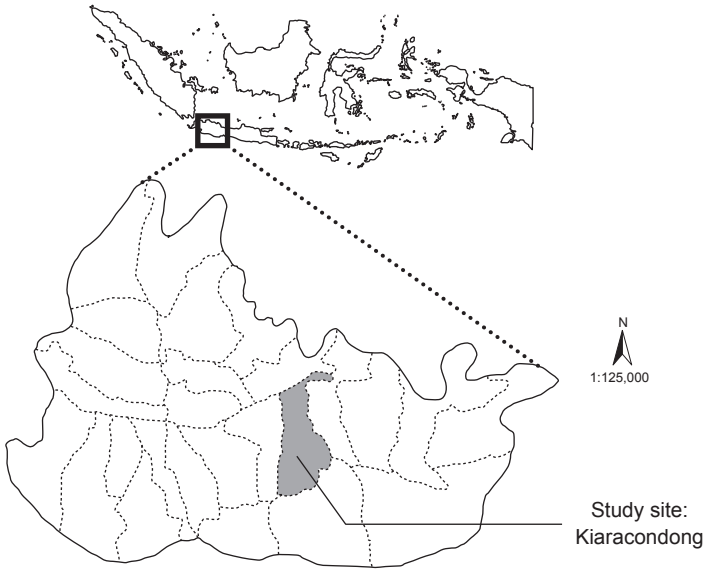

Figure 1. Study site location, Kiaracondong, Bandung, Indonesia.

using a checklist modified from WHO guidelines on handwashing for healthcare. Socio-economic status was ascertained through household monthly income and the total number of family members living in the household. The information of the school handwashing facility was also collected as supplementary data.

1.3. Procedure and measurements

Handwashing skill

Children were asked to perform their daily handwashing practice. All materials such as tap water, a water bucket with scoop, bar soap, liquid soap, and paper towels were provided by the researchers. The outer side of the liquid soap container and the bar of soap, as well as the inside of the bucket and scoop, were cleaned with water before performing handwashing but were not sterilized. We did not control either water temperature or water quality for handwashing and consider those as real conditions of the participants' living environment. The handwashing checklist was based on a modification of the hand hygiene guidelines for health care from the WHO (Figure 2), as explained elsewhere (WHO 2009). We used the checklist for every step followed by children in their handwashing behavior and used this to provide a score (maximum of 10). The time duration (1st step, 3rd-8th step, and 9th step) for handwashing was measured using a stopwatch.

Total bacteria measurements

Hand bacteria were collected before and after handwashing using 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, Japan). Before children demonstrated their handwashing skill, 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 samples were kept on ice and transported to a field laboratory within 4 hours after sampling. Total bacteria analysis was conducted at the Research Unit for Clean Technology (Loka Penelitian Teknologi Bersih: LPTB), the Indonesian Institute of Science (Lembaga Ilmu Pengetahuan Indonesia: LIPI), Bandung. Samples were processed in the laboratory by membrane filtration to detect *E. coli*. Under aseptic conditions, each sample (10 mL) was divided into low and high volumes (1.0 and

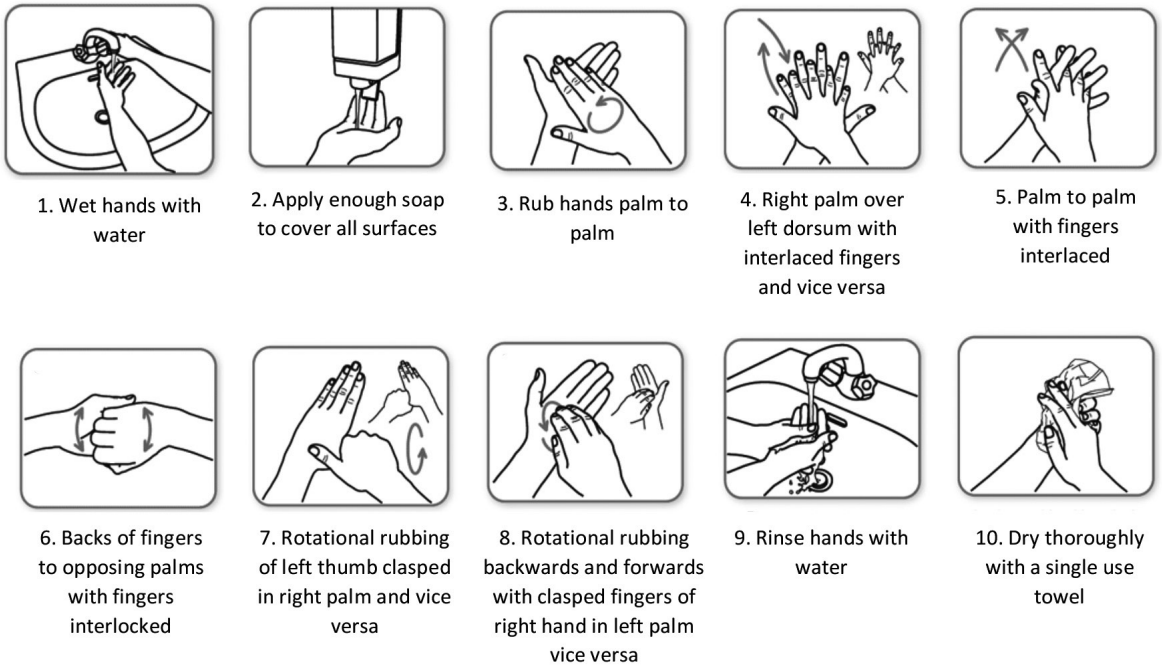

Figure 2. Modification of WHO guidelines on hand hygiene in health care. (WHO 2009)

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 on XM-G growth media (XM-G; Nissui Pharmaceutical Co., Japan) and incubated at 37°C for 20 ± 2h. The bacterial load on each media was read as colony forming unit (CFU) counts per hand. *E. coli* was determined by size and color of the colony (i.e., a blue and purple colony bigger than 1 mm). The *E. coli* bacteria count was converted to log CFU per hands. The changing of bacteria count was (the bacteria count before performed handwashing – the bacteria count after handwashing). The bacterial reduction was marked as positive results, while bacterial increased was marked as negative results.

Body measurements for nutritional status

Body weight and height for all children were measured to calculate their nutritional status. Height was measured to the nearest 0.1 cm using a stadiometer (Seca 213; Seca, Germany), and body weight to the nearest 0.1 kg using a digital weighing scale (BC-754-WH; Tanita, Japan). With reference to WHO growth data, for children above 5 years old and adolescents, child nutritional status is determined by using z-scores from height for age (HAZ), weight for age (WAZ), and BMI for age (BMIAZ) (De Onis et al. 2007). However, to have comprehensive result of all nutritional status category in the Indonesian context, we used the first Indonesian growth chart as standards from Batubara et al. (2006) to calculate z-scores. From this, we classified children based on categories such as a z-score of less than -2 SD (Standard Deviation) as reflecting under-nutrition, between -2 SD until 2 SD as normal, and of more than 2 SD as over-nutrition. Z-score less than -2 SD of HAZ, WAZ and BMIAZ were used to indicate stunting, underweight, and thinness, respectively. In the other hand, z-score more than +2 SD for BMIAZ was used to indicate overweight.

1.4. Statistical analysis

First, we conducted descriptive analysis of mean values and percentages or prevalence. Second, Spearman rank correlation test was conducted between (1) time duration of handwashing and *E. coli* count after handwashing, and

Table 1. Participants characteristics.

Category	Male n = 24	Female n =17	WHO (2009)
Age	12.06	11.88	
Height for age z-score (HAZ)	-0.35	-0.02	
Weight for age z-score (WAZ)	-0.50	-0.30	
BMI for age z-score (BMIAZ)	-0.72	2.06	
Prevalence of child thinness (%)	6.00	0.00	
Prevalence of child overweight (%)	4.00	1.00	
Before (log CFU/hand)	1.69	1.58	
After (log CFU/hand)	1.23	0.99	
Bacterial reduction (log CFU/hand)	0.70 ± 0.45		
	0.65 ± 0.44	0.79 ± 0.48	
Bacterial increase (log CFU/hand)	- 0.59 ± 0.38		
	- 0.81 ± 0.45	- 0.38 ± 0.16	
Handwashing score (step)	5.60	6.17	10
Total time of duration (sec.)	48.87	53.00	40-60
Time 1st step (sec.)	4.70	4.76	NA
Time 3rd-8th steps (sec.)	7.17	7.65	15-20
Time 9th step (sec.)	14.95	13.06	NA

This table was presenting as a mean value or percentage
Bacterial reduction is among children who had reduced *E. coli* count after handwashing n =35 (boys = 21; girls = 14)
Bacterial increase is among children who had increased *E. coli* count after handwashing n = 6 (boys = 3; girls = 3)

(2) handwashing score and *E. coli* count after handwashing. Third, comparisons analysis was done between (1) *E. coli* count before and after handwashing using paired t-test, and (2) child nutritional status and child handwashing skill (10 steps) using t-test. All statistical analyses were performed using IBM SPSS 23 for Windows.

