Sanitation in Urban Poor Settlement and the Importance of Education for the Reduction of the Diffused Pollution - A Case Study of Bauniabad, Bangladesh

Yuko Sato Yamamoto*, Katsunori Suzuki* and Bilqis Amin Hoque**

* *United Nations University Institute of Advanced Studies (UNU-IAS), 6F, International Organization Center, Pacifico-Yokohama, 1-1-1, Minatomirai, Nichi-ku, Yokohama, 220-0012 Japan (E-mail: satoyu@attglobal.net)*

** *Environment and Population Research Center (EPRC), 1/7 Block-E, Lalmatia, Dhaka-1207, Bangladesh, (E-mail: eprc@mail.bol-online.com)*

ABSTRACT

Many people in the world still cannot access to the appropriate sanitation. To halve this population is the global target. In Bauniabad, which is one of the poor settlements in Dhaka, Bangladesh, small-scale biogas plants connected to the latrines of about 100 households have been installed as a sanitation option. The purpose of this study is to clarify the background of how the local people came to use the biogas plant for sanitation purpose, and to examine the performance of the biogas plant for the reduction of the pollution load to the surrounding water bodies. The questionnaire to the local people about their behaviors regarding sanitation was conducted to know the change of their attitudes and the situation of their living environment before and after the installation of the sanitation options. The water quality analysis was conducted to review the performance of the biogas plant. From the questionnaire, it was revealed that the hygiene condition of the latrines was improved after the connection to the biogas plants. On the other hand, from the water quality analysis, it was revealed that the anaerobic digestion of the biogas plants did not work sufficiently good due to lack of maintenance.

KEYWORDS

Biogas plant; Hygiene education; Sanitation;

INTRODUCTION

Many people in the world still cannot access to the safe drinking water and adequate sanitation. Though the percentage of people using improved drinking water sources rose from 77% (4.1 billion) in 1990 to 83% (5.2 billion) in 2002, during the same period, the proportion of the world's population with access to improved sanitation only increased from 49% (2.6 billion) to 58% (3.6 billion) (WHO/UNICEF, 2004). At the World Summit on Sustainable Development (WSSD) in Johannesburg, South Africa in 2002, it was committed to halve the proportion of the people without adequate sanitation by 2015 (United Nations, 2002). However, it seems difficult to achieve this goal without accelerated efforts. One of the key issues for success is selection of appropriate options.

Bangladesh is one of the countries that many people still cannot access to adequate sanitation. It is reported that in 2000, nearly 80% of the poor people living in Dhaka did not have access to the improved sanitation facilities such as water seal toilets, flush toilets and pit latrines (UNICEF, 2001). Because there are many other urgent issues that should be solved such as flood, energy, agriculture and arsenic in drinking water, sanitation is not regarded as the priority to be solved. In Bauniabad, which is one of the poor settlements in Dhaka, several projects have been conducted to improve the sanitation situation since 1990 with the initiative of one of the authors (Bilqis Amin Hoque). The main activities include hygiene education and installation of the sanitation options. As a sanitation option, small-scale biogas plants

connected to the latrine of each household have been installed, and the local people have gradually increased the proportion of the share of the installation cost of the plants.

Biogas technology is known from many years ago. Regarding the small-scale biogas technology, many cases have been reported in China and India. It is reported that China had five million household digesters in good working order, and approximately 25 million Chinese people were using biogas (Daxiong *et al.*, 1990). In India, the effort of the national scale was made to diffuse biogas plants, and by the end of the Sixth Development Plan (1984-1985), 400,000 family-scale systems (2-8 m³ of daily gas production) and 100 village-scale systems were targeted for construction. The biogas plants in India have floating-drum type digester. In most of the cases, the input is cow dung (Lichtman, 1987). Also in Bangladesh, there are some programs to promote the biogas technology lead by Bangladesh Council for Science and Industrial Research (BCSIR), and Local Government Engineering Department (LGED) under the Ministry of Local Government, Rural Development and Co-operatives, Bangladesh (Rahman *et al.*, 1996). However, the main purpose of these biogas plant programs is to get the renewable energy, and there are few cases on small-scale biogas plant whose primary objective is to treat human waste.

