People's Perception on Ecological Sanitation and Health Risks Associated in Central Nepal

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Abstract

In 2015, it was estimated that 2.4 billion people globally still use unimproved sanitation facilities, among which 40% live in Southern Asia (WHO 2015). Ecological sanitation could be the best alternative to solve the problem of sanitation and to improve livelihood. The study was conducted in one of the Village Development Committee (VDC) of Bhaktapur district where ecosan toilet was constructed for the households with the financial and technical help from Environment and Public Health Organization (ENPHO). The present study investigated ecosan users' and non-users' attitudes towards ecosan toilet through questionnaire survey. Fifteen ecosan users and 15 non-users were interviewed. Five ecosan users were selected from abovementioned 15 users for microbial contamination. Fecal contamination on hands, shoes back, soil sample and ecosan manure sample was measured by monitoring *Echerichia coli* as a fecal indicator bacteria. The results from the questionnaire survey suggested that all ecosan user farmers agreed with the positive effects of ecosan manure in terms of fertilizer use and have not mentioned any problems on use of ecosan toilet. Although majority of the non-ecosan users are aware of the benefits of ecosan toilet but only few are willing to install ecosan toilet due to its drawbacks such as need of ash, user unfriendly and unsuitability for large size family (> 5 family members). Need of proper management of ecosan toilet and awareness campaign on self-hygiene was found to be necessary to promote effective use of ecosan toilet. The *E. coli* tests suggested that only ecosan manure is not the source for fecal transmission. However urine and ecosan manure from ecosan toilet might get contaminated by fecal microorganisms through other sources. Proper attention is necessary to reduce such contamination which is generally neglected by the users.

Keywords: ecosan, fertilizer use, households, questionnaire survey

Introduction

In low- and middle-income countries, 38% of health care facilities do not have an improved water source, 19% do not have improved sanitation, 35% do not have water and soap for handwashing (WHO 2015). About 663 million people lack access to improved drinking water sources, among which 34 million falls under Southern Asia (WHO 2015). In 2015, it was estimated that 2.4 billion people globally still used unimproved sanitation facilities, 40% of whom lived in Southern Asia (WHO 2015). To overcome this situation, ecological sanitation (ecosan) could play an important role. Ecosan is the practice of converting human urine and excreta into liquid fertilizer and compost for beneficial reuse of the nutrients contained in the urine and excreta. Materials such as ash, sawdust, and rice husks are used to cover fecal material, to eliminate odors and to absorb moisture from the excreta. Combination reuse of the fecal compost and stored urine can supply nutrients to vegetables as well as chemical fertilizers (Hijikata et al. 2014). As one type of ecosan toilet, urine diverting dry toilets (UDDT), which can separately treat human excreta and urine, have advantages for saving flushing water and sewer pipe networks (Winblad and Simpson-Hebert

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2004). The wastewater reuses would be an attractive option for rural areas in developing countries where poverty, poor infrastructure, low efficiency, government/political instability, and severe environmental condition are challenges (Ushijima et al. 2015). Many advantages such as water conservation, recycling of nutrients, affordable sanitation are associated with ecosan toilet. Ecosan practices is effective at reducing the fecal contamination of the surrounding water environment, thereby liming the health risk from unavoidable accidental ingestion of water (Harada and Fujii 2020). Yet, there is a risk of transmission of bacteria during handling of ecosan manure for which better treatment and management is necessary. These resources potentially contain microbial pathogens that mainly cause gastrointestinal infections (WHO 2006). Fecal contamination of incompletely treated excreta and other frequently contacted objects (i.e., handheld tools, toilet pits) strongly influenced hand contamination, and influenced ingested dose of fecal microorganisms, governed by hand-to-mouth contact frequencies (Julian et al. 2018). Further, overapplication of untreated wastewater and excreta can also lead to runoff and overflow after rainfall events, which can result in the contamination of surface water.

Improvement of water and sanitation in Southern Asia has been one of the most critical issues, especially in rural areas. Improving the sustainability of water and sanitation supplies has potential for both gains in health and economic development (Montgomery et al. 2009). Social attitudes and perceptions towards excreta vary with age, sex, religion, education, employment, region and physical capacity (Mariwah and Drangert 2011). Also, people's behavior towards the urine-diverting toilet and in utilizing human excreta as fertilizer is guided by their perception towards it. The respondents' attitudes and perceptions toward excreta and their decision to use excreta for agricultural purpose, however, differ to their socioeconomic characteristics (Nimoh et al. 2014). The study conducted by Andersson (2015) in Uganda reported that the supportive attitude of farmers for urine fertilization was due to its ability to ensure food and economic security given that they have few other options for soil nutrient management. The study conducted by Lienert et al. (2003) to analyze the perception of Swiss farmers indicated that 57% liked the idea of using urine based fertilizers with 42% stating their willingness to buy such products.

The main factors that motivated farmers to respond positively to reuse of urine were improved soil quality and potential of cost savings with reduced use of chemical fertilizers (Simha et al. 2017). However, limited studies on socio-technological perspective on farmers and consumers attitudes about the design and use of urine diverting toilets have been conducted till date. The re-use of human excreta and organic waste as fertilizer is not new in Nepal. Many communities have developed systems for collecting waste and using it in their fields. In mountainous regions where open defecation is difficult due to the very cold weather condition, toilets are made inside the house, generally in the ground floor which is connected with the pig shelter in the basement (Poudel and Adhikari 2015). Similarly, knowledge on using urine and feces as agriculture fertilizer is not new for Newar community in Nepal. However, these traditional practices are slowly diminishing as the younger generations hesitate to adopt it in the name of modernization (Poudel and Adhikari 2015). Those waste and excreta which were being used as fertilizer are now disposed off through sewer systems.

