Design of composting toilet for practical application in Burkina Faso

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Abstract

Resource recycling sanitation system, which utilize composting toilet, is one of the promising concept to improve the sanitary conditions in developing countries. In this sanitation system, toilet has to have two functions; sanitary equipment and fertilizer generator. As sanitary equipment, toilet has to provide clean, safe, comfortable environment for daily defecation. As fertilizer generator, toilet has to convert urine and feces into safe and good quality of fertilizer. The composting toile should be designed in order to perform both two functions in high quality, with low cost. In this research, design requirements for toilet as sanitary equipment and fertilizer generator are abstracted basing on field survey to 6 families from 3 villages in rural area of Burkina Faso. According to abstracted requirements, one design of composting toilet was proposed for rural area of Burkina Faso. The feces degradation performance was same level as commercial composting toilet and required torque for mixing was smaller than commercial screw type composting toilet.

Key words: user oriented design, resource recycling sanitation system, composting toilet

1. Introduction

Currently, in Burkina Faso, people living in rural area can access to improved toilet are 6%. In Millennium developing Goals (MDGs), the target is the number of people do not have improved sanitary facilities reduces by half by 2015. In that area, the progress of installation of sanitary facilities to achieve MDGs is too low, while more than half of the people still have open defecation culture or unimproved toilets, especially poor people. Therefore, adequate treatment to human excrement is not conducted and sanitary condition is not good. The improvement of sanitary condition is urgent task because morbidity and mortality of waterborne disease caused by poor sanitation environment show high value. In fact, the number of under 5 age children is 120 per 1000 in Burkina Faso (WHO. 2010). The mortality caused by Diarrheal diseases relating to waterborne disease is 19%, this percentage is the third biggest value (pneumonia:21%, malaria:20%. WHO. 2010).

However, effect of sanitary condition improvement does not give enough incentive for users to apply and use of toilet, since it is not easy to realize this effect. Resource recycling sanitation system, which utilize composting toilet, is one of the promising concept to improve the sanitary conditions in developing countries. Composting toilet makes it possible for users to reuse human excrement in safe way as fertilizer or soil conditioner and users get potential to increase their income by using this fertilizer to vegetable cultivation. It becomes incentive for low income farmers. On the other hand, interface design also gives one of important incentive at actual application. There are few studies on user interface design of composting toilet, though there are many technological studies on composting toilet.

The objective of this research is to design composting toilet that people living in rural area of Burkina Faso willing to choose and use.

2. Current condition and reasonable sanitation model in rural area of Burkina Faso

2.1. Field survey

The survey on toilet and related behavior was conducted in 6 families (call them family A to F) from 3 villages near Ouagadougou, capital of Burkina Faso, and Ziniaré, which is located at 35 km north from Ouagadougou. The target families were chosen by the chief of the each village. The survey was executed by oral interview, which focused on basic household information such as the number of family member, and current situation of toilet including defecation behavior.

2.2. Results of field survey

In Barkoumba village, the family consists of small nuclear families which member is father, mother and their children. In both families, they have pit latrine with the wall (Figure 1). The wall is made of local adobe bricks. The shape of the wall is like shell of a snail without roof and door. Its height is 1.5 m for hiding their body during defecation. After defecation, people washes their body with small amount of water scoped by small bucket, then the water goes into the pit. The toilet booth is square shaped of 2 m per side. People looks south during defecation, because Muslim cannot defecate facing to the direction of Mecca which is located in east-northeast. The toilet is placed near their concession, while they can access to toilet easily. Family A has experience to reuse of night soil from the human feces and compost from livestock manure, garbage, agricultural wastes etc. Both families know the value of the human feces as a fertilizer. Family A and B respectively want to use squatting toilet and sitting one. Because, squatting type is familiar with them and sitting one is easy to defecate for elder people.

