A PRELIMINARY INVESTIGATION ON THE ACCEPTANCE OF THE USE OF URINE BASED FERTILIZERS: A COMPERATIVE SURVEY WITH FARMERS AND ENVIRONMENTAL ENGINEERS

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Abstract Source separated human urine, a highly concentrated solution of nutrients, may be recycled directly or indirectly for further use as fertilizer. While environmental engineers (EnvE) recommend and set the fundamentals of this practice for valorizing a wastewater stream, farmers are the immediate group to apply urine-based fertilizers (UBF) for producing crops. A preliminary survey was conducted to assess/compare the acceptance of UBF by those two groups in Turkey focusing on awareness regarding urine as fertilizer, willingness to use natural/synthetic/urine-based fertilizers, acceptance towards three different groups of products (edible crops/industrial crops/green areas) grown using UBF, and concerns about this application. Overall, the results showed that acceptance towards UBF was considerable and in general comparable for both groups. The most obvious difference in acceptance was with synthetic fertilizers which received 92% acceptance from farmers as opposed to 26% from EnvE. It was clearly stated by the farmers that they actually do not prefer to use it however they have to as there is no current alternative for increasing the crop yield. Both groups had similar and high acceptance for indirect use of UBF for all product groups up to 88%, typically 60%. However, farmers had a greater acceptance for direct use in all categories of the group of products questioned, i.e., edible crops, industrial crops and green areas. While psychological reasons were indicated as the main drawback, over 90% accepted urine diversion.
Keywords: source separated human urine, fertilizer, nutrient recovery/recycling, acceptance of farmers and environmental engineers as occupational groups, Ecological Sanitation (ECOSAN)

1. Introduction

Ecological Sanitation (ECOSAN) is a recent sanitation concept, claiming that domestic wastewater is not a waste to be discarded but a source to be revaluated, and is based on segregation of domestic wastewater streams at the source. Among these streams, yellow water is mainly source-separated human urine with a rich nutrient content: over 80% of nitrogen (N), over 50% of both phosphorus (P) and potassium (K) in conventional domestic wastewater by mass, while covering only 1% of the volume of conventional domestic wastewater (Beler-Baykal, 2015). As N, P, and K are key plant nutrients that constitute fertilizers and urine is a concentrated stream of N, P, and K which are in the form readily available to plants, it has been suggested as an alternative fertilizer. In case of N, urea is the most dominant form in freshly excreted urine along with ammonium, however it is converted into ammonium in the process of urea hydrolysis (Beler-Baykal et. al., 2011). Application of urine-based fertilizers (UBF) in agriculture through both direct and indirect routes are possible. With direct application, urine is applied onto soil after storage for pathogenic inactivation; and with indirect application, nutrients in urine are concentrated in a different phase using processes such as adsorption/ion exchange, struvite precipitation and stripping/absorption. Subsequently, nutrients are recovered and made available to plants (Beler-Baykal, 2015).

Public acceptance is crucial to implement UBF in agricultural fields and to promote consumption of products produced from crops fertilized with UBF. Therefore, assessment of acceptance of UBF by the community, producers and consumers is an essential step. A survey conducted to assess people's attitude towards the use of urine diverting toilets (UDT) and UBF in Egypt, Iraq and Turkey revealed that the overall acceptance for UDTs and UBF was 62% and 56%, respectively (Taher et. al., 2018). Another survey with Turkish citizens to identify their preference of direct and indirect use of UBF for different groups of plants showed that 41% of total participants thought that human urine (both through direct and indirect use) is safer than synthetic fertilizers; and that although acceptance of direct use was low at 12-22%, it increased to 53-55% with indirect use (Yıldız-Dogan et al., 2015). In a survey by Cohen et. al. (2020), U.S. consumers' acceptance of UBF was examined across a range of crop products and compared to current fertilizers (organic/synthetic) and the results suggested that UBF and biosolid-based fertilizers were equally preferred and more strongly preferred than synthetic fertilizers, and UBF was most accepted for nonedible plants and least accepted with crops for human consumption. Another survey by Simha et. al (2021), with participants from 16 countries to evaluate the behavior of consumers to recycle human urine, particularly as fertilizer for food crops, revealed that 68% favored recycling human urine, 59% stated a willingness to eat urine-fertilized food, and only 11% believed that urine posed health risks that could not be mitigated by treatment. Surveys on the acceptance of farmers to use UBF are limited in the literature. One of those by Lienert et al. (2003) with 125 Swiss farmers revealed that 57% thought UBF is useful for plants and that 47% stated that they are willing to buy UBF. In a study from Nigeria, 35% of farmers thought UBF is beneficial

for agriculture while 28% said it is not hygienic for vegetable crop production (AdeOluwa and Cofie, 2012). Environmental engineers (EnvE) lead the group of professionals who suggest the use of source separated urine as fertilizer and to develop alternative ways of application of UBF to valorize a waste while controlling pollution to protect the environment, and farmers are the professional group to lead the application of UBF for producing crops. The aim of this study was to assess/ compare the acceptance of the use of UBF by those two groups in Turkey, with a sample of 76 farmers and 93 EnvE, with questions directed towards awareness/ acceptance regarding the use of urine as fertilizer, willingness towards using natural/synthetic/urine-based fertilizers, acceptance towards three different groups of products (edible crops/industrial crops/green areas) grown using UBF directly and indirectly, and concerns about this application.

