Application of Human Urine in Vegetable Production in a School Garden: A Participatory Action Research

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ABSTRACT: Urine separation toilets are a possible route for achieving maximum recovery and recycling urine nutrients. However, using fresh urine as agricultural fertilizer is problematic and controversial concerning hygiene, storage, distribution, and supply. The intervention of this study was implemented at a public high school in Nepal. This study explores the applicability of urine diversion toilets in the school setting to improve organic vegetable production from the school's Eco-garden and the status of improving sanitation. A urine diversion toilet was constructed, and hardware and software-based participatory interventions were undertaken in the schools' Eco-garden. It was found that the urine diversion toilet is useful in preventing surface water from being polluted and improving students' sanitation and hygiene behavior. When cultivating vegetables using human urine fertilizer and animal fertilizer in different plots of the same area, it is found that human urine as fertilizer increases by 40% more production of the vegetables in comparison with using animal fertilizer. It is concluded that urine-fertilized plots have more vegetables with nutrients than animal fertilizer. Human urine application could be effectively used as a nutrient fertilizer, a new area of scientific research in the research frontier.

Introduction

Human urine is one of the sources of nutrients in agricultural production. Research showed that human urine is a valuable source of nutrients for agricultural production (Esrey et al., 1998; Otterpohl, 2001). Human urine contains macronutrients such as Nitrogen (N), Phosphorus (P), and Potassium (K) required for agricultural fertilizer production (Randall & Naidoo, 2018). Human urine is valuable fertilizer, although its value is underestimated and underutilized (Andersson, 2015). Urine is a rich source of various nutrients that have been used since ancestral times to increase the productivity of plants, particularly leafy vegetables (Karak & Bhattacharyya, 2011). The use of human urine as agricultural fertilizer is receiving attention as an alternative fertilizer because it contains nutrients such as nitrogen, phosphorous and potassium. Human urine contains approximately 75-90 % of nitrogen from that urea can be extracted. The remainder is in the form of either ammonium or creatinine (Simha &

Ganesapillai, 2017). Most nitrogen fractions in human urine are taken up by plants, the same as urea or ammonium fertilizer, with a nitrogen efficiency of approximately 90% of mineral fertilizer (Andersson, 2015; Austin et al., 2005). Nitrogen is mainly in the form of urea (NH_2-CO-NH_2), phosphorus as phosphate (PO_4^{3-}), and potassium ion (K^-) and micronutrients are also present in a balanced form in human urine. Moreover, human urine is free from cadmium (Cd) and other heavy metals (Biswas et al., 2020; Boh et al., 2021; Palmquist & Jönsson, 2004).

Sanitation and wastewater management are highly pertinent for reaching several interconnected, sustainable development goals (SDGs), especially SDG 6. The provision of safe drinking water and adequate sanitation for all as well as protection of water resources against pollution, and SDG 14.1, reducing nutrient emissions to the aquatic environment (Larsen et al., 2021). Rather than further optimizing and diffusing this ageing infrastructure paradigm, radical innovations like urine source separation technologies could help improve towards faster SDG achievement. The technology would simplify on-site sanitation and develop a closed-loop nutrient cycle, allowing exceptionally high nutrient removal from wastewater and direct reuse in agricultural fertilizer. Based on a review literature, it is found how the past three decades of development of urine source separation have brought breakthroughs in toilet design and treatment processes, enabling the Ecological sanitation technology value chain to reach the SDG goal.

The sanitation sector strongly demands enabling environment and strategic steps to enhance coordination, build stakeholder alliance, synchronize diverse efforts, maintain uniformity and standard in program. It supports modalities, capacitate grassroots level stakeholders, optimally utilize local resources, strengthen grassroots level institutions and, ultimately, reduce dependency in the sanitation sector activities through shared vision. It helps to unify planning and implementation and collective result framework. The Sanitation and Hygiene Master Plan 2011 was formulated to streamline the sanitation sector activities with the broader sectoral vision. It also helps an innovative strategic orientation, multi-stakeholder collaboration and locally managed financing modalities in the context of the number of significant challenges the sector faces. The master plan has given thrust to resolve institutional, behavioral, cultural and socio-economic barriers and synergize efforts for sustainable environmental sanitation and hygiene behaviors through Eco-san toilet use. A urine-diverting toilet (UDT) is an Eco-san toilet that can provide safe, free-of-cost sanitation in various contexts worldwide (Jurga et al., 2005; Simha & Ganesapillai, 2017). Human urine harvested from UDT can be routinely used in agriculture to improve agricultural production and increase nutrients (AdeOluwa & Cofie, 2012). An enormous amount of chemical fertilizers applied to increase crop production has polluted the water, soil, and air on a large scale. In turn, this has raised consumers' concerning the quality and safety of food production. Organic farming has been promoted to restore soil health and