1.5. Ethical considerations

This study was approved by the Ethical Review Committee of The Faculty of Health Sciences, Hokkaido University (No.17-13). This study was carried out under a Memorandum of Understanding (MoU) between the Research Institute for Humanity and Nature (RIHN) and the Indonesian Institute of Sciences (LIPI). All purposes and contents of this study were explained to participants. Parents allowed their children to participate in this study by replying with written informed consent.

2. Results

2.1. Characteristics of participants

Children were the 6th grade elementary school students with age ranging from 11 to 14 years. Ten percent of the children were more than 12 years of age while most were between 11 and 12 years. Those 73% of children lived in households with a monthly income of less than 2,000,000 rupiahs (139.02 USD) per month and 56% lived in as extended family (data not shown). Referring to the first Indonesian growth chart, overall child nutritional status fitted within the normal range for both male and female participants. Whereas based on their mean value, female children tended to have higher nutritional status than male children. Moreover, based on their prevalence, 6% of underweight and 4% of overweight children were male (Table 1). In addition, we did not find a significant association of either child handwashing skills or nutritional status with socio-economic conditions.

Figure 3. Bathroom at school. (Taken by the author)

In general, children used 2 sites for handwashing at school: (1) in the bathroom using a water bucket and scoop, and (2) using tap water outside the bathroom, also without a sink. 1 sink that used to be a common handwashing site was found broken and lacking in maintenance. Obtaining clean water in the school was also difficult since we found the water pump was broken. Furthermore, 2 bathrooms that often have been used as a handwashing site were in poor condition. The bathrooms were also used by school security for washing clothes and dishes, thus became dirt and lacked space (Figure 3).

2.2. Child handwashing skills

Our results showed that children had greater skill in first 5 steps of handwashing, which is wetting hands before lathering up, until palm to palm with fingers interlaced. Skill then decreased sharply for the 3 later steps (Table 2). Unfortunately, not all children could accomplish hand drying after rinsing their hands with water following lathering. Among the overall 10 steps of handwashing score, on average, children were aware of performing 6 steps (Table 3). Children had different preference for tools and soap for handwashing. Regarding tool preferences, 85% of the children chose tap water and 15% of the children chose a water bucket with scoop. Regarding soap preferences, 59% of the children chose bar soap while 39% chose liquid soap. However, their preference for tools or soap had no significant association with the *E. coli* count on hands after handwashing.

2.3. Handwashing time duration, *E. coli* count, and nutritional status

Our findings showed that a longer time duration for wetting hands with water before lathering (1st step) was significantly associated with lower *E. coli* count after handwashing (Table 3). Handwashing was proven to significantly change *E. coli* count on children's hands (Figure 4), where the mean value of log *E. coli* count reduction is 0.70 log CFU/hand for participants who decreased the *E. coli* count. Unexpectedly, we found that in 14.6% of the children handwashing increased the *E. coli* count. Such children were found to not perform the hand drying step and tended to dry their hands using their school uniform.

The difference mean value of child nutritional status such as HAZ, WAZ, and BMIAZ for children who performed and not performed hand drying after handwashing (Table 4). The children who dried their hands properly with a single clean paper towel after handwashing had a significantly higher nutritional status in terms of HAZ and WAZ than the children who skipped this step. A similar trend was indicated for BMIAZ but this was not significant.

Table 2. Children handwashing step accomplice.

Handwashing step	Observed n (%)	Not observed n (%)
1st Step	37 (90)	4 (10)
2nd Step	39 (95)	2 (5)
3rd Step	37 (90)	4 (10)
4th Step	25 (61)	16 (39)
5th Step	23 (56)	18 (56)
6th Step	1 (2)	40 (98)
7th Step	2 (5)	39 (95)
8th Step	2 (5)	39 (95)
9th Step	41 (100)	0
10th Step	32 (78)	9 (22)

Table 3. Time allocation for handwashing practice and total bacteria after handwashing.

Outcome	Variables	Mean	Correlation
E. coli count after handwashing (log CFU/hand)	Time 1st step (sec.)	4.70	- 0.33*
	Time 3rd - 8th step (sec.)	7.40	0.06
	Time 9th step (sec.)	14.20	0.13
	Total time duration (sec.)	50.60	-0.28
	Handwashing score (step)	5.80	-0.15

*significant correlation by Spearman correlation test, $p < 0.05$

Table 4. Child nutritional status in relation to performing 10th step.

Outcome	10th Step		p-value
	Observed	Not observed	
HAZ	-0.03	-0.89	0.02
WAZ	-0.24	-1.03	0.04
BMIAZ	-0.50	-1.26	0.18

*significant difference by t-test, $p < 0.05$

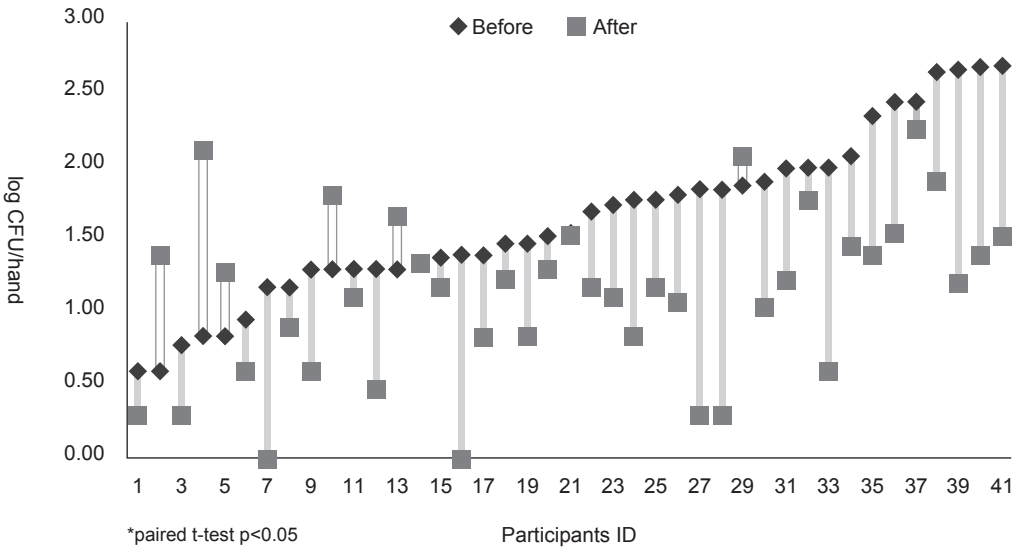

Figure 4. *E. coli* count on hand before and after handwashing for all children.

3. Discussion

3.1. Children's handwashing skills

Our results showed that 90%, 61%, and 56% of the children were accomplished in handwashing skills from the 3rd until the 5th step, respectively. This then declined sharply through the 6th to the 8th step to 2%, 5%, and 5% respectively (Table 2). A similar study conducted in medical staff (nurses, physicians and auxiliaries), found a similar pattern with greater handwashing skill in the initial steps, then decreasing for further steps to 70.6%, 30.3%, and 40.9% (Arias et al. 2016). However, elementary school children in this study showed much lower overall levels of handwashing skill than those medical staff. This may be because elementary school children rarely perform this skill in their daily life due to forgetfulness or time lacking (Lopez-Quintero et al. 2009). This result showed that elementary school children's awareness of handwashing steps is low and that handwashing guidelines from the WHO are not well implemented in elementary school children.