2. Method

In this study, two different groups, farmers and EnvE, were selected to investigate their acceptance level of UBF use. Face to face surveys were conducted with 76 farmers and 93 EnvE in Turkey. Within the scope of demographic information, gender, age, educational background and occupation were asked. All farmers lived in rural area in Edirne province while EnvE lived in urban areas in Istanbul province of Turkey. In addition to demographic questions, the survey included questions with both yes/no and multiple-choices for assessing participants' knowledge of stream segregation and ECOSAN; willingness to use UDT; acceptance of the two options of application as direct and indirect for different products; and concerns to use UBF. Information about ECOSAN, UDT and direct and indirect use of UBF was given to the participants during the survey in later phases.

3. Results and Discussion

The survey was conducted with 169 participants of which 45% were farmers, and 55% EnvE. There was an acceptable balance in terms of gender. The age range was from 15-24 to 65+ and over half was dominated by the range between 15-24 and 36-50. In terms of education, there was a big difference between the two groups. While all EnvE received university education, the largest fraction of farmers was graduates of primary school with 79%. Table 1 presents the demographic data of the participants.

Regarding knowledge of participants about ECOSAN and yellow water, farmers almost had no knowledge on those while EnvE were quite knowledgeable about them with over 70%, as shown in Figure 1. Additionally, the results showed that 44% were willing to pay extra money, and an additional 50% accepted to use UDT if it is free, indicating that over 90% of all the participants were willing to use UDTs (graph not presented here).

Table 1: Demographic data of the participants

	Farmers		Env. Eng.		Total	
	No	% in group	No	% in group	No	% in total
Gender						
Female	23	30%	74	80%	97	57%
Male	53	70%	19	20%	72	43%
Age						
15-24	2	3%	47	51%	49	29%
25-35	9	12%	27	29%	36	21%
36-50	32	42%	10	11%	42	25%
51-64	22	29%	8	8%	30	18%
65+	11	14%	1	1%	12	7%
Education						
Never went to school	2	3%	0	0%	2	1%
Primary	60	79%	0	0%	60	36%
High School	11	14%	0	0%	11	7%
University	3	4%	44	47%	47	28%
Master- PhD	0	0%	49	53%	49	29%

** Students of environmental engineering included.*

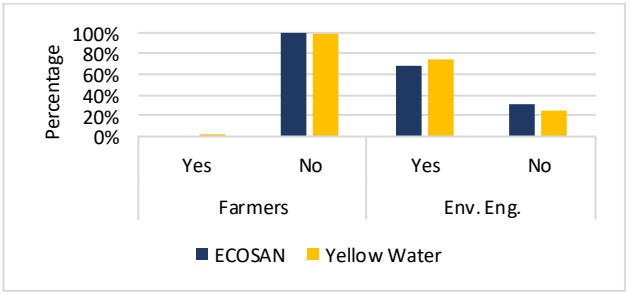

Figure 1. Knowledge on "ECOSAN" and "Yellow Water" terms

When participants were asked about their preferences of different types of fertilizers, 98% of total participants accepted to use natural fertilizers. However, only 27% of the EnvE accepted to use synthetic fertilizers while the farmers' acceptance reached 92%. Although 92% of the farmers accepted to use synthetic fertilizers, they clearly stated that they do not prefer to use it however, there is no current alternative to synthetic fertilizers for increasing the crop yield, so they have to use it.

Figure 2 presenting the preference levels of different types of fertilizers reveals that indirect use of UBF received at least 74% acceptance level in both groups. However, as long as the direct use of UBF was concerned, farmers' acceptance was considerably higher with 51% compared to that of EnvE with 19%, showing a similar trend as in Yıldız-Dogan et. al. (2015). The results indicated that there is quite a good acceptance of indirect use of urine and that it may be an alternative to synthetic fertilizers in line with the observations of Lienert et. al. (2003).