The concept of ecosan in its modern sense was first introduced in Nepal in year 2002 by the Department of Water Supply and Sewerage and WHO (ENPHO 2006). Since its introduction in Nepal, there are several modifications in ecosan toilet pans in terms of materials and types in order to suit local culture and ecology and have been constructed in difference parts of the country. There were 36 toilets in 2003 with rapid increment upto 517 toilets in 2006 (ENPHO 2006). Majority of ecosan toilets have been built in the peri-urban areas of Kathmandu valley, with few constructed outside the Kathmandu valley. A total of 2,095 ecosan toilets till 2014 have been installed in 19 districts in different regions showing potential for scaling up in diverse socio-cultural setting and geography (Aryal et al. 2015). Nepal is a potential area for ecosan approach as its numerous areas are reported lack of enough water for sanitation and under supply of chemical fertilizer for agriculture. Nepalese economy is still dominated by agriculture sector and agro-based industries. More than 80% of people (4.2 million) depend on agriculture and agriculture provides net employment to 60% of people (FAO 2017). Development of improved technologies like improved seeds, fertilizer pesticides, farming techniques and use of agricultural tools and instruments and trianed human resource have contributed largely to the agriculture production (MoF 2016).

The studies to understand ecosan users perceptions after installation of an ecosan toilet is unclear. To fully utilize hygienic human excreta, UDDT projects are also being introduced in Nepal. And most of the projects currently launched are in communities with long-standing traditions of using human waste on crops and UDDT acceptance reported is 71% (WaterAid Nepal 2008). In order to extend an ecosan toilet and to identify the target group for dissemination, perception of both ecosan users and non-ecosan users should be incorporated. Ecosan users perception will help to understand the drawbacks associated with ecosan toilet and to minimize those drawbacks in future. Non-ecosan users perception will help to understand their concept towards ecosan technology, willingness to install such technology and to have modification in the system as per needed.

This study also tried to evaluate the risk of excreta reuse due to handling of ecosan manure. *Escherichia coli* is a member of the fecal coliform group and is a more specific indicator of fecal pollution than other fecal coliforms. To understand the fecal transmission, only *E. coli* tests was conducted in this study due to limitation of resource. Generally, due to the long tradition of urine and excreta reuse in Nepal, most ot the users think that it is safe to use urine and excreta in agriculture. However, studies showed that the waste produced from those ecosan toilets is unsafe for use in agriculture and increases the health risks to the communities (Morgan and Mekonnen 2013). The addition of ash and lime reduces smell, covers the excreted material which in turn reduces the risk for flies and improves the aesthetical condition, decreases moisture content and promotes pathogen die-off through the elevated pH effect (Schonning and Stenstrom 2004). But, if an ecosan toilet is not well managed, it may increase the transmission of diseases like diarrhea and helminthis in the community (Jimenez et al. 2007; Schonning et al. 2007). The risk of fecal matter to the ecosan users varies depending upon the handling behavior or the application practices. The use of human excreta in agriculture is beneficial if it is composted well and did not associate risks with the use of composted excreta if it was dry and lacked odour (Jensen et al. 2008). Hence in this study, risk perception of users and *E. coli* tests were combined so as to understand the handling behaviours and fecal contamination associated due to such practices.

1. Methodology

1.1. Study Area

The study was conducted in a village (21.39° North and 85.25° East) of Bhaktapur district in October 2018. The district is surrounded by Kathmandu (Capital city of Nepal) in the west and North. The population of the district is 304,651 (The total population of the village is about 5,689 with households 1,257) (CBS 2011) with an annual population growth rate of 2.96%. About 54% area of the district belongs to urban areas due to the access of road, transportation, health, education facilities and due to boundary with Kathmandu. The district is an ancient agrarian town with a predominantly Newar population. The houses are traditionally made of clay and bricks. The traditional houses were well adapted to the local climate with the use of local building materials (Gautam et al. 2019). However, traditional houses are being replaced by the contemporary ways of construction, modern design and technology including aritificial materials (Rijal 2012). Agriculture is the primary occupation of the households in the district and is considered as the pocket areas for wheat crops, commercial vegetable production, cereal production, and organic agriculture. Livestock is one of the primary sources of income for the rural areas in the district and is associated with agricultural farm. Ecosan toilets for 60 households were installed in the village by the financial and technical help from Environment and Public Health Organization (ENPHO) in 2007/2008. During that time, ecosan was the new term in the study area. ENPHO informed the households with no toilets about the benefits and use of ecosan toilet. The main aim of ENPHO was to motivate to use toilet and to help households technically and financially to construct toilet was to meet the country's agenda to make a country open defecation free (ODF). There was no hard and fast rule for the households to choose and construct ecosan toilet. The households were given options of biogas toilet, normal pit latrine and ecosan toilet. The decision to choose the type of toilet was with the households head (some might discuss with the households members). Depending upon the land availability, households preferences, ecosan toilet was constructed for 60 households. After several years, a sanitation campaign was started in 2011 to declare the district ODF and became the first ODF district in Kathmandu valley. This village was chosen as a study area because the area represented an example of both ecosan and non-ecosan toilet and hence the perception of ecosan users and non-ecosan users would be well understood.

1.2. Population sampling, data collection and compliance

This study was based on questionnaire survey and *E. coli* tests. Ecosan toilet users' in the community of the study area were listed from the data of ENPHO. The respondents were randomly selected for questionnaire survey from the list mentioned above. Interviewing and sampling for *E. coli* tests were conducted only after people's consent with explanation of study objectives, anonymous data handling, and a publication way.