3.2. Children's handwashing time duration and *E. coli* count

Handwashing was proven effective in eliminating *E. coli* on hands (Figure 3) since in 85% of the children total bacteria were reduced after performing handwashing. We found that a longer total time duration to complete all steps of handwashing tended to produce larger reductions in *E. coli* count, although significant differences were not observed (Table 3). We found children typically spent less than 20 seconds on lathering (Table 3), lower than the time were found in a previous study (Jensen et al. 2017). Thus, it made bacteria reduction in this study also lower than that study. According to that study, 20 seconds spent on lathering using antimicrobial soap reduced the *E. coli* count on hands by 1.95 log CFU/hand. A similar study in school children revealed an *E. coli* count reduction of 0.66 log CFU/hand after rubbing hands with non-antimicrobial soap for 15 seconds (Pickering et al. 2010). Therefore, allocating sufficient time for handwashing using antimicrobial soap is necessary for greater bacteria reduction (Pickering et al. 2010).

Moreover, spending more time pouring water onto hands before applying soap and before lathering significantly lowered *E. coli* count after handwashing (Table 3). The mean value for this 1st step was 4.7 seconds in the current study, although there are no specific guidelines available. Considering this result, 39% of the children spent less than 5 seconds on pouring water and 10% of them skipped the 1st step and went directly to the 2nd step. In other words, children needed to spend more time pouring water to perform both wetting hands before handwashing, and rinsing hands after lathering, for further bacterial reduction. Therefore, children need to apply more water for a longer total duration of handwashing to prevent contamination exposure from fecal-hand or fecal-mouth transmission (Oswald et al. 2008). However, Bandung is even not facing water scarcity, but having problem with access to sufficient quantities of water (Marcotullio 2007). This matter also presents a challenge for children to perform through handwashing.

3.3. Drying hands, *E. coli* count, and child nutritional status

Result showed 6 cases where children had increased *E. coli* count after handwashing (Figure 4). Those children were observed not performing 10th step correctly but they were drying their hands with their school uniforms (Table 2). The main possibility for the source of contamination is their school uniforms, which are exposed to bacteria while playing outdoors. A similar concern was found in a study of nursing students who had bacterial contamination during their shift in the hospital; not changing their uniform increased contamination (Callaghan 1998). Furthermore, wet hands after insufficient drying can encourage bacteria to develop more rapidly after touch-contact bacterial transfer, even after handwashing (Huang et al. 2012). Therefore, hand drying should not be neglected as an integral step of handwashing (WHO 2009) and we suggest using a single clean paper towel to

dry hands for the most effective reduction of bacteria (Huang et al.2012).

Moreover, children who were observed performing hand drying had better nutritional status in terms of HAZ and WAZ, but not in terms of BMIAZ (Table 4). Since children who failed to perform hand drying had fecal bacteria contamination on their hands, they also have a higher possibility of fecal oral transmission that leads to repeated gastroenteritis or severe diarrhea. Thus, it could cause nutrient malabsorption resulting in faltering growth (Korpe and Petri 2012). This finding is also in line with that of our previous study, where not performing hand drying significantly increased the risk of child stunting (Adjusted Odds Ratio (AOR): 2.37; 95% CI: 1.13-4.96) (Otsuka et al. 2018b). Therefore, fully accomplished handwashing skills are entirely necessary to prevent bacteria transfer from hands which results in lower child nutritional status.

3.4. Limitations

This study was conducted mainly through observation and direct assessment. It was able to address scientific questions in relation to handwashing skills, total *E. coli* count, and the nutritional status of elementary school children. However, there were some limitations to this study. First, as a cross-sectional study with a small sample size we could not determine causal relationships for all variables related to the study indicators. Second, we did not record children's illnesses for previous years as a direct cause of lower child nutritional status. Despite this, we believe that further studies on hand hygiene and child nutritional status are potential fruitful research areas since handwashing is not only critical for healthcare workers but also for children. Further research with a larger sample size, using a longitudinal study design, and assessing children's hygiene behavior, is needed to provide more robust data with regards to the importance of handwashing skills for child health.

Conclusion

This study revealed that the available guidelines are not well understood or implemented. Factors that affect total bacteria reduction after handwashing are: (1) time duration for handwashing, especially for wetting hands before lathering; and (2) performing comprehensive handwashing skills including drying hands with a single paper towel. Although handwashing is not directly related to child nutritional status, improper hand drying which results in hand contamination may lead to a lowering of child nutritional status.

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Acceptability Factors of Agro-Sanitation Business Model in Light of Time Allocation: Case of Rural Households in Burkina Faso

Ken USHIJIMA[1], Seydou DICKO[2], Taro YAMAUCHI[1,3], Naoyuki FUNAMIZU[4]

[1] Research Institute for Humanity and Nature, Japan

[2] Graduate School of International Media, Communication, and Tourism Studies, Hokkaido University, Japan

[3] Faculty of Health Sciences, Hokkaido University, Japan

[4] Muroran Institute of Technology, Japan

Abstract

In a pilot study of an agro-sanitation business model introduced in Burkina Faso, only one of four pilot families succeeded in earning cash from their agro-sanitation business. We conducted a time allocation survey of these pilot families and several control families to measure the additional workload resulting from the application of the agro-sanitation business model. We then sought to identify differences between the family that succeeded in its adoption of the model and those that did not, and attempted to determine the factors that explained these differences. Overall, we found that (1) the additional workload seems small in comparison to other work, (2) among the activities associated with the agro-sanitation business, processing products for sale and selling in the market require considerable time, although the time for these activities was not distinguishable from the time required in customary practice, (3) characteristic differences in time allocation were mainly observed in working-age females, (4) a significant feature of the working-age females in the successful pilot family was the allocation of considerable time for economic activity in the dry season and for subsistence activities in the rainy season, and the relatively short time devoted to housekeeping in the rainy season and to personal activities throughout the year, and (5) important factors for success appear to be that the women in the family are familiar with selling their products in the market and are able to manage their time efficiently. Based on these findings, reasonable strategy for diffusing the agro-sanitation business model should include focusing on women as the key players, identifying women who have features similar to the women in the successful family described in this study, and devising an effective cultivation schedule that considers their seasonal time allocation.

Keywords: agro-sanitation business, sanitation value chain, time allocation

Introduction

A resource-oriented sanitation system that utilizes human excreta as a valuable resource is considered by many to be an important countermeasure to improve sanitation in developing countries and a promising concept for the creation of a sustainable recycling society (e.g., Lopez et al. 2001; Winblad and Simpson-Hébert 2004). Many related technologies have been developed (e.g., Porto and Steinfeld 2000; Ito et al. 2008), and there have been a number of reported trials. However, such systems continue to struggle for acceptance by potential users.

Ushijima et al. (2018) pointed out the mismatch between the wants of toilet users and the generally encouraged technology and actions promoting sanitation improvement or the building of a recycling society, and noted the importance of the social system in establishing the value chain or value network to solve this mismatch. As one

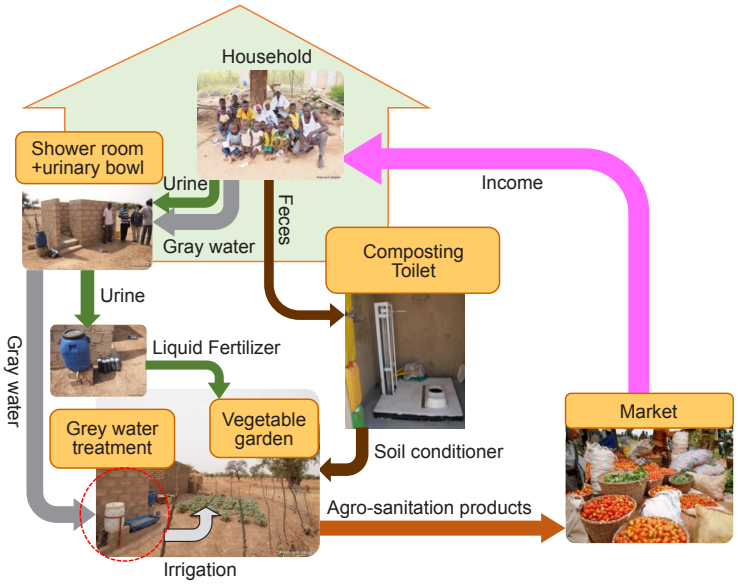

Figure 1. Agro-sanitation asset and value chain. (Drawn by the author)

