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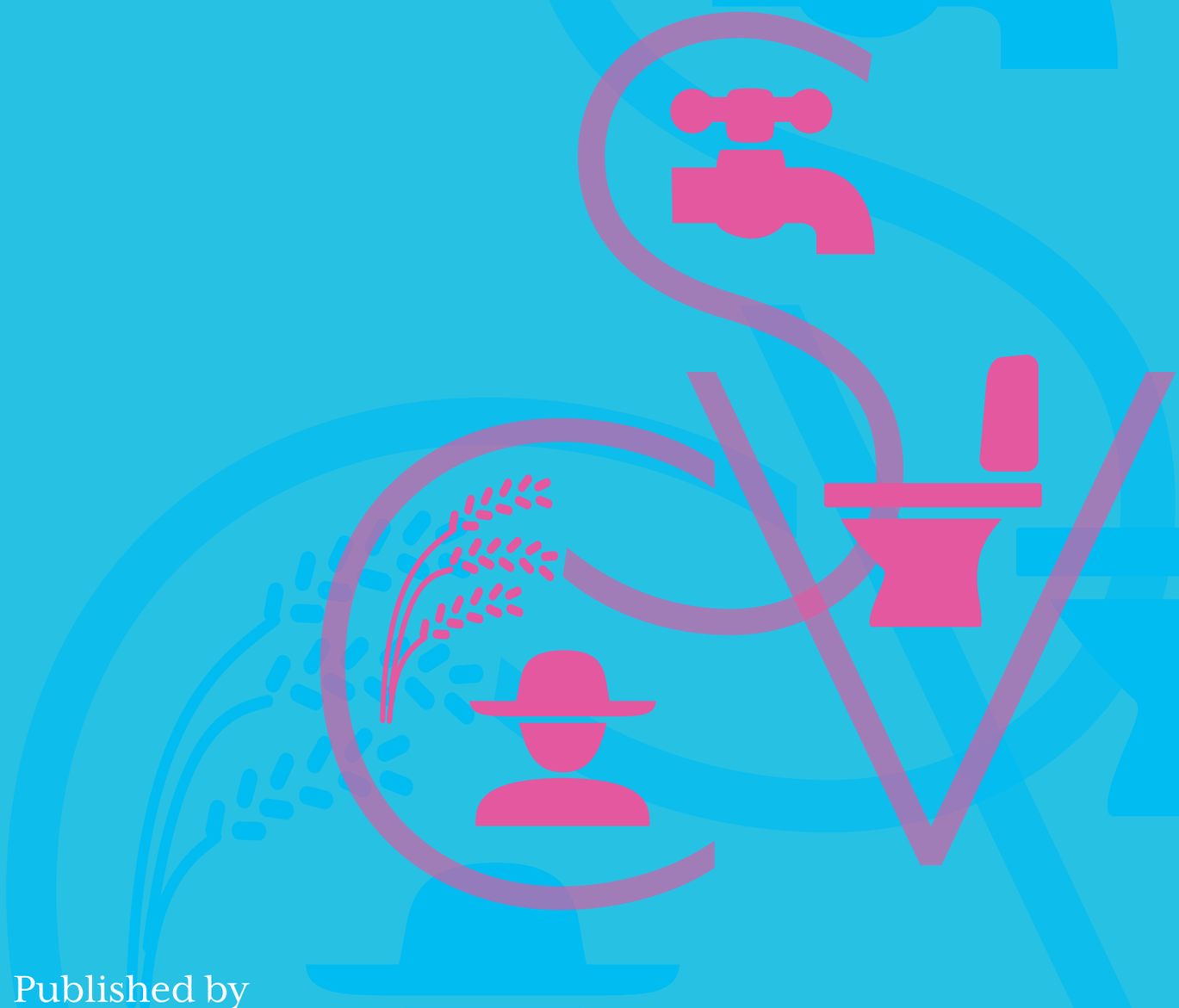

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SANITATION VALUE CHAIN: First issue published

We are delighted to announce the launch of *Sanitation Value Chain* (*SVC*) and the online publication of the first issue of the journal at [http://www.chikyu.ac.jp/sanitation_value_chain/journal.html].

As a fully open access publication, *SVC* provides maximum exposure for published articles, making the research available to all to read and share.

SVC publishes high quality peer-reviewed research papers on all aspects of the science, technology and cultures of sanitation. *SVC* is now inviting new submissions from researchers around the world. Articles published in *SVC* are free of charge and fully accessible via the journal website. Details on manuscript preparation and submission are available on the website.

We sincerely hope that through its published articles, *SVC* will provide up-to-date information about new and exciting research results in the domains of sanitation and its value chains to the scientific community.

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SANITATION VALUE CHAIN

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CONTENTS

Original Articles:

Interdisciplinary Water and Sanitation Project in Burkina Faso

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Abstract

Interdisciplinary project on water and sanitation was performed in Burkina Faso from 2010 to 2015. The title of the project was “Development of sustainable water and sanitation systems in the African Sahel region”, and the project was supported by SATREPS (JST and JICA) and collaborated with International Institute of Water and Sanitation (2iE). The main purpose of the project was to develop and demonstrate the new system of water and sanitation based on the concept of “do not mix” and “do not collect” water and wastewater. In the project, we have proposed the following concept that the water and sanitation system is not a technical system, but it is characterized comprehensive system which includes functions for institutional design, finances and human resources development. The project proposed several element technologies for sanitation which includes composting toilet; gray water reclamation unit; urine recovery unit; and agricultural technologies for effective uses of compost and urine and salt management of soil. The project also proposed the business model for installation of the system. New water and sanitation system tried in Burkina Faso will be an adequate system not only for the developing countries, and the proposed system might be considered to indicate the future direction of water and sanitation system.

Keywords:Sanitation; value chain; business model; urine; feces; gray water

Introduction

The United Nations reported that the world population in 2050 will reach to 9.7 billion. Food production to support this population has already become a global discussion. But the discussion on how to treat solid and liquid waste from human from this population is not active, in spite of such fact that 36% of people do not have a proper sanitation in 2012 (World Health Organization and UNICEF 2014).

It is well recognized that “Sanitation” is the hygienic means of promoting health as well as treatment and proposal of human waste which includes human excreta, solid waste, greywater, and sanitation is one of the important factor to control material flow and resource management. This study categorizes sanitation systems into following three generations; the Primitive, the Modern, and the Postmodern Sanitation (Ushijima et al. 2014). The system which relies on only natural purification and natural material cycle system is categorized into the Primitive Sanitation, such as open defecation. The next generation, the Modern Sanitation, is defined as the sanitation purposing safe separation and disposal of human waste from human living environment. Urbanization and modernization made people difficult to continue the Primitive Sanitation. MDGs is directed to a transition from the Primitive to the Modern sanitation. However, there is a case where it is difficult to change sanitation from Primitive to Modern in developing countries, because the Modern Sanitation requires overall ability of policy, financial, legal, institutional design and technology of national and local governments as the implementing body. On the other hand, in developed countries, including Japan, the following question has been

beginning to be discussed: Can we support the current sanitation infrastructure (the Modern Sanitation) in the future low economic growth and depopulating society?

The authors have organized the interdisciplinary research team and conducted a joint research project in Burkina Faso (see Figure 1), West Africa which title was "Development of sustainable water and sanitation systems in the African Sahel region." This project was supported by SATREPS and collaborated with Internal Institute of Water and Environment (2iE). The project was the international collaboration project with 2iE and its aim was to develop and demonstrate the new system development of water and sanitation based on the concept of "do not mix" and "do not collect" water and wastewater. The Burkina Faso is a country located in Sahel region where the influence of global climate change is visible and the poverty index is very high. And the project also aimed to develop the joint research center on water and sanitation in West Africa with human resources through the joint research. In this contribution, a part of the research results and the concept of this project are introduced.

Figure 1. Burkina Faso.

1. Interdisciplinary approach is essential in water and sanitation study

In Japan, the population that use the so-called centralized sanitation is about 79.7% in the 2013 fiscal year (Ministry of Land, Infrastructure and Transport 2015). The centralized sanitation is a system with sewer pipe network and treatment plant for collecting and treating wastewater (human waste is also included). The remaining 21.7% of the people are using so-called decentralized sanitation (Jokaso about 8.9% and vault toilet about 11.4%). In order to explain that sanitation is not just engineering system, the Jokaso and vault toilet are picked up here as an example. And the interdisciplinary of sanitation is outlined by using this example and the reason why the decentralized sanitation in Japan is working well is discussed.

Jokaso is a waste water treatment apparatus installed in each home. This apparatus does not function well only be installed, but it requires a mechanism to recover the sludge generated by processing the waste water. In other words, collection of sludge by vacuum car and treatment facilities for processing the collected sludge are required. Further, it is also necessary to maintain the quality of the effluent from Jokaso so as to satisfy the effluent quality criterion. In addition, in the vault toilet system, the collection and transport system and treatment facilities for collected human waste are required. These requirements are summarized as such related stakeholders related to decentralized sanitation system as users of toiler and/or Jokaso; group for maintaining Jokaso; group for collection and transport of sludge and human excreta; group for operating treatment facility. In many cases, the collection industry and septic tank maintenance industry is a private enterprise, management

and operation management of human waste treatment facilities are making organized around the local government. In addition, in the case of Jokaso there is a mechanism that municipalities install Jokaso. Local government becomes the operating body, set up Jokaso on personal grounds and operates it.

This mechanism is also characterized from the flow of money. There is a policy to promote the installation of Jokaso by financial system, this is called as "municipalities installation type Jokaso". In this financial system, the user of Jokaso is asked to pay only ten percent of the cost of Jokaso, and the rest of the initial cost is covered by national and local government. The maintenance of Jokaso is also supported by local government. Local government make a contract with maintenance company and user of Jokaso will pay the cost of maintenance to local government as a "Tariff". Operation of treatment facilities of sludge and human waste are managed also by local government. In some cases, more than one local government form te part-affairs associations and these association have a responsibility of operation and maintenance of treatment facility. In addition, technical standards for Jokaso have been set, and qualification system of technicians involved in maintenance has also been developed.

In this way, sanitation is not just a technical system, but it is characterized as a comprehensive system that includes functions for institutional design, policy, finances and human resources development. Therefore, there is a necessity to study for sanitation is interdisciplinary.

In addition, in Japan through the 1970s from the 1950s, national government set the policy that the system with the vault toilet + collection + treatment facility should be installed first and government supported this policy by financial support. This policy was easily accepted by people because people had a tradition to recognize human excreta as an agricultural resource (fertilizer).

Currently in Japan, sanitation including the sewerage system and decentralized system has been widely recognized as a "public service". In other words, sanitation in Japan is carried out based on the following conditions: (1) local government is main player of the system and has a responsibility of sanitation; (2) local governments has enough creditworthiness for the initial investment and has a governance capacity. In addition, user does not recognize the benefits from sanitation as "prevention of disease, reduction of health care costs, environmental protection", although these benefits are evaluated in monetary sense. But even in such situations, user pays the cost of sanitation without any doubt. Therefore, the attitude of people to human excreta should be considered in the discussion on sanitation system.

2. New approach proposed by SATREPS project: Agro-Sanitation and its concept

2.1. Current situation of Burkina Faso

First, current state of sanitation in Burkina Faso is summarized briefly. Poverty is as important as other Sub-Saharan countries in Burkina Faso. The population who is less than the poverty level is up 43.9 percent in 2009. (National Institute of Statistics and Demography Burkina Faso 2010). Although the main industry of Burkina Faso is agriculture, its productivity is low, and it has received the damage of drought caused by global warming. In particular, a decrease in vegetable production, decrease of forest, and the erosion of soil are significant. According to the statistics of 2010, the 74% of the soil has received the adverse effect, and it has dropped a big shadow on food production (Mortimore 2010:134-143; Ministry of the economy and finances Burkina Faso 2011).

In addition, due to the lack of sanitation, pollution of water resources is also a major problem. According to

the 2010 data (Ministry of agriculture and the hydraulics Burkina Faso, 2010), the coverage rate remains at 3.1 percent, against 14 percent in urban areas, and only 1% in rural areas. Lack of sanitation facilities is also causing the problem of public health, and water-based disease such as diarrhea accounted for 17% of under 5-year-old mortality rate (World Health Organization and UNICEF 2005).

2.2. Approach used in SATREPS project

Therefore, in this study, for the purpose of escape from the poverty cycle in Burkina Faso of the rural areas, it was conceived cooperation between sanitation and agriculture, such as shown in Figure 2 (Agro-Sanitation). In other words, (1) the introduction of sanitation system improve the health status of people; (2) the sanitation system provide agricultural resources (fertilizers and irrigation water and contributes to increasing the agricultural production and promoting the increase of revenue; (3) also, food production also contributes to the improvement of the nutritional status of people.

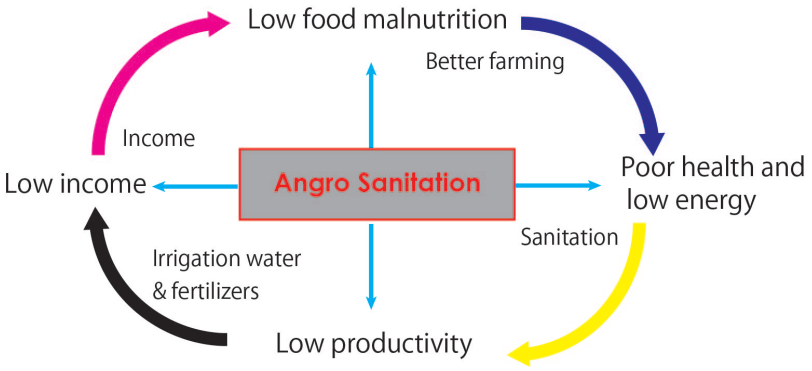

Figure 2. Agro-Sanitation and the cycle of poverty.

Then, when the introduction of sanitation in rural areas of West Africa Burkina Faso, it is determined that it is difficult to introduce the same kind of mechanism as Japan.

One of the reasons is that there is not enough system to support sanitation system in Burkina Faso. In other words, the financial capacity of local governments and human resources are not sufficient, and it may be difficult to foster the groups which support sanitation system.

The second reason is related to the issue on the values of people to the sanitation system. In Japan, the sanitation system is well recognized as an important system for protecting public health and conservation of environment, and user is willing to pay tariff and sharing the cost. In fact, the mechanism of sanitation is reducing medical costs of the society. On the other hand, in the rural areas of Burkina Faso, as described above, it has been delayed installation of sanitation. This may reflect the values of people who set lower priority to sanitation than other things. Therefore, it is decided that the installation model used in Japan is not applicable to rural area in Burkina Faso.

Therefore, in this project the following such a strategy (introduction model that takes into account the population of the value chain (Funamizu 2013) were investigated. That is, it was examined whether it is possible to incorporate sanitation systems in residents value chain.

First, the material (Nitrogen, Phosphorous, water) flow of farmers' life is analyzed, and the results showed that (Ushijima 2013): 1) the amount of water used in the living system is comparable to the amount of water required for small vegetable garden; 2) nitrogen and phosphorus that has been discarded as human waste is

comparable to phosphorus and nitrogen amount required for the small garden; 3) arable area is constrained by the amount water available. Then, the analysis of value chain of people showed that composting of feces, use of urine as a liquid fertilizer and re-use of treated gray water as irrigation water was to increase the cash income of people and this could be an incentive for the introduction of sanitation.

In other words, the possibility of integrally designed sanitation and agriculture has been shown. And, we determined the following items as basic idea of this Agro-Sanitation:

- Recognize gray water and black water as a personal property
- Treat black and gray water to improve their value
- Use reclaimed black and gray water as an agricultural resources
- Recognize the Sanitation System as an "agro-sanitation asset" which provide income to users
- Create micro-finance system for supporting this model
- Develop the hard ware to fulfill the possible loan supported by the income from human excreta.

Figure 3 is showing the structure of the Agro-Sanitation. In the system, feces, urine and gray water are separated at the source ("Don't mix") and they are reclaimed at source respectively ("Don't collect") and used as agricultural resources. Element technologies supporting the present system are (1) recycling of feces: compost toilet, (2)recycling of urine: retention of urine and disinfection unit; (3) Reclamation of the gray water: slanted soil system; (4) agricultural technology for efficient use of recovered resources. In other words, feces is composted by compost toilet and used as a soil conditioner. Urine is stored and used directly as a liquid fertilizer after disinfection by solar heat. Gray water from bathing and washing closes and dishes are reclaimed by the slanted soil system and used as irrigation water. It should be noted that, since the electrical supply is not available in the rural areas of Burkina Faso, the use of electricity is not assumed. And since there is no water supply facilities, the amount of water available per capita per day was about 20L (field survey by the result).

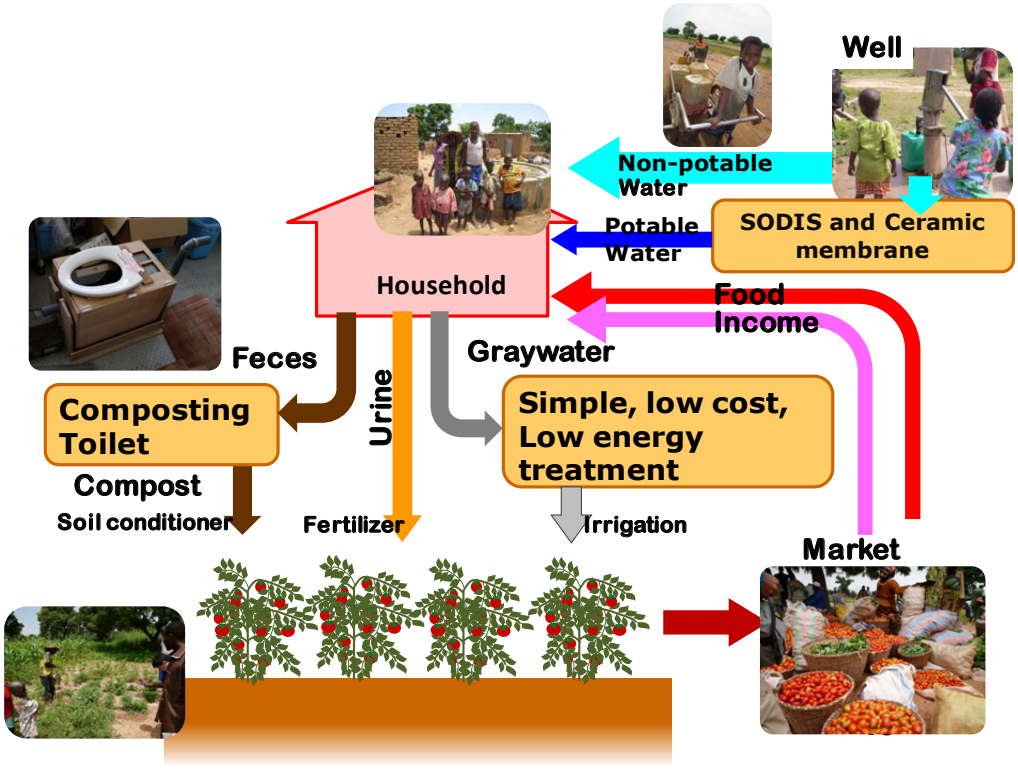

Figure 3. Schematic description of Agro-Sanitation. (Adopt from Funamizu(2015). Photos by Ushijima)

2.3 Research structure of SATREPS project

Research strategy for development and demonstration of this Agro-Sanitation were prepared as shown in Figure 4. The strategy included (1) Proposal of the model for installation; (2) Development of engineering technology; (3) agriculture technology; and (4) pilot study at four villages.

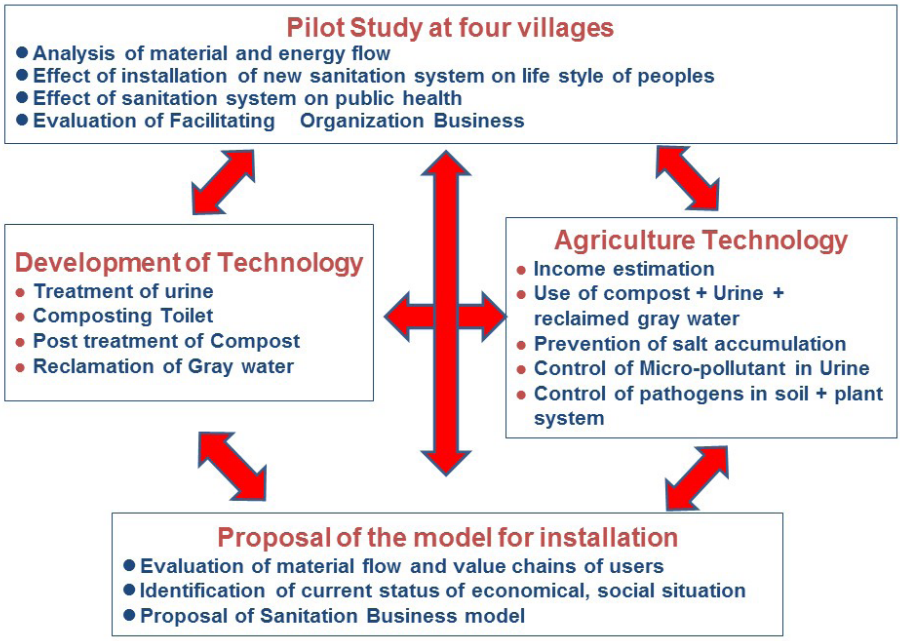

Figure 4. Structure of project.