The total number of respondents was 30 comprising 15 households (25% of ecosan toilet installed) with ecosan toilet in their house and 15 households (same number as ecosan users') from 1,193 households with toilet other than ecosan. As this study tried to focus on perception of households about ecosan use, the number of interviewed households was limited because many of the ecosan users gave up ecosan at the time of survey. The major reasons for giving up ecosan were building of new house with flush toilet, destruction of house and toilet due to earthquake of 2015, difficulty to get ash and inconvenience to use by new members. All interviewed households (except one) belonged to the Newar communities, who in ancient days used toilet wastes collected from several households outside of their village. The questionnaire for the study was comprised of three main sections. The purpose of section I was to establish the socio-economic and cultural profile of the respondents, section II sought details of their farms and the type of farming they pursued, livestock reared, section III looked for insights into the respondents' perceptions, attitudes, inclinations, and willingness to shift towards use of ecosan toilet and human excreta based fertilizers.

Five households with ecosan toilet were selected to conduct *E. coli* tests. The sample was taken from both hands and both shoes back of the member handling ecosan manure. The samples were collected two times by using a swab test kit (ST-25 PBS; ELMEX, Japan). The first sample was collected before touching ecosan manure, i.e. before ecosan manure was applied in the field. The second sample was collected from the washed hand after the application was completed. Similarly, the soil before and after the application of ecosan manure was tested to understand the difference in presence of *E. coli* on soil before and after application. Urine samples were not collected for *E. coli* tests because in the study area very few households (13.3%) were found collecting urine separately for agricultural use.

1.3. Microbiological analysis

The collected soil samples and ecosan manure samples were analyzed for fecal indicator (*E. coli*). In this study, *E. coli* was considered to be the faecal indicator bacterium to infer the presence of fecal microorganisms, potentially including fecal pathogens. *E. coli* has been widely applied in risk assessment studies in the form of faecal indicator ratio. *E. coli* were cultured following a method 9215A in Standard Methods (Clesceri et al. 1998) using XM-G Agar (Nissui, Japan). This is one of the essential indicators when evaluating microbial risk from various fertilizer products including faeces (Feachem et al. 1983; Sidhu and Toze 2009). Soil sample (10 g) and ecosan manure sample (10 g) were homogenized using a minishaker separately in 100 ml of buffer phosphate solution. After this 10-fold dilution series with buffer solution was prepared as extract liquid. The extracts were filtered through a membrane filter with pore size of 0.47 µm, upon which the bacteria were trapped. The filter was then placed on petri dish with XM-G Agar and incubated at 37°C for 24 h. According to the colar profile of colonies, the number of *E. coli* colonies on each petri dish were counted and the results were expressed as colony-forming units per gram of sample (CFU/g) according to FAO (2001).

The sample in the swab test kit was mixed properly before pouring into the membrane filter with pore size of 0.47 µm. The filter was placed on petri dish with XM-G Agar and incubated at 37°C for 24 h. According to the color profile of colonies, the number of *E. coli* colonies on each petri dish were counted and the results were expressed as colony-forming units (CFU/hand or CFU/shoes' back).

1.4. Calculation and statistical analysis

E. coli concentration data were normalized by log transformation before analysis of variance (ANOVA). Statistical analysis was conducted using IBM SPSS Statistics 20.0 (IBM, USA), where a significant difference was reported at a 5% significance level.

2. Results and discussion

2.1. Socio-economic characteristics of respondents

The results of the socio-economic characteristics of respondents for ecosan users and non-ecosan users are presented in Table 1. During the questionnaire survey, 53% respondents were female in the households with ecosan toilet and 47% respondents were female in the households with no ecosan toilet. The average age of respondents was 46.6 years and 40.1 years in ecosan users and non-ecosan users respectively. The average household size was 5.5 and 4.9 in ecosan users' and non-ecosan users, respectively. The average size of family in Nepal is 4.6 with 17.1% nuclear households (family size 1–2) (CBS 2014). The transition from joint family to nuclear family is found increasing in the study area. The average farm size was similar (0.10 ha) in both types of households. The largest amount of vegetable producer among three districts in Kathmandu valley is Bhaktapur with an average landholding size of 0.15 ha for crop farming (MoAC 2006). Land holding size per family and field size have both decreased markedly in recent years (Deshar 2013). All households in the study area were found using LPG for cooking purpose. The study area in previous days used to use firewood for cooking purpose but gradually shifted from traditional cooking practice to use LPG due to lack of firewood and high availability of LPG with additional benefits such as its convenience, smoke free and time saving nature. All non ecosan users have pour flush toilet facilities in their house. Poor households are less likely to use the improved sanitation facility whereas most of the rich households have access to improved pour/flush toilet (MoH et al. 2017). The study conducted in Nepal by Budhathoki (2019) reported that poor households are less likely to have piped water connection in their home which limits access to the improved flush toilet. The principal occupation of both households was farming where rice, green vegetables, cauliflower were cultivated. Less than 7% of the farmers belonged to the age category < 30 years, showing consistency with the result from Sharma (2007) and Rajan (2003), reflecting the ongoing demographic crisis in Indian agriculture in which young people are increasingly less inclined to look to farming for their livelihood. Nepal's agriculture is also facing labor crisis, resulting in barren lands due to youth's migration either to the city or to abroad in search of quality living and to earn money. In Nepal, the proportion

Table 1. Socio-economic characteristics of respondents.