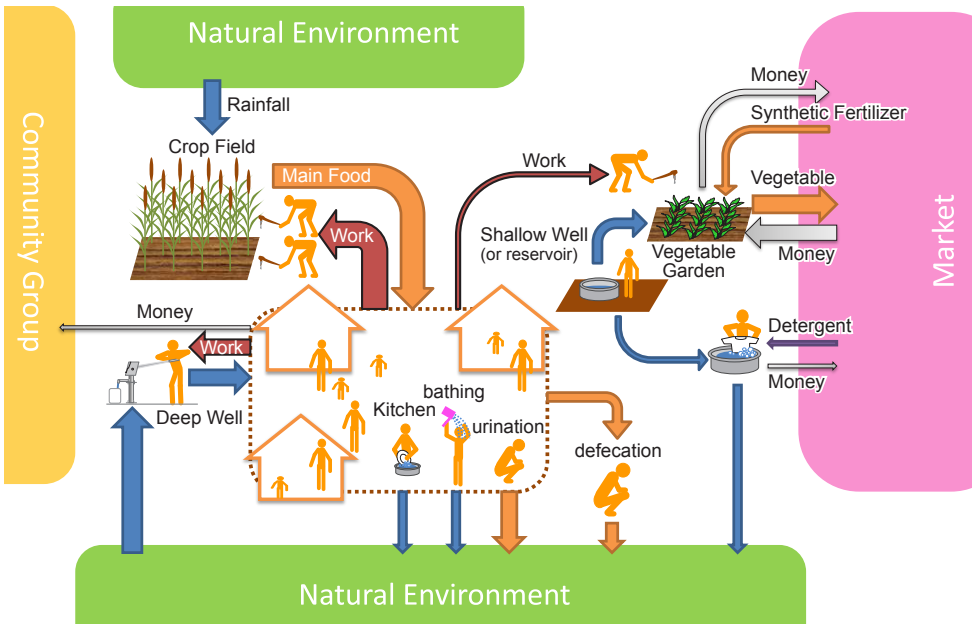

Figure 2. Current value flow network in rural household in Burkina Faso.
(Reproduced from Ushijima et al. 2015: Figure 1)

application, Ushijima et al. (2019) proposed an agro-sanitation business model for the West African country of Burkina Faso based on the sanitation value chain idea. The model attempts to increase the income of local farmers by use of the agro-sanitation system and enable the farmers to use the sanitation system sustainably. In this model, the farmers use an agro-sanitation asset consisting of a composting toilet, a shower room with a grey water treatment facility, and a urinary bowl with a storage tank. From this asset, the farmers obtain soil conditioner, irrigation water and liquid fertilizer (Figure 1). The three obtained agricultural resources are used not for the farmers' main crop field but rather for a small vegetable garden, since, as the current value flow network (Figure 2) shows, their major cash-producing activity is selling vegetables from a small garden. Hijikata (2019)

calculated the expected maximum income increase from this business model on the basis of designing a practical crop rotation, stating that the increase ranges from 8,637 to 14,526 FCFA per capita per year. Although this corresponds to only 11 to 22 Euros, the gross national income (GNI) in Burkina Faso is approximately 355,000 FCFA per capita per year. Furthermore, a previous study by Ikemi (2017) that included the study sites used in our present study indicates that 53% of respondents in the study had an income of less than 125,000 FCFA per year. Given this income information, Hijikata's estimate of the expected maximum income increase from employing the agro-sanitation business model seems not insignificant.

The SATREPS project, titled "Improving Sustainable Water and Sanitation Systems in the Sahel Region in Africa: The Case of Burkina Faso" (Funamizu 2017), conducted a field test of the model with four pilot families in Burkina Faso. The pilot families were not compelled to use the agricultural resources produced from the agro-sanitation asset for cultivating vegetables to be sold; rather, they were allowed to choose any of their crops or vegetables to cultivate. As a result, all four pilot families chose to cultivate vegetables for their own consumption during the first year of the study. These included okra, eggplant, and cowpeas. However in the second year, one of the four pilot families chose to cultivate vegetables such as chili to sell in the market and succeeded in earning a cash return. Although we were unable to determine the exact amount of income that was derived from this activity, we consider this case a successful application of the sanitation business model since the family embraced the concept and used it to increase their income on their own initiative.

This study had three main objectives: (1) to evaluate the additional workload required in adopting the agro-sanitation business model, (2) to identify the differences between successful cases and the others, and to determine what factors explained these differences, and (3) to suggest appropriate strategy for diffusing the agro-sanitation business concept. To pursue these objectives, a time allocation survey was used.

1. Materials and method

1.1. Overview of the study site

In Burkina Faso, where the study was conducted, home owners are obligated by law to construct a wastewater treatment facility on their land and to manage it appropriately (Law of public sanitation, No. 022-2005/AN). However, the law does not provide a clear strategy, a detailed support system, or the technology for doing so. As a result, only 7% of the population in the rural areas of Burkina Faso had access to basic sanitation facilities in 2015 (UNICEF 2019). Many people urinate in the walled shower space in their living area, and open defecation is still common in these areas (Ushijima et al. 2012). The 2013 under-five mortality rate has been reported as 84.6 per 1000 live births (WHO 2018), with diarrhea causing 10% of these deaths (WHO and UN 2015). Water and sanitation are clearly urgent issues in Burkina Faso. However, the implementation of a modern sanitation system requires a high level of governance and a substantial economic background. The GNI of Burkina Faso in 2017 was only 590 USD per capita (World Bank 2019), which makes it extremely difficult to introduce a modern sanitation system in the near term.

Burkina Faso is an agricultural country. More than 90% of the labor force is employed in the agriculture sector, and 29.9% of GDP is produced by agriculture (FAPDA 2014). However, the environment for agriculture is severe. Burkina Faso is located in the Sahel region and its climate is of the semiarid type, which means there is little precipitation. Furthermore, irrigation facilities are very rare in rural areas of the country. The main soil type is Lixisols, which requires frequent fertilization and careful erosion control (Driessen and Deckers 2001).

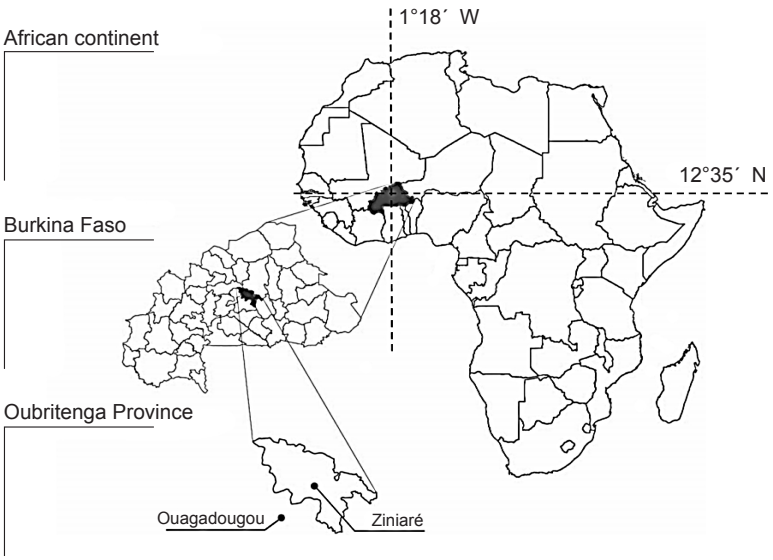

Figure 3. Location of Oubritenga Province, Burkina Faso.

Table 1. Attribute of target families.

Village	K village				B village			
Pilot/control	Pilot family		Control family		Pilot family		Control family	
Size category	Extended family	Nuclear family	Extended family	Nuclear family	Extended family	Nuclear family	Extended family	Nuclear family
Household ID*	KPLE	KPLN	KCTE	KCTN	BPLE	BPLN	BCTE	BCTN
Household member Religion	21 Christian	6 Christian	18 Muslim	6 Christian	25 Muslim	9 Muslim	28 Muslim	14 Muslim
Work-female (person)	4	1	4	1	7	1	7	5
Work-male (person)	4	1	1	1	7	3	7	3
School-female (person)	6	2	4	1	4	2	4	2
School-male (person)	2	1	9	3	6	3	7	1
Other (person)	5	1	0	0	2	0	3	3

*First character indicate village name (K or B), second and third indicate pilot (PL) or control (CT), last indicate extended family (E) or nuclear family (N).