In Kologonduesse village, the structure of the families and their buildings are similar to one of Barkoumba village. The numbers of the family members of C and D are 24 and 8, respectively. Family C practices open defecation and D has squatting type and pit latrine with snail type wall made of brick with cement. The direction of defecation of family D is east, because they are Christian and no regulation for direction of defecation. The distance between their concession and the toilet is about 100m. Both families know the impact of utilization of human feces. Family D has utilized their night soil to their farmland. Both of them want to have squatting type toilet.

The ethnic of Kamboinse village is Mossi, and the religion is Muslim. The numbers of person of Family E and F are 10 and 11, respectively. Family E has 2 pit latrines of concrete building with iron door and metallic roof. When the pit of one toilet is full, they close it then start using the other. The sizes of the toilet rooms are 2 m x 2 m and 2 m x 1 m. The lager room shares with place for shower and urination. On the other hand, Family F has squatting type toilet similar to one in the rural area. The size is 1.5 m x 1.5 m and enclosed with the wall of local bricks. The toilets in both families are in the concessions with access from the inside. Then direction of defecation is south in both families. Family E doesn't use their night soil, and Family F utilize in their farmland. They want to have sitting style toilet.

2.3. Summary of current toilet

The summary of results is in Table 1. Five of six families have toilet. All are pit latrine with wall which is made of local adobe bricks or cement. Only one family has toilet with rooftop and door. Others have toilet with just wall, and the surrounding shape is like "G" (Fig.1). The height of wall is 1.5 m, which is high enough to hide squatting person. The sizes of toilet room are; smallest one is 1.5 x 1.5 m, largest one is 2 x 3 m. Total 8 -24 persons use these toilet.

Table 1. Summary of the field survey

Family	A	B	C	D	E	F
Village	Barkoumba		Kologonduesse		Kamboinse	
Ethnic	Peul		Mossi		Mossi	
Religion	Muslim	Muslim	Christian	Christian	Muslim	Muslim
Num. of members	24	9	24	8	10	11
Num. of adults	12	2	8	2	4	4
Num. of children	12	7	16	6	6	7
Practice of defecation	Squatting	Squatting	Open defecation	Squatting	Squatting	Squatting
Type of the toilet	Pit	Pit	-	Pit	Dull type	Dull type

Style of the toilet booth	"G" type wall	"G" type wall	-	"G" type wall	Double pit latrine with concrete building	Only wall
Construction material for the toilet	Local brick	Local brick	-	Brick with cement	Cement	Local brick
Size of the toilet	2 m x 1.8 m	2.3 m x 1.9 m	-	1.6 m x 1.5 m	3 m x 2 m	1.5 m x 1.5 m
Direction of defecation	South	South		East	South	South
Distance between toilet and concession	Side of the concession	Side of the concession	-	100 m	Inside of the concession	Inside of the concession
Practice to reuse night soil	Yes	No	-	Yes	No	Yes
Requested type of the toilet	Squatting	Squatting	Squatting	Squatting	Squatting	Squatting
Use of fertilizer	Yes	Yes	Yes	-	Yes	Yes

Fig 1. Toilet room

2.4. Sanitation model concept

It is not easy to make rural people invest in sanitation system because of their low income. Especially for sanitation, the expected results of improved sanitation are improvement of sanitary condition and the depression of water born diseases. Despite this important improvement, adoption takes time and is not clearly shown to general people. Some other clear incentive is necessary. One possibility is obtaining an income increase through a resource recycling system. In our concept, wastewater and excreta will have new values as irrigation water and fertilizer, and this will provide another value as agricultural products following cultivation. If farmers could sell the products and increase their income, it will be a great incentive for application (Ushijima et al. 2012).

3. Design requirements

3.1. Function to be provided by toilet in resource recycling sanitation system

In the resource recycling sanitation system, toilet has to have two functions; sanitary equipment and fertilizer generator. As sanitary equipment, toilet has to provide clean, safe, comfortable environment for daily defecation. Water flush toilet in developed countries is successful case to provide this function in high quality however it requires large amount of water and expensive additional facilities. In rural area of Burkina Faso, different approach is required. As fertilizer generator, toilet has to convert urine and feces into safe and good quality of fertilizer. In the resource recycling concept, amount and quality of fertilizer largely affects on income by agricultural production. Thus, toilet in resource recycling sanitation system has to perform both two functions in high quality, with low cost.