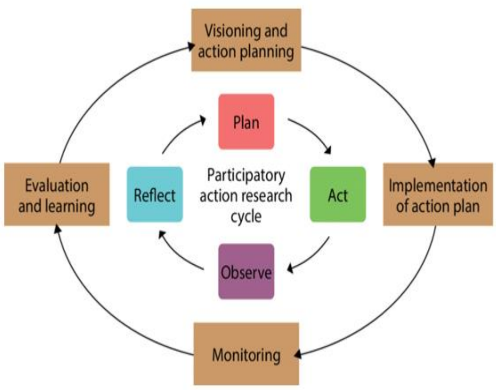


Figure 1: PAR Design

fertility through organic matter (Lind et al., 2000). Because of tthis the study has kbeen conducted on using human urine as an agricultural fertilizer in a school garden through a urine diversion toilet. It was conducted in a community school in Nepal, linking ecological sanitation to classroom teaching and learning. A urine diversion toilet has been constructed and used as an intervention package. This study aimed to change students' hygiene and sanitation behavior using Eco-san toilets, improve organic vegetable production, and assess the applicability of UDT and Eco-garden in the school setting.

Methodology

Research Design and Methods

As guided by the pragmatist view, the research design included qualitative and quantitative (QUAL-QUAN) data embedded with the participatory action research (PAR) approach. PAR has been rising as an emergent methodology in the educational field that challenges traditional hierarchies between the researcher(s) and being researched. In this PAR, research participants are called co-researchers and research is conducted 'with participants' in a partnership rather than 'on participants' treating them just as information providers (Jacobs, 2016). We chose the PAR approach as it helps for a deeper understanding of activity-based learning by participating students, teachers, parents, and PAR committee members through UDT and Eco-garden activities. In this study, we started inductively, meaning the co-researchers worked with particulars before generalizations. We tried to understand classroom practices from the researchers' and participants' perspectives and examined their experiences. The first author used the PAR approach to challenge the traditional top-down approach to the bottom-up (Mikkelsen, 2005).

Study Site

This study was carried out in one public school in Nepal. This school was purposively selected based on the selection criteria formed by NORHED/ *Rupantaran* (Rupantaran means transformation in the Nepali language) Project, Tribhuvan University, Nepal. NORHED/Rupantaran had the necessary funding for the intervention of this study. The school has five hundred students, owing to land for the Eco-san toilet and school garden construction. The school has female teachers, motivated teachers for collaborative learning, active and functional School Management Committee (SMC), Participatory Action Research Committee (PAR), School Management Committee, child clubs, and Eco-clubs. Also, the school's electricity facility and drinking water and availability of adequate land to conduct the study components such as the Eco-san toilet are the fundamental requirements for this study. Based on these criteria, the study site was selected for this study.

Research Participants and Selection Procedure

One community school and basic level students (grade 4-8), teachers teaching at the same level, and the school management committee (SMC) members were the co-researchers in this study. Also, the participatory action research (PAR) committee, child club, and eco-club members were selected using purposive sampling with voluntary participation as per the protocol of PAR. Five FGDs with teachers, SMC/PAR committee members, students, and one interview with the headteacher were conducted. A total of 53 participants consisting of 26 male and 27 female students groups, participated in FGD (Table 1), whereas only one male participant was involved in the interview.

Table 1: *FGD participants*

Participants	FGDs		
	Male	Female	Total
Students (senior graders, 6-8)	5	6	11
Students (junior graders, 4-5)	4	6	10
Teachers	5	5	10
SMC/PAR	7	4	11
Child-club	5	6	11
Total	26	27	53

In addition, the performance of human urine in vegetable cultivation and students' sanitation behaviour observation was also done to collect the data.