The demonstration sites were Kamboinse village (Mossi) near Ougadougou, capital city of Burkina Faso; Barkonba village (Fulani) near Ziniare; and Kologondejess village (Mossi) as well as village which is suburb of Bobo-Dioukasso. The toilet room was constructed in each pilot family and composting type toilet was installed in it. And the urinary was installed in the water bathed place. This construction adapted the such life style of people that they urinate at the water bathed place and defecate at farmland. In order to recover the drainage after bathed water, the floor with waterproof mortar was installed at bathing place and treatment unit for gray water was set next to the bathing place

In the study of the model for installation of sanitation units, analysis of the economic, social and educational situation of farmer were performed as well as the analysis of material flow and value chain, and then a business model for installation was proposed. The development of engineering technology was related to resources recovery technology from feces, urine and gray water. The composting technology of feces have been developed by authors (Lopez Zavala et al. 2004; Hotta and Funamizu 2007: 3412-3414; Ito et al. 2006; Hotta and Funamizu 2009) and the design principles have been also proposed (Lopez Zavala 2006). In the project, based on the above mentioned technical experiences, the structure of toilet and toilet room were developed by obtaining several feedbacks from users. In addition, the fate of parasite eggs, protozoa and pathogenic bacteria and virus were monitored and the health risk assessment was performed. Urine was stored in the plastic tank through a urinal which was installed in the bathing place. Stored urine was then transferred to a plastic bottle and set on the roof of toilet room. By this operation, urine was disinfected by solar heat.

Gray water was reclaimed by slanted soil treatment unit. Gray water just flows down in soil layer of this slanted soil treatment by using gravity force. Since this unit does not require any energy supply like electricity

nor special character soil, the unit is sdequte for de-centralized system (Ushijima et al. 2013a).

2.4 Agriculture technology

The purpose of the study on agricultural technology development is to consider the following matters: (1) how to use recovered compost, urine and irrigation water in agriculture; (2) how sanitation can contribute to increase income through supplying agriculture resources. Also, in general, in the re-use of human waste and wastewater micro-pollutants such as pharmaceuticals should avoid to enter the circulation of the material recycling loop. Therefore, we added the following topic in the research: (3) study of the fate of malaria pharmaceuticals in soil drugs associated with use of compost and urine.

(1) How to use the recovered compost and urine

In the semi-arid regions such as Burkina Faso, salinity management associated with the use of compost, urine is important as agricultural technology. That is, in the semi-arid regions, because the water evaporation amount is larger than the rainfall, salts in irrigation water, urine and compost may be gradually accumulated in the soil. This accumulated salt may cause the adverse effect on crop. For this reason, the study of the relationship between the rate of compost, urine application and salt accumulation in soil was important.

According to the studies by the greenhouse (Sene et al, 2013), 1) in the case of continued about excess urine fertilization three times also, inhibitory effect on crop growth was not observed; 2) if urine is applied based on proper Nitrogen amount based on the fertilizing criteria, about 50% of applied salts was absorbed by the plant. These results as well as vegetable cultivation results in the demonstration experiment site gave the following urine application method (Funamizu 2015):

- Since urine has high Nitrogen supply capacity, but low capacity of phosphorous, it is effective to use urine with compost which has high phosphorous supply capacity;
- It is effective to set the amount of urine in accordance with the nitrogen requirements of the crop;
- It is better to fertilize urine divided into several times.

Also, in order to obtain the adequate water management method that takes into account the salt accumulation in the soil, two methods were compared: the salt removal by rinse by rain fall (rising method) and high salt absorption effect crops from the soil (cleaning crop method). As a result, salt cleaning effect due to rainfall was higher than the cleaning crop method, and also adequate amount of urine for avoiding salt accumulation in soil. Further, as a method for enhancing the salt cleaning effect due to rainfall, calcium salt addition method was also examined and the result showed that the calcium salt addition method could mitigate the adverse effect caused by excess amount of urine application.

Status of the field is shown in Figure 5 which was taken in January 2013.This time was the dry season and it was not raining since October 2012. Therefore, usually no vegetable production was possible in this season, but in the pilot family, they were able to grow okra as shown in the photograph. Such a combination of agriculture and sanitation system was an important part of this project.

(2) Fate of malaria medicines in the soil (Funamizu 2015)

Anti-malarial drugs are used in Burkina Faso. Some of the drugs are discharged in the urine, and this means that the anti-malarial drugs may enter into farmland. Therefore, the fate of malaria medicines in soil-plant system was examined. The experimental results showed that chloroquine, quinine, pyrimethamine, sulfur ferredoxin was higher degradable in the soil, doxycycline, artesunate, mefloquine, lumefantrine was poor degradable in the soil. Among pharmaceuticals showing low degradablity in the soil, doxycycline, artesunate and mefloquine

Figure 5. Farm land having our sanitation system where cultivation was possible even in dry season.
(photos by Hijikata)

transition to plants was detected, but lumefantrine was not detected. The transition of pharmaceuticals having low degradability from soil to plant is reported, but the fate of pharmaceutical having high degradability such as lumefantrine is not well-examined. One of the possible reasons why lumefantrine did not move to plant may be hydrophobic nature of lumefantrine and adsorption or adsorption to the roots and/or the soil surface prevent the movement of it. It is necessary to further verification. Moreover, the similar degradable test with disinfected soil showed the significant decrease of degradation of pharmaceuticals. But the addition of compost to disinfected soil promoted the degradation. These results implied biological degradation of anti-malarial.

(3) Income estimation of installation of sanitation facilities (Funamizu 2015)

In the Agro-Sanitation where sanitation and agriculture are integrated, the value of the resources (fertilizers and irrigation water), which is collected by sanitation, can be evaluated as additional income of sanitation facility users. Cultivation possible area was estimated by using the following results: Interviews on daily use of water in rural area (Ziniare suburbs); FAO estimation method for required irrigation water; recovery amount of Nitrogen and Phosphorous from feces and urine. In addition, the model for comprehensive crop rotation model was also proposed based on the survey results on vegetable distribution system in the region; farming schedule; and climate condition. Then the income of farmers (user) was estimated from agricultural products. The results gave the following findings:

- In the dry season, gray water produced from one person will give 2.3-4.4 m^2 of cultivation possible area in Zineare suburbs, and 2.9-6.9 m^2 in Bobo suburbs. This means that, assuming a family with six members, one family can cultivate 14-26 m^2 of farmland in Zinare and 17-41 m^2 in Bobo by gray water from bathing place in the dry season.
- Considering the yield obtained pilot farmland and the data on vegetable trading price in the market, the proposed crop rotation model with sanitation facilities will produce about 23 € /capita in Ziniare and 33 € /capita in Bobo. Assuming 6 persons per family, the value of sanitation facilities is estimated as 140 € in Ziniare suburbs and about 200 € in Bobo suburbs. The added value to the entire value chain is estimated to be about 250 € per family in Ziniare and to be about 300 € in Bobo suburbs.

Summary

The sanitation system proposed at the SATREPS project was introduced in this article. SATREPS project carried out in West Africa Burkina Faso was collaborative research project. The proposal of a new sanitation system that includes the business model for installation, which is a joint research achievements, will give

the opportunity of a paradigm shift both for regional planners of social infrastructure facility and for the international donor. In addition, the proposal indicates the direction of the future of the sanitation system.

New sanitation system that was tried in Burkina Faso is adequate not only for the developing world without infrastructures such as electricity and water, but also for developed world. In other words, the idea that has been proposed by author provides the direction of the future development of the sanitation system which includes the construction of "resource-recycling society" and "low-carbon society". Burkina Faso is one of the countries that can be carried out the introduction of the world's state-of-the-art system because many of the infrastructure are in the development or planning stage. This trial is a new initiative that was ahead of the rest of the world.

The reasons why the proposed system is considered to indicate the future direction are summarized from a variety of point of view as follows (Funamizu 2012, 2013):

a) The world economy

It has already been recognized that to install a sewer pipe all over the world is far beyond the economic level of the whole world and that sewerage system is not a solution for the corresponding of the sanitation problem. Also, in Japan, where aged and depopulated society is coming, it is recognized that Japanese economy can't meet the demand of rehabilitation of sewerage infrastructure especially for small and medium-sized municipalities. The mechanism of the new sanitation is needed. In particular, in Japan about 70% of the initial construction costs of sewerage system are used for sewer pipes. Moreover, it is unclear that ensuring maintenance costs of sewerage system (maintenance costs especially pipe) is capable future. That is, the system which does not require a pipe is required.

b) The sustainable water cycle

The current water use system (the water intake upstream of the basin, after the water distribution, water use and collection of wastewater, discharge of the treated water to the downstream) is considered to distort the water cycle structure of the region. In addition, in the low shallow groundwater level areas, leaks from the sewer occur, and sewer pipe has become a soil contamination source. On the contrary, in the underground water level is high region, there is a case where groundwater is penetrating into sewer pipes and the total amount of wastewater to be treated is increasing. The system without pipe, "Not collected" system is required.

c) Water resources management

In urban areas, only a small part of high quality of tap water is used for potable purpose, and most of it is used in toilet cleaning and watering. Namely, substantial amount of drinkable water are used for just transporting pollutants to wastewater treatment plant. The region, where drinkable tap water can be used such just to transport the polluted materials such as feces, is very limited. The sanitation system without using water, "Don't collect system", is needed.

d) Management and re-use of nutrients

Among the nutrients (phosphorus and nitrogen), which are a fertilizer component, phosphorus is a limited resource and the recovery of phosphorus has been demanded. In addition, in the contrary, phosphorus and nitrogen in the waste water are causing eutrophication in lakes. The recovery of fertilizer element and re-use them at agriculture is urgent issue. However, because wastewater also simultaneously contains harmful components as well as useful components, it is not easy to reuse them effectively.

Among wastewater from several appliances, wastewater from toilet (black water) contains about 44% in organic matter, about 97% in the ammonia nitrogen, accounts for about 80% phosphorus. This means that separation of black water makes nutrient recovery easier. Namely, Separation and treatment of black and gray water at source, "Don't mix" and "Don't collect" system is desired.

e) Treatment technology

In order to construct the new sanitation system, it is necessary to consider what should be treated and how the waste water treated from its occurrence form. The following principle of water treatment is well-known, "The wastewater with simple constituent gives simple treatment process. It is easier to treat wastewater from a single source than from waste

water consisting of a variety of sources." This principle gives the opportunity for re-considering and re-constructing new treatment system both for developing and developed world.

f) Culture related to water

Water use pattern and the way how people relate to water have been developed as a unique culture in each region. And, the norm to human waste is also closely related to the religion and culture. Current status of the sewer system is uniform in structure and concept and there are no big differences among countries. This is not said to be sustainable, there is a need for a variety of systems. The concept that "Do not mix", "Don't collected" offers the possibility of a variety of system.

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Microbial Risk Assessment for Agricultural Production Cycle of On-site Resource Oriented Sanitation Systems: A Case of Burkina Faso

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Abstract

On-site resource oriented sanitation system is one of expectable concepts to address a protection of water resources in developing countries due to low installation cost and resource recovery from human excretes. The present study investigated fates of indicators and pathogens originated from greywater and compost in soil to assess microbial risks when the greywater and compost are reused. Compost and greywater obtained from pilots in Burkina Faso were amended in experimental field with lettuce cultivation and the fate of pathogens in the soil was measured. The results suggested that (i) bacterial fates in compost reuse were fitted to log normal linier and those in greywater were maintained in field soil (ii) the bacterial end-off kinetics in Soudano-Sahelian climate were more rapid than that of reference values. (iii) the reduction of *E. coli* and *Salmonella* in the present condition was significantly different but that of *Salmonella* and *Enterococci* had no difference. (iv) effect of contaminated soil on annual risk probability was lower than direct handling of greywater and compost but not negligible. The present assessment also suggested that presented current model were required further technical improvement from the view of the biological risks.

Keywords: Composting toilet; Greywater reuse; Inactivation rate constant; Salmonella; Ascaris eggs

Introduction

Wastewater reuse is emerging as an integral part of water resource management, promoting the preservation of adequate quality fresh water and reducing both environmental water pollution and overall supply costs. Source separation of feces, urine and greywater (all domestic sewage, with the exception of wastewater generated by toilets and bidets) simplifies each treatment for reuse purposes. In particular, the reuse of greywater for garden irrigation has an estimated potential to reduce domestic water consumption by up to 50% (Friedler 2004). Urine-diverting dry toilets, which can separately treat human feces and urine, have advantages for saving flushing water and sewer pipe networks (Winblad and Simpson-Hebert 2004). Combination reuse of the fecal compost and stored urine can supply nutrients to vegetables as well as chemical fertilizer (Hijikata et al. 2014). Therefore the overall wastewater reuse for the garden can alleviate stress on depleted water resources while both reducing burdens for water and wastewater costs and enhancing garden activities. The wastewater reuses would be an attractive option for rural area in developing countries where often faces poverty problem, poor infrastructure, low efficiency and instability of government, and severe environmental condition (Ushijima et al. 2014). To address the overall reuse concept, one rural model with a low-cost mixing type dry toilet (composting toilet) (Yabui et al. 2012) and a slanted soil greywater treatment system (Ynoussa et al. 2014) has been tested in

houses of small scale farmers, as a case of Burkina Faso where is located in sub-Sahel Africa.

From a hygienic perspective, these resources potentially contain microbial pathogens that mainly cause gastrointestinal infections (WHO 2006). To manage the microbial risk, adequate treatments and handlings for the compost and greywater have been successfully studied (Shuval et al. 1997; Ottoson and Stenström 2003; Nakagawa et al. 2006; Schönning et al. 2007; Maimon et al. 2010). However, little information is available in a scenario of combination reuse of compost and greywater in terms of the microbial risk. In particular, effect of contaminated soil by both compost and greywater on the risk for farmers and consumers is still unclear.

Hygienic safety is generally discussed in terms of quantitative microbial risk assessment (QMRA), which is comprised of four steps: hazard identification, dose-response assessment, exposure assessment and risk characterization (Haas et al. 1999). The QMRA requires researchers to assume exposure scenarios and to use end-off kinetics of target microorganisms for each situation. The exposure scenarios were assumed by agricultural styles and tools (Seidu et al. 2008) and the end-off kinetics in soil are influenced by climate and soil properties (Zaleski et al. 2005). Assuming the combination reuse in a situation of Burkina Faso as a model case, the exposure scenarios and the die-off kinetics in contaminated soil were investigated to assess the risks for gardeners and consumers in the current rural model, in the present study.

1. Material and Methods

Compost and greywater

The composting toilet and slanted soil greywater treatment system was installed in two rural villages where located 40 km far from capital city Ouagadougou, in Burkina Faso. Compost samples were obtained from the composting toilet of 4 pilot families in October 2013 and April 2014. Totally 8 samples were measured. Most contaminated sample was applied for the present field test. Greywater samples were obtained from same 4 pilot families every week during April and March in 2014. The measuring samples were separately collected in the pilot-site but samples for field test was mixed in 200 L plastic tanks and storage in experimental field.

Field experiment

Obtained samples were applied in field cultivation test with lettuce on April to March, 2014 in an experimental site where is localized in a campus of International Institute for Water and Environmental Engineering (2iE) whose geographic details are 12°27’39.74”N and 1°32’54.78”W. Compost amendment with tap water irrigated plots (C+T), Compost amendment with greywater irrigated plots (C+G), chemical fertilizer with greywater plots (NPK+G) and chemical fertilizer with tap water plots (NPK+T) were prepared with three replications. Compost of 2 kg-wet and chemical fertilizer of 100 g was applied for one plot (1.56 m^2). Ten liter of greywater and tap water was applied in the plot every day. Soil samples were collected from 0-5 cm depth every week. Microorganism measurements and dry weight were analyzed.

Biological measurement

Compost and soil samples of 25 g (w/v) were homogenized in 225 mL of buffer phosphate water and a 10-fold dilution series with ringer solution was prepared as extract liquid. *Escherichia coli*, fecal coliforms and fecal *Enterococci* were cultured following a method 9215A in standard methods (APHA 1998). Relevant dilutions were spread on plates in duplicate on the following selective media; chromo cult coliform agar ES (Difco, France) incubated for 24 h at 44.5°C for Fecal Coliforms; same agar incubated at 37°C for *E. coli*; Slanetz Bartley agar incubated for 48 h at 37°C for *Enterococci*. For *Salmonella*, the extract liquid was diluted with

9 mL of Rappaport Vassiliadis media and different dilutions (100 to 10^{-6}) of three to five repetitions are made for each sample. The diluent were incubated for 24h at 37°C as testing process and then it was sown in Chrom Agar media on petri dish. The media was incubated at 37°C for 24h as confirmation process. The results were presented as Most Numbers Probable per gram (MNP/g) with Mac Grady table. For *Ascaris* eggs, compost and soil samples of 25 g were homogenized with 225 mL of 0.1% Tween 80 for 1 min using a blender and screened through 4 layers of wet gauze folded. The filtrate was collected in round bottom flasks and allowed to settle for 3 hours. *Ascaris* eggs were determined by the US EPA protocol (1999) modified by Schwartzbrod (2003) with a modified density of zinc sulfate (Z_nSO_4) saline solution. In the case of greywater measurement, the same method was applied except extraction step.

The results for *E. coli*, fecal coliform, fecal *Enterococci* and *Salmonella* were expressed to log normal No./g-dry. end-off kinetics were presented as inactivation rate constant (Kazama and Otaki 2011) using equation (1):

$$\text{In}\,(N / N_0) = - kt \qquad (1)$$

where, N is concentration of microorganisms at t; N_0 is concentration of microorganisms at time 0; k is inactivation rate constant; t is cultivation time after compost amendment.

One-way ANOVA, two-way ANOVA, Tukey HSD as a post-hoc test, significant correlation and model fitting were conducted with IBM SPSS Statistics 21 software.

Quantitative microbial risk assessment

Compost and greywater potentially contain hazardous of pathogens such as bacteria, virus, protozoa and helminthes that mainly cause gastrointestinal infections (WHO 2006). The present assessment selected risks of *Salmonella,* rotavirus and *Ascaris* infections.

For Dose-response assessment, Beta-Poisson model was used and the annual infection risk was calculated with equation (2) and (3):

$$P_{annual} = 1 - [1 - Pi\,(d)]^{\,n} \qquad (2)$$

$$Pi\,(d) = 1 - [1 + (d / N_{50})\,(2^{1/\alpha} - 1)]^{-\alpha} \qquad (3)$$

where P_{annual} is the annual risk probability, n is the number of the event, Pi (d) is the risk probability per one series of events, d is the ingested number of pathogens, N_{50} is a median infection dose and is a model parameter. Assuming 4 times lettuce cultivation, 4 is plugged in the n. Parameters of N_{50} and α for each pathogens were summarized in Table 2.

Exposure scenario for farmers and consumers in the present model was summarized in Table 1. Expectable exposure events for famers were determined with field observations (Hijikata et al. 2014). The exposure quantities were referred from previous reports (Table 1). Regarding the scenario for consumers, it was assumed that 12 g of lettuce was consumed every week and the lettuce was not washed (Ackerson and Awuah 2012). A quantity of contaminated soil on the lettuce was obtained from the present study: washed the cultivated lettuce in the field test with 0.1% tween 80 of 100 mL, 3 times; the washed liquid was collected and filtered with 0.45 µm pore filter; weight the filter after one day in an oven at 105°C. Dose amounts per 1 series of cultivation/consumption presented a sum of ingestion dose, which calculated with frequency, quantities, pathogen concentration of each matrix and end-off kinetics. The parameters for pathogen concentrations were summarized in Table 2. Values of a worst case and a typical case were obtained from maximum and mean values in the field

observation.

In terms of risk characteristic, 7.7×10^{-4} for *Salmonella* as general diarrheal infection (WHO 2006), 1.4×10^{-3} for rotavirus (Maimon et al. 2010) and 1.0×10^{-2} for *Ascaris* (Mara et al. 2007) was applied as tolerable risk corresponded to WHO guide of DALY 10^{-6} reduction in developing countries.

Table 1. Exposure scenarios of farmers an d consumers for the present risk assessment.