Variable		Frequency (%)	
		Ecosan users	Non-ecosan users
Gender	Male	8 (53.3)	7 (47.0)
	Female	7 (47.0)	8 (53.3)
Age	20–29	1 (6.6)	1 (6.6)
	30–39	3 (20.0)	7 (46.6)
	40–49	6 (40.0)	5 (33.3)
	50–59	3 (20.0)	2 (13.3)
	60 and above	2 (13.3)	0 (0.0)
Household size	5 and below	10 (66.6)	9 (60.0)
	6 and more	5 (33.3)	6 (40.0)
Source of income	Farming only	2 (13.3)	1 (6.6)
	Farming + service	10 (66.6)	10 (66.6)
	Farming + casual labor	3 (20.0)	2 (13.3)
	Farming + family business	0 (0.0)	1 (6.6)
	Farming + remittance	0 (0.0)	2 (13.3)
Landholding size	Below 0.1 ha	9 (60.0)	10 (66.6)
	0.1–0.5 ha	6 (40.0)	5 (33.3)
Livestock	Cow	3 (20)	2 (13)
	Goat	11 (73)	9 (60)
	Chicken	8 (53)	10 (67)
	No livestock	0 (0)	3 (20)

of economically active population depending on agriculture had fallen from 81 percent in 1991 to 60% in 2011 with significant drop in GDP (CBS 2014). Most of the household members of rural Nepal have been abroad for foreign employment. Remittance has become the major part of the national economy as it shares 26.9% in GDP in 2016/17 (Sapkota 2018). After returning home, only a few of them have been engaging in agriculture (Chaudhary 2018). Almost all respondents surveyed did not wish to disclose their income whereas most of them mentioned no savings from their income.

Higher number of households (11 ecosan users, 13 non-ecosan users) have land less than 0.1 ha. The study conducted by Maltsoglou and Taniguchi (2004) in Nepal concluded that the househods that have the average largest herd size (3.5 Tropical Livestock Unit (TLU)) are located in the mountains compared to rural hills (3.1 TLU), Terai (2.7 TLU), urban areas in Kathmandu (1.0 TLU) and in other urban areas (1.5 TLU). Fewer households own livestock in the urban areas in Kathmandu and in other urban areas (FAO 2004). The higher number of livestock in the households with ecosan toilet (0.85 TLU) might reflect the need of manure to use in their farm no matter through any source, chemical fertilizer or cattle manure or ecosan manure. Farm size and livestock number reared were related to each other among non-ecosan users (higher the landholding size higher is the livestock number, $r = 0.988$ ($p < 0.01$)) as in other parts of the country but the result was contrast in the households with ecosan users with low land holding size (Figure 1).

Landholding size and TLU was negatively correlated among ecosan users with low landholding size. Ecosan user households with low landholding size prefer to have more cattles in order to fulfill fertilizer demand for their land. Because the available land size is small, ecosan manure in addition to cattle manure is preferred as a substitute to chemical fertilizer. This is the reason that even after the collapsing of the house due to devastating earthquake of 2015, households would like to keep their ecosan toilet by repairing the damage. In contrast, the non-ecosan user households whose house was collapsed by the earthquake of 2015 built new houses and did

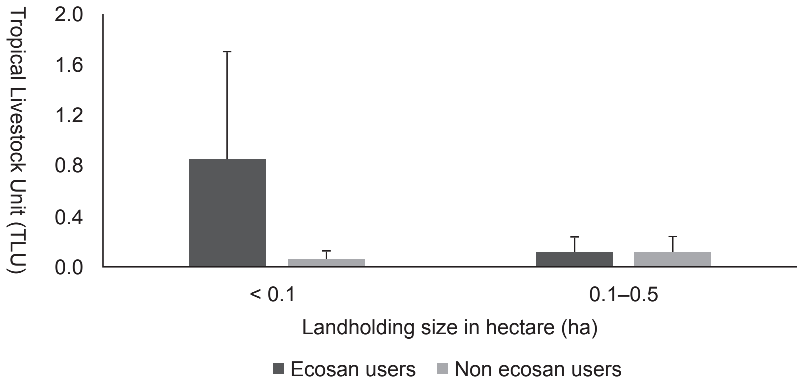

Figure 1. Relationship between landholding size and number of livestock of each household in the study area.

not want to keep cattles because of their thought that livestock decrease the aesthetic value of modern house. Non-ecosan users more likely depend upon chemical fertilizer to fulfill the fertilizer demand. Recently, people are selling land in the high price and interested to construct so called modern building or sophisticated house. The young generations do not want to engage in the activies like farming and livestock rearing. Most commonly used chemical fertilizers in the study area are urea, di-ammonium phosphate and murate of potash. The price of these fertilizer are NPR 18, 45, and 32 per kg (100 NPR = 0.83 USD as of 2020/08/09) respectively (MoAD 2016). In addition, sea freight, port clearance and the cost of transportation can accout for as much as 20% of the cost of delivered fertilizer. Being the study area is not far from the Kathmandu valley, there is no constraint of chemical fertilizer as in other rural hilly areas. The households involved in agriculture does not have pressure to seek for the alternavites of chemical fertilizers in terms of availability. These might be the reasons of having lesser livestock number in the households.

2.2. Ecosan toilet in the study area and users perception

Table 2 presents the results of the facts in today's scenario of ecosan toilet in the study area. All interviewed ecosan users mentioned that the motivating factor in installing ecosan toilet in their house was the campaign started by ENPHO during 2007/08. The financial and technical help from ENPHO was the attraction to install ecosan toilet in their house at that time. The decision to construct either pit latrine, ecosan toilet or biogas toilet was decided by the family members depending upon the choice and need. Cultural and social norms play an essential role in deciding which type of sanitation system to use. According to Harada and Fujii (2020), even without cultural background of human excreta use, a high demand for feces use could be successfully created through association with a perception of the value of feces in agriculture.

There are many traditional examples of wastewater and excreta management in several parts of Nepal. Sherpas in mountainous regions still feed their feces to pigs, Newar of Kathmandu valley still use feces in producing vegetables, a farmer in middle hill still uses greywater in their kitchen garden (Poudel 2015). Local people are worried about the use of chemical fertilizers, as they believe that these fertilizers cause soil compaction, which hinders other farming operations (Poudel 2015). Human excreta are considered to be the richest manure and are collected in a special dry latrine pit. Such systems are accepted in those communities not only because people are poor but because of the long traditions of using human waste in crops. However, these traditional practices are slowly diminishing as the younger generations hesitate to adopt it in the name of modernization. Thapa and Kattel

Table 2. The facts associated with ecosan users.