The purpose of this study is to document how the local people came to use the biogas plant for sanitation purpose, and to clarify the performance of the biogas plant for the reduction of the pollution load to the surrounding water bodies. For this purpose, the questionnaire survey to the local people, interviews to the local stakeholders, and water quality analysis of the biogas plants were conducted.

BACKGROUND

Study area

Bangladesh lies in the northeastern part of South Asia, and has an area of 147,570 km². It is one of the most densely populated countries of the world, with a population of about 129 million in 2001 (Bangladesh Bureau of Statistics, 2002). Dhaka is the capital city of Bangladesh, and Bauniabad is one of the urban poor settlements in Dhaka (Figure 1). The Government of Bangladesh established Bauniabad in 1990 as a special resettlement for the poor, who lived in another informal settlement in Dhaka, because the development activities had started there. The 2600 squatter families were resettled in 0.36 km² area on the side of an embankment. The high earthen bank was constructed to protect the area from a surrounding river. Each family was allotted a plot of about 9.18 m² (approximately 2.4 m width by 3.7 m length). The allottees received contracts for the plot through payment over an agreed period after

Figure 1. The study area (left; Bangladesh, middle; Dhaka city, and left; Bauniabad).

which they would own the premises.

The plots are arranged in five blocks as shown in Figure 1 (right). Each block has 22 lanes, except for Block D, which has 24 lanes. Originally, there were about 12 houses on each side of the lane. Every plot was provided with an alternate pit latrine, which were built next to the dwelling units. The alternate pit latrine consisted of a platform with a squatting pan and water-seal structure, two separate adjacent pits and a cover slab. The platform with the squatting pan was to be placed on the pit that was in current use. When the first pit filled up, the squatting pan was to be moved on the top of the second pit. It was expected that this alternating provision would allow adequate time for the pit contents to decompose and to allow safe handling of the sludge. For drinking purpose, one deep hand pump was installed for 12 households. Although plot contract was originally awarded to 2600 families, according to the local leaders, currently there are more than 7000 families due to normal family growth and to some families renting a part of their houses to other families.

History of a series of efforts in Bauniabad

One of the authors (Bilqis Amin Hoque) has been involved in the water and sanitation project in Bauniabad since 1993. The activities are divided into four phases: (i) Water and sanitation evaluation in 1993; (ii) Educational intervention on water and sanitation from 1995 to 1997; (iii) Research and development of technologies from 1997 to 1999; and (iv) Promotion and installation of options from 1999 to present. Though the detailed information is missing because of no record available, followings are the brief summary of the activities in each phase based on the information from Bilqis Amin Hoque.

Water and sanitation evaluation: 1993. Concern, an Irish NGO, was mainly involved in water, sanitation, drainage and other environmental health improvement in the area from the early years of the resettlement. Their program mainly included education and motivation about latrine use, installation and use of tube-wells, and health interventions. They also made attempts to establish a mechanism for emptying the pits when the pits filled up with sludge. Concern commissioned Bilqis Amin Hoque to evaluate the water and sanitation situation in 1993 (Hoque et al., 1994). It was observed during the evaluation that the installed water and sanitation options were fully used by the people. However, the latrines were maintained so poorly that concentrated human waste pollution from the latrines created serious and huge problems within the community; the pits were overflowing, leaking or broken. It was found that the people in the community were not provided with appropriate knowledge or a system of maintenance. It was said that this is because the local people as well as the donor agency were not involved at the stage of planning and implementation of water and sanitation options.

Educational intervention on water and sanitation: 1995-1997. The educational intervention on water and sanitation was conducted in Bauniabad and selected poor settlements in rural area of Dhaka. The objectives of the project were to study the needs of the people and to improve their situations on water and sanitation through a community based educational intervention. The local people were using pit latrines and hand pumps which were installed at the beginning of the establishment of Bauniabad area. The main activities included; (i) a baseline and needs assessment survey, (ii) training of volunteers, (iii) community education on water and sanitation by trained volunteers and project workers, and (iv) follow-up surveys. The main achievement during this period was that an Environmental Health Committee was formed with elected members and local leaders in order to involve and build the capacity of possible local informal institutions. The committee planned and coordinated the implementation of the educational intervention with the project members. Trained volunteers and the project workers provided educational messages on operation and maintenance of the existing options and on selected improved water and sanitation behaviors.