3.2. Interface requirements as sanitary equipment

Interface design of toilet is essential for providing clean, safe and comfortable defecation environment. Especially in these points, comfortableness is largely related current lifestyle. Our policy for designing toilet is minimizing their behavior change, because generally smaller change becomes advantage when applying new technology (Rogers, 1982). Therefore abstracting design requirements from current toilet design and related behavior is necessary process.

According to field survey results, current toilet room is surrounded by “G” like shaped wall (Fig.1). Set new toilet unit in existing toilet room or newly constructing similar design of toilet room seems better. Almost all people currently defecate in squatting style, however some of interviewees showed interest into seating style, because it is friendly for aged person. So far both options have possibility. For Muslim users, who occupy 60.5 % (CIA 2012) of population, toilet has to accept or have additional facility to accept water for washing anus after defecation. Furthermore, direction of squatting or seating has to be considered before construction, because they are prohibited to defecate with facing to or show their back to Mecca. Non-Muslim users use toilet paper or wooden stick to clean their anus. Preparing trash box for these materials or acceptance of these materials in composting reactor is required.

3.3. Technical requirements as sanitary equipment

To achieve low cost system, production, maintenance and repair should be done by user or local factory. Therefore, toilet should be made by locally available materials, without special machine or tools as possible. In this context, simple mechanism is better. In rural area, electricity is not available, therefore system requires power supply have to be avoided. Manual hand power is available for operating the toilet, however not so heavy work is acceptable because target user includes from children to elder. In this study, maximum acceptable force was set as 100 N, with referring that children carried 20 L water tanks as daily work.

3.4. Requirements as fertilizer generator

As a fertilizer quality, issues to be discussed are (i) pathogen, (ii) nutrient contents and its balance, (iii) maturity as compost, (iv) contamination by micro pollutant, heavy metals. Furthermore, (v) easy handling is also important in practical agricultural activity.

There are varieties of composting processes, and each process has requirements. In terms of cost regulation, the system requires special microbe is not preferable. Temperature control is also difficult without electricity. Some of composting process requires matrix such as sawdust. In this case, matrix which is available in Burkina Faso has to be chosen.

4. Currently available resource recycling toilet

4.1 Major types of resource recycling toilet

Resource recycling toilet can be grouped into two, according to its composting process. One is equipping mixing device. Intermittent mix of feces and matrix such as sawdust performs aerobic degradation of feces. Advantages of aerobic degradation are; no or a few nuisance smell are generated, rapid decomposition speed (Lipez et al, 2005), easy handle of the compost. Major types of this group are screw type (e.g. SEIWA DENKO model, GreenLy model) and drum rotating type (Sun-Mar model). The other group does not have mixing device. The most primitive type of this group is pit latrine, and advanced type of this group is ECOSAN model. ECOSAN model uses ash to kill pathogens and to mitigate nuisance smell. The biggest advantage of this group is simplicity of the system.

Table 2. Size of composting toilet for 3-5 person use.

[mm]	Screw type		Drum rotating type
	SEIWA DENKO	Gleenly	Sun-Mar
depth	973-1257	720	1121
width	620-650	400	551
height	483-623	600	723

4.2 Matching with requirements as sanitary equipment

The size of current major models of screw type and drum rotating type (table 2) are able to be set in current toilet room (table 1). On the other hand, ECOSAN model proposes toilet unit including toilet room, which has roof top and door (ECOLOGICAL SANITATION, 2001). It might be able to design similar to current toilet room, however reconstruction of current toilet is necessary.