Target	Event	Ingestion matrix	Ingestion scenario	Event no./year	Quantities/event
Farmers	Compost amending	Compost	Compost handling with naked hand	4	300 mg[a]
	Plowing	Soil contaminated by compost	Soil touching at 0 day after plowing	4	100 mg[b]
	Seeding	Soil contaminated by compost and greywater	Soil touching of soil at 1 day after plowing	4	100 mg[b]
	Irrigation	Greywater	Handling of watering cans or bucket	300	2 mL[c]
	Weeding	Soil contaminated by compost and greywater	Soil touching at 20, 40 and 60 days after plowing	4 for each day	100 mg[b]
		Greywater on leaf	Touching of plants leaf	12	1 ml[d]
	Harvesting	Soil contaminated by compost and greywater	Soil touching at 75 days after plowing	4	100 mg[b]
		Greywater on leaf	Plants touching	4	1 ml[d]
Consumers	Eating	Greywater on leaf	Eating lettuce without wash	52	10.8 mL /100g[e] (eat lettuce of 12 g/day[f])
		Contaminated soil on leaf			0.6-2.3 (1.4 g) /100g* (eat lettuce of 12 g/day[f])

a: Nakagawa et al 2007; b: Mara et al. 2007; c: Ackerson and Awuah 2012; d: Maimon et al. 2010; e: Shuval et al. 1997; f: Seidu et al. 2008.
*obtained in the present study

Table 2. Parameters for the present risk assessment.

Constituent	Initial concentration		Concentration in soil		End-off kinetics in soil		Dose-response (Beta-Poisson)	
	compost [No./g-DW]	greywater [No./100mL]	compost [No./g-dry]	greywater [No./g-dry]	inactivation rate constant	T_{90}	α	N_{50}
Salmonella								
typical	4.9×10^{2}*	3.5×10*	2.2×10*	2.1*	4.1×10^{-2} for compost & no decay for greywater	(24±2)	0.3126[b]	23600[b]
worst	2.0×10^{3}	4.1×10^{2}	8.7×10^{2}	4.6×10				
Ascaris								
typical	3.4*	4.6×10^{-1}*	5×10^{-1}*	1.6×10^{-2}*	625[a] for compost & no decay for greywater		0.104[c]	859[c]
worst	27	9.8×10*	4	1.9×10^{-1}*				

a: WHO 2006; b: Haas et al. 1999; c: Navarro et al. 2009.
*obtained from the present mean of Enterococci with existed ratio in analyzed greywater and compost (pathogens/ Enterococci).

2. Result and Discussion

Microbial existence in pilot materials

Microbial existences and the concentration in compost and greywater, which collected from pilot sites, were summarized in Table 3. *Salmonella* and *Ascaris* eggs were rarely observed in pilot samples but these pathogens were existed in only one compost sample. The pathogens contaminated compost sample was used for further experiment in the present study. In the case of greywater, *Ascaris* eggs were not observed and *Salmonella* was sometimes. It has been reported that *Ascaris* eggs were frequently observed in fecal sludge collected from unsewered latrine in urban, Ghana, and the concentration in co-composting sample was initially 81 eggs/ g-dry sludge (Kone et al. 2007). In previous study by Sossou et al. (2014), we also observed existences of helminthes in collected feces in urban, Burkina Faso, and *Ascaris* concentration in compos with the fecal sample

Table 3. Initial concentration of indicators and pathogens in collected materials.

	Compost [No./g-dry]			Greywater [No./100mL]	
	Range	Amended sample	Mean	Range	Mean
E. coli [log_{10}CFU/unit]	1.9-7.7	5.1	4.2	2.8-6.1	4.7
Fecal coliform [log_{10} CFU/unit]	2.9-5.6	4.1	4.1	3.6-7.5	5.3
Enterococci [log_{10} CFU/unit]	4.1-7.8	6.2	5.6	2.7-6.8	4.4
Salmonella [log_{10} MPN/unit]	*n.d.* -3.3	3.3	-	*n.d.* -2.6	-

was initially 106 eggs/g-dry compost. Comparing to these reports, the concentration and existent frequency of *Ascaris* was lower in the present. This may be influenced by food culture in rural area, Burkina Faso, since population in the rural rarely eat fresh vegetables and most of meal was boiled at once. Concerning the geographic context, therefore, the present data was used for the QMRA as a current rural model.

Microbial reduction in compost and greywater reused fields

Concentrations of *E. coli*, fecal *Enterococci* and *Salmonella* in C+T plots were significantly decreased (Figure 1). For C+G plots, the significant decrease was observed in *E. coli* and *Salmonella* but not in *Enterococci*. For NPK+G plots, the concentrations of *E. coli, Enterococci* and *Salmonella* were not changed significantly and maintained at the level of 1-3 log and 1-2 log, respectively. For control plots of NPK+T, *E. coli*, *Enterococci* and *Salmonella* were rarely detected. Regarding on fecal coliform, the clear tendency was not observed in all treatments and the concentration of log 2-3 was detected even in NPK+T plots. From these results, it

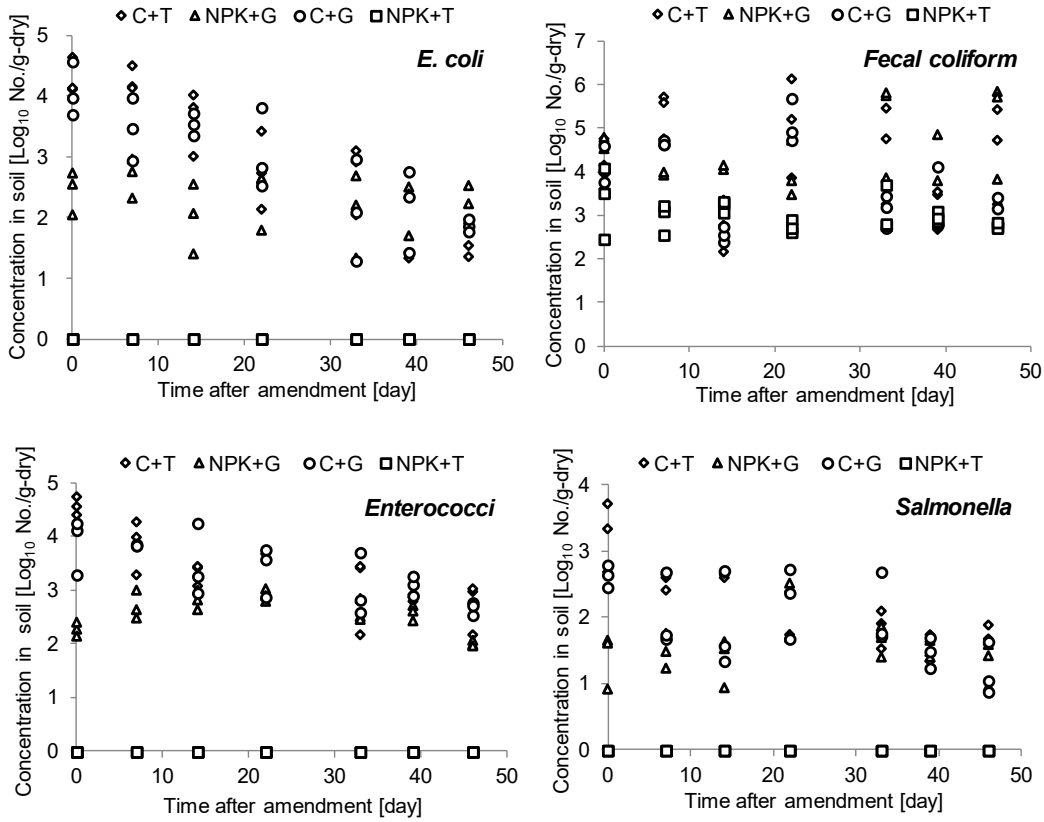

Figure 1. Fate of bacteria in field soil.
C+T, compost amended plots; NPK+G, greywater irrigated plots; C+G, compost and greywater applied plots; NPK+T, chemical fertilizer and tap water applied plots.

was suggested that (i) bacterial concentrations in C+T supposed to be modeled by die-off kinetics (ii) the concentrations in NPK+G was mainly maintained due to continuous greywater irrigation and the concentration would be affected by greywater concentration (iii) the concentrations in C+G might be difficult to fit the simple die-off kinetics but it would be decreased at first and maintained at the same level of NPK+G at the end. In addition, it would be difficult to apply fecal coliform value as an indicator of enteric pathogens for the risk assessment related to soil pathway.

Ratios of *E. coli*, *Enterococci* and *Salmonella* in C+T plots were significantly correlated and fitted to a linier model (Figure 2). Inactivation rate constants for the three bacteria were $5.8\pm0.4\times10^{-2}$, $4.7\pm0.4\times10^{-2}$ and $4.1\pm0.4\times10^{-2}$, respectively. Using the obtained kinetics, times for 90% inactivation (T_{90} value) for the three bacteria were calculated to 17±1, 21±2 and 24±2 days, respectively. The T_{90} values were relatively rapid than reference values of 25±5 for *E. coli* and 35±5 for *Salmonella* in soil (WHO 2006). This difference might be caused by dried and high temperature in Soudano-Sahelian climate. Furthermore, two-way ANOVA and post-hoc test by Tukey HSD showed that the time dependent change of *E. coli* and *Salmonella* ratio was significantly different but not in *E. coli* v.s. *Enterococci* and *Salmonella* v.s. *Enterococci*. This statistic result suggested that it would be better to apply original end-off kinetics of *Salmonella* or that of more tolerable bacterial indicator than *E. coli* for *Salmonella* infection risk related to soil. The possible indicator may be *Enterococci* or *Enterococcus* feacalis as its represent. Although it has been reported that the bacterial group regrows in composting process and was recommended to be eliminated as an indicator for *Salmonella* (Tønner-Klank et al. 2007), the

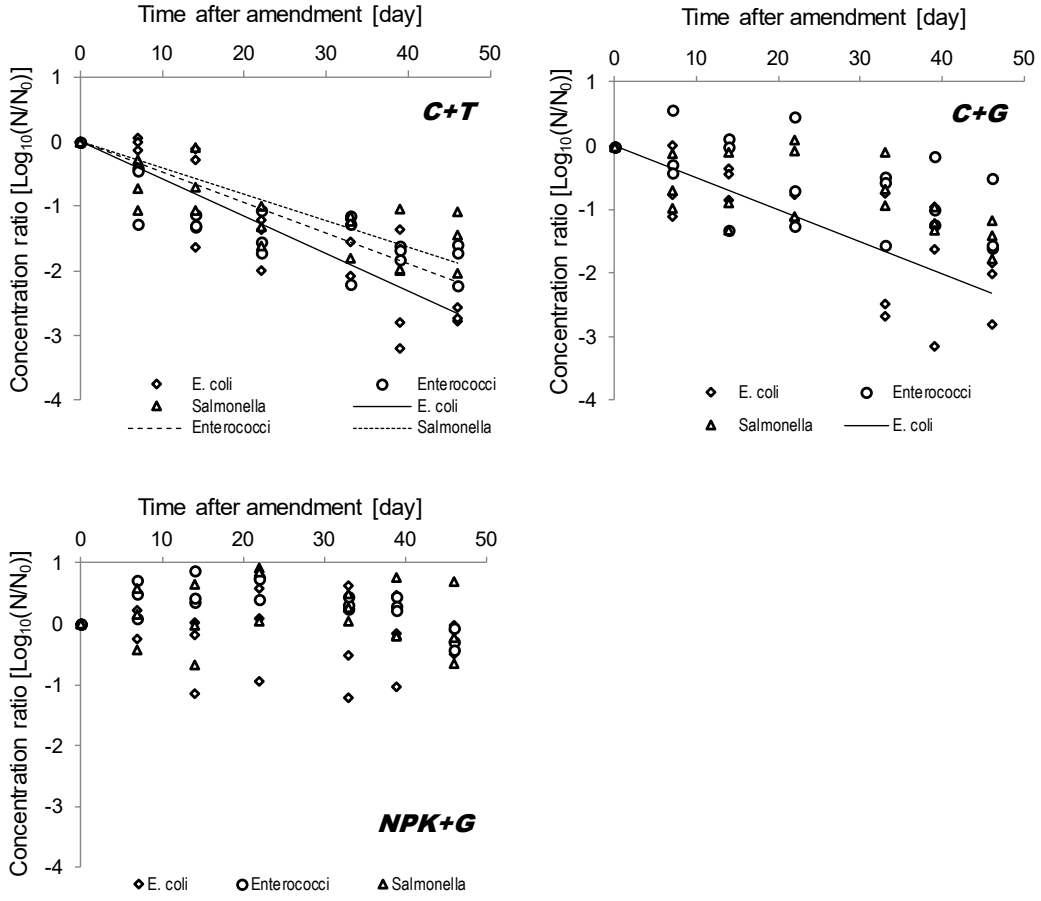

Figure 2. Time dependent changes of bacterial concentration ratio in compost amended plots (C+T), compost and greywater applied plots (C+G) and greywater irrigated plots (NPK+G).
Lines in the figures represents significant model fitting on approximate linier ($p < 0.05$).

tolerability is higher than *E. coli* (Christensen et al. 2002) and the fate is similar with *Salmonella* in greywater (Ottoson and Stenström 2003). In the present study, additionally, regrowth and unclear fate of the group was not observed in soil system and the end-off kinetics was not significant difference with *Salmonella*.

Concentration of *Ascaris* eggs in compost amended soil was initially 4.0±0.4 eggs/g dry soil (Figure 3). The count was not observed in NPK+G and NPK+T plots. Although the count was missed in sometimes probably due to ununiformity of amended compost and low diffusivity of the eggs in the soil, an obvious outlier was not found in the present data set except not detected. Because of the fluctuated data set, the correlation and model fitting was not significant. Therefore, only the initial concentration was used for the present QMRA but die-off kinetics was extrapolated from reference data (WHO 2006).

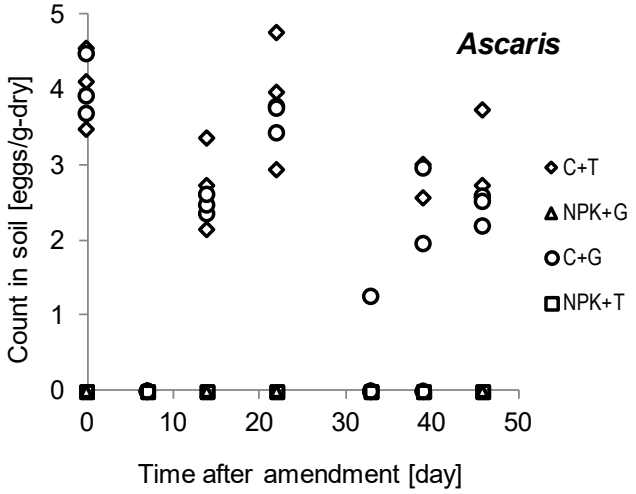

Figure 3. Concentration of Ascaris eggs in field soils.

Quantitative microbial risk assessment

Parameters used in the present QMRA was summarized in Table 2. The obtained data in the field was filled in parameters for *Salmonella* and *Ascaris* risk as a worst case since these microorganisms were rarely observed in the present samples. Parameters for a typical case of these two microorganisms were calculated with means of fecal *Enterococci* concentration in the present samples and existence ratio (pathogens/ *Enterococci*). Parameters for rotavirus risk were calculated with mean (as typical case) and maximum (as worst case) of *E. coli* concentration, using a ratio of rotavirus (1/100,000 *E. coli*) (Mara et al. 2007).

All annual risks by the three pathogens for farmers were exceeded to the target tolerable risks in both typical and worst case (Figure 4). Furthermore, the annual risks for consumers were also exceeded to the target tolerable risks excepting *Salmonella* risk in compost reuse (Figure 5). These results suggested that further investigation for greywater treatment system and compost handling was recommended to improve the safety management from both technical and practical views. Regarding the risks in compost reuse, Schönning et al. (2007) has recommended human manure storage for 6-12 months for adequate handling of urine diverting dry toilet. For mixing type composting toilets, the adequate maturation period would be shorter, since *Ascaris* eggs in co-composting with agricultural bulk agents in the toilet decreased from 106 eggs/g-dry to 1 eggs/g-dry for 2 months (Sossou et al. 2014). To shorten the maturation period, addition of alkaline agents such as lime and ash (Newabaga et al. 2009; Kazama and Otaki 2011), co-composting with urea (Nordin et al. 2009) and solar heating (Redlinger et al. 2001) would be further solution as post inactivation treatments. The present result also indicated that risk probabilities for greywater reuse were almost similar magnitude level with compost

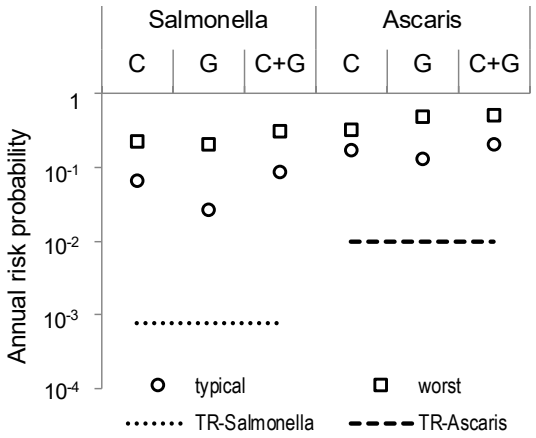

Figure 4. Annual risk probability for famers in a typical and worst case.
TR, tolerable risks corresponded to DALY 10^{-6} reduction.

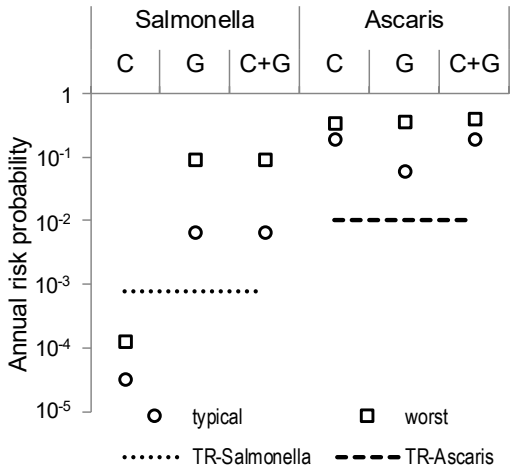

Figure 5. Annual risk probability for consumers in a typical and worst case.
TR, tolerable risks corresponded to DALY 10^{-6} reduction.

reuse. One possible explanation may be higher exposure frequency of greywater even though the contaminant concentration was lower. In Soudano-Sahelian climate, more frequent irrigation is necessary due to high evapotranspiration, particularly in dry season. The geographical characteristics might elevate the microbial risk of greywater reuse. It is well known that drip and subsurface irrigation system is effective both water saving and hygienic risk reducing. More cost effectively, using watering cans with caps also reduce on their spouts reduces water intensity of splashes (Seidu et al. 2008).

Annual risk probabilities by different matrix in compost and greywater reuse were presented in Figure 6. The result showed that effect of contaminated soil on the risks was lower than direct handling of greywater and compost but not negligible. Similar finding has been reported by Seidu et al. (2008) which pointed that on farm soil contamination is the significant health hazard in wastewater reuse for lettuce gardens. Some reports for QMRA have assumed that feces amended soil or greywater irrigated soil are same contaminant concentration with the original materials (Schönning et al. 2007; Mara et al. 2007; Maimon et al. 2010). From the field observation in the present, however, the concentration of indicator was lower than that of original materials. For instance, *Enterococci* ratio of compost and its amended soil was approximately 0.184 (soil/compost) and the ratio of greywater and irrigated soil was approximately 0.014 (soil/greywater). This is probably due to

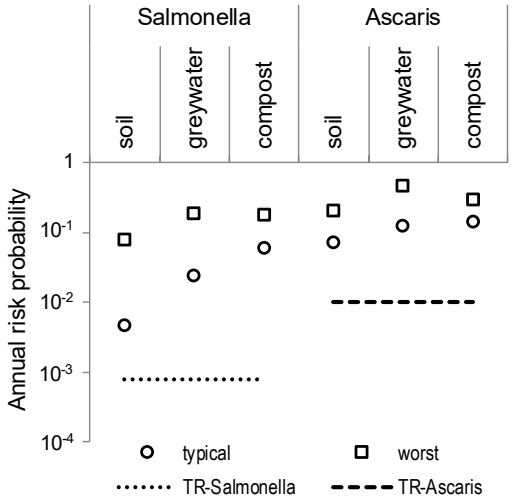

Figure 6. Annual risk probability for famers mediated from contaminated soil, greywater and compost.
TR, tolerable risks corresponded to DALY 10^{-6} reduction.

dilution of compost and permeability of greywater. These ratios would be changed by soil properties and input concentrations. Therefore, fate of indicators in soil and effect of the soil concentration on that on leafs should be further investigated.

Conclusion

The present study evaluated fates of indicator and pathogens originated from greywater and compost in soil to assess microbial risks for production cycle of combined resource oriented sanitation system. The results suggested that (i) bacterial fates in compost reuse were fitted to log normal linier and those in greywater were maintained in field soil, (ii) the bacterial end-off kinetics in Soudano-Sahelian climate were more rapid than that of reference values, (iii) the reduction of *E. coli* and *Salmonella* in the present condition was significantly different but that of *Salmonella* and fecal *Enterococci* had no difference, (iv) fecal coliform did not play a role of indicator in soil and (v) effect of contaminated soil on annual risk probability was lower than direct handling of greywater and compost but not negligible. The present QMRA also suggested that annual risks of current on-site resource oriented sanitation system were exceeded to tolerable risks. Therefore, on farm handling of compost and greywater should be further investigated from practical and technical views.