Variable	Level of agreement (%)	
	Yes	No
ENPHO as a motivator to install ecosan toilet	100	0
Continuous use of urine and excreta as fertilizer till date	100	0
Urine is collected separately to use as a fertilizer	13.3	86.6
Use protective measure while handling urine and excreta	46.6	53.3

(2019) mentioned moderization as a regular process of change that happens by adopting new tools and technology. It provides opportunities for people to leave the village and joint family system and shift to the industrial areas. It has affected the family structure, marriage system, prevailing social norms, values and cultures in Nepal. The study also reported that in the rural areas of Nepal where the impact of modernization is less, the joint family is practiced whereas in the cities and urban dewllings, nuclear family system is in existence. A similar culture of using human waste in farm was adopted in ancient days in the study area. The use of human excreta as a fertilizer has a history of more than 200 years in Nepal (Ho and Mathew 2002). They mentioned in their book that sanitation systems in cities, where night soil was collected door to door and taken to surrounding farms for crop fertilization can be dated as far back or further.

According to the ENPHO personnel, because of the long tradition of using human waste, 60 households agreed to construct ecosan toilet in their house in 2007/08. All ecosan users interviewed during this study were using ecosan toilet continuously till date. All users were found using urine and excreta as a source of fertilizer. After years, majority of the households (86.6%) (Table 2) changed the habit of urine collection. Although similar result of using urine by lesser households compared to the households using feces was reported in Malawi in the study by Harada and Fujii (2020) the reason for not using urine is different. According to Harada and Fujii (2020), no use of human urine from ecosan toilet in Malawi was related with no use of animal urine leading to psychological constraint for use of human urine. In contrast, in this study the respondents mentioned that they do not collect the urine from the ecosan toilet separately but use them by mixing with the kitchen waste and cattle manure. Although the respondents are aware of the positive effects of urine as fertilizer value, the reason for not collecting urine is related to the fast filling of the collecting tank, problem associated with storage of urine and difficulty to carry out urine in the field because of its large volume after dilution. The study area is located in the hilly region and terrace farming is common practice. Because majority of the farms are located farther from the house, the family members found it difficult to carry the urine jar to the field. Instead, to recover the fertilizer value of urine, the households mix urine with the households' manure (kitchen waste and cattle manure collected outside of the house). They believe that the urine accelerates the manure decomposition rate and manure could be utilized whenever necessary. It also solved the problem of storage, carrying urine to the field and need of water for dilution.

It was found from the survey that after defecation, ash was used as an additive to sanitize fecal matter. All interviewed households mentioned that they wait for six months to use excreta as a fertilizer. The ash had a higher effect on the operational parameter (increase pH and decrease moisture content) during storage compared to the sawdust (Niwagaba et al. 2009). Demonstration on urine and feces use for agriculture enables the participants to recognize the effects of human waste on agriculture (Harada and Fujii 2020). However the perception of people on agricultural value of urine and feces is associated to the continuous use. In this survey we found that the ecosan users are not much conscious about health risk, which was justified by the result that 53.3% respondents were found not using any protective measures while handling ecosan manure (Table 2). All interviewed respondents agreed on the positive effect of ecosan toilet in terms of fertilizer use of urine and excreta. Eighty percent of the respondents mentioned that they do not have any problem caused by ecosan toilet and is the reflection of positive side of ecosan toilet. Majority of the respondents mentioned that they could harvest 220–250 kg of ecosan manure in one year (half in six months period). Being majority of households have land less than 0.1 ha, the amount of ecosan manure harvested is enough if cattle manure incorporated with urine is applied together with ecosan manure. In the case if number of cattle reared is small or zero, the farmers need to supply chemical fertilizers to meet the fertilizer demand. Among 15 respondents, 2 household (13.3%) had 6 members in the family and 13.3% had more than 6 members in the family. No complaints or burdens regarding emptying pit was explained by the respondents during the survey. Despite of awareness about the use of ecosan manure, construction of modern house, interest on employment activies other than farming, less availability of land size, water availability, and easy accessibility of chemical fertilizers were observed as factors that distract households to adopt or to continue ecosan toilets.

2.3. Perception of non-ecosan users toward excreta reuse for agricultural purpose

This section presents the results on the respondent's (non-ecosan users) perceptions and knowledge towards using urine and excreta for agricultural purpose, their willingness to construct ecosan toilet and their attitude towards the products grown by using ecosan manure (Table 3). Among the respondents, it was found that although these non-ecosan users are using either pit latrine or flush toilet, 87% of the interviewed respondents had experience of ecosan toilet use (Table 3). Twenty-seven percent respondents (4 households) mentioned that they had used ecosan toilet in their previous house (old ecosan users') and 60% (9 households) respondents replied that they had used ecosan toilet in their neighbors' house. Among 15 respondents, only 13% (2 households) respondents were found who has not used ecosan toilet till date. It was understood from the survey that during the devastating earthquake in 2015, 3 households lost their houses along with their ecosan toilets. Once the house was recovered after earthquake, the households switched from ecosan toilet to the ordinary or flush toilet. The reason for not constructing an ecosan toilet in the new house is due to the perception that such ecosan toilet is suitable only for old and traditional house. Availability of large space around the house, use of firewood for cooking in those houses making ash available to use in ecosan toilet and engagement of household members in agriculture best suited to ecosan toilet in traditional houses. In contrast, lack of space in the newly constructed house as a result of increased land price, family members wish to install toilet inside the house, gradual decrement of agricultural land tended to make the ecosan toilet unsuitable for modern houses (Table 4). Construction of a new house with modern toilet is the necessity of new generation. One of the previous users among the interviewed respondent mentioned that they shifted from ecosan toilet to modern toilet due to the wish of the younger family members. The respondents also mentioned that people gradually started nuclear family and seek other income generating sources giving up farming.