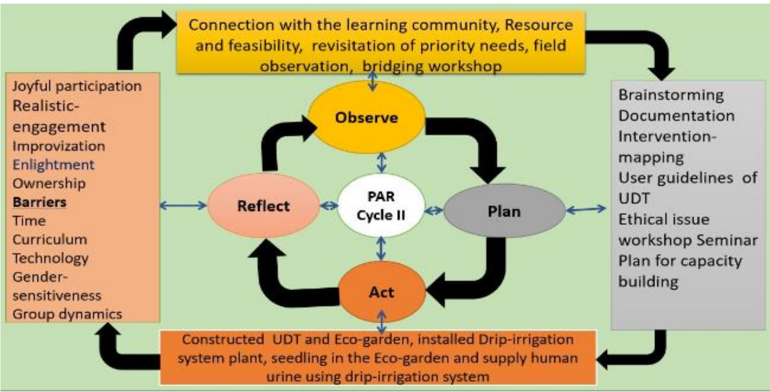
Tools, Methods, and Procedure of Data Collection

Data were collected through primary sources only. However, some literature like journals, textbooks, and working papers were used to review. Primary sources were focus group discussions (FGDs), interviews, and observation. FGDs and interviews were conducted to assess the perceived difference in the tastes of vegetables produced from human urine as agricultural fertiliser against other fertilizers. The observation was done to see the effectiveness of human urine application in vegetable cultivation and students' sanitation behavior. The weight of five types of vegetables (pumpkin, cucumber, gourd, cauliflower, and cabbage) produced from Eco and non-Eco Garden at harvesting was measured. Reflective notes were also recorded and used multimodel evidence like photographs and audio-video tapes.

Interventions

This PAR study is based on interventions in three cycles with a stepwise process. In the first PAR cycle, three sensitisation sessions were conducted on introducing a urine diversion toilet (UDT), its benefits, and its challenges. In the second cycle, constructed a model UDT, Eco-garden in the land adjoining toilet, underground urine reserve tank, soak pit and installed drip-irrigation system to supply water-diluted urine in the Eco-garden. Similarly, in the third cycle, two workshops were conducted with the research participants, students, teachers, SMC/PAR members, child club, and Eco-club members on using guidelines of UDT, drip-irrigation system and seedling vegetables in the Eco-garden applying human urine as a fertiliser. The workshops were facilitated by the first and the second authors.

Figure 2: *PAR activities*



Procedure of Cultivation Experiment

After constructing the Eco-san toilet, an Eco-garden with 26 plots covering 0.3 hectares of land was maintained. The size of each plot, either for urine application or animal fertilizer, was 45 feet in length and 4 feet in breath of 15 m^2. As suggested by the study (Anna Richert & Dagerskog, 2010; Pradhan et al., 2007), diluted human urine in the ratio of 1:3 (one part urine and three-part water) was supplied only in 50% plots where animal fertiliser was used in remaining 50% plots. The treatment consisted of two concentrations, treatment 1: human urine as a fertiliser (1:3 urine and water) and treatment 2: animal fertiliser.

The urine was collected from 227 boy students and collected 1000 litres from 9 urinals in a month in the school. The urine was stored for one month (March 1, 2018, to April 30, 2018) at 25ºC to 33ºC. Storage raises the pH and kills potential pathogens in human urine (Goetsch et al., 2018; Lahr et al., 2016). A storage time of one month is reported as adequate to mitigate risks associated with even urinary tract viruses (Goetsch et al., 2018). Studies also show that human urine was stored for the former reason and appropriate dilution. The diluted urine in 50% plots and animal fertiliser in 50% of plots were supplied using the drip irrigation system.

In the school's Eco-garden, pumpkin, cucumber, gourd, cauliflower and cabbage were cultivated. From planting to twenty days before harvesting, diluted human urine was used four times. At harvesting time, the weight measurement of vegetables produced using human urine

Figure 3. Cultivation experiment using urine fertilizer

and animal fertiliser were recorded separately. Qualitative information regarding the perceived taste differences between vegetables grown using human urine or animal fertiliser was identified based on the group discussion. At the same time, the applicability of UDT in a school setting was also assessed through group discussion.