Most models of screw type are seating style, however there are a few squatting model (Bio-Lux). Drum rotating type has only seating model (Composting Toilets By Sun-Mar 2012). ECOSAN has both types (EcoSanRes 2012). When putting screw type or drum rotating type on the ground of current toilet room, the height of toilet seat or toilet bowl from ground level is 0.48-0.72 m therefore steps of 0.13-0.37 m for seating model and 0.48-0.72 m for squatting model is required respectively. Because the wall height of current toilet room was approximately 1.5 m, squatting type might require additional height of wall.

All three types cannot accept large amount of water, therefore it is necessary for all toilets to build washing space for Muslim users, as ECOSAN proposing (ECOLOGICAL SANITATION, 2001). Muslim users are prohibited to defecate with facing to or show their back to Mecca. All three types do not have special requirement related to direction, therefore it is possible to construct upon appropriate direction. Regarding toilet papers, screw type and drum rotating type can decompose them, however ECOSAN recommends to put trash box for toilet papers. Regarding wooden stick to wipe anus, there are no countermeasure information from producing company or organization.

4.3. Matching with technical requirements

ECOSAN toilet is made by concrete and adobe. It is possible to obtain in Burkina Faso. And in Burkina Faso, local people can build ECOSAN toilet because it is not required special tools and technique to build it. Screw type is mainly made from stainless steel, which requires special device and advanced technique to manufacture. Drum rotating type is mainly made by fiberglass however it uses double layered complicated system and also uses stainless steel in some part.

The daily operation of ECOSAN type is just put the ash. Screw type and drum rotating type requires rotating screw or drum. Ribbon screw type (SEIWA DENKO model) requires large power (Yamazaki, 2007), and it is impossible to rotate directly by hand power. GreenLy has special screw shape which has low friction, and it is possible to rotate by hand power. Drum rotating type is also possible to rotate by hand power.

ECOSAN toilet has 2 holes and is used until one toilet chamber is full. After that, it is closed and another one is started to use. The term of available a chamber is normally 2 ~ 6 months. The frequency of taking compost from screw type is two or three times in a year. Drum rotating type does not have clear information however the product manual mentions that available 6 ~ 8 weekends by 3~4 persons using.

4.3 Matching with requirements as fertilizer generator

Screw type with heating system can eliminate pathogen by heat however it is impossible without electricity. Therefore, secondary treatment is required for screw type and drum rotating type. ECOSAN type uses ash to increase pH and eliminate pathogen. In all model, all nutrients are entered and kept except for nitrogen loss by Ammonium gas.

The work of taking compost from toilet should not be difficult. In the case of ECOSAN, toilet has a hatch on the sidewall of tank for taking compost hence users can take compost on the ground level. On the other hand, most of screw type has a hatch on the top of reactor therefore it is little bit difficult to take the compost. Furthermore, most of the model cannot remove the screw, which makes difficult to access to compost. In the case of drum rotating type, the work of taking compost is just drawing of finishing drawer.

Regarding maturation period, ECOSAN toilet required more than half of year drying period of excrement (ECOLOGICAL SANITATION, 2001). The compost produced by screw type need no maturation time after taking (Bio-Lux 2012). The compost produced by drum rotating type need more than a month for maturation and drying (Composting Toilets By Sun-Mar 2012).

In Burkina Faso, it is difficult to obtain sawdust therefore toiler is required that it can treat excrement with other materials. ECOSAN toilet does not use matrix during treat, however it require adding ash after defecation (EcoSanRes 2012). Ash is material can obtain at there. Regarding screw type, crushed corn stalk, crushed rice straw, rice husk and rice husk charcoal has been tested and reported as available matrix (Hijikata et al 2011). In the case of Drum rotating type, normally woody material is used as matrix, moreover rotten wood, chip of bamboo and hardwood chip are available matrix (Composting Toilets By Sun-Mar 2012).