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Potential of Treated Wastewater Reuse for Agricultural Irrigation in Ouagadougou, Burkina Faso

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Abstract

Ouagadougou, the capital city of Burkina Faso, is located in dry savanna and the issue of water scarcity is of particular concern since water shortage affects the local economy. Treated wastewater from treatment plants can be reused for irrigation. Currently, stabilization ponds are widely used in Ouagadougou, however, the effluent could adversely affect crop production due to low water quality, especially during the dry season. Therefore advanced pond systems are required. This study focuses on wastewater management in urban areas, and discusses the application of high-rate algal ponds (HRAPs) to treated wastewater reuse for agricultural irrigation. Compared with conventional stabilization ponds, HRAPs indicated a lower risk of microbial pathogen contaminants in treated water and higher removal efficiency of nutrients from wastewater. When the effluent from stabilization ponds and HRAPs were used as irrigation water, the estimated yields of tomato production were expected to be 10,208 t and 17,488 t, respectively. Since HRAPs have the advantage of a significantly shorter HRT compared to stabilization ponds, evaporation loss is reduced. Thus, when introducing sewage treatment, it is necessary to consider not only the impact of effluent on the environment, but also the value of irrigation water.

Keywords: Irrigation; Grey Water; Sahel Africa; High Rate Algal Ponds

Introduction

In Sub-Saharan Africa, cereal yields are extremely low; they are at least twice as low as those observed in South and Southeast Asia (Rockström et al. 2006), since the potential for irrigation expansion is limited by surface water and groundwater availability. Burkina Faso is a landlocked country located in Sub-Saharan Africa. It has three major biomes. Sahel (northern region) has an annual precipitation of 400–600 mm and potential evapotranspiration of over 1,900 mm. Moist Guinea Savanna (southern region) has more than 1,000 mm of annual rainfall and potential evapotranspiration of 1,700 mm or less. Dry Savanna (central region) has an annual precipitation of 600–1,000 mm and evapotranspiration of 1,700–2,000 mm (UNEP 2010). Burkina Faso receives most of its rain between June and September (more than 500 mm), and this typically provides water for crops and livestock. In 2011, 80% of the country's active population was engaged in agriculture, and the proportion of the total gross domestic product contributed by this sector was 33.8%. However, the rainfall in Burkina Faso has declined rapidly, and the 2000–2009 average was approximately 15% less than the average in 1920–1969 owing to a significant reduction in the number of rainy days between June and August during the rainy season (Lodou et al. 2013). The water shortage is rapidly becoming a critical concern as it affects the local economy, which

is mainly based on agriculture. Water resource management to improve irrigation has important implications for hunger and poverty. Therefore, strategies to develop technologies such as water harvesting are required to improve and stabilize food crop production.

Stabilization ponds are widely used in developing countries for wastewater treatment owing to their simple construction and operation, cost effectiveness, and low maintenance and energy requirements. High-rate algal pond systems (HRAPs) have been developed as advanced integrated wastewater pond systems (Oswald 1995; Green et al. 1996). Since, the systems have low investment and operation costs, and are simple management solutions for greywater, it has considerable potential to upgrade stabilization pond. HRAPs would be of great benefits due to less suspended sludge in effluent and rapid retention time.

This study focuses on wastewater management in Ouagadougou, an urban area in Burkina Faso, and discusses the application of HRAPs and the potential of treated wastewater reuse for agricultural irrigation.

1. Materials and Methods

Study site

Ouagadougou, located in a Dry Savanna region, is the capital and largest city of Burkina Faso, with a mean annual precipitation of 740 mm and daily temperatures reaching 40 °C or more in April, the hottest month of the year. The annual potential evapotranspiration in the city is estimated to be 2,080 mm (Wang et al. 2007). Therefore, it has been experiencing water shortages. The National Water and Sanitation Office (L'Office national de l'eau et de l'assainissement; ONEA), a public sector and financially autonomous entity, manages sanitation services, including sewage and wastewater treatment, in urban areas. The wastewater treatment plants in Ouagadougou were designed for population equivalents of 140,000, and mainly utilize the lagoon system (stabilization pond).

The Kossodo wastewater treatment plant is in an industrial area and currently treats 5,400 m^3/day of influent wastewater from domestic areas, hospitals, commercial, and industrial areas. Industrial influent from a brewery and a slaughterhouse represent 60% of the total influent. A conventional stabilization pond was installed as a wastewater treatment system, which consists of an anaerobic pond and a following maturation pond at the hydraulic retention time (HRT) of around 30 days. The new development district Ouaga 2000 is located south of the city centre, and commercial facilities and government buildings are currently being built in this area to promote urban development. Therefore, a plan has been developed to augment the treatment capacity of the Kossodo wastewater treatment plant (phase II) to 11,600 m^3/day to account for the expected increase in influent. This study included a literature review and an interview with representatives at ONEA in April 2014. The water quality analysis of the treated water (effluent of the Kossodo wastewater treatment plant) and environmental water samples taken from Dam and river (Barrage) near the Kossodo wastewater treatment plant was performed. The sampling sites are shown in Figure 1.

Electric conductivity (EC) and pH were measured by electrode method in a bucket of the sampling water on each sampling site. Samples for COD, total nitrogen (TN) and total phosphorus (TP) were collected with conical tubes from the bucket and stored in a freezer at -20°C. These parameters were measured with Hach test tube kits, which were reactor digestion method (Hach method 8000), persulfate digestion method (Hach method 10071) and PhosVer® 3 ascorbic acid method with acid persulfate digestion method (Hach method 8190), respectively. These values were determined by DR2800 spectrophotometer (Hach) after heat digestion by DRB200 reactor (Hach).

High-rate algal pond system (HRAP)

A bench-scale HRAP reactor was developed to execute the operation of the pilot plant; it was implemented at the 2iE campus in Ouagadougou, and simulated greywater treatment under arid and semi-arid conditions (Derabe Maobe et al. 2011a, Derabe Maobe et al. 2011b). This system adopts a gravity sedimentation process to control the hydraulic retention time (HRT) and solid retention time (SRT) in a way that allows algae recirculation and high performance of solid-liquid separation. It is equipped with a sedimentation tank and a common screw mixer instead of paddle wheel mixers, which is specially manufactured in an industrial country, for introducing to developing countries. The HRAPs were evaluated in this study on the basis of the performance of the bench-scale HRAP reactor.

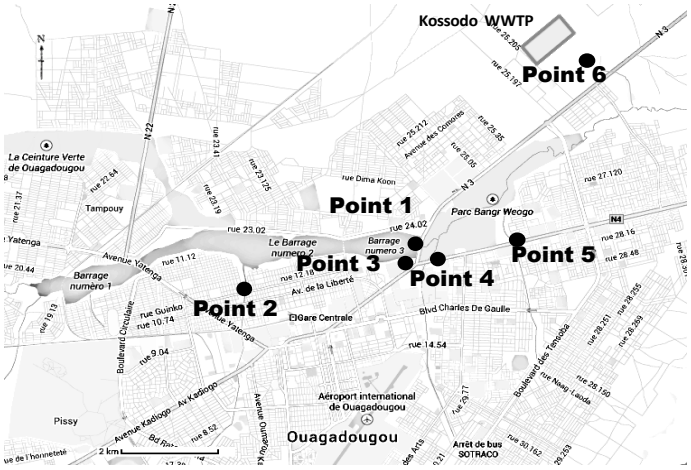

Figure 1. Sampling location at dam in Ouagadougou.

2. Results and Discussion

Impacts of wastewater reuse for agriculture in urban area

Agrarian economies commonly raise concerns about the competition for water resources with other sectors. In case of Burkina Faso, The competition between the agriculture sector (51% of total) and domestic water use (46%) is growing, according to Food and Agriculture Organization of United Nations. However, the treated urban wastewater could add to the total water available for irrigation without any competition from the domestic sector. Figure 2 shows the split between urban and rural populations in Burkina Faso as a percentage of the total population for the period 1960–2012. As reported by the World Bank, in 2012, the urban and rural population growth rates (annual %) were last measured at 5.99 and 1.71, respectively, which indicates a continuing trend of rapid urbanization. The amount of wastewater is expected to increase due to the increasing urbanization and the rising number of people with sewerage connections owing to the subsidies given in the connection fee (90% of total) by ONEA. Associated with rapid urbanization, “collected wastewater” is expected to become a potential resource through wastewater management and wastewater treatment system contributes to expand available irrigation area and its productivity.

Microbial pollution of wastewater treatment effluent

When used for irrigation, microbial pathogen contaminants in treated wastewater pose a health risk. Hamouri et al. (1994) indicated that the removal of each type of indicator bacteria tested during wastewater treatment

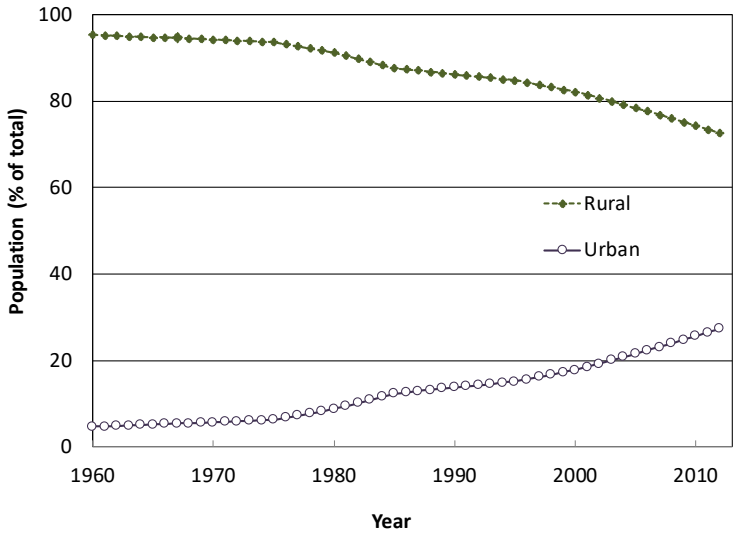

Figure 2. The percentage of urban and rural population in Burkina Faso from 1960 to 2012.

in the HRAPs system is over 90% (92% of total coliforms, 99.9% of fecal coliforms and 99.8% of fecal Streptococci). Takahashi et al. (2014) investigated the effect of disinfection on the removal pathogen bacteria and viruses using a bench-scale HRAP reactor, and more than 2 log units of Escherichia coli were removed within 2 days, and a 4-log reduction of viruses was observed within 3 days.

Microbial pollution of wastewater treatment effluent in the urban area of Ouagadougou (including at the Kossodo wastewater treatment plant) was estimated by Nitiema et al. (2013). Table 1 shows the concentration of *E. coli* in wastewater treatment plants and its predicted value for HRAPs treatment. Although the stabilization pond in the wastewater treatment process reduced indicator bacteria by 1 log unit, the concentration of *E. coli* in the maturation pond did not meet WHO standards or national guidelines recommend for wastewater use in agriculture (<1,000 CFU/100 mL). Even though the application of HRAPs requires careful monitoring of indicator bacteria and viruses in Burkina Faso, it might reduce the concentration to less than 1,000 CFU/100 mL.

Table 1. The concentration of indicator bacteria at wastewater treatment plants during the dry season.

Treatment plant	Concentration of *E. coli* (CFU/100mL)[a)]			Predicted *E. coli* conc.
	Anaerobic pond	Maturation pond	Discharge pond	in HRAP[b)]
Kossodo	11200	0	3300	112
Abattoir	172000	6450	10400	1720
2iE	129200	22800	33400	1292

a) Nitiema et al. 2013
b) The values are estimates from Takahashi et al. 2014

Effect of HRAPs on nutrient removal

For the reuse of effluent from a wastewater treatment plant, based on an interview, ONEA identified a problem at the Kossodo wastewater treatment plant. Specifically, the quantity of treated water was related to crop

production because nutrient removal was not sufficient due to influent variability (consisting mostly of industrial wastewater) and the lack of industrial pre-treatment, especially during the dry season. The pH, electrical conductivity (EC), chemical oxygen demand (COD), total nitrogen (TN) and total phosphorus (TP) were measured in environmental water samples taken from dam near the Kossodo wastewater treatment plant (Figure 1), the result are summarized in Table 2. The concentrations of COD, TN, and TP in effluent from wastewater treatment plant (point 6) were significantly higher than the ones of in the environmental waters from dam and river (point 1, 2, 3, 4 and 5). Bassan and Strande (2011) reported water quality of the effluent from Kossodo wastewater treatment plant. The COD concentration in effluent was 128–346 mg/L (average, 254 mg/L), higher than the standard for discharge (<150 mg/L). Phosphorus and nitrogen were poorly removed. The nitrate and orthophosphate concentrations of nutrients in effluent were 0–7 mg/L (average, 2 mg/L) and 7–38 mg/L (average, 26 mg/L), respectively.

The carbon and nutrient removal efficiencies of the stabilization pond (Bassan and Strande 2011) and HRAPs are summarized in Table 3. The COD removal efficiency of the stabilization pond was low (44%), and the HRAPs had generally higher carbon and nutrient removal efficiency compared to the stabilization pond. The different the HRT and SRT condition in HRAPs were compared, and lower nutrient removal efficiency was observed in longer SRT (20 days).

While there is an advantage that available nutrients left in the effluent decreases irrigation costs due to less fertilizer usage, depending on the type of crop, the concentrations of carbon and nutrients influences crop production. For example, agricultural water standards for paddy rice irrigation established by the Ministry of

Table 2. The water quality of environmental water and the effluent from the Kossodo wastewater treatment plant.

		pH		EC (mS/cm)		COD (mg/L)		TN (N mg/L)		TP (P mg/L)	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Point 1[a)]	Dam lake	8.41-9.21	8.73	246-353	312	12-47	29	0.1-1.5	0.8	0.03-0.06	0.05
Point 2[a)]	Drainage canal	8.57-9.21	8.96	446-916	702	42-76	59	1.9-10.8	6.4	0.11-0.16	0.13
Point 3[a)]	Drainage canal	6.71-7.39	7.21	314-617	482	36-47	41	16.7-24.9	20.8	0.67-1.60	1.13
Point 4[a)]	Main river	7.15-8.78	7.89	405-497	459	33-47	40	4.1-4.7	4.4	0.23-0.25	0.24
Point 5[a)]	Drainage canal	6.81-8.14	7.47	281-496	338	42-53	48	8.0-10.7	9.4	0.41-0.60	0.50
Point 6[b)]	WWTP effluent	8.21-8.54	8.38	1293-1852	1573	99-195	147	16.0-30.9	23.5	2.55-5.64	4.10

a) The enviromental water samples were corrected on July, September 2012 and April 2013. (N=3)

b) The effluent samples from Kossodo wastewater treatement plant were corrected on September 2012 and April 2013 (N=2)

Table 3. Nutrient removal efficiency for a stabilization pond in Ouagadougou and a bench-scale HRAP reactor.

	Removal efficiency (%)				
	Stabilization pond[a)]	HRAP[b)]	HRAP[c)] (HRT: 8 days)		
	(HRT: 30 days)	(HRT: 10 days)	SRT:10 days	SRT:15 days	SRT:20 days
COD	44	-	-	-	-
Filterd BOD_5	96	-	-	-	-
TOC	-	61	-	-	-
Nitrate	17	-	-	-	-
TN	-	58.8	65.4	55.8	21.3
Orthophosphates	13	33.4	-	-	-
TP	-	30.2	21.8	15.4	3.7

a) Bassan and Strande, 2011

b) Derabe Maobe et al., 2014

c) Onodera et al., 2014

Agriculture, Forestry and Fisheries in Japan recommend less than 1 mg/L of total nitrogen and 6 mg/L of COD because nitrogen and COD concentrations of irrigation water affects rice growth and yield. More than 3 mg/L of TN would cause a reduction in yield. A COD of 20 mg/L would be projected to result in a 10–12% reduction in yield. The excess nitrogen leads to a reduction in productivity of nitrogen sensitive plant by rank growth, such as soybean and paddy rice.

Therefore, the concentrations of carbon and nutrients in treated water must be considered for irrigation use. HRAPs have advantage that it could reduce this effect by controlling HRT and SRT.

Water usage and potential amount of irrigation

Dirja et al. (2003) has calculated the water quantity necessary to tomato, green pepper and cucumber based on agriculture experiment in 1999-2002, the irrigation water was administered by dripping using microsprinker. Ushijima et al. (2012) has been reported tomato cultivation yield based on household survey in the rural area of Burkina Faso under the dry season. Estimated water consumption and average yields were summarized in

Table 4. Water consumption and average yields.

Crop	Water consumption	Average yields (ton/ha/year)	Reference
Tomatoes	4545 m^3/ha/year	78.6	Dirja et al. 2003
Green peppers	4014 m^3/ha/year	37.3	
Cucumbers	4300 m^3/ha/year	53	
Tomatoes	50 m^3/ha/day	80	Ushijima et al. 2012

Table 4. In case of tomatoes production, a recommended irrigating norm was 4,400-5,000 m^3/ha/year or 50 m^3/ha/day, and average yield was 80 ton/ha/year in either case. Total pond area of stabilization pond was calculated by based on Kossodo wastewater treatment plant. In case of HRAPs, total pond area was calculated based on the allowable water depth (1 m) and the volume of treated wastewater. When it comes to water consumption rate in Burka Faso mentioned above, agricultural and domestic water use account for 51% and 46% of total, respectively. Given the value of sewage water equal to domestic water, it is estimated that the amount of agricultural water is 1.1 times as much as sewage water. Based on the water quality of the effluent from the stabilization pond, such as the concentration of *E. coli* described above, we hypothesize that the effluent is needs to be diluted 3-fold with agricultural water before use. Hence, the decrease factor was considered as 0.55 in the estimation. Available water amount of irrigations were estimated in Table 5. In the result of estimated tomatoes

Table 5. Estimation of available water amount for irrigation from treatment plan and predicted tomatoes production yield.

	Influent (m^3/day)	HRT (day)	Total volume of pond (m^3)	Total pond area (m^2)	Amount of evaporation[a] (m^3/day)	Decrease ratio	Available water amount for irrigation (m^3/day)	Available area for irrigaion[b] (ha)	Predict tomato production yield (ton/year)
Stabilization pond[c]									
Current	5,400	30	162,000	95,789	553	0.55	2,970	59	4,752
Phase II	11,600	30	348,000	191,578	1,107	0.55	6,380	128	10,208
HRAPs[d]	11,600	10	116,000	116,000	670	1.00	10,930	219	17,488

a) Annual evaporation is caluculated by 2080mm (Wang et al. 2007).
b) Water consumption is caluculated based on 5L/day/m2 . (Ushijima et al. 2012).
c) The plant capacity is calculated based on the data of the Kossodo treatment plant.
d) The depth of pond in HRAPs: 1 m.

production yield in case of phase II (influent of treatment plant: 11,600 m^3/day), stabilization pond and HRAPs would be expected 10,208 t and 17,488 t, respectively. Rapid retention time of HRAPs has contributed to the increase in production due to less water loss by evaporation not only water quality of effluent.

Conclusion

It is clear that water usage will increase due to new public and commercial facilities and residences at urban area in Burkina Faso, and the urban sewage system is a valid water source for irrigation. While, water discharged from these large-scale facilities are expected to contain high concentrations of carbon and nutrients. Therefore, sewer systems, which will grow in the future, must be considered to apply the technologies with the higher removal efficiency than conventional lagoon systems. HRAPs may assist the treatment of wastewater and its reuse in irrigation, and it is strongly required by using pilot plant to demonstrate the validity and estimate practical applicability.

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Sanitation Project in Rural Africa Examined Based on Local Economy, Education and Community Participation: A Case Study of Burkina Faso

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Abstract

This study discusses the possibility of a better management of sanitation project and the business model based on community participation in rural Burkina Faso. The case study was carried out based on the local residents' economic and educational situations as well as their experiences of community-based organizational activities. This paper is focusing on the relationship patterns among their income, educational backgrounds, and participants' experiences of community activities. Survey results show that people who have no primary education but have literacy education earn higher income than those with primary education. With regard to experience of community-based organizational activities, it has no relationship to both educational backgrounds and income levels. However, the incomes of those who have an experience of externally funded project or microfinance are higher than those who do not have the experience. For a success of sanitation project, a mechanism should be put in place to enable local residents appreciate the potential economic effects of the sanitation project through their interaction with external stakeholders. In order to create additional motivation for participants, it would be also effective to incorporate some literacy education services into the sanitation project for the purpose of income improvement. This study suggests a new approach for the success of the sanitation project. The local residents' participation in externally funded project with enhancement of literacy skills leads to an improvement of both sanitation and income.

Keywords: Popular participation, Community-based organization, Economic and educational situations, Rural development, Burkina Faso

Introduction

Improvement of water and sanitation in Sub-Saharan Africa has been one of the most critical issues, especially in rural areas. Improving sustainability of water and sanitation supplies has potential for both gains in health and economic development (Montgomery et al. 2009). Many studies and projects have been implemented for a sustainable sanitation system, but large-scale success has not been found yet (Haq and Cambridge 2012). Previous studies report that current concepts or schemes on sanitation are not sufficient enough to resolve the stagnant situation of the sanitation improvement (Ushijima et al. 2015). It has also been reported that several water and sanitation projects failed not because of funding problem but because of ineffective systems and policies as well as misunderstanding of socio-economic issues in rural Africa (Jonah et al. 2015).