Data Analysis

Qualitative data obtained from five FGDs and in-depth interviews were tape-recorded. The recordings were transcribed into Nepali and then translated into English. Then the data were thematically analysed to understand how UDT, and Eco-garden-related collective works played a role in transforming the sanitation behaviour of students, the performance of human urine as fertiliser and the applicability of UDT in the school setting. Similarly, the data obtained from the field by cultivation experiment were analysed using simple statistics or frequency measurement to reach a specific conclusion.

Results

The result of the study was based on the perceived benefits of UDT and the application of human urine as an agricultural fertiliser in the school's Eco- garden.

Eco-san toilets led to a change in sanitation behavior

Considering the present sanitation situation in school, an Eco-friendly alternative with an Eco-san toilet was established. The technology of Eco-san toilet constitutes three steps containment, sanitisation and recycling, which are practised by collecting in underground tanks and finally applying in the field as fertiliser. Using a urine diversion toilet has improved the school's sanitation behaviour and condition. When asked about the changes in the sanitation situation of the school and the students here after the construction and use of the Eco-san toilet, a male teacher stated,

> Before constructing a model Eco-san toilet in school, some boy students used open urination. The underground safety tank was also not in good condition. There was faecal sludge everywhere around the safety tank. It caused problems such as foul-smelling and surface water contamination. But these problems have been solved after constructing and using Eco-san/UD toilet. (FGD, a male teacher)
>
> After the availability of Eco-san toilet in school, open defecation practice of students has been removed, and school surroundings are also found clean (IDI, Headteacher)
>
> Our sanitation behavior has improved due to well-equipped Eco-san toilets, adequate water, and hand washing stations with soap. (FGD students)

Perceived benefits of Eco-garden and Application of Human Urine as Fertilizer

This study provided a rich insight into how public-school teachers, students, and the SMC/ PAR committee conceptualize the application of Eco-garden in the school. The findings relating to Eco-garden construction and its use proposed by this study is an important aspect, from now on, in implementing human urine as fertilizer. In the community school in Nepal, this study draws the connection between action and reflection in participatory action research, specifically Eco-garden activities and producing vegetables with and without urine fertilizers. Co-researcher's garden experiences were amazing and valuable for the study and vegetable production by using Eco-garden.

Research participants like teachers and students generally had a positive attitude towards using human urine as fertiliser. Thus, they frequently used Eco-garden as a part of the study and for the production of vegetables. In this context, one of the students in FGD stated:

> The Eco- Garden is meaningful experiential learning where we can grow various vegetables. We produce cabbage, cauliflower, pumpkin, cucumber and gourd from the school's Eco-garden, which was a part of learning. (FGD, a female student.)

Consistent with this opinion of the student, another student stated:

> I am happy to construct an Eco-garden in the school. I shared with my parents that we built Eco-garden in the school. It is a part of our learning. We will grow vegetables in the Eco garden. (FGD, a male student)

In the same way, the headteacher in the interview opinioned:

> I understand more about ecology, what biodiversity is, how we conserve biodiversity, and the importance of biodiversity to ecology, humankind, and the community. This lets me know that students can protect the environment by planting vegetables. (IDI, Headteacher)

In addition, another participant asserted that,

> Human urine is a very good fertiliser that is always available whenever we need it for vegetables in our school garden. It is also available without paying because we get it from our school's toilet. (FGD, SMC/PAR member)

After implementing the Eco-san system in school as a model project, many of the neighboring school and community people also cascaded the model. One parent nearby the school said, his yield tripled when he used human waste to fertilize his fruit and vegetable crops. He also reported that the vegetables produced using urine fertilizer were sold at a higher price than others because they were organic.

Cultivation Experiment

After constructing UDT and installing a drip-irrigation system plant, the field was prepared and planted vegetable seedlings in the Eco-garden. Out of 26 plots, 50% were supplied with diluted human urine (1:3) as fertiliser, while the remaining 50% were supplied with animal fertiliser. At the time of harvesting, the weight of 25 pieces of each type of vegetable was measured to identify the performance of human urine as agricultural fertilizer and animal fertilizer. The result from the weight measurement of vegetables produced using human urine as fertiliser and animal fertiliser is presented in figure 4.