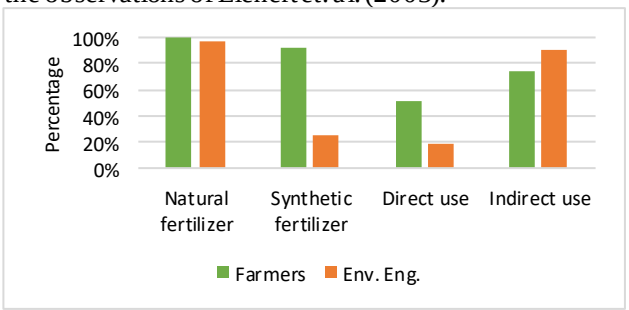

Figure 2. Acceptance of natural fertilizer, synthetic fertilizer, and direct and indirect use of human urine

The attitude of the participants regarding the use of human urine directly and indirectly to fertilize edible crops is shown in **Error! Reference source not found.** (a) and (b). Figure 3 (a) shows that farmers had a higher approval for direct use of human urine as compared to EnvE for each crop type. For both applications of using human urine as fertilizer, the highest

preference of both farmers and EnvE was for nuts while the lowest was for uncooked vegetables which points at hygienic concerns of the participants. As the outer shell prevents direct contact with UBF, nuts were more preferable. Since microbial activity is expected to cease due to thermal treatment upon cooking, and uncooked vegetables lack this protection, they were preferred the least. In terms of direct use, the opinion of the two groups were obviously different in the sense that the acceptance of farmers were typically two times as much of that of EnvE. The difference between the two groups practically disappeared and the acceptance of both increased when the application was switched to indirect use. Although farmers had a greater acceptance for direct use for all edible crops, the preferences of farmers and EnvE were quite similar for indirect use. Like direct use, nuts received the highest preference of both groups.

The distribution regarding acceptances for direct or indirect use of human urine as fertilizer for industrial crops is illustrated in Figure 4 (a) and (b). The results revealed that farmers had higher approval than EnvE for direct use and indirect use for each crop type. The approval of both groups increased with indirect use, similar to their preference for edible crops. Regarding both application types, the trend for preference of both groups followed hemp, cotton, tobacco and sugar. Sugar which is ingested and tobacco which has mouth contact were the least preferred industrial products, again showing the hygienic concerns of the participants.

The acceptance of both groups for direct and indirect use of UBF in green areas is presented in Figure 5 (a) and (b). The direct use of UBF in landscape had the highest acceptance level in both groups with 75% for farmers and 67% for EnvE. EnvE preferred direct use of UBF in school/university gardens at the lowest rate as 1%, while farmers preferred children's playground and their own gardens least with 43%. Unlike direct use, acceptance levels of indirect use of UBF in green areas was observed in higher level and quite close to each other in both groups. The results showed that EnvE accepted the indirect use of UBF the most in public parks with a rate of 71%. It is to be noted that although the acceptance of EnvE was only 2% for direct use in children's playground, the level raised to 55% with indirect application. Farmers showed the highest acceptance for landscape irrigation with 84%.

Overall, farmers had a greater acceptance for direct use in all categories as compared to environmental engineers. There seem to be two reasons for that. First, farmers are aware of the possible benefits of urine as fertilizer from practice and do not consider urine as objectionable, as may be the case with Env E who live in an urban setting and are not familiar with field experience. Secondly, using it directly necessitates storage only and hence bears less burden as it eliminates any further processing for indirect use which may need special expertise that may be hard to provide in their agricultural town. Moreover, as no processing is necessary for direct use, it is cheaper and easier to apply. From the perspective of EnvE, they are aware that indirect use provides additional benefits by eliminating some of the further burdens like salinity, pH and probably reduction in terms of other undesirable constituents like pharmaceuticals and hormones, and therefore they prefer indirect use over direct use (Beler-Baykal, 2015).

When participants were asked about their concerns for UBF, the highest concern was observed as psychological reasons with 48% of total participants. 20% and 14% of total participants stated hygiene and odor as their other concerns, respectively. Only 3% of participants had hesitations in terms of economic reasons. Besides these, 27% of all participants accepted to use UBF without any concerns. Additionally, when they were asked about the group recommendation with which they will be encouraged to use UBF most, farmers said that they would be encouraged with a recommendation from agricultural engineers while EnvE preferred recommendations from academicians (graph not presented here)

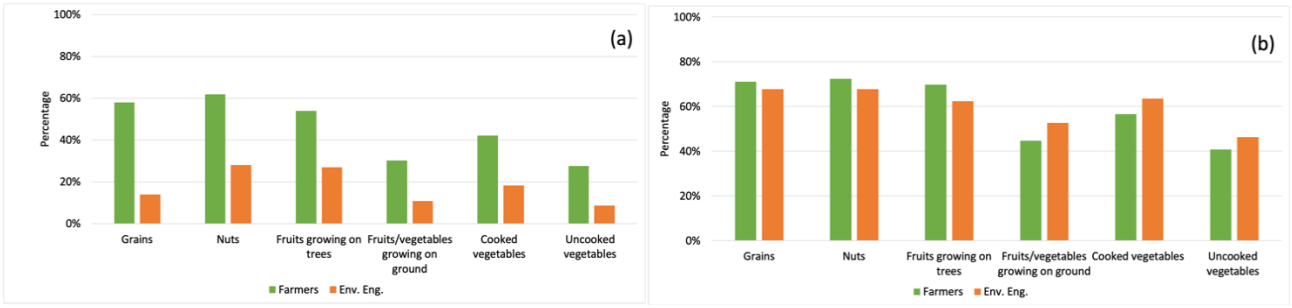

Figure 3. Preference for edible crops: (a) direct use and (b) indirect use of human urine as fertilizer