1.2. Target families

For this study, the pilot and control families were chosen from two villages (village K and village B) in the Oubritenga province of Burkina Faso (Figure 3). The residents of village K are Mossi, the major ethnic group in Burkina Faso; they speak Mooré, a Gur language of the Niger-Congo language family. Most of the villagers are crop farmers. Their religions include Islam, Christianity, and Animism. Village B is inhabited by the Fulani people; they speak Fulfulde, a North West Atlantic language of the Niger-Congo language family. As far as we could determine, all the people in village B are Muslim. Originally nomadic pastoralists, they changed to a settled lifestyle and combined herd and farm activities some decades ago.

The chiefs of each village selected one extended family and one nuclear family from their village to serve as pilot families (details are provided in Table 1). The components of the agro-sanitation asset were installed in the living areas of each of the four pilot families by the SATREPS project in June 2012, and a field test was conducted until February 2015. As mentioned in the introduction, only one of the families (the KPLE family in Table 1) chose to cultivate vegetables to sell using the agro-sanitation asset and succeeded in earning cash from their sales.

Ideally, in order to be in a position to better discuss the impact of this agro-sanitation business model application, the survey should have been administered to the same pilot families before and after the application. However, the project schedule did not allow us to do so. To offset this limitation, four additional control families were selected from the same villages using the same procedure and criteria as were used for the pilot families. In conducting our analysis, we classified members of the families participating in the study into four categories according to gender and whether they were school age or working age. The four categories were labeled "Work-female," "School-female," "Work-male" and "School-male." The "Other" category in Table 1 includes children under five years of age and persons who were continuously absent from the compound for more than half of the observation periods. We excluded the data for this "Other" category from the analysis.

1.3. Hypotheses

Before starting the field test, we formulated three hypotheses relating to the research objectives mentioned above:

(1) An increase in income can be an important incentive; therefore, once the pilot family understands that the agro-sanitation asset can be used to earn money, they will spontaneously begin their agro-sanitation business.

(2) Although the husband makes most of the important decisions in the traditional cultures of both villages, the agro-sanitation asset will be maintained at the practical level primarily by women, and therefore women are the real key persons in the family's acceptance of the agro-sanitation business.

(3) Given the overall workload of crop cultivation, the additional workload associated with the agro-sanitation business model is acceptably small.

Based on the time allocation results of the survey and additional qualitative information, the validity of these hypotheses is assessed and promising strategy for encouraging the application of the agro-sanitation business model are proposed.

1.4. Time allocation survey

This study employed a modified household rounds spot-check method. In the original household rounds spot-check method (Yamauchi 2018), the observer would make his/her rounds at several households at a predetermined time interval and check the activities of all household members. However, in this study, we arranged to have one observer or one assistant observer for each family, and had the observer or assistant observer record the household members' activities at predetermined time intervals. Before going into the field, the assistants received instruction on how to observe. However, we were unable to conduct a field trial before initiating the survey. Therefore, we prepared one or two extra observers who made their rounds at each household site periodically, usually three or four times each day, and conducted a data check and briefing with the observers and assistant observers should there be any questions/problems. The extra observer(s) would also temporarily replace the regular observers or assistants in order to give them a break from their duties. Thus, this modified method reduced the burden on each observer and enabled us to prepare a sufficient number of assistant observers within our limited training time. We do, however, recognize the disadvantage of this modified method in that it presented a higher risk of bias and uncertainty caused by the use of immature assistants and the temporary replacement of the regular observers.

A time allocation survey was conducted in the two villages, first in village K, then in village B. In each village, the two pilot families and the two control families were observed simultaneously. We assigned an observer or assistant observer to each household's compound for 72 hours (except for nighttime); during the period of observation, the observer or assistant observer monitored the activities of all household members every 30 minutes. Observation began each day at 5:30 a.m. and ended at 9:00 p.m., which meant that activities

were observed 32 times in a day, or a total of 96 times over the 72-hour observation period. In the subsequent analysis, the activities observed at each prescribed point in time were considered as representative of the household member's activity during the full 30-minute period associated with that point in time, as was the case in the original household rounds spot-check method. Observed activities were classified into seven groups: subsistence, housekeeping, economic, personal, social and educational, miscellaneous, and unknown. The "unknown" category was used for cases in which the observer was unable to identify the activity, such as when the activity took place in a private room. These seven groups were further divided into sub-groups, as shown in Tables 2 and 3. Because our focus was on the agro-sanitation business model, we separately identified the cultivation of a small vegetable garden as "commercial cultivation" and assigned it to the "economic" group, whether or not the products from the activity were actually sold.

Observers were also asked to note, insofar as possible, what household members were doing between the scheduled observation times. Data from these informal observations were used as qualitative, supplemental information.

Generally, a time allocation survey should be done over a long period of time. However, due to the limitation of project resources, including manpower, 72 hours was the maximum feasible observation period. To compensate for this limitation, the 72-hour observation periods were repeated four times: April 2013 (late dry season), July 2013 (early rainy season), October 2013 (late rainy season) and December 2013 to January 2014 (early dry season).

2. Results and discussions

2.1. Differences between pilot and control families

In order to assess the additional workload associated with the agro-sanitation asset, we compared the time allocation data of the pilot families and the control families in the rainy season (Table 2) and the dry season (Table 3).

During the rainy season, most household members, including the children, were involved in crop-related work. Our time allocation results for this period indicate that substantial time was devoted to the "crop cultivation" activity, a sub-group of the "subsistence" activity, in both the pilot and control families. However, we found that the "subsistence" activity times of the Work-female group in the pilot families was significantly longer than in the control families (Mann-Whitney U test, $p<0.05$). On the other hand, the "personal" activity and "social and education" activity times of the Work-female group in the pilot families were significantly shorter than in the control families. As for other activities during the rainy season, the "housekeeping" activity time of School-males in the pilot families was significantly shorter than in the control families. No significant differences between the Work-female/School-male groups in the pilot and control families were observed for other activities. There were no significant differences for any of the activities between Work-males/School-females in the pilot and control families during the rainy season. Overall, the significant differences that were found in the rainy season are interesting but seem not to be directly related to the application of the agro-sanitation asset.

The dry season data also reveals some differences between the pilot and control families. For example, the "economic" activity time of the Work-females in the pilot families was significantly longer than in the control families (Mann-Whitney U test, $p<0.05$). On the other hand, the "social and education" activity time of the Work-females in the pilot families was significantly shorter than in the control families (Mann-Whitney U test, $p<0.05$). No significant difference was observed in other activities of the Work-females, nor were any significant differences found between the pilot and control families for any of the activity times of School-females, Work-males, and School-males in the dry season. In the observed "economic" activities of the Work-females in the pilot

Table 2. Averaged time allocation of pilot and control families in dry season. Unit is minutes / day, and standard deviation in parenthesis.