This study has taken into account the capability of a new sanitation business model which can contribute to improving both sanitation and income (Ushijima et al. 2015). The business model concept is for local residents, such as peasants living in rural Africa, not only to manage hygiene but also to generate some value from food or cash crops. It will in turn generate profit by utilizing a water and sanitation system. The value chain cycle should

be autonomously operated through participation of local residents in their respective communities.

From the above point of view, this paper examines the possibility of a successful sanitation project including the business model by community participation. A case study in rural Burkina Faso is applied to analyze in this study. Various studies on rural Burkina Faso have described that peasants' income, which mostly depends on agriculture, is instable and vulnerable (Kawada 1973; Shimada 2001). Some of them emphasize the importance of investment in education and development of agricultural technology (Sakurai and Inoue 2014). There are also studies that have verified the formation process of residents' self-organizational capabilities through their group activities of microfinance (Ikemi 2011; Kumashiro 2014).

The case study in this paper discusses the results of a field survey in rural Burkina Faso. The purpose of the survey is to examine the local residents' economic and educational situations as well as their experiences of community-based organizational activities. These local residents' characteristics are regarded as important socio-economic factors to consider more effective and sustainable sanitation system by popular participation. In this paper, the main findings are based on the relationship patterns among their income, educational backgrounds, and experiences of community activities.

1. Research Area

The research areas are four villages in rural Burkina Faso as postrayed in Figure 1. Two of them, called Kologondiessé village and Barkoundouba village, are located in Central Plateau region about 45 km north-east far from the capital of Ouagadougou. The other two villages are called Makognadougou village and Dabokry village. Makognadougou village is located in Hauts-Bassins region which is the seat of the second largest city, Bobo-Dioulasso about 350 km south-west far from Ouagadougou. Dabokry village is located in Cascades region which capital is Banfora about 435 km south-east from Ouagadougou.

Figure 1. Research area.

A field survey was conducted in the four villages in October 2014. The methods are questionnaire and interview surveys targeting adults mainly who are living in rural areas, and aged 20 years or older. The total number of respondents is 148, including 84 males and 64 females. The average age is 41.3 years. Table 1 shows an outline of the research villages on the number of respondents, their average age, religious ratios, and ethnic compositions.

The questionnaire of the survey includes the following three main categories: education (educational backgrounds, literacy ability), economy (income, expenditure, spending purpose, savings, occupation, type of agriculture and crops), and community activities (participation in local residents group or organization, externally funded project including a water and sanitation improvement project, and microfinance). For the purpose of comparative analysis in this paper, only income is analyzed as the category of economy.

Table 1. Overview of the four research villages.

	Kologondiessé	Barkoundouba	Makognadougou	Dabokry	Total
Number of respondents (male/female)	40 (25/15)	38 (22/16)	19 (12/7)	51 (26/25)	148 (85/63)
Average age (youngest/oldest)	44.4 yrs (20/80)	42.5 yrs (20/75)	36.9 yrs (20/56)	40.5 yrs (20/67)	41.3 yrs (20/80)
Religion (number of respondents)	Catholic 60% (24) Muslim 32% (13) Protestant 5% (2) Animism 3% (1)	All Muslim	Muslim 47% (9) Protestant 37% (7) Animism 11% (2) Catholic 5% (1)	All Muslim except 3	Muslim 71% (105) Catholic 19% (28) Others 10% (15)
Ethnic group (number of respondents)	All Mossi	All Peulh except 1	Bwaba 58% (11) Mossi 37% (7) Dafin 5% (1)	Mossi 35% (18), Dioula 19% (10), Tiéfo 12% (6), Sambla 10% (5), Peulh 6% (3), Bobo 6% (3), Forgeron 4% (2), Dagari, Dogossé, Karaboro, Toussian 2% (1) per each	Mossi 45% (66) Peulh 27% (40) Bwaba 7% (11) Others 21% (31)

2. Survey Results

2.1. Educational context

The composition of respondents' educational backgrounds is shown in Table 2. For reference, according to World Bank data, the gross enrollment ratio of primary education in Burkina Faso is 85%, secondary is 26%, and higher is 5% (World Bank 2013a, 2013b). Compared to these data, the Table 2 illustrates that the respondents' educational achievements and their literacy ability are generally quite low. For example, regarding the educational background, those who had no primary education (or less of that) account for 75% of the total respondents.

Table 3 shows their literacy ability measured by self-assessments and educational backgrounds. More than 70% of the total respondents answered as "Low" or "Incapable" for their literacy ability. From the table, it can be seen that the literacy ability of those who have formal education ("Primary" or higher) is basically higher than that of those who does not have any education or have non-formal education ("Literacy" or "Religious").

There is a feature of literacy education that has been found through this survey. The education program is conducted by a literacy center with the support of local government and international organization in each rural area (Takeshita 2000; UNESCO 2012). It is not a public school, but the participants recognize or call themselves

Table 2. Educational background.

(Unit: people)

	Male	Female	Total	%
No education	31	32	63	43%
Literacy	24	21	45	30%
Religious	2	1	3	2%
Primary	13	8	21	14%
Secondary	13	1	14	9%
Post-secondary or higher	1	1	2	1%
Total	84	64	148	(100%)

Table 3. Literacy ability (self-assessment).

(Unit: people)

	No education	Literacy	Religious	Primary	Secondary or higher	Total	%
Incapable	62	6	1	3	1	73	49%
Low	1	25	1	4	2	33	22%
Normal	0	8	0	5	2	15	10%
High	0	6	1	5	7	19	13%
Perfect	0	0	0	1	4	5	3%
N/A	0	0	0	3	0	3	2%
Total	63	45	3	21	16	148	(100)

"students" as if they are attending public school. Among the total of 148 respondents, 16 had secondary education or above. 8 out of the 16 respondents who had secondary education or above are as follows: 1 elementary school teacher, 1 junior high school teacher, and 6 working as village advisors. The village advisors are called "animateurs", who in some cases work as literacy education teachers. Among those 6 village advisors, only one person had primary school education with "high" level of literacy ability.

Some other respondents answered that they were taking literacy education course during agricultural offseasons. Considering these circumstances, when it comes to employment or status in rural area, literacy ability would be more important than primary education. Through interview survey, it is speculated that local residents have shared this belief.

2.2. Economic situation

Figure 2 shows the respondents' approximate annual income. It was not easy to get answers on the question of resident's annual income, because the respondents are mainly occupied with agriculture and they do not have clear idea about their own incomes. According to World Bank (2013c) report, gross national income (GNI) per capita in Burkina Faso in 2013 is 720 US dollars which is about 355,000 CFA (approximately 500 CFA to the US dollar). About 45% of population in Burkina Faso live with less than 1.25 US dollars per day (UNDP 2014). Considering the facts and advice from local staff of International Institute for Water and Environmental Engineering (2iE), the answers of annual income questions on the questionnaire were decided to be the following 6 categories initially: less than 25,000 CFA, 25,000-50,000 CFA, 50,000-75,000 CFA, 75,000-100,000

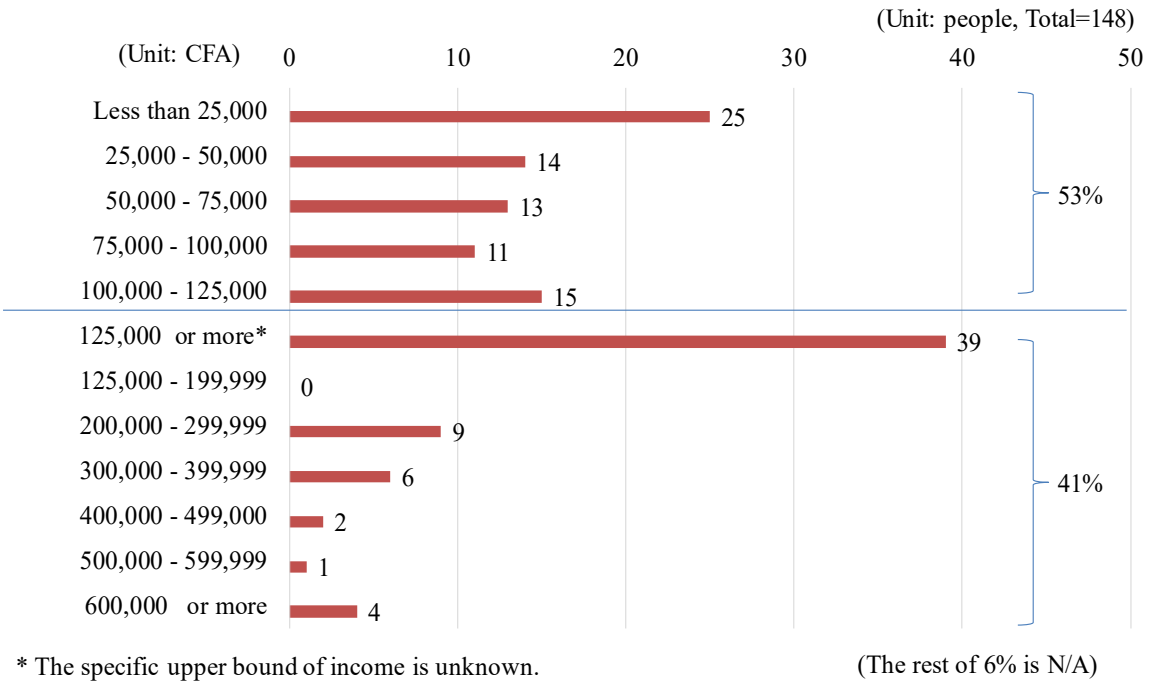

Figure 2. Annual income.

CFA, 100,000-125,000 CFA, and more than 125,000 CFA. In fact, the respondents who chose the last category of more than 125,000 CFA of annual income were unexpectedly many. Therefore, additional information on the approximate numerical value of income was asked to the same respondents. The responses to that particular question are shown in the bar graph of Figure 2. In this study, 125,000 CFA is considered as the border between relatively "low-income" earners and relatively "high-income" earners. The low-income group accounts for 53% and the high-income group accounts for 41% of the all respondents. It indicates that the ratio of low-income people is higher than that of high-income people.

2.3. Relationship between education and income

Table 4 shows the relationship between the respondents' educational backgrounds and income levels. When "No education" group is compared to the other three educational background groups ("Literacy", "Primary", and "Secondary or higher"), those three groups relatively have higher income than "No education" group. It is not so surprising, however, in the comparison between "Literacy" group and "Primary" group, it illustrates that "Literacy" group has relatively higher income than "Primary" group. Within "Literacy" education group, the ratio of high-income earners is higher than that of low-income earners. By contrast, the ratio of low-income earners is higher than that of high-income earners within "Primary" education group.

Based on the above findings, it can be presumed that literacy ability is more helpful than taking primary education to increase income for the local residents. Literacy education has a characteristic that not only young children but also adults can receive it. In other words, for adult peasants with no educational background, it is impossible to take primary education, but it is still possible to take literacy education if they have a will to learn. Therefore, it can be said that people with literacy education (but no primary education), who took the education when they were adults, are generally perceived to have stronger motivation to develop their literacy ability for more and better economic activities.

Table 4. Relationship between educational backgrounds and income distribution.

(Unit: people)

(Unit: CFA)	No education	Literacy	Primary	Secondary or higher	Total	
Less than 25,000	14	5	5	1	25	
25,000-50,000	10	3	3	1	14	
50,000-75,000	3	3	0	2	13	53%
75,000-100,000	5	3	1	1	11	
100,000-125,000	7 62%	5 42%	3 57%	0 31%	15	
125,000 or more*	17	13	4	5	39	
125,000-199,999	0	0	0	0	0	
200,000-299,999	2	4	2	1	9	
300,000-399,999	1	2	1	2	6	41%
400,000-499,999	2	0	0	0	2	
500,000-599,999	1	0	0	0	1	
600,000 or more	0 37%	3 49%	0 33%	1 56%	4	
N/A	1	4	2	2	9	
Total	63 (100%)	45 (100%)	21 (100%)	16 (100%)	148	

* The specific upper bound of income is unknown.

2.4. Evaluation on community-based organization

The community-based organization in this study is defined as a group formed by regional members having some common purpose (Sato 2004). Respondents' evaluations on the activities of community-based organizations practiced in their villages are summarized in Table 5. In addition, their recognitions or expectations on the effects of the organizations in expanding their economic activities or improving their quality of life are provided in Table 6. According to the two tables, about 75% of the respondents have experiences of participation in certain community-based organizations. Both tables demonstrate that their evaluations of those activities are generally positive. The recognition on the effects of the activities is slightly lower than the evaluated satisfaction. On the other hand, 20% of the respondents do not have experience of participation. Even though they have no experience, they could still evaluate those activities, and the result is relatively low. However, their expectation to improve their quality of life by the activities is relatively high.

The result indicates that most of people, regardless of experience, have an expectation of improving their economic situation as well as quality of life through participation in community-based organizational activities, although it depends on the contents of the activities. Despite the expectation, some people do not participate

Table 5. Evaluation on activities of community-based organization.

(Unit: people)

Participation experience	Satisfaction with activities of community-based organization				
	Not satisfied	Sowewhat satisfied	Satisfied	N/A	Total*[1]
Yes	4 (4%)	24 (21%)	80 (71%)	4 (4%)	112
No*[2]	7 (23%)	1 (3%)	3 (10%)	19 (63%)	30

*[1] Among total 148 respondents, 6 people had no answer.

*[2] 11 respondents answered even though they have no experience of participation.

Table 6. Recognition (or expectation) on the effects of community-based organization.

(Unit: people)

Participation experience	Recognition (or expectation) on the effects of community-based organization in expanding economic activities or improving quality of life[*1]				
	Do not think so	Somewhat think so	Think so	N/A	Total[*2]
Yes	2 (2%)	27 (24%)	75 (67%)	8 (7%)	112
No	3 (10%)	4 (13%)	11 (37%)	12 (40%)	30

[*1] For those who do not have participation experience of community organizational activities, the answer of "recognition" was replaced to "expectation" on the questionnaire.

[*2] Among total 148 respondents, 6 people had no answer.

in community-based organizations owing to concerns about risk. They are worried that these activities might not work successfully or might be a burden to the participants after they heard about others' unsuccessful experiences directly or indirectly through rumors. Regarding that, when a sanitation project involved with community-based organization is planned and designed, it is necessary for the external stakeholders or project providers to take into account local residents' value and intention in their communities.

2.5. Relationship of group activities with income

The relationship between respondents' experience of community-based organization and their income is tabulated in Table 7. As this table shows, there is no significant correlation between those two. The income distribution of people with experience of community-based organization is nearly the same as that of people without the experience. In another analysis on the relationship between their experience of community-based organization and their educational backgrounds, the results show no significance of correlation between those two. The results are not tabulated in this paper because similar patterns with Table 7 were demonstrated. In other

Table 7. Relationship between the experience of community-based organization and income distribution.

(Unit: people)

(Unit: CFA)	Yes		No		N/A	Total	
Less than 25,000	17		6		2	25	
25,000-50,000	9		3		2	14	
50,000-75,000	8		5		0	13	53%
75,000-100,000	11		0		0	11	
100,000-125,000	13	52%	1	50%	1	15	
125,000 or more*	29		10		0	39	
125,000-199,999	0		0		0	0	
200,000-299,999	6		3		0	9	
300,000-399,999	6		0		0	6	41%
400,000-499,999	1		1		0	2	
500,000-599,999	1		0		0	1	
600,000 or more	4	42%	0	47%	0	4	
N/A	7		1		1	9	
Total	112	(100%)	30	(100%)	6	148	

* The specific upper bound of income is unknown.

words, residents' participation in community-based organization is not influenced by their educational level or economic situations and vice versa.

The relationship between the experience of externally funded project and income distribution is different from the result of Table 7. The group of people with an experience of externally funded project has relatively higher income than the other group without the experience as it is shown in Table 8. A similar result can be obtained

Table 8. Relationship between the experience of externally funded project and income distribution.

(Unit: people)

(Unit: CFA)	Yes		No		N/A	Total	
Less than 25,000	5		16		4	25	
25,000-50,000	1		11		2	14	
50,000-75,000	2		10		1	13	53%
75,000-100,000	0		11		0	11	
100,000-125,000	2	34%	13	55%	0	15	
125,000 or more*	8		31		0	39	
125,000-199,999	0		0		2	0	
200,000-299,999	4		3		0	9	
300,000-399,999	2		4		0	6	41%
400,000-499,999	2		0		0	2	
500,000-599,999	0		1		0	1	
600,000 or more	3	66%	1	36%	0	4	
N/A	0		9		0	9	
Total	29	(100%)	110	(100%)	9	148	

* The specific upper bound of income is unknown.

Table 9. Relationship between the experience of microfinance and income distribution.

(Unit: people)

(Unit: CFA)	Yes		No		N/A	Total	
Less than 25,000	7		17		1	25	
25,000-50,000	2		10		2	14	
50,000-75,000	3		10		0	13	53%
75,000-100,000	1		10		0	11	
100,000-125,000	2	41%	13	55%	0	15	
125,000 or more*	12		27		0	39	
125,000-199,999	0		0		0	0	
200,000-299,999	4		5		0	9	
300,000-399,999	2		4		0	6	41%
400,000-499,999	1		1		0	2	
500,000-599,999	1		0		0	1	
600,000 or more	2	59%	1	36%	1	4	
N/A	0		9		0	9	
Total	37	(100%)	107	(100%)	4	148	

* The specific upper bound of income is unknown.

from Table 9. This table shows the relationship between residents' experience of microfinance and their income distribution. The group of people with an experience of microfinance also has relatively higher income than the other group without the experience.

Summary and Discussion

The main results from the field survey conducted in this paper are summarized in four noticeable findings. First, with regard to education in rural area of Burkina Faso, literacy ability is considered as a more important factor than primary education. The importance of literacy ability is widely recognized and shared among local residents. Second, when it comes to income levels, people with literacy education but no primary education have a relatively higher income than those who have primary education. Third, according to the result of comparative analysis between people with and without the experience of community organizational activities, the experience has no relationship to both educational backgrounds and income levels. Both of the two groups have almost the same result. Fourth, however, the incomes of those who have an experience of externally funded project or microfinance are relatively higher than those who do not have such experiences.

Using the findings of this paper, several suggestions are proposed for a better management of sanitation project by community participation in rural Burkina Faso and, by extension, in rural Africa. First, after understanding residents' general recognition about the importance of literacy ability, it is necessary to discuss how the sanitation project can effectively incorporate with literacy education. For example, a sanitation project attempts to provide literacy classes for the participants. It can also be considered to devote a certain portion of project revenue to tuition and purchases of educational materials for their literacy education. I also suggest a possibility of new concept of business model based on the field survey results. Local residents' participation in externally funded project and enhancement of literacy skills lead to the improvement of both sanitation and income. Second, it is essential to deepen local residents' enthusiasm to participate in systems of the business model. Attending to such activities as sanitation project or other externally funded project can help to improve their income and quality of life. It requires more efforts of interaction between project providers and local residents. Third, for medium-and long-term sustainability of sanitation development project, a thoughtful management strategy for the local communities remains to be required. If the opportunities of access to external funds are cut off, residents may lose income when they only participate in their community-based organizational activities. Fourth and finally, profit structure of community-based organization needs to be changed for the sustainability of sanitation project. The change makes it possible to achieve sustainable development even without combining community-based organizational activities with microfinance or external funding. Furthermore, greater attention should be paid to certain ways of stimulating participants' proactive actions and their mental qualifications such as strong will or motivation to accomplish and willingness to invest.

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Land Utilization System in Burkina Faso: A Case Study in Ziniaré

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Abstract

In Burkina Faso, the rights to land utilization and distribution have been generally defined by the traditional "first occupant" rule. New comers have been given rights to land utilization from the first occupant. But this rule is now changing because of many factors which are recently emerging such as administrative, legal and economic system changes, land nationalization, population growth, desertification and diminishing pasture land, urbanization, modernization, globalization, social structural changes, mentality changes, commercialization, and so on. Many small farmers are obliged to cope with this new situation. This study is composed of three parts: first we briefly overview traditional rules in Burkina Faso regarding land utilization; then recent situations are described in two ways: legal changes, and observations and perceptions expressed by our interviewees; and finally we present one of our case studies conducted in a Mossi village in the province of Plateau Central as an example of changes occurred in production and consumption systems at a large household: a way how a polygamy family shifted from a "collective" to an "individual" system?