Figure 4: Performance of urine fertilizer in school's eco-garden

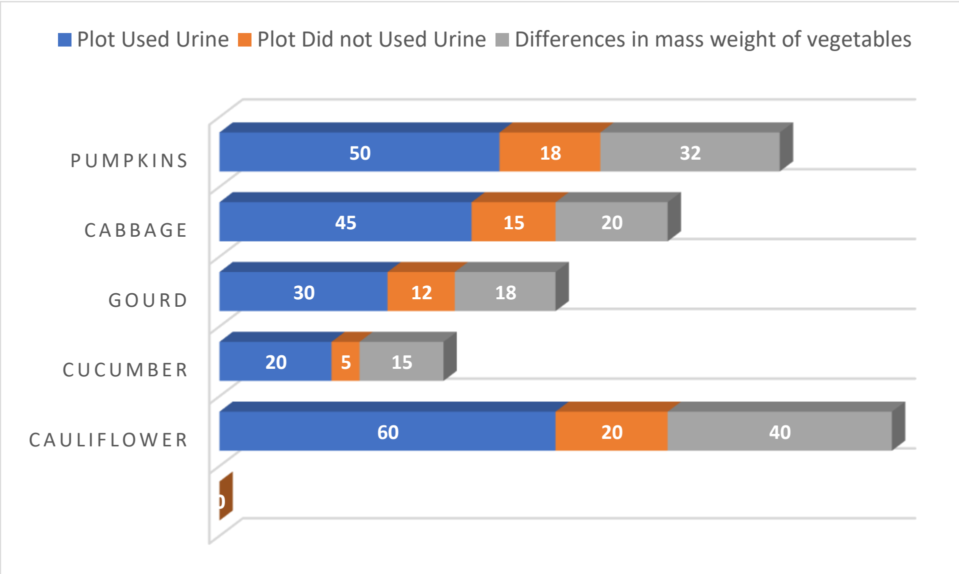


Fig. 4 shows the difference between the total weight of the pumpkin, cabbage, gourd, cauliflower and cucumber from the plot where urine is used as fertiliser and from the plot where it is animal fertilizer. The weight of 25 pieces of each type of vegetable was measured. The weight of 25 pieces of pumpkin was 50 kg, cabbage 45 kg, gourd 30 kg, cucumber 25 kg and cauliflower 60 kg from urine supplied plots. In contrast, pumpkin was 18 kg, cabbage 15 kg, gourd 12 kg, cucumber 15 kg, and cauliflower 20 kg were produced from plots where urine fertilizer was not used. The total weight differences from the plot using urine fertilizer and animal fertilizer were pumpkin 32 kg, cabbage 20 kg, gourd 18 kg, cucumber 15 kg and cauliflower 40 kg. The result showed variation in the weight of vegetables compared to human urine fertilizer and animal fertilizer application as fertilizer. The plant in urine treatment plots showed a positive impact in growth and production against the non-treatment plots of urine or greater weight of vegetables produced from plots using human urine as fertilizer than those from animal fertilizer. The weight of vegetables in the plots using urine fertilizer and animal fertilizer is shown in Table 2.

Table 2. Weight measurement of wegetables

Vegetables	Plot used urine fertilizer		Plot used animal fertilizer		Weight Differences (More quantity in urine applied plots in kg)
	Pieces	Weight (kg)	Pieces	Weight (kg)	
Cauliflower	25	60	25	20	40
Cucumber	25	20	25	05	15
Gourd	25	30	25	12	18
Cabbage	25	45	25	15	30
Pumpkins	25	50	25	18	32

Similarly, when we asked about the taste difference between vegetables produced using human urine fertilizer and animal fertilizer, a male teacher stated:

> Vegetables and cucumber produced using human urine as fertilizer are much tastier than those produced without human urine as fertilizers. Nowadays, we often cook vegetables from our Eco-garden in our school, where human urine is used as fertilizer. (FGD, a male teacher)

Similarly, in focus group discussion among child club claimed,

> We found that Eco-san toilets and Eco-garden are very effective for sustainable sanitation and garden-based pedagogy solutions. Eco-san toilet has proved useful for us as we have been able to supply diluted human urine through a drip-irrigation system and eat organic vegetables produced from our Eco-garden. (FGD, a female child-club member)