Among the total respondents, 83% replied that they had tasted the products grown from ecosan manure which represented that the respondent consumers do not mind consuming products grown from ecosan manure. They got those products from their neighbours who had an ecosan toilet in their house and raised the crops or vegetables using ecosan manure. It is common mostly in the village of Nepal to share or exchange newly grown vegetables among the neighbours. Among those respondents who tasted products from ecosan manure, 60% mentioned better taste of product grown compared to the one grown from chemical fertilizer while 33% mentioned no difference on taste in the product grown from ecosan manure and other fertilizer. This result showed the possibility of ecosan toilets still exists if toilet could be served with some modification and if it could be adjusted to modern toilets. The market for organic vegetable is gradually growing in Kathmandu valley but not all the farmers have the access to that market. Since the vegetables grown in this study area are

Table 3. Non-ecosan users' knowledge on ecosan and products grown from ecosan manure.

Statement	Yes	No	Need to think
Willing to install ecosan toilet at home	20	67	13
Tasted products grown from ecosan manure	93	7	
Aware of positive effect of human waste	74	26	
Ever used ecosan toilet	87	13	
Knowledge of ecosan toilet	93	7	

Table 4. Non-ecosan users statement to no interest for ecosan toilet construction.

Reasons for not having willingness to construct ecosan toilet	Respondents No (%)
No space/ No ash	6 (40)
Not user-friendly	1 (6.6)
Already have toilet	3 (20.0)
No idea	2 (13.3)

less in amount, the farmers sell the vegetables together with the vegetables grown by using chemical fertilizers. It would be an advantage for the farmers if the market for the products grown from ecosan manure worth more monetary value based on the taste and quality. It is also interesting to note from this study that even though the respondents did not have ecosan toilet in their house, they were seen irrigating their farms with sewage and greywater, pipes linked from their toilet to farm. They would like to use it as an agricultural value on their farm. This will save their money necessary to pay for the disposal of toilet waste and add nutrients to their field. Generally, in the Kathmandu valley with pour flush toilet, the toilet waste is collected in a septik tank. Once the tank is filled, the designated authority will visit the house to remove the toilet waste after paying the specified amount (money). They have mentioned that the authority charges around NPR 5,000 (100 NPR = 0.83 USD as of 2020/08/09) to remove the waste from their toilet.

In Nepal, farmers take raw (fresh) excreta from latrines to their vegetable gardens and grow good quality vegetables, which are tasty and are in high demand (Mishra 2003). In Siddhipur village of Nepal, most of the farmers use animal manure and raw human excreta as fertilizer for crops and vegetables. They have been doing this practice since ancient days, although it was considered unhygienic by the villagers (Mishra 2003). In our study area, although the respondents are aware of positive effect of ecosan toilet and do not hesitate to consume products grown from ecosan manure, the willingness to construct an ecosan toilet is less (20%) (Table 3). Ishii and Boyer (2016) also mentioned that 84% of students in the university of Southeastern region of United States would demand source separation systems to be installed in their halls of residence although their demand declined significantly when the respondents were asked their willingness to pay for it by themselves. In contrast, Lamichhane and Babcock (2013) reported that more than 60% of their test sample of 132 people from the University of Hawaii indicated their willingness to pay an extra $50 to install a urine diverting toilet. One reason that discourages interviewed respondents (40%) from constructing an ecosan toilet is the need of ash to sprinkle after defecation. People living in the outskirt of Kathmandu valley shifted from firewood to gas stove to cook their food. It became challenging to manage ash for ecosan toilet. Only few people (6.6%) mentioned that such type of toilet is suitable for the family with 4–5 members in their house. They mentioned that if the household size is large, the toilet pit fills earlier before six months' time frame, storage time will be less, and frequent emptying of vault would be additional work. Building a ecosan toilet for a family of 5–7 members is ideal but in case that household members are more, the faeces collection chamber should be designed to accommodate higher number of users (UNICEF 2011). The number of pathogens in fecal material during storage will be reduced with time due to natural die off, without further treatment (Schonning and Stenstrom 2004). Less storage time of excreta than recommended (six months) increase health risks for farmers due to the incomplete sanitization of feces.

2.4. Microbial risk assessment and existence in collected samples

Farmers and consumers exposure to ecosan manure was analyzed for risk assessment and are presented in Table 5. Majority of the farmers who planted crops three times in a year refers to the fact that they deal with ecosan manure for at least three times in a year (Table 5). Compost amending, plowing, seeding, weeding and harvesting are the major works that have direct or indirect contact with ecosan manure. Some farmers were found irrigating their field with the greywater using the pipe linked from their toilet to the farm. During irrigation, farmers did not wear protective clothing and were in direct contact with the irrigation water. Accidental ingestion of irrigation water and consumption of irrigated vegetables are the exposure paths. According to Julian et al. (2018), *E. coli* contamination of excreta and other frequently contacted objects strongly influence hand contamination and *E. coli* contamination of excreta and hand-to-mouth contact frequency influence ingested dose. The effects of contaminated soil on health were lower than direct handling of greywater and compost (Hijikata et al. 2017). Mostly Nepalese people consume green vegetables or other crops after cooking. The risks and existence of fecal microorganisms might be lower if consumed cooked, compared to vegetables consumed raw. Regarding the risks in compost reuse, it is recommended to store human manure for 6–12 months for adequate handling of UDDT (Schonning et al. 2007). The ecosan user households in the study area were found adopting a similar storage period of at least six months before applying to the farm as instructed by ENPHO. All interviewed ecosan user used ash as an additive after defecation. The ash or lime is added after each defecation to lower the moisture content and raise the pH to 9 or higher thus creating dryness (Winblad and Simpson-Hebert 2004).