Keywords: Burkina Faso; Land ownership; Rights to land utilization, Farmers, Rural area

Introduction

The Améli-Eaur project started in 2010 in Burkina Faso, by a joint team of Hokkaido University and 2iE (Institut International d'Ingénierie de l'Eau et de l'Environnement), aiming at improvement of farmers' productivity using waste water and compost. Beside the main project theme, we noticed that rural people's life has been affected by new changes which are occurring nationwide in Burkina Faso in connection to land utilization. Farmlands and pasturelands alongside asphalt roads have been enclosed year by year by fences, thus excluding farmers and herders. In rural areas we have sometimes heard about new conflicts occurred between different ethnic groups because of land shortage. In villages in the outskirts of the capital city, traditionally cultivated lands have become inaccessible because of new public arrangements such as "lotissement" (systematic land parceling for houses construction) or construction of big buildings. We have also heard about displacement of farmers due to gold or other mining exploitation.

This is why we are interested in looking at the ways of land occupation, utilization and ownership.

This paper is consisted of three parts: first description of traditional systems concerning land utilization and its rights in Burkina Faso, then glance at recent changes, and finally presentation of a large poligamy family case in a Mossi village.

1. Methods

The research about the general system, both traditional ways and modern legislation setting in Burkina Faso, was done through documentation (Boutillier 1964; Matlon 1994; Konate 1992; and national laws and strategies)

as well as interviews of university professors, village chiefs and NGO officials. Interviews of village farmers and women were also undertaken for complementary information gathering.

The case studies were conducted in the Mossi village K. and the Peul village B. in Ziniaré area in the region of Plateau Central of Burkina Faso. (Both are pilot villages of the Améli-Eaur project, but in order to avoid to disclose individual information, only initials are put.) In this paper, the case of a Mossi peasant family of Village K. is presented. Regarding the case study, in addition to the observations which were conducted throughout the Améli-Eaur project (several days each in 2011, 12, 13 and 14), interviews were undertaken with Mr. M.C. and some of his family members on the 2nd April, 7th June and 23rd August of 2014 by the author. The language used was Mooré which was translated into French, or sometimes directly in French.

2. Tradtional System of Land Ownership and Utilization System in Burkina Faso

Generally speaking, land ownership and utilization system in Sub-Saharan Africa is very different from Europe or Western style administration countries where the registration system is established with land title documents or written lease contracts. In Burkina Faso, traditional rules have reigned for a long time, and it is after the colonial time that the government tried to introduce Western systems. Traditional and modern systems thus coexist still now, and people are struggling to adapt themselves to these sometimes ambiguous, sometimes contradictory, or conflicting situations.

According to the interviews with Prof. Ouedraogo B., Prof. Ouedraogo F.B. and Mr. Bombiri F., the followings have been (and still are) commonly recognized systems in many ethnic groups in Burkina Faso. The literature of documents such as Boutillier 1964; Matlon 1994 confirms this statement in many parts of their papers.

1) The first person who settles in a place has the ownership (or, the rights of distribution) of the land. It has been thought that a wild land is inhabited by the genii, and the first person could live there after an agreement with them. Therefore he will serve as the mediator between the genii and those who come to live there afterward. In Boutillier J-L., the first comer is called “chef de terre”.
2) Those who come to settle down there later will be given the land by the first settler. At that time, there were three cases: a) Those who cleared wild lands have the utilization right for ever, with hereditary right. b) Those who could (were allowed to) plant trees have the utilization right for ever, with hereditary right. c) Those who planted cereals have the temporally utilization right without hereditary right.
3) The possibility to inherit land or a house belongs to men, and women are not concerned. However there are very minor exceptions which differ from one ethnic to another. Among the Mossi, a woman may be given a tiny land near her house with its crops (mainly okra-bombo) to be stored in her hut. She can even sell this land. In the same manner, in some ethnics women can be given a small land for a specific crop: for example, among the Bissa living near Tenkodogo, a small peanut land, and among the Gouin near Banfora, a small paddy field.

3. Recent Changes of Land Utilization and Ownership System in Burkina Faso

For a long time in the Sahel region, there has been always enough wild land to absorb new comers or new generations. In this situation, the importance was not the land itself, but the ability or needs to utilize it.

However nowadays the situation regarding the land has been drastically changed. (The recent land scarcity problems are repeatedly stated in literature such as Boutillier 1964; Matelon 1994)

First of all, the needs for land has increased due to tremendous population growth and pastoral migration pushed by desertification. Second, sudden urbanization has brought a construction boom of houses, offices, factories, commercial malls, hotels etc. This phenomenon has seriously affected rural areas situated near cities and alongside asphalt roads. Vast areas are fenced off by global enterprises or business men, and farmers are kicked off and pastoralists can no more let their herds in the fence. Systematic land arrangement for houses construction ("lottissement") has deprived farmers from the land formerly utilised for cultivation. (This can be compared to the "enclosure movement" occurred in England in the early 1700s.) The third element is mineral deposit which is abundant in Burkina Faso. There are now serious conflicts with big mine companies. In this regards, land nationalization often causes tremendous problems to farmers.

The RAF (Réforme Agraire et Foncière), initiated in 1984 by Thomas Sankara, and modified several times afterword, was strengthened by a law in 2007 and 2009, which legalized the principle of land nationalization in Burkina Faso. Usually individuals have the right to utilize their land, however according to the new law, once the land is declared "utilité publique", the land can be confiscated by the national or communal administration.

For the moment farmers do not seem anxious about the nationalization of farming land per se. According to the interviews done with farmers, they think that the land which is only used for agriculture/animal husbandry will not be confiscated. But there is an apparent common trend to legalize their rights to land by documents. They began to register their "utilization rights" at the communal administration office which has not been their habit before. The "first occupant's right" is, however, not to be registered. This is still so strongly and commonly recognized in the community. Another reason of the non-registration of the "first occupant right" might be the fact that it does not concern "utilization right", but a sort of "ownership" or "land distribution right" ("chef de terre" according to Boutillier's terminology), which means less compatible with the modern nationalization system.

Another significant change is recently observed in the people's perception of land. Wide range of people in Burkina Faso began to consider the land as "the property which will yield big money". As the result, farmers and pastoralists also look at the land, not only as a place for subsistence in agriculture or pasture, but also as the place from where they can expect money. Many interviewees, living in variety of places such as rural areas of Ziniaré, Dédougou and Banfora, and in the city of Ouagadougou, confirmed this change of perception. For instance, one farmer living in a village far from a town and an asphalt road, told the author that in the future his land might be sold for a huge amount of money like the lands near Ziniaré city right now. This trend, still not so eminent in deep rural areas, begins however to affect farmers' mentality, behaviour and tradition.

Regarding women and the land, the situation is also changing. Among the Mossi, the farm land has been owned (i.e. with established utilization right) by a man (head of the household), and all the family, including several wives and children, have worked together in his land. Nowadays we noticed that in some families, the land is divided between wives and big children, and each member of the family work separately in their parcels, after working in the man's ones. The crops are also for their own. The wives use their own harvest to prepare meals, with an eventual subsidy from the husband at shortage situations. In the following chapter, we would like to present a case of a farmer's family.

4. The Case of Mr. M.C.'S Family in the Village in Ziniaré Area

4.1. About the Village K.

The Village K. is a typical Mossi rural village, situated at one km from the asphalt road near Ziniaré. It has 750 inhabitants. Some families are Muslims, and some others Christians. These two religions cohabit apparently without conflicts. All the heads of the family in the village are male, and the majority are polygamy. As frequently seen in Burkina Faso, the characteristic of the house is a big compound (called "concession" in French) composed of many huts, granaries (store huts) and very important courtyard(s) which serve(s) as a multipurpose space like living, dining, kitchen, atelier, laundry etc. In average there are 6-7 huts/houses and seveal granaries per compound, with 18-19 people living there. The common type of construction of house is in mud brick. All the households have traditionally lived on subsistence agriculture (mainly sorghum, millet, maize, rice and beans) All the women grow also okra (as the main ingredient for "toh" saurce), and some Christian women are engaged in production of "doro"(local beer) in the courtyard for their cash earning.

It is said that around seventy years ago, there was a problem of bandit in the village, and to solve this problem, Mogho Naba (King of the Mossi) sent one of his sons, who became the chief of the Village K. He had 17 wives. (One of his wives is still alive and is among our interviewees.) This Mogho Naba's son's story illustrates very well what the literature describes: Mogho Naba has expanded his territory by sending his relatives to villages as the head of administration. The son of Mogho Naba had a large labor force composed of his 17 wives and their children. This allowed him to cultivate a huge space of land and enjoy a big economic capacity ensuring his political power. In this sense also, the Village K. is a typical Mossi village.

4.2. Mr. M.C., his family and lands

Mr. M.C., 67 years old (born in 1947), is the head of a family of 18 people living in the compound of six huts and four granaries. He lives with three wives (the first wife is 46 years old, and two others both around 30 years old), one grown up daughter and 13 children at school age or younger (of whom nine sons and four daughters). He has six more adult children (of the first wife) who live in cities or nearby villages. The religion is Islam.

Mr. M.C.'s father was not native from this village. He had had some problem in his native village, and migrated here. (According to our hearings, his case is not an exception: this sort of situation has very often happened in Burkina Faso, and has easily been accepted in the migrated places.) He asked for some lands to the chief of the village (who was "chef de terre"), and got the same lands that his son, Mr. M.C. actually cultivates. No payment was asked.

When Mr. M.C.'s father died thirty years ago, his four sons inherited the land which was divided into four. However, Mr. M.C.'s three brothers have died, and their sons all live now in big towns. As only Mr. M.C. lives actually in the village, all the lands are exploited by him, except for a small parcel given to his sister-in-law (a wife of a brother) who lives next to Mr. M.C.'s house.

Mr. M.C.'s right as the user of the land is well recognized by the village chief (descendant of Mogho Naba). The documents which prove Mr. M.C.'s rights exist both at the communal office and at the house of the village chief. The right of the village chief is widely and solidly recognized by all the villagers as well as by the commune, but there is no written document on it.

4.3. Working system

Mr. M.C. has four field areas and one paddy field near the dam site, totalling more than four hectares to cultivate. Before, these lands were cultivated by all the family in a collective way, and the use of the crops also in common under Mr. M.C.'s management.

Three years ago, the first wife was separated from the collective work, by being given her own land in all the five fields. Mr. M.C. explains this separation "because of her age". She became old, and could no more work

as before. This affected negatively the collective work (i.e., other wives work less than before). Examples of this type of separation can be found in the documentation (Konate 1992), according to which among the Mossi, when a woman reaches the menopause, she is given her own land to have her own economic life. In the case of Mr. M.C.'s first wife, she has ten children, the majority of whom have grown up and live in other places. We can easily imagine that even though she can no more work like before, she should surely be helped by her sons.

One year later, the other two wives claimed their lands, and Mr. M.C. responded in dividing all his lands between his wives and himself. All the five fields were divided each to three wives, and some parts to himself. Now the wives work at their own parcels, with their own children, after having worked together for Mr. M.C.'s land. The crops from each field are stored in each storing hut, and used by each wife to prepare meals or sold to buy school materials and clothes of her own children. Older children (around ten year old or more) are also given small parcels from their mother's field, and the harvest is stored separately in their mother's storing hut. They sell the crops for their own use such as school materials, clothes or sweets. In addition, the eldest son (12 years old) living in the house possesses five goats which he takes care of. But all the chickens of the house belong to Mr. M.C.

Mr. M.C. considers this new system "very good", as it yields more productivity because "the wives work harder than before" driven by 1) rivalry and 2) responsibility (the wives have to feed and satisfy the needs of their children by themselves). But the opinion of a grown-up son (a teacher in a city) of the first wife is different: "young wives should be losers, because they have to work harder with their small children in the fields."

4.4. Consumption system

In contrast to many other African countries, in Burkina Faso, meals are taken in groups and never all the family members together. The husband never takes meals with his wives. (According to Mr. Frédéric Bombiri and Ms. Véronique Cassando: "it is prohibited that a husband takes a meal with his wife."). At Mr. M.C.'s household, meals are taken in six groups: Mr. M.C., two groups of elder boys, and each group of three wives (the mother, daughters and babies).

Preparation of everyday meals also changed. Before it was collectively done, in turn, by three wives. Every three days, one wife had prepared six groups of food. Cereals for the main dish (usually "toh") had been provided by Mr. M.C., and the seasonings and herbs for the sauce were each wife's responsibility. After the division of land, wives carry all the responsibility. Every day, each wife prepares two meals for six groups. Each wife has to provide both cereals and herbs and seasonings. At the time of shortage, Mr. M.C. subsidies cereals. The daughters of each wife are in charge of fetching water to fill their own mother's "canary" (big pottery).

4.5. Changes in the Village K.

Documents (Konate, Boutillier, Kawada) mention that in Mossi villages, the prevailing system has been collective farming in the family: father's land is cultivated together by all the family, and harvested crops are stored and managed by the family chief for common consumption. It has been the same in the Village K. An interviewee, the former village chief's 16th wife, now 80 years old, confirmed that at her time all the 17 wives lived in 17 huts in the same compound, worked together, and consumed together. At that time, all the households in the village had the collective system, and there were no households where the wives had separate parcels. According to Mr. M.C. and other interviewees, in this village, this collective system still prevails in small households, but in large families, the trend goes to divide lands and economy.

Conculsion

The land utilization and ownership system now seems to be on its turning point in the long history of Burkina Faso. Traditional systems, so far widely recognized, are still prevailing in many places especially in rural areas, but new phenomena are emerging. Farmers are facing this new situation, and seeking ways to cope with it.

The case study showed that the land utilization system is also changing in some farmers' households. And it also revealed that this change has modified the economic management system within the family: from collective to individual way.

Urbanization and modernization quickly emerging in Burkina Faso have also given negative effects on traditional systems of land utilization. The shortage of land has become seriously felt in some parts of rural areas. All these factors risk to more seriously affect land heritage and utilization systems and thus drastically change all the social aspects in Burkina Faso in the near future.

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Political Participation by African Peasants as Development Actors of Integrated Water Resource Management

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Abstract

This paper is aimed at verifying the change of historical phases to overcome modernization, through the process of African peasants' participation in policy-making of integrated water resource management. To do that, it is important to criticize modern values like "rationality" and "efficiency" in order to explain why African peasants were marginalized from the political power during the colonization and authoritarian regime. And modern phenomena will be compared with postmodern one in regard to the social status of peasants, their availability of new technology and their rights to water. They overcome the dualistic system between modern administrative and traditional society. Some of them manage new technology according to their life style and treat easily it as their daily routine to increase agricultural production. Their application of new technology does not bring them a huge scale of colonial plantation but their life restructuration as social and economic actors. We will see also them using cross-national knowledge and technology to make decision of water resource as political actors. That is a new style of Nation-State under the influence of transnational elements. Without political participation of peasants as stakeholders, we will not be able to keep sustainable water resource management.

Keywords: African peasants; Cross-national knowledge; Integrated water resource management; Modernization; Water democracy

Introduction

This study aims at verifying that African peasants can participate in policy-making of integrated water resource management, because they have overcome modern method of development. It means that they are in the phase of historical change to overcome modernity. During the modernization, they were marginalized from the political power under the colonization and authoritarian regime (Linz 1975). Why were they considered to be incapable to participate into the development? To answer to this question, criticism of modern values like "rationality" and "efficiency" will be carried out (1.1.). In the field study, we can see that Burkina Faso peasants, dropouts of modern development in the era of Revolution (1.1.), have handled and applied a new system of compost toilet according to their life style and traditional culture (2.1. & 2.2.). The arguments of this paper are an observation of JICA and JST project (SATREPS) named "Improving Sustainable Water and Sanitation System in Sahel Region in Africa: Case of Burkina Faso". Finally, the concept of rights to water will be clarified so that African peasant would put water democracy into effect (3.1. & 3.2.).

1. Social Status of African Peasant

In this part, it is important to understand that African peasants were marginalized during modernization period

like colonization and nation building after the Independence (1.1.). Then using the result of field survey, the reality of rural community will be clarified, which has overcome the heritage of modernization (1.2.).

1.1. Acculturation of rural community under the colonization and the development policy of Nation-State in Africa

In Europe, a new social class appeared with their wealth kept from Middle Age. This class became Gentlemen or bourgeoisie in the 17th century in England, who was able to make a protest against King to look for the economic liberty and make a decision according to "rationality" and "efficiency", value of modern period (Fukuda 1985). They became citizen who can vote to decide national policy after the people's revolution.

French bourgeoisie thought that civil society and republic regime were not realized in Africa. Jean-Jacques Rousseau proposed "State of nature" where "Social contract" took effect between society and individual. His idea were a base of the French Revolution and republic regime. He criticized inequality and political struggle in Europe and suggested Europeans to be back to the "State of nature" but he was indifferent to African slave. Jules Ferry, Ministry of Education in the French third Republic, promoted the education of citizen to realize their equality in the republic regime but he was the driving force of colonization in Africa. It was not contradictory, because he thought that Africans were not able to bring the European notion of freedom and equality into effect (Sartre 1964). It took more than one century that Europe get used to different culture overcoming some notions like "barbary", "primitive" and exoticism of Africa. Then some African countries got independence in 1960[1)].

Let us verify a modern history of Burkina Faso peasants who the Thomas Sankara government confronted. After the coup d'état in 1980, by the anti-government group of Sangoulé Lamizana, the third Republic regime finished and three military governments continued. Savonnet-Guyot (1986: 162) says that the military regime was instable, because the power struggles inside military elite caused a lack of policy consistency. Then the labor union and traditional chiefs criticized such an inefficiency of the governments. Finally, after coup d'état in 1983, Thomas Sankara's socialist government was established.

Sankara was a military elite of Marxism-Leninism. He became a chairman of National Revolutionary Committee (CNR) and the head of State. Pro-sankarists got many important posts of regime. Committee of Revolutionary Defense (CDR) and CNR went into the local autonomy to realize their politics. The Court of popular revolution impeached the principal persons of the former government. Though CDR got supports and popularities of youths, unemployed persons and unaffiliated voters, the local peasants had the tendency to obey their traditional chief. This political choice of peasants threatened Sankara's regime (Savonnet-Guyot 1986: 180-181; Bamouni 1986: 106).

Sankara's socialist government considered labors, petit bourgeois, unemployed (lumpen proletariat) and peasants as the popular mass. According to the authority's thinking, peasants were the bases of economic development. The government used peasants as labors for the agrarian reform, infrastructure of water supply, welfare and health policy and agricultural policy. In consequence, it was too heavy a burden for the peasants. Moreover, Sankara didn't control well the traditional chiefs and he couldn't get support of peasants. He wasn't able to mobilize the local population without intermediation of traditional chiefs. Sankara couldn't reform and modernize rural traditional communities. It is difficult that State administration works in the traditional society, because this society keeps its own value and political system. Sankara's development model, where peasants have to be integrated, became a typical case of African modern State that cannot be compatible with traditional society (Bamouni 1986: 119-122, 130-135; Savonnet-Guyot 1986: 188; Zagré 1994: 166, 172-177).

1.2. Reality of rural community after the modern agricultural policy

Comparing with such a modernity like colonization and authoritarian regime after the Independence, it will be clear how African peasants have overcome the modernity.

According to Ouédrago (1990), the traditional community is composed by ideology, morality and religious value in Burkina Faso. It must assure its lineage members of property, welfare and security. There they have relationship of mutual aids. In Mossi ethnic group, the elder class plays legislative, administrative and judicial roles and there are youth group and women group. Occupation groups like peasants, smith and "griot" musicians of oral history don't take economic activities to get money but self-sufficiency. Savonnet-Guyot (1986) describes, as community functions, the authority of lineage, the cooperative spirit of agricultural work and the social status. These functions are useful to prevent the community from being divised. She says that they are incompatible with the modern Nation-State.

Hydén (1980: 40, 229-230; 1987; 2006: 54, 61, 64) said that African peasants have "Economy of Affection", which they have as moral and rationality to take care of the members of their traditional community. He is very tired of their attitude, which prevent them become citizen and modernize an agriculture. His theory is not sufficient to explain their real situation of community. They overcome the dualistic system between modern administrative and traditional society.

To verify it, a survey was done from 2010 to 2011. It is aimed at investigating peasants' life style and traditional community's social system. The method is a "deep" interview with Burkinabe actors, like persons of ministries, local government (Commune), NGO, agricultural producers' organizations, women association and peasants. It is a communicative approach between interviewer and respondent in order to find and clarify the social problems. The results of this field survey have been gotten as follows. According to these results, their local knowledge and autonomic capacity are persuasive and the real Burkinabe traditional life sometimes survives and sometimes coexists with the modern State administration:

a) Traditional chief has a power to make a decision of village. On the other side, a village adviser, "conseiller villageois", plays an intermediate role between village and local government. Therefore peasants overcome the dualism of modern and traditional life.
b) Many cases have been recognized as wise way of life. Facing the lack of water, peasants use a local knowledge to reserve water. For example, they damped up a river to make a reservoir, but they decided to stop using this water because of the sanitation problem. They try many ways of save water and are flexible to learn agricultural technique from their neighbors. They have knowledge on what is an effectiveness or demerit of compost and chemical fertilizer. They sometimes store agricultural production for low season of harvest to sell it at high price.
c) The local population has only a small production to consume in their own village. And they are dependent on the subsidy of government. It is difficult for them to be economically independent. They struggle for their daily life. Some peasants group collects fees from each family according to every family income proportion, rich or poor. That is a moral and autonomy of rural community.
d) Gender role is important for social and economic development. Men grow millets for the exportation to the neighbor countries. But women make a vegetable garden for their family consumption. Women are unsatisfied from their shares in the family income. It can bring the change of family system and social status of women.