Although the level of knowledge about health impacts caused by unsafe drinking water and inappropriate sanitation improved significantly, according to the baseline and follow-up surveys, 98% of the sampled households used only one of the pits of the alternate pit latrine. The other pit was no more used and the people extended their house to the area where the other pit existed. It was observed that about 56% of the pits were leaking and/or overflowing. It was because the local people had no proper option to empty the contents of the pits, and/or they were not affordable to ask professional scavengers (sweepers) to clean up the pits. Consequently, the local people continued the practice of emptying the contents of the pits in the drains beside the roads as well as in surrounding water bodies during nights, though they were educated those would cause the health problems. The project members or the local Environmental Committee could not make any acceptable arrangement between the scavengers or other organizations about emptying the contents of the pits.

Research and Development of Technologies: 1997-1999. A research and appropriate technology development project was conducted from late 1997 to 1999 based on the needs expressed by the people and the experience gained during the preceding educational intervention in Bauniabad and in another poor settlement. The main objective was to test pilot plants comparing locally available technologies modified to address the local conditions with the involvement of the local people as much as possible. The local Environmental Health Committee, which was formed during the previous study, participated in the planning and implementation of the project.

Two twenty-feet-deep single pit latrines, two twenty-feet-deep twin pit latrines, two septic tanks and three biogas plants connected to the latrines of about 100 households were installed and tested in Bauniabad and another poor settlement. The wastewater quality of the systems was observed for approximately 6 months during 1998-1999. It was revealed that biogas plant removed more than 80% of 5-day biochemical oxygen demand (BOD_5) and nearly 80% of chemical oxygen demand in potassium dichromate method (COD_{Cr}). Though still the concentrations of BOD_5 and COD_{Cr} of the effluent of the biogas plant were high (210 mg/L and 301 mg/L, respectively), overall, the biogas plant system was found to be the most acceptable with the lowest installation cost per capita, assuming that almost no operation and maintenance requirement in first one year, and production of biogas for cooking as by-product.

A survey concerning the willingness to pay for the installation, operation and maintenance of various options for water and sanitation was conducted before the testing of options. The result showed that most people did not want to pay any money for any options. Then, first biogas based option and other options were installed free. After the testing of the options, two biogas-based options were installed at cost sharing basis with the users of the option contributing on average 4 US dollar per household as installation cost. In addition, they agreed to bear 100% of the cost of the cleaning of the connection system such as pipes and connection pits in the case of blockage. At this stage, the regular maintenance and cleaning of the biogas plant itself was considered unnecessary. After the testing period, the design was handed over to the Plan International, which is one of the international NGOs. They helped the local people to install the biogas options by sharing a part of the installation cost.

Biogas plant sewerage system in Bauniabad

Based on the results of the test plants, the local people requested for further installation of the biogas plants. Accordingly, biogas plants have been actively installed since 1999. As of now, total of 20 biogas plants are in operation in Bauniabad. Each plant is connected to about 100 existing household latrines. Biogas plant consists of inlet tank, methane fermentation chamber with hydraulic chamber, and soak pit. The total capacity of the fermentation chamber and hydraulic chamber is about 13 m³. The plant adopts the gravity flow system and no energy required for the system. The treated wastewater flows into the soak

pit, and overflow of the soak pit is discharged into the surrounding water bodies such as a canal and ponds. It is reported that there is no soak pit in most of the biogas plants installed in recent years. In these cases, the water from the hydraulic chamber directly flows into the water bodies as effluent. As for a fermentation chamber, a fixed dome digester which is widely used in China was adopted. Though the biogas plant was originally designed to treat human waste of about 100 households' members, it is presumed that more than twice of human waste is flowing per biogas plant because of the growth of the number of the people living in one plot, causing less hydraulic retention time for fermentation.

METHODS

Household based interview

The interviews to the household members in Bauniabad were conducted by trained female interviewer teams. As there were sometimes more than 3 families in one plot though originally one family was allotted to a plot, plot based systematic and proportional sampling was conducted. About 8% of the total number of plots (222 out of 2688) was included in the survey. The housewife or main female member of the first household from the selected plot was requested for the interview. The questionnaire used for the interview was on socio-economic status of the respondent, sources and practices about drinking water, types of latrines, cost and financial aspects, local community participation, hygiene practices, and other water and sanitation issues.