5. Discussion

5.1. Design concept

If we put the weight on agricultural aspect, maturation period is one of the most important factors. In terms of this, aerobic degradation system is preferable. Furthermore, both screw type and drum rotating type have possibility to put in present toilet room. Issues to be solved for these two types are materials and manufacturing. Therefore it is worth to design simpler aerobic composting toilet by locally available materials without special technique.

5.2. Design proposal

We designed reactor rotating system shown in figure 2. In general, tank rotating system adopt cylindrical tank, on the other hand, we made it as rectangular because it is easy to make from board materials. The reactor itself is rotating to mix the compost. Inlet of feces equips flap with hinge, which automatically close when reactor was rotating. Reactor wall was made by water proof plywood board. As a rotary shaft, steel pipe which passes through the reactor was used. Handle was attached to pipe end. In order to lock rotation while seating on the reactor, wooden block is inserted below the reactor. The block becomes footrest (Figure.3). The size of reactor is 40 x 60 x 40 cm. Total width, depth and height of toilet unit are 60 cm, 135 cm and 55 cm respectively. This toilet requires small footprint therefore it is possible to put in present toilet room.

Proposed toilet is seating type. Squatting type requires outer box for step on, otherwise user has to squat on narrow step on the reactor. Another advantage of seating style is required height of wall, to hide defecating person. If user squat on the reactor, required height is higher than seating.

The process to take compost is easy in this model. Reactor can be removed and carried to appropriate area, such as farmland, and just turn it with opening top hatch. Utilized tool for making toilet were electric drill-screwdriver, jigsaw and acrylic cutter. All materials can be obtained in Burkina Faso and these toilets need not to advanced technique to make.

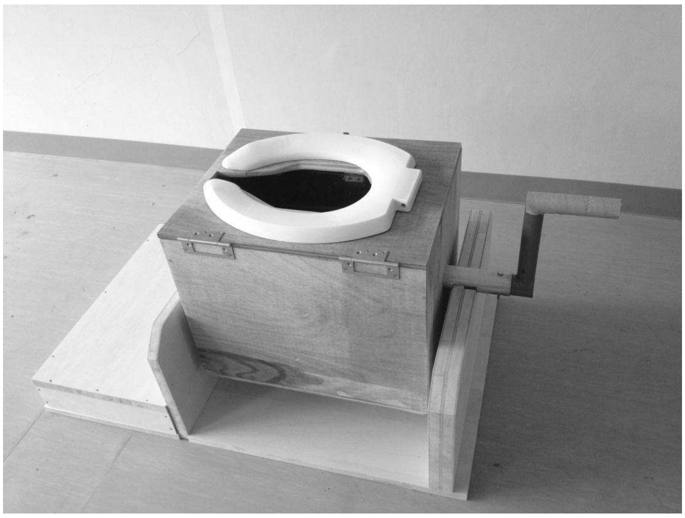

Figure.2 The composting toilet we designed

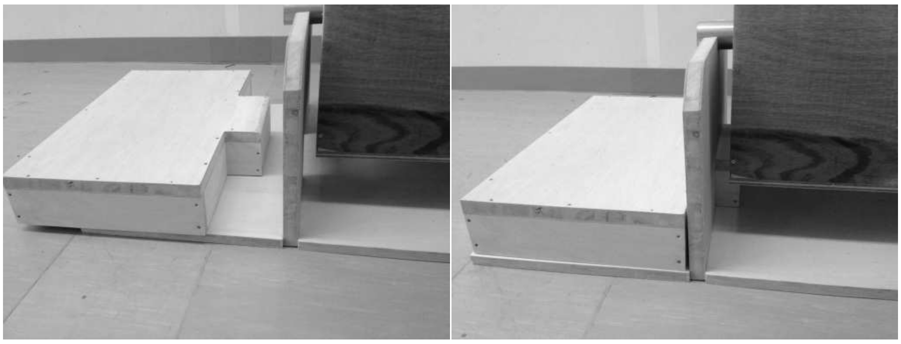

Figure.3 Rotation stopper. Free (left) and locked (right).