Discussion

The research findings of this study were consistent with the findings of several studies that considered sanitation, where the PAR interventions in terms of the Ecological sanitation system were implemented. It indicated that a sustainable sanitation solution could end open defecation through normalization and monitoring the use of an Ecological sanitation system (Dickin et al., 2017; Machado et al., 2021; Rajbhandari, 2008). The research findings related to the participants' perceptions are consistent with a similar study conducted in Nepal found students enjoyed working in the school garden and becoming happy and cheerful (Acharya et al., 2020). There was no sign of fear and loneliness in the students' demeanours when they participated and learned in the school Eco-garden. They developed great enthusiasm for doing activities. Inconsistent with the study findings, it is found that Eco-garden is an essential arena in schools for transformative learning strategies from learning to earning (Boh et al., 2021;

Harder et al., 2019; Mkhize et al., 2017) Consistent with the findings, it was found that urine diversion demonstrates its potential to separate and collect nutrients elegantly, and the desire to control pathogens and micro-pollutants helps in sanitation (Harada & FUJII, 2020). It was found that teachers' perceptions of the urine diversion toilet and using human urine as a fertilizer for the school garden were positive. However, some teachers disliked this toilet due to a perceived foul odour and the uncomfortable sitting position on the UDT, particularly for females. They felt using urine as fertilizer was unnecessary (Matsebe, 2011; Roma et al., 2013). One of the key lessons drawn from the study is that schools, in collaboration with local governments, should employ participatory approaches to understanding and engaging local stakeholders, including teachers, to minimize negative perceptions before the application of human urine as fertilizer in the school garden (Ignacio et al., 2018).

It is also found that teachers and SMC members experienced the garden as an opportunity to learn and get first-hand experience in growing vegetables by applying human urine as fertilizer. This study's findings were similar to those that established that knowledge of urine application in the field is beneficial (Mariwah & Drangert, 2011). Similarly, (Segrè Cohen et al., 2020) found that human urine diversion and recycling is a viable and energy-efficient means of recovering nitrogen, phosphorus, and potassium from wastewater. As the research participants in this PAR study, the first and the second authors reflected that the vegetables produced in the school Eco-garden using human urine yield more than those using water only. It was found that the taste of the vegetables was good and it was delicious. It is mirrored that the Eco-garden is the place for transformative learning for school children. It is the source of converting waste into a resource. Eco-garden is the place to do the first-hand experiment, understand nature, and control pollution, and an arena of learning through collaboration. In this regard, Acharya, Budhathoki, Bjønness, & Jolly (2020) found that students can learn a lot from the garden by meaningfully engaging in activities. Planting flowers, fruits, vegetables, and medicinal plants in the school garden helps maintain greenery. As the school is a part of the wider community, knowledge related to retaining the vegetation can be transferred to the surrounding community, which helps meet SDG to some extent.

Conclusion

The present study concludes that public schools in Nepal need to construct Eco-garden as a resource for learning and earning. It is supposed that teachers, students, and SMC members realize Eco-garden activities play an essential role in sharing the knowledge and skills connected with garden activities to students as a framework for learning. The cultivation experiment found a difference in the weight of vegetable biomass produced from the plots using human urine as agricultural fertilizer, comparable to biomass with the plot using animal fertilizer. If the urine collected from UDT could replace chemical fertilizer, the money spent buying chemical fertilizer would be saved. Further cultivation experiments on human urine proved that the performance of human urine as agricultural fertilizer is perfect.

The paper recommends that Eco-garden activities should provide opportunities for active learning, focusing on students' and teachers' engagement and interaction instead of excessive lectures in the basic level public schools in Nepal. When government and non-government organizations including the department of education build buildings in community schools, the concept of ecosan toilet should be included. Finally, a small but strong suggestion would be to construct an Eco-garden in every public school and grow vegetables that help provide nutritious food for the school children in mid-day meals. Mixing human urine with pH and low salt content subtracts could be vital which need to be the area of further research.

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Ethical Statement

This research was conducted according to the Declaration of Nepal Health Research Council (NHRC) guidelines and the Nepal Government. The Ethics Committee approved all procedures involving human subjects of the NHRC. Consent was obtained from all the research participants.

Disclosure statement

The author reported no potential conflict of interest.

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