Participatory data collection

The focus group discussions per block were conducted among the local women in two rounds. The purpose of the focus group discussions was to understand their views and refine the historical information. The first round of focus group discussions were done before the household based interview. It helped to collect the information as well as to develop the interview questionnaire. For example, the women were targeted for the household interviews based on claims made during the first round of focus group discussions that women managed the water and sanitation practices and options while men were often busy earning incomes. The second round of focus group discussions were done after the interview survey for further collection of data and clarification of certain views expressed in the interviews. In addition, the males were also interviewed to compare and to understand the situations.

Water quality analysis

The wastewater samples were collected in December 2003 from total four different biogas plant sewerage systems with and without a soak pit. As shown in Figure 2, five samples from each system were collected from: Point 1; connection pit at the end of a lane, Point 2; inlet chamber in front of the fermentation chamber considered as influent, Point 3; hydraulic chamber, Point 4; soak pit or after hydraulic chamber when there is no soak pit which are considered as effluent, and Point 5; the canal or the ponds into which the effluent was discharged. In addition,

Figure 2. Sample collection points of biogas plant system.

four samples were collected from pit latrines, which are not connected to the biogas plant sewerage system. In most of the cases, the wastewater at sampling point 2 (inside of inlet chamber), point 3 (inside of hydraulic chamber) and point 4 (inside of soak pit), were found to be in solidified states. In such cases, the overflowing wastewater was sampled.

The pH, conductivity, temperature, fecal coliform (FC) count, BOD₅, COD_{Cr}, COD in potassium permanganate method (COD_{Mn}), and nitrogen compounds (nitrate nitrogen, nitrite nitrogen and ammonium nitrogen) of each water sample were analyzed. The BOD₅, COD_{Cr}, COD_{Mn} and nitrogen compounds were analyzed by Bangladesh University of Engineering Technology (BUET). The test for pH, conductivity and temperature were all done on-site, and the FC count was conducted at the environmental laboratory at EPRC.

RESULTS AND DISCUSSION

Sanitation practices

Figure 3 shows the change of the use of sanitation options according to the questionnaire survey. After 1999, 72% of the people interviewed who were using pit latrine or open latrine before 1995 changed their sanitation options to biogas-connected latrines. This result confirms the active installation of the biogas plant since 1999. However, still more than 20% and about 6% of the people interviewed are using pit latrine and open latrine, respectively.

Figure 3. Change of the use of sanitation options.

Table 1 shows the claimed performance of the sanitation options according to the household interview. Before 1999, more than 40% of the people interviewed were suffered from overflow of the latrine or the bad smell of the latrine, and about 30% had the feeling that the latrine was in dirty condition. After 1999, the claim of the overflow/smell decreased to 5%, and nearly 70% felt the latrine had no problem. This means that the hygiene condition of the latrines has improved after 1999. Considering the fact that the most of the people interviewed were using pit latrine before 1999 and had their latrine connected to biogas plant since 1999, it can be said that the connection of their latrine to biogas plant contribute to the improvement of the hygiene condition of their living environment. At household level, there was no blockage in a pipe without any complicated maintenance and cleaning. Therefore, the biogas plant system was revealed to have the function of getting rid of human waste continuously from the households. Though still the domestic wastewater such as kitchen wastewater and bathing wastewater is directly flowing into the roadside ditches and seems to be the non-point sources, it is a big improvement of human waste in urban poor settlement becoming point sources.

Table 1. Claimed performance of the sanitation options from household based interview.

	Overflow/smell (%)	Disposal problem (%)	Dirty (%)	No problem (%)
Before 1995	43	28	28	0
1996-1999	40	10	29	1
1999-Present	5	3	12	69

Change of the cost sharing

The installation cost of biogas plant sewerage system is about 120,000 to 152,000 Taka (1 US dollar=57.80 Taka in October 2002). During first testing of the system in 1995, the local community was not asked for any cost. After the testing period in 1996, the community requested the installation of biogas plant to the Plan International, because people came to know the benefit of having the connection of their latrines to biogas plants. At the installation, the community agreed to share the 20% of the installation cost and the 100% of cleaning cost of pipes and connection pits if the blockage happens. Subsequently, the cost sharing increased significantly over time. The community agreed to share 30% of the installation cost in 1998, and 40% in 2001 and 2002. Before testing period of biogas plant in 1995, according to willingness-to-pay survey, the people did not want to pay anything for any sanitation options. Considering this fact, it is the dramatic improvement of the people's attitude toward the cost sharing. It can be good examples that though people are poor living less than 1 US dollar per day, they accept to pay for it when they understand the option is good for them.