5.3. Evaluation of composting unit

Performance of proposed compost toilet was tested as follows. Every weekday, 1 kg of pig manure, which can be regarded as equivalent to 5 to 10 persons' feces, was putted into the reactor filled with 40 L of sawdust. This amount of sawdust is equivalent to that 5 persons can use screw type for 3 to 4 months. Experimental term was 3 months. Total weight and water contents were measured once a week. Required torque to rotate the reactor was also measured.

Figure 4 shows degradation ratio of proposed toilet and commercial composting toilet which mix the matrix by screw in dry weight. The degradation ratio of proposed toilet is in middle of two commercial composting toilets' degradation ratios. This result implies that rotating system's degradation ratio is almost same level as the commercial composting toilets.

Figure 5 shows required torque for rotation. This figure also includes the torque to rotate the screw type. When composting in same matrix weight, required torque for rotating system was almost 1/2 of commercial composting toilet. The observed maximum required torque for rotating system was around 15 Nm, which equivalent to 74 N on the handle.

Matrix volume increase was observed. At the 63th day, half of matrix are removed because matrix volume exceeded 80 % of reactor capacity and matrix slightly moved in the reactor. After that, the experiment was continued.

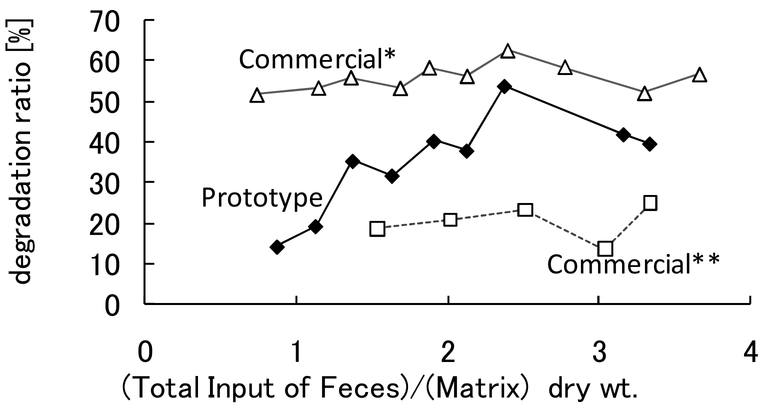

Figure.4 Degradation rate. Commercial* and Commercial** was

redraw from Nakaoka 2010 and Yamauchi 2011 respectively.

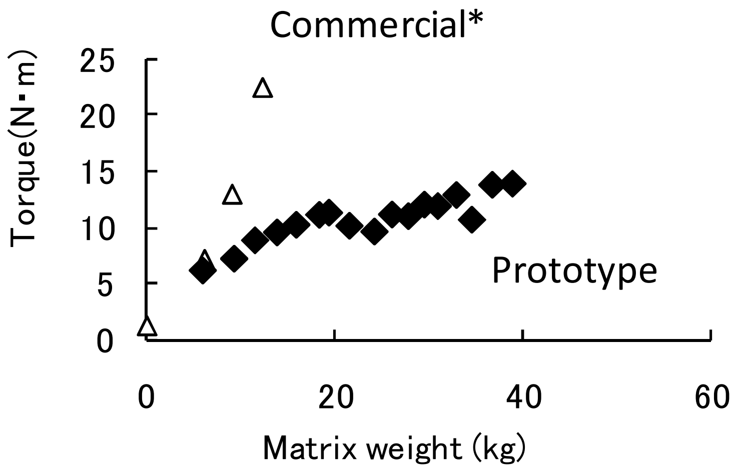

Figure.5 Required Torque. Commercial* is redrew from Yamazaki 2007.

From the result of treatment performance test, 5-10 persons can continuously use this toilet for 2 month at least. Required force to rotate did not exceed 100 N during treatment performance test.