Regarding the use of personal protective equipment (PPE), it was confirmed from the ENPHO staffs that during the installation of ecosan toilets in the study area they had instructed to use gloves and masks while taking out the ecosan manure from the filled pit and while using ecosan manure as a fertilizer. Though proper instruction was delivered, from the questionnaire survey result it was observed that more than 50% respondents (Table 2) did not use any precautions like gloves or masks while dealing with ecosan manure. It reflects the respondents are less concerned about health risks due to handling of ecosan manure or do not want to invest money on those precautions. As reported in Knudsan et al. (2008), personal ptotective equipment, although perceived to be beneficial, is often neglected due to costs and/or perceived convenience. The households did not hesitate to touch the ecosan manure with the bare hands. It was also observed that after finishing their work on the farm, they are conscious of washing hand but not conscious of washing legs or shoes. From the survey, it was found that ecosan users in the study area believe that it is safe to use human urine and ecosan manure as a fertilizer and did not show more concerns for health risk. This perception about ecosan manure came from older generations who used to use these products in their farm. In rural India, farmers have been observed to rely on the advice of people they know, family members, and in many cases, helpful neighbouring farmers rather than expert advice (Simha et al. 2017). Proper guidance and knowledge about possible health risk due to mishandling and improper management of ecosan toilet and ecosan manure should be delivered to the locals so as to minimize the health risks.

Table 5. Exposure scenario of farmers and consumers for risk assessment.

Target	Event	Ingestion means	Ingestion scenario	Event no. /year
Farmers	Compost amending	Direct contact with compost	Handling of compost with bare hands	3
	Plowing	Soil contaminated by compost	Soil touching after applying compost	3
	Seeding	Soil contaminated by compost	Soil touching after plowing	3
	Irrigation	Greywater	Handling of a watering can or bucket or pipes running through greywater	6
		Soil contaminated by compost and greywater	Soil touch twice or thrice for weeding	
	Weeding	Greywater on leaves and stems	Touching of plant leaves containing greywater	3
		Soil contaminated by compost and greywater	Soil touching for removing vegetables	
	Harvesting	Greywater on leaves and stems	Touching of plants	3
Consumers	Eating	Raw eating vegetables	Eating vegetables raw or not properly washed	

Microbial contamination in soil and ecosan manure

For soil samples collected from five households before and after application of ecosan manure, *E.coli* concentration (CFU/g) was measured. *E.coli* was detected in the all the soil samples. Presence of *E. coli* in soil in the initial state before applying ecosan manure suggested that the source of fecal microorganisms in the soil was not only the ecosan manure (Figure 2). Besides ecosan manure, other sources such as irrigating water, cattle manure, chicken manure might be the contaminating source of fecal microorganisms, including *E. coli*, in soil. Several factors such as temperature, moisture, nutrients either alone or in combination with soil organisms influence the growth and survival of *E. coli* in soil (Ishii et al. 2010).

Among 5 ecosan manure samples collected, *E. coli* (CFU/g) was detected in samples of 3 households (HH 1, 4, 5) whereas no *E. coli* was detected in ecosan manure samples of 2 households (HH 2, 3) (Figure 2). No *E. coli* detection on 2 households might suggest that proper management of an ecosan toilet could play a role to sanitize the excreta, lowering the health risks of using excreta.

Microbial contamination in hands and shoes back

For all 5 households, 10 hand samples (5 right hand, 5 left hand) and 10 shoes back samples (5 right shoes, 5 left shoes), *E. coli* concentrations was measured. Although the households are concern of washing hands after dealing with ecosan manure, higher concentration of *E. coli* ($\log_{10}$ CFU/hand) even after washing hand (Figure 3) was observed. Although there was no significant change in *E. coli* concentration in hand before and after handling among the housholds, no *E. coli* concentration in hand samples was found in HHs 2 and 4. Higher concentrations of *E. coli* on hand before handling ecosan manure might also indicate that only ecosan manure is not the source for fecal contamination on hand. *E. coli* counts in the faeces with ash decreased with decreasing moisture content and gradual increase in pH during the storage period (Niwabaga et al. 2009). No change in *E. coli* concentration even after washing hand suggests that the concentration could be affected by water used for washing hand and the way of washing.

Among 5 shoes back samples, in HHs 3, 4, and 5, no *E.coli* ($\log_{10}$ CFU/shoes) was detected on shoe sample even before and after dealing with ecosan manure (Figure 4). Significant difference in *E. coli* concentration on shoe back before and after washing was observed with high concentration of *E. coli* in shoes back after dealing with

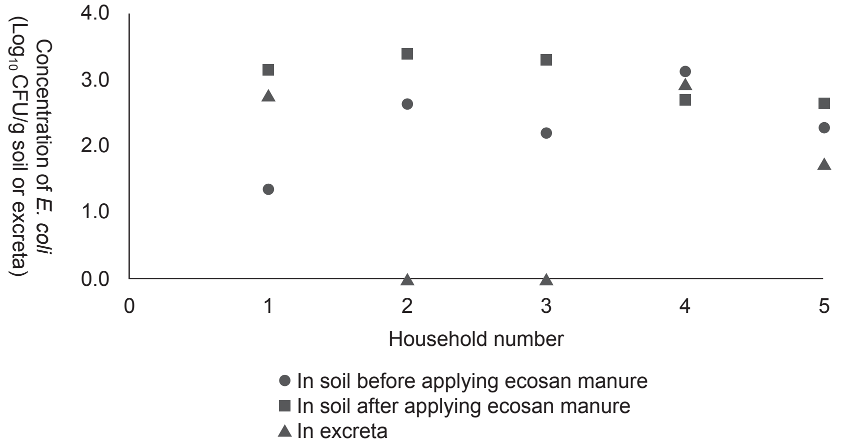

Figure 2. Concentration of *E. coli* in soil and excreta due to ecosan manure among five households.