2. Peasants' Adaptation to the Technology

This project is a proposal for the Burkina Faso peasants to settle water and sanitation problems and to increase

agricultural production using a new technology of compost toilets. This project team installed some compost toilets into the pilot families for monitoring of this toilets. It chose for the pilot Village Barkounba and Village Kologondiousse in Ziniaré where it takes one hour by car from the capital Ouagadougou. And Kanbouansse has been one of the pilots as periphery of urban zone. In this chapter, using theoretical thinking (2.1.) and result of field survey through the interview with pilot family (2.2.), it can be clarified what kind of impacts have been imported by the technology to the African rural community.

2.1. Technology and system of production in the modern period

In 19th century after the Industrial Revolution, European powers established a capitalism to exploit colonies for the investment and for the trade. This was an Imperialism (Darby 1987). The traditional value of local society prevented capitalistic management. So, colonial power wanted to destroy local social system to supply manpower, making people free from traditional status or custom. And it had to introduce modern system like plantation, infrastructure, education, law and life style. Moreover, the modernization or capitalism, being imported in Africa, brought the damage to natural environment, the huge consumption of resource and the stereotyped way of implementation of development policy.

To think about the impact of technology on the African rural community, it is helpful to make reference to Heidegger (2009), German philosopher. He says that the technology is not only a means but also human activity. Technicians have to step up their idea to technology. It is necessary to use it well and to look for its reality. Using it, we, human being, must confront what has been caused by technology. According to Heidegger, the reality of technology exists in the natural environment and technical experts often misunderstand that all natural phenomena are calculated. Heidegger found the possibility of catastrophe caused by technology and proposed that we must resettle negative heritage of technology with new technology. He thinks about the causal relations between natural environment and technology. His idea is applicable to think how technology can adapt to each local culture of Burkina Faso.

Kawada (1999) emphasizes the possibility of human capacity and various types of civilization. He thinks that the superstructure of cultural value like social system, arts and law, has an effect on infrastructure of technology. From this point of view, he compares Japanese, French and African civilizations to understand what a development is. He points out a problem that final object of development has been the European or American type of civilization. Is a human being's political and social life so stereotyped that only one value is in use in the world? Why is the social system made in Europe strong and powerful? Because, in the field of political science, European civilization makes power struggle for technology innovations, huge riches and industrial structures, where capitalism and expansive State power have a structure to control people.

2.2. Innovation after the overcoming of modernization

Kawada's theory on civilization is interesting for us to understand African culture. He recognizes three types of civilization. First type is Japanese civilization. Japanese use human capacity to operate a machine. Second is European one. In this civilization, people can economize physical energy, using tool and technology. And the last is African culture. Kawada is famous for the research on Mossi language communication in Burkina Faso. African people can adapt their physical capacity to the severe nature environment. So, they need strong and limber bodies. It is low cost and ecological culture. They try to coexist with nature.

In the Mossi community, there are a king and his descendants as traditional authorities. Their community is composed of lineages. They practice the polygamy and religious ceremonies, and live in the compound (concession, in French) with head of family, some wives, old men, children and domestic slaves. They cook in

the open-air inside of their compound. Often girls go drawing water with a wagon from a well far away from their houses. They put it in a jar to keep it drinkable. They use shower room where they urinate. They defecate open outside of their compound. It is risky to be attacked by animals or to be victims of crime in the dark night. The toilet system of this project is suitable for the Mossi cultural life style, because it makes compost after separating feces and urine.

Our social science team did a field survey about pilot families on March 2014.[3)] It aimed at getting data on the impact of compost toilets into their life habit. The questions were about the following changes:

- Economic growth: peasants can nor calculate neither estimate their incomes. But it is important to ask them how much monthly income and consume, in the rainy season and dry season.
- Working hours, working style and gender roles in family life;
- Production in the garden: genres, quality and price of vegetable production;
- Cultural life style and opinion about the water and sanitation;
- Social network: producers' organization, relationship with neighbors, gender groups, etc.;
- Flexibility and satisfaction about this project's toilets.

In fact, members of pilot family told freely us their impression, claims and demands. Sometime they were proud to tell us their success story. As result of this survey, some differences have been evident among these families like the following.

a) Flexibility or applicability in the Mossi family in Kologondiousse are remarkable. Particularly women told us positively their experiences and took initiative to manage this system. They are motivated, because women are realists to confront some difficulties of daily life. They said that they wanted to try other vegetable production. Their opinion is showed in the next table:

Table 1. Results of interview with Mossi families in Kologondiousse.

	Satisfaction with technology	Working situation and income	Agricultural production	Reaction of neighbors	Impression (security and cleanliness)
Woman of Family 1	Washing the clogging stones is a hard work. No problem for the smell with a mask. It is easy to use. I understood how to use in the workshop. It will be better to give a slope for the sewage.	I sold beans to get money. I have been motivated for the agricultural production thanks to the workshop for the population. Women clean the toilets and men seed.	Some geckos ate it in the dry season. I try to increase sorts like okra and eggplant. I chose these sorts according to each season. I am satisfied with the crop.	This toilet has a good reputation and our neighbors often come seeing it. I am proud to show them our toilet and harvest.	Using toilet inside of compound, it is not necessary to go to outside. Water is not enough. I thought that harvest is impossible in the dry season.
Man of Family 1	I am satisfied with technology. But I need some support to extend this system near to the dam. No problem for the smell.	It is not so difficult work.		Neighbors will understand why we use urine. But it is expensive to maintenance. So it is difficult for them to buy it.	We eat vegetables grown with urine. I am satisfied with shower inside our house. It is good for the cleanliness. But water is not enough.
Head of Family 2	I am content with technology. Troubles have decreased after the repair. Washing the clogging stones is a hard work.	Harvest of okra is good. It was unnecessary to buy vegetables.	We got a vegetable garden. I need technical guidelines for other agriculture produce.	Neighbors are interested in it.	No mental problem for using urine.

b) On the other side in Kanbouansse, periurban near to the capital, the cunning and claimant attitude was found, because the population depends on the money economy.

Table 2. Results of interview with Mossi family in Kanbouansse.

	Satisfaction with technology	Working situation and income	Agricultural production	Reaction of neighbors	Impression (security and cleanliness)
Head of Family 1	I hate to have my hands smelling urine. Tank of gray water is full in the rainy season. Women often use it.	Income was less than my expectation's. We have used more water and soap. We could not increase okra and its income. So, we eat it by ourselves. Using a lot of time for its maintenance, we have difficulty of getting food.		Design is popular among our neighbors.	Necessities (buckets and gloves) are not enough. I am worried about disease. To continue this system, we need economical support. Give us soaps.

c) Some researchers in our team emphasize the ethnic aspect as reason why Fulbe ethnic group in Barkounba refuse human excreta. This ethnic group complain about the operating of compost toilet. But based on the next result of Fulbe pilot family's interview, it is doubtful to recognize the ethnic reason, because some individuals can adapt to the new technology. Applicability doesn't depend on ethnic group but on individual capacity.

Table 3. Rresults of interview with Fulbe pilot family in Barkounba.

	Satisfaction with technology	Working situation and income	Agricultural produce	Reaction of neighbors	Impression (security and cleanliness)
Head of Family 1	It sometimes has been broken or clogged in time of mixture. Problem of smell. I am afraid of outbreak of mosquitos. Mixing system is difficult. The materials for washing the stones were not sufficient.	Harvest has increased in the vegetable garden (4 times harvests in 2013). But it was not enough to sell. To get quantity to sell, we need a big scale of land near to the dam.	I can manage a vegetable garden. But I need technical guidelines for the millet produce.	I give some harvest to my neighbors.	Water is not enough. It is more safety to go defecating inside of compound than outside. I cannot use compost, because I think that it is dirty. Using urine causes a religious problem.
Mother of head of Family 1	It is a new habit to use compost and urine. But I can do it if I am persuaded of the explanation.	I don't think that we have more works to do.	Men produce in the vegetable garden. We consume its harvest by ourselves.		It is safety and we can take a shower any time. We have to get used to new way. But the explanation is not sufficient.
Couple of Family 2	It often is clogged by stones. We need some materials like gloves. Stocked urine stinks. No problem for the convenience.	Harvest is not big. Our children darw water, women clean the tiolets and men maintain them.	We want to learn technical guidelines, because some buds fell down.		In time of defecation, we can protect ourselves from animals' attacks. It is clean. Water is not enough. We want to continue this system.

Ethnicity is a notion that is changeable and crystallized in the process of modernization. Amselle (1990: 143, 212-213) said that original ethnicity was composed by plural elements of "logic of hybrid (logique de métissage)". For example, the Fulbe ethnic group, in general, speak Fulbe language and live by livestock. But in reality, there are people who recognize themselves as Fulbe though they don't fit this definition. According to Amselle, the ethnic loyalty and identity prevent African people from being motivated to labor for the colonial administration and agricultural plantation, so colonial governor integrated African communities into the units of "Indirect Rules" administration to hide autochthonous loyalty and identity. Thus, European colonization wanted to realize "Colonial Peace (la paix coloniale)". He suggests that the integration of traditional community in the modern administration brought paradoxically identity crisis and artificial ethnicity.

What has brought such a difference between the pilot families? As result of the survey about pilot families, it has been clear that this project's new technology needs the punctuality, curiosity and motivation of individual to succeed in operation of compost toilets and in agricultural production. It needs also optimist spirit to get in habit of routing work for the toilet operation. These results of the field survey suggest some African peasants' flexibility towards new technology. If African peasants understand this project's concept and efficacy, they will be able to apply their way of life and agriculture to this project's system.[4)]

The application by local population to this new technology can bring a growth of family income and their life restructuration as social and economic actors. It is to say that this technology does not bring a stereotyped mass-production of the modern period but can be applicable to the toilet users' life style and cultural value. It is possible to say that our new toilet and water system is one of civilizations, Japanese type, "dependence on human ability" according to Kawada's theory, because human power is required to make it sustainable. The local people need the capacity to continue and routinize these operation and maintenance. It depends on how the members have motivations to make this new technology work.

3. Participatory Democracy and Nation State

This paper is verifying a historical paradigm change where African peasants can be recognized as actors of "integrated water resource management". For that, it is important to understand that water has been one of the human rights (3.1.) and how actors manage water resource as their rights (3.2.).

3.1. Water administration in the modern period

This part discusses about values and rights that were formed under the modern State regime and the economic system and defines what is a right to water. So, it will be possible to see the capacity limit of State administration and international treaty or agreement concerning water resource.

Under the feudalism, Gentry or Yeomen appeared as rich men in England. They became middle class who demanded their rights, in particular freedom of economical act and business, from the king. In the political sciences, we have big two categories of human rights. One is civil rights like freedom of press, thought and religion, right to vote, freedom of association, equality under the law and prohibition on torture. Private property is also involved in these civil rights. These kinds of human rights were created during the period of Enlightenment. According to the idea of natural rights, the people thought that the human being has rights by nature. In the 17th century, the bloodless revolution came to make the king compromise with the middle class. In other side, in the French Revolution, the royal family was killed by the radicals.

In the 19th century, these middle class and bourgeois became the capitalist investors. They got a lot of money with agriculture during the feudal era. They invested to create manufacture and industries. Thus, the capitalistic

economy-system was established. Under this economy-system, the small peasants lost their lands, because the capitalists shut out them to start the plantation, big scale of agricultural production. This is the Enclosure in the English history. So, they had only their manpower to be labors and proletarians. In the beginning of industrialization, labors' position was very miserable. To overcome such a bad working condition, other concepts of human rights were established. It is the right to life for health, education and welfare. It has been important to assure people of minimum level of life. [5)]

In this historical evolution, the concepts of human rights have been multiple. We have now new rights; right of environment, right of information, right to portrait, right of minority or aborigines, etc. And today these human rights must be assured by international treaties. Civil human rights have been written on International Covenant on Civil and Political Rights. Human right to life have been written on International Covenant on Economic, Social and Cultural Rights. These international agreements were signed in 1966 and came into force in 1973. Human rights became a transnational concept assured by international society, because Nation-State often violates them.

The realism of international political sciences thinks that the Nation-State has a nature or destiny to seek powers and national interests, for example security of territory against the foreign enemy, economic interests, technological innovation and priority of diplomatic position. But according to the evolution on Nation-State, its role and function have been changed (Kamo 1991).

International regime theory criticizes the realism to establish rules and consensus of international economic policy. But international regime system runs the risk of making ambiguous decision because of power struggle inside of the process of decision making, where greats powers intervene. It takes the form of a difficult consensus process of Framework Convention on Climate change.

Next according to these concepts, let’s try to define water as human rights and human security. Water is necessary and indispensable to survive. Water is for keeping a life. According to the concepts of civil human rights, water belongs to individual for his life. So, it leads to the private ownership of territory of water supply and it causes conflicts over the water. On the other hand, according to the concepts of human right to life, water is commons, common property assured by the public powers for example State administration, UN special organizations like UNICEF, UNDP, World Bank, etc. For example, the first international organization was established as International River Commission in 1958 to settle a water problem of the Rhine and Danube rivers that flows among many countries. Many NGOs and civil society groups are against the privatization and commercialization of water. They often criticize some enterprises that make and sell water productions.[6)] But to keep water clean or make the reuse of water, investments and costs are needed. It is doubtful that the public powers are able to fund their budget for that.

Water is considered as human rights and human security. For that, many actors concern water problems and they have to participate to the political decision. It is named “water democracy”. Moreover, today water is transnational issue as indispensable condition of human rights and life. That is a human security suggested by Amartia Sen and Sadako Ogata. On the basis of this idea, UN established Millennium Development Goals. They think that these goals are indispensable condition to life of human being. They are aware of not only security of Nation-State (Clausewitz 1968) but also security of individual life.[7)]

In the 1990’s, another theory, constitutionalism, was established. Wendt (1999) created this theory, applying sociology, cultural studies and psychology. He tried to focus the national agencies that act for social system, cultural value and identity. He explains the internal and external connection of these national agencies that make impacts on international economy and politics. But he recognized only national agencies. African actors, in particular peasants who are marginalized from State administration, are not considered as national agencies. Any

theories above-mentioned cannot well explain internal and external actors' interrelationships.

3.2. Integrated water resource management after overcoming the modern development

Many scholars thought that traditional peasants weren't able to have relations with external actors. Dahl (1987) is one of these scholars. In the "Polyarchy" of Dahl, democracy has been established with lobbing groups' participation. At contrary in the oppression regime, people is confronted with few of freedom, low participation of social groups and mass manipulation by elite. Dahl thinks that the groups which participate in decision-making are only enterprises and labor unions. To participate in the democracy, it is necessary to be rational enough to understand liberal economics. From Dahl's point of view, traditional community is autarchic, customary and exclusive, where local population insists on faith and unequal social ranking. So, he has not found any possibility of political participation of African peasants.

In the 1990's, African authoritarian regime fell down because of its bad economic policy and illegitimacy. In the globalization after the end of Cold War, the aides from the Soviet Union stopped. These African States had to accept IMF and World Bank's conditionality and to make their economic policy liberalistic. It caused the unemployment problem, poverty and insecurity (Banque mondiale 1994). In this social and political disorder, people particularly mass peasants have been dependent on not State administration but ethnic identity for their survival. They have crystalized an exclusive ethnicity (Nabeshima 2004). It has been a strong tendency in a democratization or multiparty system (Nnoli 1989). This tendency is, for the scholars who think that only rational citizen can participate in the politics, so chaotic as to deny modernity.

Is the political participation authorized only in the advanced countries? Aren't African peasants "citizen"? Aren't they capable to make a rational decision? Eke (1992) adopts a wider definition of citizenship than European individualism in order to recognize African traditional and ethnic groups as citizen. To break a stereotype model of political participation, Sen (1992) proposes a variety of concepts of happiness and welfare. Depending on cultural value of local population, they can decide the purpose and method of development. According to him, to realize welfare of each local population, it is necessary to develop their "capability". For that, health, medicine and education are indispensable. His theory is possible to overcome a stereotype of modernity.

Water is a target of conflict and, at the same time, of joint control. It is to say that water has become an object of politics. We should settle democratically such conflicts of water. To realize this water democracy, integrated water resource management is an important and useful concept. It involves all stakeholders and actors, for example, local population in the river basin, agriculture producers, industries that use water. It concerns water administration by local government and ministries. Two actors are added in this paper; one is transnational actors that link the local knowledge to the foreign one and second is traditional peasants who work for autarky. It is radical change to recognize these actors in the integrated water resource management, because African traditional peasants are not compatible with modernization.

To make the technology work, it is necessary to understand the local decision making. In general, rural community inclines to be conservative toward the new technology. Without authorization of traditional chief, the community members cannot accept it even after verifying that this technology does not break a taboo and not bring division to the community. It means that in the rural community, decision making functions on the initiative of traditional chief under the modern State administration. It is their political legitimacy.

Harbermas (1979) cautioned against the capitalism, which control and destroy the humanity. At that time 1970's, market economy was so incontrollable for the government that people looked for only the economic growth and forgot human life. He called it "Colonization of human life". He proposed a public agreement of

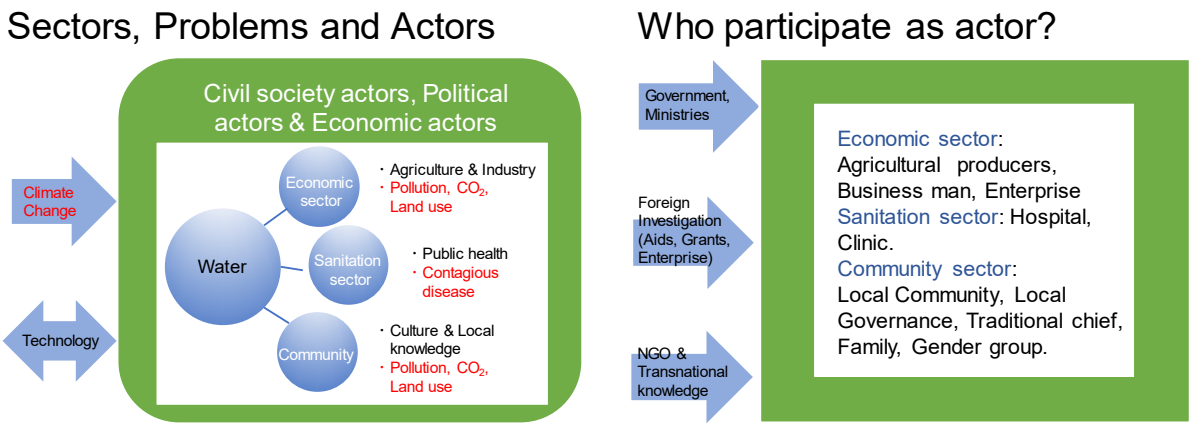

Figure 1. Image of integrated water resource management.

civil society to settle this problematic situation. Political participation is important to make consensus between administrative elite and citizen. He trusts the rationality that comes from liberal discussion among peoples. This is a social corporatism, which is different from national corporatism where State integrates all social actors and movements. In Europe, autonomy or self-decision functions to choose something rational. But in African traditional community, agreement is not made by autonomous individuals but by the duality of power between modern administration and traditional chefs. This is different from the democratic decision making in Europe.

If African peasants use their local knowledge and the transnational one, their rural community will develop as autonomic organization for agricultural development and water sanitation. Some of them manage new technology according to their life style and treat easily it as their daily routine to increase agricultural production. This indicates a cross-national knowledge and technology. Moreover, it can be also an opposing argument against constitutionalism, because it is possible to recognize African peasants as actors who can build the transnational relationship. New African concept of Nation-State consists of African social autonomy and the cross-national linkage. That is paradigm change to overcome modern development, because Nation-State and modern civil society can be restructured.

Conclusion

We don't know when we, human beings of the present age, have gone out of the modern phase to overcome modern development. Phenomena verified in this paper as overcoming of modernity is still invisible, because it has created nor huge production neither infrastructure. It looks rather chaotic. Moreover, it is doubtful that transnational networks will bring big powers to marginalize again African peasants.

But African traditional peasants have dynamics to change themselves according to the new social and political condition (Balandier 1971). Transnational exchange between local knowledge and exterior technology will help them to accelerate their change. So, African peasants, who were considered incapable and irrational in the era of modernization and nation building, have been recognized as actors of social and economic development. Without political participation of peasants as stakeholders, we will not be able to keep sustainable water resource management.