In addition, we also tested degradation performance of crushed rice straw and rice husk charcoal as matrix. Both of materials showed good degradation ratios like sawdust (Yabui 2010). The compost of rice husk charcoal was tested as fertilizer (Moustapha et al. 2012). From this result, Komatsuna cultivated with rice husk charcoal compost were grew compared with nothing added soil.

5.4. Expected Advantage

The compost made by this composting toilet is possible to use with no or short maturation time. Yamauchi et al (2012) tested sawdust, rice husk and rice husk charcoal for plant growth test. They suggested that maturation time is not required. However, putting lime in compost is required to inactivate fecal coliform bacteria (Tezuka et al.2012).

6. Conclusions

In this research, design requirements for toilet as sanitary equipment and fertilizer generator. On the basis of these requirements, one design of composting toilet was proposed for rural area of Burkina Faso. The feces degradation performance was same level as commercial composting toilet and required torque for mixing was smaller than commercial screw type composting toilet.

Reference

Bio-Lux, Seiwa Denko http://www.seiwa-denko.co.jp/biolux/top.html (accessed 15 May 2012. in Japanese)

CENTRAL INTELLIGENCE AGENCY
https://www.cia.gov/library/publications/the-world-factbook/geos/uv.html (accessed 15 May 2012)

Composting Toilets By Sun-Mar http://www.sun-mar.com/ (accessed 15 May 2012)

EcoSanRes http://www.ecosanres.org/index.htm (accessed 15 May 2012)

ECOLOGICAL SANITAION (2001). Swedish International Development Cooperation Agency, Stockholm, Sweden (in Japanese)

Hijikata N., Yamauchi N., Yabui K., Ushijima K., Funamizu N. (2011) Characterization of several agricultural wastes as a matrix of composting toilet –from fecal degradation to reuse as a soil conditioner-. Proc. 8th IWA International Symposium on Waste Management Problems in Agro-Industries, pp.317-324, (in press)

Narita H,. Lopez Zavala, M.A., Iwai K., Ito R., Funamizu N., (2005) Transformation and characterisation of dissolved organic matter during the thermophilic biodegradation of faeces. *Water Research* **39**, 4693-4704

Nakaoka E. (2010) Low cost composting toilet for Sahel region, Bachelor thesis, Hokkaido University, Sapporo, Japan (in Japanese)

Rogers E. M. (1983). *Diffusion of innovations*, Third edition, the free press, New York, USA

Sene M., Hijikata N., Ushijima K., Funamizu N. (2012). Effect of Human Urine application volume in Komatsuna growth. *Water Science and Technology*, (submitted)

Tezuka R., Hijikata N., Kazama S., Soussou K. S., Funamizu N (2012). Inactivation mechanism of pathogenic bacteria using lime and ash in composting toilet. *Water Science and Technology*, (submitted)

UN Millennium Project | Goals, targets&indicators,
http://www.unmillenniumproject.org/goals/gti.htm#goal7 (accessed 15 May 2012)

Yabui K. (2011) Evaluation of the prototype composting toilet for Sahel region, Bachelor thesis, Hokkaido University, Sapporo, Japan (in Japanese)

Yamauchi N. (2011) Evaluation of agricultural waste as a composting matrix from capability of feces degradation and soil conditioning, Bachelor thesis, Hokkaido University, Sapporo, Japan (in Japanese)

Yamauchi N., Hijikata N., Ushijima K., Funamizu N. (2012). Effect on compost maturity by type of matrix and lime treatment after removal from composting toilet. *Water Science and Technology*, (submitted)

Yamazaki H. (2007) Candidates of bio-toilet matrix, Bachelor thesis, Hokkaido University, Sapporo, Japan (in Japanese)

World Health Organization (WHO) http://apps.who.int/ghodata/?vid=590 (accessed 15 May 2012)

World Health Organization (WHO) http://apps.who.int/ghodata/?vid=160 (accessed 15 May 2012)

World Health Organization (WHO) http://apps.who.int/ghodata/?vid=10012 (accessed 15 May 2012)