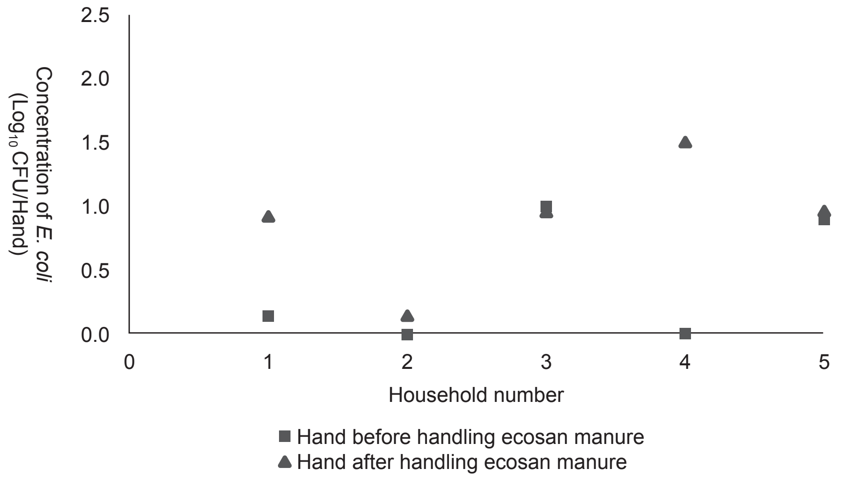

Figure 3. Concentration of *E. coli* on hand before and after using ecosan manure among five households.

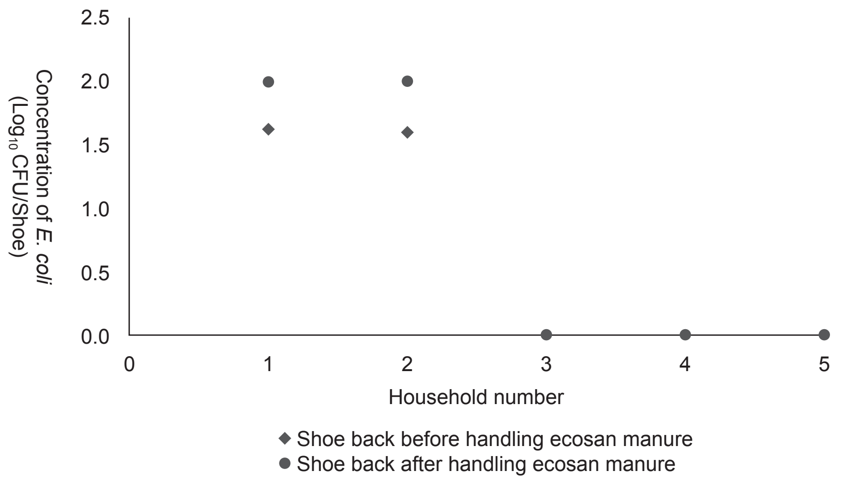

Figure 4. Concentration of *E. coli* on shoe before and after using ecosan manure among five households.

ecosan manure or after coming back to home from outside. It is related with the facts that household members were conscious on washing hand but not for washing legs and shoes after finishing their work. It also reflects to the fact that if we give proper attention to the washing not only while dealing with the ecosan manure but during other households activities, it might have positive effects on reducing fecal contamination on hands, leading less fecal exposure and better human health. Along with sanitation, proper hygiene management training and provision of clean drinking water might be the components necessary to achieve the health improvement in the area. Farmers need to be educated on precautionary measures to avoid health hazard from excreta reuse (Cofie et al. 2010). The current situation about locals' perception might help to address health risk issues associated with ecological sanitation technology and can play a role in dessimination and expansion of such technology. Simha et al. (2017) indicated that for farmers in India to adopt human waste as a fertilizer, they must know someone who uses/used it and/or must be convinced of its crop productivity potential.

Conclusion

This study investigated both ecosan user and non user households' attitudes, and perceptions toward human excreta reuse for agricultural purpose in the study village of Bhaktapur district in Nepal. Farming is the predominant occupation in the study area, and ecosan toilet was disseminated for several households by the financial and technical help from ENPHO. The study found that majority of the respondents in the study community disagreed that excreta is the waste. However, some households were found continuing ecosan toilet till date while some previous users already shifted from ecosan to other toilets due to the choice of younger generation to build modern toilet. This result reflects that though non-ecosan users are also motivated to use products from ecosan manure as an fertilizer amendment, the desire of the new family members in the house and concept that ecosan toilet is not suitable in modern house is the factor that disable users to continue it. To minimize the rate of discontinuation after the dissemination of new technology, it is necessary to monitor the condition of toilet and provide suggestions for the bettermentof the toilet, to increase ecosan users and to promote excreta reuse in farming. Open discussions on the benefits and risks associated with excreta reuse in agriculture could enrich farmer's knowledge on the handling and appropriate use of excreta as fertilizer. The study concluded that ecosan manure is not only the source of fecal microrganisms. Ecosan manure might get contaminated by fecal microorganisms through other sources if handled unappropriately. Proper attention should be done to reduce such contamination which is generally neglected by most users. Further research on the factors that influence farmers decision on excreta reuse for agricultural purpose and perceptions on health risks is recommended to avoid contamination of ecosan manure and associated negative health impact by fecal microorganisms. Time to time and door to door supervision on toilet management and modification to meet the need of younger generation is also recommended for the long-term sustainability of the ecosan.

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