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Notes

1. Lévi-Strauss, in *La pensée sauvage* (1962), doesn't think that the "primitive" society is more inferior than the civilized society and emphasizes that the real society is mixed with "hot society" (not civilized society) and "cold society" (modern society).
2. This is a short mention about organization of local administration in Burkina Faso. There are 13 Régions (its head is "Gouverneur") and 45 Provinces. Département and Commune are set up under the Province. The head of "Département" is "Préfet" and Commune's one is "Mairie". Commune, with more than 10,000 population and budget of more than 15,000,000 CFA, is classified into "urban" and others Communes are into "rural". And there are 8,317 villages all over Burkina Faso and its representative is "Délégué". (Yahmed 2005: 84) Administrative districts in Ziniaré are as follows:
   - Région Plateau Central: advisory committee makes a plan and take it in force for the interests of Plateau Central;
   - Oubritenga is one of 3 Provinces. Capital of Oubritenga is Ziniaré.
   - Under the Province Oubritenga, there are 7 Communes (1 urban and 6 rural) and 7 Départements. One of Communes is Ziniaré. Mairie was established in 2006 for the decentralization. So, it is said that Préfet is inclined to be so conservative that he checks Mairie's movement.
   - In Ziniaré, there are 217 villages, where traditional chief exists as different authority from modern administrative Délégué.
3. It is Hokoyama, Yamauchi, Ushijima, Nabeshima and Burkina Faso staff member that did a field survey.
4. Throughout the field survey from 2010 to 2011, members of NGO, which practice organic agriculture using compost, agriculture producers, members of women's organization and traditional chief all said that the peasants can understand the scientific evidence, and if they are convinced by the reality of agricultural production's growth, they must accept a new way.
5. See Fukuda (1985) to understand a history of European modern period.
6. Water Justice is a world grass-roots movement that was established in World Social Forum in 2004. http://www.waterjustice.org/?mi=15&a=true (Accessed May 19, 2014).
7. Clausewitz defined, during Napoleonic Wars, that war is a result of all means of diplomacy. That is a classical view of national security.

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Assessing the Impact of Improved Sanitation on the Health and Happiness of a West African Local Population: Concepts and Research Methodology

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Abstract

Worldwide, nearly 90% of child deaths due to diarrhea have been attributed to unsafe water, inadequate sanitation, and poor hygiene. Furthermore, in developing countries, 2.5 billion people still lack access to improved sanitation facilities. In a collaborative project between Japan and Burkina Faso (Améli-Eaur Project, 2010–2015), we have installed composting toilets in pilot households in three rural villages near Ouagadougou, the capital city of Burkina Faso. For local farmers, we have promoted a breakthrough agro-sanitation business model that involves using fertilizer in human excreta form to grow vegetables for sale in the local market. In the next step, we intend to assess the composting toilet's impact on the local population's health and quality of life (QOL). We will conduct a comparison survey of households and villages where composting toilets have and have not been installed. The survey will cover the following three topics: (1) Lifestyle and Water Use; (2) Health and Nutrition; and (3) Happiness and Well-Being. We hope to demonstrate that improvements in health and QOL are crucial to the success and sustainability of composting toilet sanitation programs implemented in local West African communities.

Keywords: Basic human needs (BHN); Happiness; Health and nutrition; Improved sanitation; Quality of life (QOL)

Introduction

Worldwide, nearly 90% of child deaths due to diarrhea have been attributed to unsafe water, inadequate sanitation, and poor hygiene. The United Nations Millennium Development Goals (MDGs) aim to "halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation" (Target 7. C) (UN 2000). The proportion of people using an improved water source rose from 76% in 1990 to 89% in 2010. Thus, from 1990 to 2010, over 240,000 people a day gained access to improved sanitation facilities. However, 2.5 billion people in developing countries still lack access to improved sanitation facilities, and over 40% of all people without improved drinking water live in Sub-Saharan Africa. In a collaborative project between Japan and Burkina Faso (*Améli-Eaur* Project 2010–2015), we have installed composting toilets in pilot households in three rural villages near Ouagadougou, the capital city of Burkina Faso (Yabui et al. 2012). Additionally, we have provided a breakthrough agro-sanitation business model to local farmers; this involves using human excreta as a fertilizer to grow vegetables that can be sold in local markets (Ushijima et al. 2014). The main achievements of the project are as follows:

1) Based on material flow and value chain analyses, we conceived a business model to create value from sanitation mechanisms in rural Burkina Faso and evaluated its feasibility by performing a simulation.
2) We developed technological elements (e.g., composting toilets, gray water treatment equipment, and

technologies for agricultural use), performed a demonstration at a pilot site, and implemented at least one cycle of kaizen improvement.

3) We conducted a cultivation test using gray water, urine, and composts and predicted the yield and revenues that will be produced as a result of agro-sanitation.

In the next step, we intend to assess the impact of the composting toilets on the local population's health and quality of life (QOL) because although we intend to support the area's economic development, we believe that improvements in people's health are also necessary if composting toilets are to prevail and the sanitation system is to be sustainable. This article introduces the framework and methodologies that will be employed by us in assessing the project's impact on the local population's health.

Social needs in Burkina Faso

As in other Sub-Saharan countries, 43.9% of Burkina Faso's population exists in dire poverty (2009). Agriculture is the nation's primary industry; however, for the past 50 years we have witnessed serious challenges such as decreased rainfall (15–30%), the isohyetal line's southward shift by about 200km, and prolonged drought. A steady supply of safe drinking water and more widespread use of sanitation facilities are one of the Millennium Development Goals (MDGs). In Burkina Faso, however, the percentage of the rural population with access to appropriate sanitation facilities (toilets) is still extremely low at less than 1% (14% in urban areas) (Ministry of Agriculture and Hydraulics 2010). For this reason, the mortality rate for children aged five and under is unusually high at 98/1000 (compared to 3/1000 in Japan), with waterborne diseases such as diarrhea accounting for 14% of the child mortality rate (WHO 2014).

Given this situation, the Burkina Faso government formulated the National Program on Drinking Water Supply and Sanitation (PN-AEPA 2015) in 2006. Nonetheless, the growth of sanitation facilities in rural areas has so far progressed very slowly, and enhancing its growth has been a formidable national challenge. At the root of this problem lies the fact that the country is also confronting inadequate financial power and a lack of capacity for program management in the bureaucratic sector in charge of public health for rural communities (PN-AEPA 2015). Introduction of sanitation facilities is listed as a promotional focus in Burkina Faso's Strategy for Accelerated Growth and Sustainable Development (SCADD), established in 2010. In addition, procurement of clean water and sanitation facilities has been recognized as an important challenge in the nation's next AEPA five-year plan (2015–2020) in accordance with the Sustainable Development Goals (SDGs) following the United Nations' MDGs.

1. Concepts and Discussion

We will conduct a comparison survey of households and villages where composting toilets have and have not been introduced. The survey aims to analyze the following three main topics: (1) Lifestyle and Water Use, (2) Health and Nutrition, and (3) Happiness and Well-Being (Figure 1). Next, we plan to build a three-dimensional, sustainable model of a Sanitation Value Chain in which four elements—agricultural production, household income, food and nutrition, and health—spin around the axis of Happiness (Basic Human Needs: BHN and Quality of Life: QOL) (Figure 2). In the following sections, each of these concepts and elements will be explained in turn.

Lifestyle and water use

A time-allocation survey will be conducted to quantitatively examine the behavioral patterns of adults and

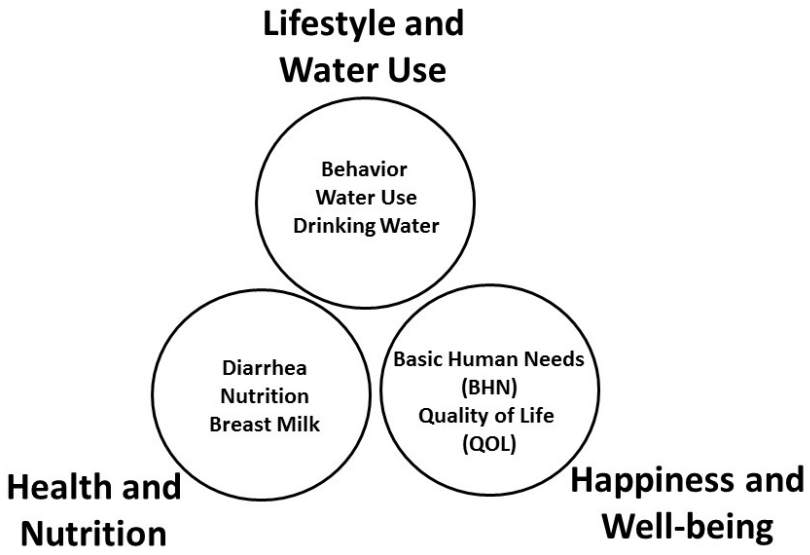

Figure 1. Research framework.

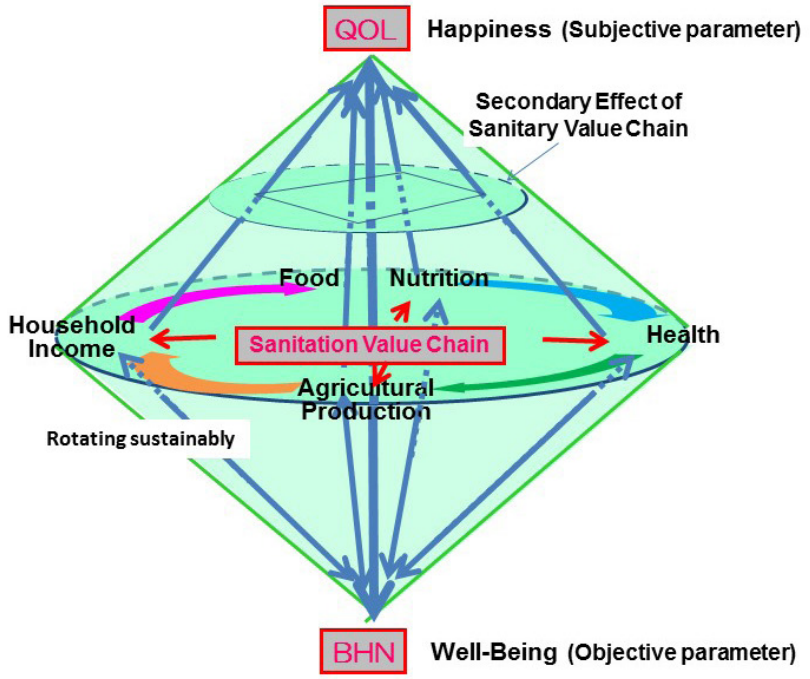

Figure 2. Sanitation Value Chain—Happiness Spinning-Top Model.

children, particularly with regard to water use in daily life and subsistence activities. Two types of observation methods will be used: "continuous observation of a particular individual" and "checking a particular spot at regular intervals" (Suda 1994). Information concerning the procurement and usage of water, including how drinking water is obtained, how much time is spent procuring it, how much physical effort is expended in the procurement process, and in which places water is available for washing, bathing, drinking, and toilet-related activities, will be collected. In addition to these aspects of water use in daily life, water use in subsistence

activities such as agriculture will also be examined.

Health and nutrition

Diarrhea is a leading killer of the world's youngest children, accounting for 11% of deaths worldwide among children under the age of five years (UNICEF 2012). This toll is highly concentrated in the poorest regions and countries and among the most disadvantaged children within these societies. Nearly 90% of deaths due to diarrhea occur in Sub-Saharan Africa and South Asia. Exclusive breastfeeding during the initial six months of life is one of the most cost-effective child survival interventions and greatly reduces the risk of death due to diarrhea among young infants (UNICEF 2012). Optimal breastfeeding practices are vital in reducing the morbidity and mortality rates due to diarrhea. Our research will focus on children's health and nutrition. Because children are the most vulnerable members of a population, examining their health status can teach us not only about the health of the children themselves but also about that of the whole population. We will conduct a survey concerning the following points: (1) the incidence of diarrhea in children and (2) the adequacy of nutrition among mothers and children.

Happiness and well-being

The ultimate goal of development is human happiness (Schneider 1995). Happiness is a noble goal for everyone on earth, and furthermore, if economic development projects are to be sustainable, they must take local people's happiness into account. A report by the Club of Rome answered the question, "What is human happiness?" The report mentioned constant interplay between two levels—the individual level and the social level. Furthermore, human happiness consists of "Happiness" that is a highly subjective and personal notion and "Well-Being" that is a relatively objective concept (Schneider 1995). We will apply the concepts of "Quality Of Life" (QOL) and "Basic Human Needs" (BHN) in examining human happiness as defined by the Club of Rome (Figure 3).

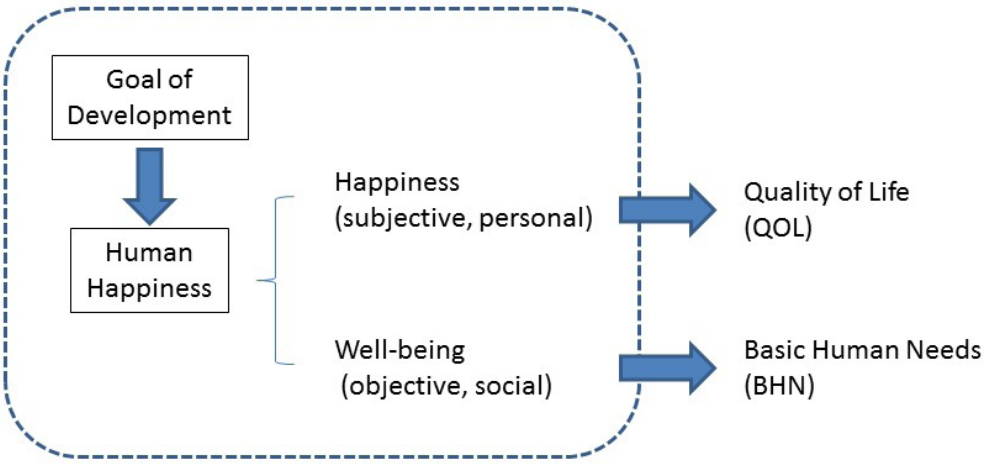

Figure 3. Relationship among development, quality of life (QOL) and basic human needs (BHN).

Basic human needs (BHN)

The fulfillment of BHN is a development theory proposed since the latter half of the 1960s, and used as a means of distributing income to the poor propounded by the International Labor Organization (ILO) at the World

Employment Conference held in 1976 (ILO 1977). The following two interrelated categories are its main targets. The first category includes basic items to meet minimum personal consumption at home, including clothing, meals, and a place to live, with sufficient furniture and household goods. The second category includes public services supplied by the regional community, namely, safe drinking water, sanitation facilities, public transport, and educational facilities. As implied by its emphasis on the household, this is a bottom-up development theory, with people at its center, as opposed to a top-down economic growth strategy that presupposes the role of the state.

The attainment of BHN was originally proposed to eradicate poverty. However, if one considers various challenges associated with development, eradication of poverty is not necessarily the only goal. According to prior studies and activities focused on BHN such as UNDP's Human Development Index (HDI) and Multidimensional Poverty Index (MPI), indices for assessment can be classified into the following categories: "Standard of Living," "Knowledge," "Health," "Subsistence, Food, and Nutrition," and "Social and Politics" (Table 1).

Table 1. Examples of indices for assessment of basic human needs (BHN).

1. Standard of living
Employment, Income, Possession of goods, Food consumption, Housing, Sanitation, Energy
2. Knowledge
Literacy, Local Language, Education
3. Health
Safe Water, Health Service, Longevity, Infectious Disease, Disease and Injury, Nutrient Intake, Child Mortality, U-5 Nutritional Status
4. Subsistence, Food, and Nutrition
Food Availability, Garden, Natural Resource, Land Productivity, Labor Productivity, Livestock
5. Social and Politics
Women's Participation, Social Welfare, Political Stability, Crime, Security, War, Liberty, Justice, Equality

Quality of life (QOL)

The concept of QOL, as such, can be related to Aristotle of ancient Greece (Fayers and Marchin 2000). QOL, as used today, is a concept that arose in the post-World War II period. Active research has been conducted in the fields of medicine and public health in attempts to define, measure, and evaluate QOL. This is often called health-related QOL (HRQOL). However, using only the narrow definition of QOL (HRQOL) is inadequate, especially considering community residents' QOL in the process of development; hence, we need a broader definition on the concept of QOL. Metaphysical matters should also be comprehensively taken into account, for instance, values like motivation and happiness in one's life, as well as religion and faith. Among many different methods of QOL evaluation and questionnaires developed in various fields, this project selected and implemented the WHOQOL (simplified version WHOQOL-BREF, Table 2), a questionnaire developed in recent years by the World Health Organization (WHO 1996).

Two reasons for using WHOQOL are, first, its approach to attempting to gain a holistic understanding of many events related to an individual's personal life, rather than just a measurement of a certain function of, or

damage to, the human body or some disease's instrumental impact. In this respect, WHOQOL differs from many other QOL evaluation questionnaires whose application is limited to the medical category. Second, WHOQOL aims to enable international and intercultural comparisons of QOL data. QOL questionnaires have been mainly developed in Western countries, but each country targeted only its own domestic population. WHOQOL was instead developed based on the belief that previous questionnaires had not been well designed in terms of applicability to populations from diverse nations and regions of the world (Yamauchi et al. 2010).

Table 2. WHOQOL-BREF.

Domain and questions
Overall Quality of Life and General Health
How would you rate your quality of life?
How satisfied are you with your health?
Domain 1: Physical Health
To what extent do you feel that physical pain prevents you from doing what you need to do?
How much do you need any medical treatment to function in your daily life?
Do you have enough energy for everyday life?
How well are you able to get around?
How satisfied are you with your sleep?
How satisfied are you with your ability to perform your daily living activities?
How satisfied are you with your capacity for work?
Domain 2: Psychological
How much do you enjoy life?
To what extent do you feel your life to be meaningful?
How well are you able to concentrate?
Are you able to accept your bodily appearance?
How satisfied are you with yourself?
How often do you have negative feelings such as blue mood, despair, anxiety, depression?
Domain 3: Social relationships
How satisfied are you with your personal relationships?
How satisfied are you with your sex life?
How satisfied are with the support you get from your friends?
Domain 4: Environment
How safe do you feel in your daily life?
How healthy is your physical environment?
Have you enough money to meet your needs?
How available to you is the information that you need in your daily-to-day life?
To what extent do you have the opportunity for leisure activities?
How satisfied are you with the condition of your living place?
How satisfied are you with your access to health services?
How satisfied are you with your transport?

Sanitation-happiness integrated model

This project's fundamental concept lies in the creation of value through construction of a sanitation value chain. Rather than emphasizing economic loss due to insufficient sanitation facilities, as was often previously claimed, this concept focuses on the creation of a value chain comprising various entities relating to sanitation, including its users. As a model, this concept addresses its ability to generate diverse benefits of return to each entity. Specifically, this model inspires an image of a rotating chain of four elements—agricultural production, household income, food and nutrition, and health. Moreover, the model introduces happiness as a new perspective to ensure sustainability of the model's functionality. Specifically, the BHN (social welfare, objective parameters) and QOL (personal happiness, subjective parameters) axis is defined to provide a panoramic view of the value chain model, that is, an inclusive three-dimensional spinning top model is constructed so that the value chain model will continue to spin around this central axis in a sustainable manner (Figure 2).

Conclusion

In Burkina Faso, our project's goal is to improve the local population's health and QOL. We have already installed composting toilets in pilot households and have begun implementing a new agro-sanitation business model in rural villages. Furthermore, we aim to assess improved sanitation's impact on the local population's health and QOL. We will also be conducting field surveys assessing the lifestyles, health, and happiness of the local population. We intend to prove that besides economic development, improvements in health and QOL are extremely important to the success and sustainability of composting toilet sanitation programs implemented in local communities in developing countries.

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Notice to Contributors

Aims and scope

Sanitation Value Chain publishes research papers on all aspects of the science, technology and cultures of sanitation. An outline of the journal's scope includes: Humanity and Sanitation, Public Health and Risk Assessment, Business Models of Sanitation, Resources Recovery and Reuse in Sanitation, Socio-Economic Aspects of Sanitation, Technical Aspect of Sanitation, Sanitation and Agriculture, Field Study of Sanitation.

Types of manuscripts

The journal accepts **original articles**, **research reports**, and **reviews** that have not been published before. All these papers will be open-access and peer-reviewed.

Original articles may be anywhere from 2,500 to 6,000 words in length. **Research reports** are up to 4,000 words, shorter than major articles, restricted to straightforward presentations of research results. **Reviews** cover contemporary trends and topics relating to sanitation values chain.

Each article should be accompanied by a title page that includes: all authors' names, institutional affiliations, address, and e-mail address. The title should be less than 145 characters (not including spaces). Subtitles should be no more than 40 characters (including spaces), up to six keywords. Abstract should be no more than 300 words.

Submission and peer-review process

Submissions are double-blind peer-reviewed. Manuscripts must be submitted as a word document in electronic format by e-mail. Submissions will be immediately acknowledged but due to the review process, acceptance may take up to three months.

Submissions are first evaluated by the editors. If felt to be suitable for publication, manuscripts will move into the double-blind review process. Following the advice of reviewers, the editors will write report on the result of manuscripts and decide whether the piece a) is appropriate to be published with minor or no changes; b) need to be revised and resubmitted; or c) is to be rejected.

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