	Work-female		Work-male		School-female		School-male	
	Pilot (N=13)	Control (N=17)	Pilot (N=14)	Control (N=12)	Pilot (N=14)	Control (N=11)	Pilot (N=11)	Control (N=20)
Subsistence	23 (32)	23 (39)	94 (195)	211 (302)	5 (5)	13 (19)	8 (11)	16 (26)
Crop cultivation	10 (25)	18 (40)	32 (116)	7 (19)	1 (1)	13 (19)	0 (0)	4 (12)
Livestock	13 (15)	5 (9)	62 (161)	205 (307)	5 (5)	0 (0)	8 (11)	13 (23)
Fishing/Hunting	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Housekeeping	325 (97)	289 (157)	46 (69)	43 (37)	85 (88)	118 (53)	21 (23)	19 (22)
Cooking	197 (113)	164 (93)	1 (3)	13 (28)	40 (55)	58 (42)	2 (8)	8 (14)
Water drawing	39 (29)	44 (33)	10 (23)	4 (7)	25 (17)	35 (23)	17 (17)	8 (9)
Cleaning house	19 (19)	6 (5)	0 (0)	0 (0)	2 (5)	1 (3)	0 (0)	0 (1)
Treating children	7 (12)	11 (19)	0 (0)	1 (3)	0 (0)	8 (10)	0 (0)	1 (2)
Laundry	16 (13)	20 (18)	2 (5)	0 (0)	4 (4)	4 (5)	0 (0)	2 (3)
Other housekeeping	46 (62)	43 (118)	32 (68)	25 (29)	14 (34)	12 (10)	2 (4)	5 (8)
Economic	100 (154)*	16 (59)*	94 (207)	83 (157)	4 (7)	0 (0)	2 (7)	0 (0)
Business	100 (154)	13 (47)	74 (207)	0 (0)	4 (7)	0 (0)	0 (0)	0 (0)
Commercial cultivation	0 (0)	3 (12)	19 (48)	83 (157)	0 (0)	0 (0)	2 (7)	0 (0)
Personal	265 (108)	303 (139)	176 (71)	253 (218)	215 (83)	228 (78)	232 (72)	252 (84)
Rest	112 (87)	155 (115)	60 (51)	151 (201)	47 (48)	90 (71)	95 (71)	69 (50)
Sleeping	100 (48)	102 (55)	77 (44)	67 (41)	109 (53)	80 (41)	89 (13)	127 (37)
Eating	23 (16)	34 (17)	20 (16)	23 (25)	50 (31)	42 (13)	43 (14)	43 (20)
Shower**	7 (9)	4 (5)	5 (7)	8 (8)	2 (4)	10 (7)	2 (8)	4 (4)
Toilet**	1 (2)	2 (5)	2 (5)	2 (3)	2 (4)	1 (3)	0 (0)	2 (5)
Urination**	2 (4)	1 (2)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)	1 (2)
Other personal	20 (49)	5 (10)	11 (14)	2 (5)	5 (6)	5 (7)	2 (4)	4 (5)
Social and education	82 (22)*	138 (50)*	226 (193)	160 (197)	529 (128)	524 (144)	509 (166)	571 (149)
Communication	50 (35)	121 (53)	134 (136)	69 (44)	45 (44)	47 (29)	25 (27)	34 (22)
Religious	18 (20)	9 (15)	32 (64)	11 (19)	33 (41)	22 (61)	37 (50)	9 (25)
School	14 (24)	8 (20)	55 (136)	71 (190)	343 (182)	339 (209)	251 (232)	372 (214)
Playing	0 (0)	0 (0)	6 (14)	8 (19)	98 (125)	95 (160)	192 (157)	155 (146)
Studying	0 (0)	0 (0)	1 (1)	0 (0)	10 (12)	20 (29)	5 (8)	3 (8)
Miscellaneous	28 (20)	48 (35)	56 (41)	125 (128)	47 (32)	25 (14)	124 (146)	51 (67)
unknown	139 (86)	143 (110)	269 (243)	85 (106)	76 (71)	53 (58)	64 (43)	49 (29)
Total	960	960	960	960	960	960	960	960

* Statistically significant difference by Mann-Whitney U test (P<0.05)

**Applied agro-sanitation asset had toilet room and shower room separately, and urinary bowl was set in shower room. Therefore, observer estimated the target person's activity in shower room as "shower" if observer heard the sounds of taking shower and the person came out with wet hair, and as "urination" if the person came out quickly with dried hair. There also are possibility to urinate in toilet room, however we could not distinguish it, therefore we classified all activities in toilet room just as "toilet."

Table 3. Averaged time allocation of pilot and control families in rainy season. Unit is minutes / day, and standard deviation in parenthesis.

	Work-female		Work-male		School-female		School-male	
	Pilot (N=13)	Control (N=17)	Pilot (N=14)	Control (N=12)	Pilot (N=14)	Control (N=11)	Pilot (N=11)	Control (N=20)
Subsistence	306 (272)*	147 (175)*	301 (205)	236 (190)	315 (274)	112 (117)	245 (259)	211 (113)
Crop cultivation	298 (275)	124 (175)	268 (212)	122 (166)	307 (276)	104 (123)	182 (234)	164 (135)
Livestock	8 (16)	23 (71)	32 (89)	115 (155)	8 (8)	8 (16)	62 (184)	39 (59)
Fishing/Hunting	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	8 (19)
Housekeeping	250 (139)	235 (108)	45 (85)	28 (19)	92 (90)	120 (76)	17 (34)*	38 (23)*
Cooking	191 (104)	143 (79)	11 (16)	12 (13)	55 (53)	55 (43)	4 (8)	20 (17)
Water drawing	32 (32)	34 (38)	1 (3)	2 (3)	17 (33)	37 (40)	3 (8)	14 (16)
Cleaning house	2 (4)	7 (9)	1 (2)	0 (0)	2 (4)	2 (3)	0 (0)	0 (0)
Treating children	7 (8)	20 (23)	1 (1)	1 (2)	3 (7)	8 (17)	0 (0)	1 (1)
Laundry	13 (17)	22 (22)	0 (0)	1 (1)	12 (20)	10 (13)	0 (0)	1 (4)
Other housekeeping	5 (10)	9 (23)	32 (86)	13 (17)	3 (8)	7 (11)	10 (18)	2 (4)
Economic	19 (33)	38 (56)	22 (37)	60 (82)	2 (5)	37 (79)	0 (0)	25 (60)
Business	14 (33)	14 (35)	12 (31)	8 (21)	1 (5)	0 (0)	0 (0)	0 (0)
Commercial cultivation	5 (10)	25 (49)	10 (26)	52 (79)	1 (1)	37 (79)	0 (0)	25 (60)
Personal	163 (92)*	258 (94)*	275 (176)	248 (121)	212 (65)	239 (82)	262 (95)	238 (57)
Rest	110 (88)	174 (88)	140 (93)	164 (93)	97 (47)	132 (61)	111 (71)	109 (49)
Sleeping	17 (10)	40 (28)	55 (49)	37 (46)	62 (37)	59 (50)	92 (57)	81 (34)
Eating	23 (15)	31 (14)	20 (14)	24 (16)	42 (10)	43 (16)	51 (23)	43 (19)
Shower**	5 (7)	6 (5)	5 (7)	13 (22)	2 (5)	4 (5)	1 (2)	1 (3)
Toilet**	3 (5)	1 (2)	1 (3)	2 (4)	2 (5)	1 (3)	1 (3)	0 (1)
Urination**	1 (1)	1 (4)	1 (3)	1 (2)	0 (0)	0 (0)	1 (3)	0 (1)
Other personal	2 (3)	4 (7)	52 (161)	5 (8)	7 (7)	1 (3)	5 (7)	2 (4)
Social and education	32 (26)*	101 (73)*	85 (78)	112 (77)	219 (184)	258 (74)	295 (143)	337 (125)
Communication	22 (19)	73 (56)	31 (34)	75 (56)	23 (30)	29 (48)	26 (45)	22 (22)
Religious	10 (16)	17 (35)	48 (66)	19 (33)	1 (2)	2 (8)	1 (1)	4 (12)
School	0 (0)	1 (2)	0 (0)	0 (0)	109 (151)	146 (114)	64 (109)	206 (148)
Playing	1 (2)	10 (16)	7 (8)	18 (26)	72 (98)	64 (65)	201 (158)	87 (96)
Studying	0 (0)	0 (1)	0 (0)	0 (0)	14 (24)	17 (19)	2 (4)	18 (22)
Miscellaneous	18 (19)	38 (29)	41 (38)	101 (86)	32 (28)	79 (83)	41 (40)	48 (47)
unknown	164 (112)	140 (130)	190 (196)	176 (148)	83 (62)	115 (77)	100 (88)	64 (57)
Total	960	960	960	960	960	960	960	960

* Statistically significant difference by Mann-Whitney U test ($P<0.05$)

**Applied agro-sanitation asset had toilet room and shower room separately, and urinary bowl was set in shower room. Therefore, observer estimated the target person's activity in shower room as "shower" if observer heard the sounds of taking shower and the person came out with wet hair, and as "urination" if the person came out quickly with dried hair. There also are possibility to urinate in toilet room, however we could not distinguish it, therefore we classified all activities in toilet room just as "toilet."

families, most involved processing materials for sale and selling in the the market, activities that are classified in the "business" sub-group. A potion of these activities might be related to the agro-sanitation business in the successful pilot family (KPLE), as will be discussed later; however, these activities included the normal activities associated with the family's usual business, such as brewing and selling local beer.

Thus, with respect to the agro-sanitation business, we did not observe any significant additional workload measured in time allocation, with the exception of some "economic" activities that might possibly be associated with the agro-sanitation business. Activities directly related to the management of the agro-sanitation asset, such as toilet cleaning, shower room cleaning, and watering the agro-sanitation garden were qualitatively observed in the Work-females' activities during some of the intervals between the pre-determined observation points; however, these activities tended to be too short to be included in the time allocation data collected at the specified 30-minute intervals.