Performance of biogas plant

Figure 4 shows BOD₅ of each sampling point of biogas plant systems. Comparing the data at Point 2 and Point 4, it was revealed that the anaerobic digestion did not perform well as designed, and it could not reduce the pollution load to the surrounding water bodies. It was observed that the inside of the hydraulic chambers and soak pits was solidified and the actual volume for fermentation was reduced than designed. The reason of the solidification seems that the people had considered the biogas plant as maintenance free and there was no mechanism to clean the fermentation chamber. In addition, because the same design with same capacity as test plants was used for every biogas plants installed in Bauniabad, it is clear that number of the people using per latrine increased than the testing period. This may also cause the insufficient retention time for anaerobic digestion. Therefore, though the hygiene condition of the living environment was improved, the biogas plant system does not sufficiently reduce the pollution to the surrounding water bodies.

Figure 4. BOD₅ of the each sampling point of the biogas plant systems with and without a soak pit.

Point 1: Connection pit, Point 2: Inlet tank, Point 3: Hydraulic chamber, Point 4: Soak pit (left) and after hydraulic chamber (right).

It seems that these improper design and improper management were because of the lack of appropriate technical knowledge. Therefore, there is a possibility to improve the performance of the plant with the appropriate design considering the proper number of connection based on the capacity of the fermentation chamber, and the establishment of the mechanism of regular maintenance and cleaning.

Importance of Education

Though biogas option itself have many problems in design and the maintenance methods, which should be improved and considered in the future, the community of Bauniabad has achieved some kind of improvement in regards to the attitude of the local people toward the improvement of their living

condition though they are poor. The following points are considered as the factors of the improvement; i) hygiene education in combination with appropriate technology, ii) formation of the local committee, which can act as the connection point of the conversation between the local people, donor agencies, and the local government, and iii) involvement of the local people before installation of the sanitation options.

To operate and maintain the biogas plant system continuously, it is necessary to establish the operation and maintenance system including the maintenance cost sharing by the local people. At this stage, it is still impossible for the local people to share all of the expensive installation costs. However, they have gradually increased the proportion of the installation cost share. This is because the people were involved from the beginning of the installation and they understood the benefit of the option from the combination of hygiene education and their experience from the test plants.

CONCLUSIONS

From the study, the following conclusions were gained;

- From the results of the questionnaire, it was revealed that the hygiene condition of the latrines was improved after the connection to the biogas plants. At household level, there was no blockage in a pipe without any complicated maintenance and cleaning. Therefore, the biogas plant system was revealed to have the function of getting rid of human waste from the households continuously.
- From the water quality analysis of the biogas plant system, it was revealed that the anaerobic digestion of the biogas plants did not perform well as designed, and the water quality of the discharge from the plants could not sufficiently reduce the pollution load to the surrounding water bodies such as a canal and ponds. It was partly because the people had considered the biogas plant as maintenance free and they did not do any maintenance at all with lack of the appropriate technical knowledge. Also, the retention time of the fermentation seemed to be not sufficient enough because of the number of the people using latrine increased because of the growth of the people living in the same plots than testing period. This means that there is a possibility to improve the performance of the plant with the regular maintenance and cleaning, and the modification of the design based on the appropriate number of connecting households.
- To operate and maintain the biogas plant system continuously, it is necessary to establish the operation and maintenance system including the maintenance cost sharing by the local people. At this stage, it is still impossible for the local people to share all of the expensive installation cost. However, they have gradually increased the proportion of the installation cost sharing. This is because the people were involved from the beginning of the installation and they understood the benefit of the option from the combination of hygiene education and their experience from the test plants.
- It is possible to change the attitude of the local people toward the improvement of their living condition though they are poor considering the following factors; i) hygiene education in combination with appropriate technology, ii) formation of the local committee, which can act as the connection point of the conversation between the local people, donor agencies, and the local government, and iii) involvement of the local people before installation of the sanitation options.

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