These results would seem to support hypothesis 3, which states that the additional workload required for the agro-sanitation business would be acceptably small. Indeed, the daily maintenance and vegetable cultivation times associated with the agro-sanitation asset seem quite small relative to the other activities observed in the study. As for the workload associated with processing materials for sale and selling in the market, a portion of the time involved might be connected to the agro-sanitation business, which should be taken into account when application and diffusion strategies are discussed.

2.2. Time allocation in the successful family

As described above, we observed several significant differences in time allocation between the pilot and control families. However, most of these differences seem not to be directly related to the use of the agro-sanitation asset but rather are a feature of the normal activities of the families. Therefore, it seems reasonable to describe the features of each family before identifying the distinctive time allocation features of the successful (KPLE) family.

Figures 4 to 7 show the average dry-season time allocation of the Work-females, School-females, Work-males and School-males in each family. The overall tendencies of the time allocation of Work-females in the dry season (Figure 4) are very similar except for the "economic" activities and "personal" activities in two cases—the successful pilot family (KPLE) and one of the control families (KCTN). These two cases show a large "economic" activity component, while in the other families, the time allocated to these activities is quite small or zero. On the other hand, these two cases show a smaller portion of "personal" activity time than any of the other cases.

The time allocation of Work-males in the dry season varies greatly by family. Among the pilot families, Work-males in the successful pilot family (KPLE) show a comparatively large portion of "economic" activity, but the difference is not as clear as in the case of Work-females. The overall tendencies of time allocation for School-females and School-males in the dry season are similar.

Figures 8 to 11 show the average time allocation of Work-females, School-females, Work-males and School-males in each of the families during the rainy season. Although time allocation varies by family in all groups, one common tendency appears to be that the "subsistence" activities of women (both Work-females and School-females) in village B are shorter than in village K. Work-males in village B also show comparatively shorter "subsistence" activity times than those in village K; however, the difference is not so clear as in the case of Work-females and School-females. One obvious feature of the successful pilot family (KPLE) during the rainy season is that their "subsistence" activity time is longest among all the groups, whereas the time allocated for "economic" activity is very small relative to other cases where "economic" activity was observed.

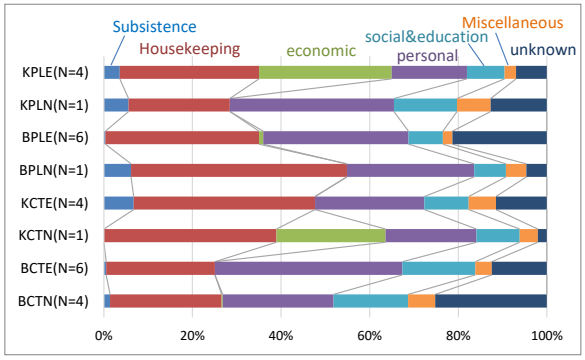

Figure 4. Time allocation of work-female in dry season by averaged per each family.

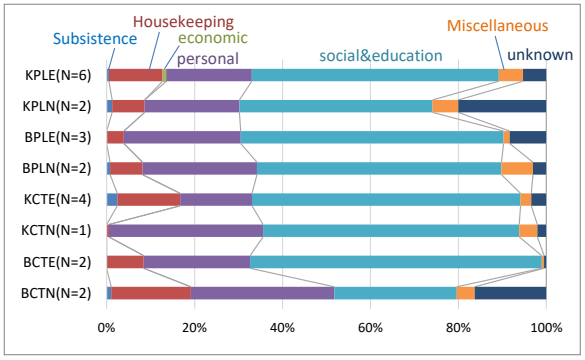

Figure 5. Time allocation of school-female in dry season by averaged per each family.

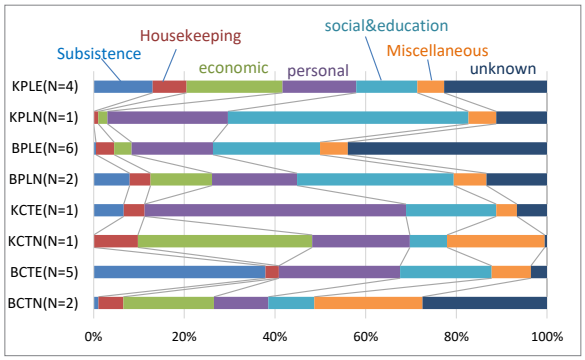

Figure 6. Time allocation of work-male in dry season by averaged per each family.

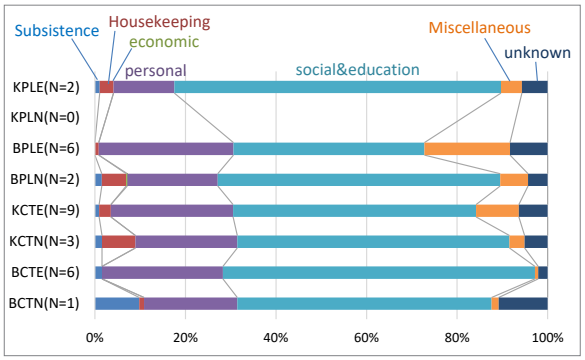

Figure 7. Time allocation of school-male in dry season by averaged per each family.

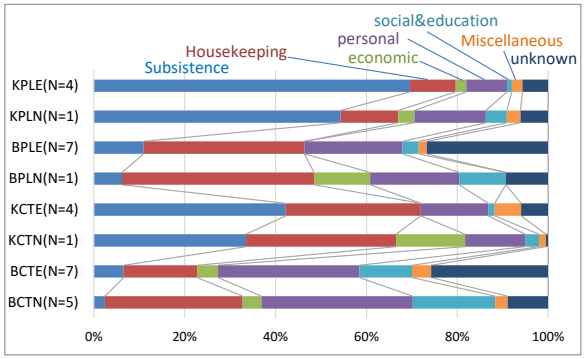

Figure 8. Time allocation of work-female in rainy season by averaged per each family.

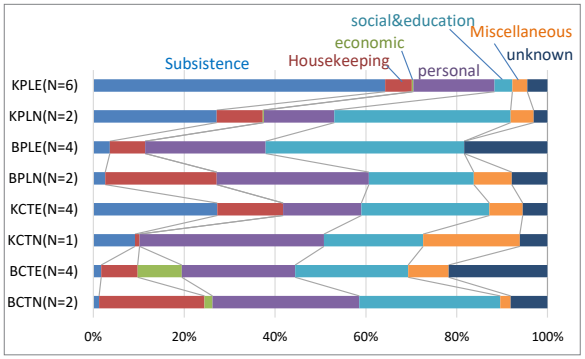

Figure 9. Time allocation of school-female in rainy season by averaged per each family.

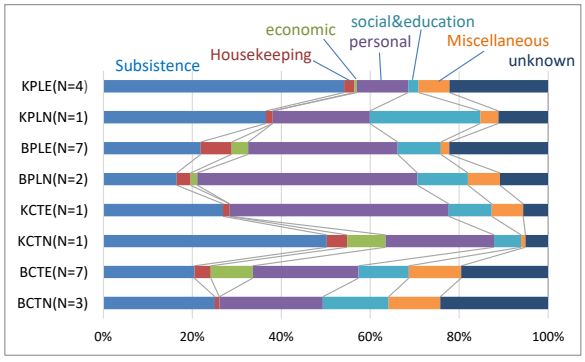

Figure 10. Time allocation of work-male in rainy season by averaged per each family.

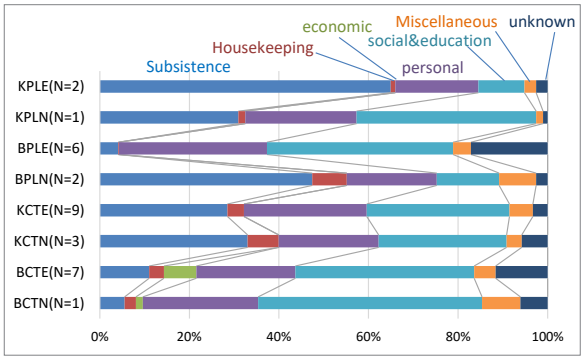

Figure 11. Time allocation of school-male in rainy season by averaged per each family.

2.3. Details of the "economic" activity by Work-females in the successful pilot family

As noted, the most distinctive features of time allocation in the successful pilot family (KPLE) were observed among the females, especially the Work-females. Therefore, in this section, we focus on the Work-females in the successful pilot family (KPLE) and attempt to identify factors that may be related to their acceptance of the agro-sanitation business concept.

First, in comparison to the other pilot families, a rather substantial amount of time was allocated to "economic" activities by the Work-females in the successful family (KPLE) during the dry season. The "economic" activities of these Work-females through both the dry and rainy seasons consisted of brewing traditional beer (20.5%), selling traditional beer (27.0%), packaging vegetables for sale (11.5%), and selling the family products in the market (41.0%). The first two of these activities, totaling 47.5% of the identified "economic" activities, are not associated with the agro-sanitation business; the remaining two activities (52.5% of the "economic" activities) are possibly connected to the agro-sanitation business.

As for the control families, considerable time was allocated for "economic" activities by the Work-females in the KCTN family. In fact, the average time allocation per day was similar to that in the successful pilot family (KPLE), though its composition was a bit different: selling vegetables (19.1%), cooking commercial food (25.0%), and selling commercial food (55.9%). In Burkina Faso, women have traditionally earned cash income by selling various products or food at market, although the way of selling and the specific products tend to vary by ethnic group and household (Saul 1981; Kavane and Wydick 2001; Sida 2004; Oladeji et al. 2006). In terms of ethnicity, the two families described above (KPLE and KCTN) were both in village K, which is inhabited by the Mossi. However, we also observed milk processing and sales activity in village B (during the rainy season, 5.5 continuous hours by one Work-female in the BPLN family), although this involved a rather short time allocation compared to other activities.

Thus, the observed "economic" activities by women that could possibly represent an additional workload associated with agro-sanitation overlap customary practices, which themselves vary by household (as seen in both the pilot and control families). Consequently, the longer observed time allocation for "economic" activities on the part of the Work-females in the successful pilot family (KPLE) might simply be attributable to distinctive characteristics of the family. In other words, basic family characteristics—primarily a familiarity with spending time selling items in the market—may have made it easier for the KPLE family to accept the agro-sanitation business concept. If so, families similar to the KCTN family in this regard would seem to make a promising target for the successful application of the model.

2.4. Time management of the Work-females in the successful pilot family

In seeking to more fully understand the time allocation of Work-females in the successful household, the question arises: "How do these women manage to have the time for 'economic' activities?" One possible explanation is that the women in the successful family spend less time on "personal" activities compared to those in the other families, as can be seen in Figure 4. However, during the rainy season, when their "economic" activity time is short, their "personal" activity time is also shortest among the eight targeted families. It seems, then, that their time spent on "personal" activities is normally quite short.

Generally speaking, one of the most time-consuming tasks of women in Burkina Faso is housekeeping. Our time allocation data tend to support this. In order to estimate the total "housekeeping" workload in each of the families in the study, the time allocated for "housekeeping" by the various family members was combined. The results vary widely by season: 5.8 to 51.7 hours/day in the rainy season and 6.2 to 39.9 hours/day in the dry season. There is less variation if the aggregate values are divided by the number of household members: 0.7 to

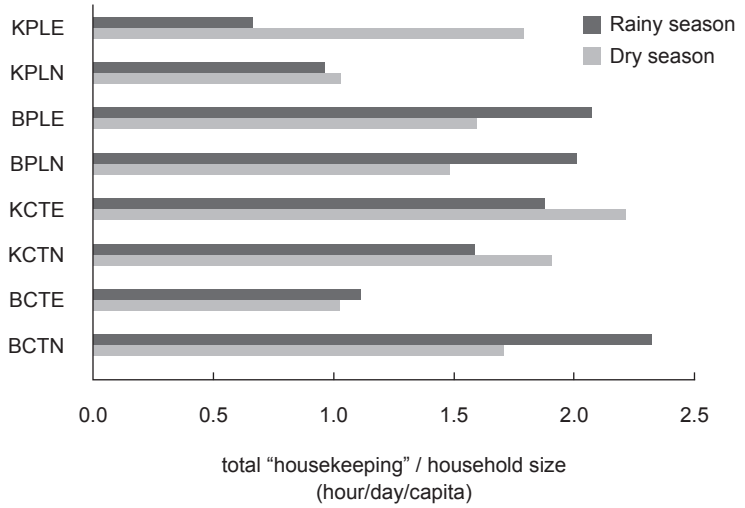

Figure 12. Total time allocation for "housekeeping" per capita in each family.

2.3 hours/day in the rainy season and 1.0 to 2.2 hours/day in the dry season (Figure 12). Seasonal differences in these values in each family are small, except in the case of the successful family (KPLE). Housekeeping per capita in the KPLE family during the dry season is in the middle among the eight targeted families; however, during the rainy season, it is smallest among the families.

Another major task for women in Burkina Faso involves "subsistence" activities. Total time allocation for "subsistence" in the surveyed families varies widely: 15.3 to 161.6 hours/day in the rainy season and 0.8 to 32.3 hours/day in the dry season. As these activities relate mainly to crop cultivation in the rainy season, seasonal differences in time allocation are large in all households. As noted, the time allocation for "subsistence" activities in the successful family (KPLE) is longest among the eight targeted families.

The data thus suggest that Work-females in the successful family (KPLE) work hard at "subsistence" during the rainy season and then shift to "housekeeping" and "economic" activities during the dry season, while Work-females in the other pilot families shift from "subsistence" activities mainly to "personal" activities. In terms of our qualitative observations, women in the successful family (KPLE) appeared very busy and did everything very quickly. This is likely why they are able to perform their housekeeping duties in a short time during the rainy season. Furthermore, this efficiency may contribute to their ability to find the time for "economic" activities during the dry season. A similar seasonal shift in time allocation was observed in one of the control families (KCTN).

2.5. Application strategy of agro-sanitation business model

Results of the time allocation survey support hypotheses 1 and 2, although it is difficult to validate these hypotheses directly due to the limitations of the research design. Regarding hypothesis 3, the activity of processing products for sale and selling in the market was shown to invole considerable time in the successful family; however, this was not easily distinguishable from the customary practice of the family.

For the effective application and diffusion of the agro-sanitation business concept, creating successful local cases and thereafter diffusing the idea through the community network are important (Rogers 1983). Thus, it is important to create one or more successful cases as a starting point. This means that choosing the pilot families is crucial. Kavane and Wydick (2001) mention the effect of social norms on the time allocated to economic activities by women in Burkina Faso. Other studies also mention that these activities vary according to the family situation,

including such factors as the financial resources and mindset of the household head (e.g., Saul 1981). In fact, the results of this study also show some variety in the time allocation among families. Therefore, one of the promising strategies for promoting adoption of the model would be to choose families with features similar to the families in previously successful cases. According to our results, this means, for example, choosing families in which the women have experience selling in the marketplace. Furthermore, busy women seem to be more promising than women who have excess "spare" time.

In summary, we propose the following strategy to promote the adoption of the agro-sanitation model: (1) The business model should be designed to maximize its acceptability to women; (2) In the early stages of diffusion, busy women who are acccustomed to selling products such as food and traditional beer in the market should be targeted as potential adopters of the model. When success is achieved, word of these succsessful cases should be widely disseminated to other women in the village; and (3) an appropriate cultivation schedule for commercially valuable vegetables should be devised—one that requires a minimum additional workload in the rainy season and harvesting in the dry season.

Conclusion

Although there are some limitations to the study design, results of the time allocation survey generally support our hypotheses. We found that

- The additional workload associated with adopting the agro-sanitation business model seems small compared to other work.
- Among the activities related to the agro-sanitation business, processing products for sale and selling in the market require a considerable time allocation, although these activities and activity times were not easily distinguishable from customary practice.
- Differences in time allocation were mainly observed in Work-females.
- Noteworthy features of the Work-females in the successful pilot family included a substantial time allocation for "economic" activities in the dry season and for "subsistence" activities in the rainy season, and a relatively short time allocation for "housekeeping" in the rainy season and for "personal" activities throughout the year.
- Having women in the family who are familiar with selling their products in the market and who manage their time efficiently appears to be an important factor for successful adoption of the model.

Based on these findings, strategy for diffusing the agro-sanitation business model should focus on women as the key players. Priority should be given to identifying women who have characteristics similar to the women in the successful family described in this study and to devising a cultivation schedule that considers their seasonal time allocation.

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