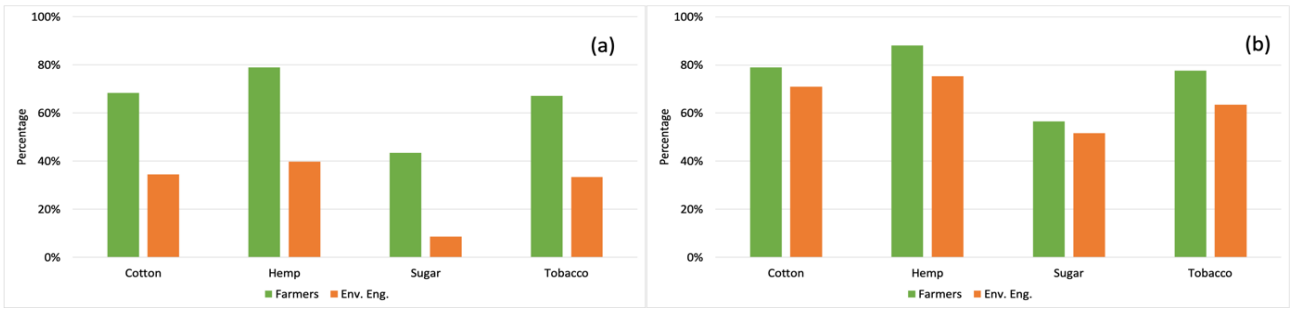

Figure 4. Preference for industrial crops: (a) direct use and (b) indirect use of human urine as fertilizer

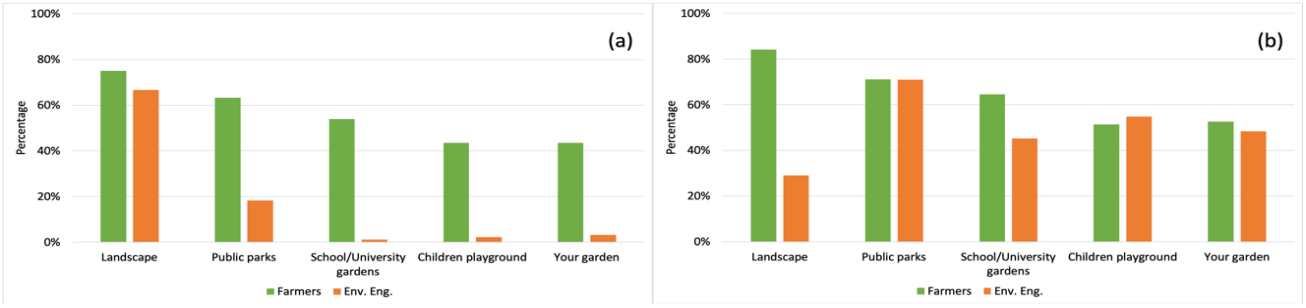

Figure 5. Preference for green areas: (a) direct use and (b) indirect use of human urine as fertilizer

4. Conclusion

A preliminary investigation was conducted on the acceptance of the use of urine-based fertilizers among farmers and environmental engineers in this study. Questions were focused on awareness/acceptance regarding ECOSAN, yellow water, UDT and urine as fertilizer; willingness to use natural/synthetic/urine-based fertilizers; acceptance towards three different groups of products (edible crops/industrial crops/green areas) grown using UBF through direct and indirect routes; and concerns about this application.

The results revealed that as opposed to environmental engineers who are considerably knowledgeable about ECOSAN and yellow water, farmer's knowledge was extremely limited. However, over 90% of participants in total accepted to use UDT.

Overall, the results showed that acceptance towards UBF was considerable at least for selected products and in general comparable for both groups especially for indirect use. Farmers and environmental engineers had similar and higher acceptance for indirect use for all three product groups up to 88%, typically 60% direct use received a lower preference. However, farmers had a greater acceptance as compared to environmental engineers for direct use in all categories.

The most obvious difference was in terms of synthetic fertilizers which received 92% acceptance from farmers who clearly stated that they do not prefer to use it however, as there is no current alternative to synthetic fertilizers for increasing the crop yield, they had to use them, as opposed to 26% with environmental engineers. It can be interpreted that the use of UBF can be a promising alternative to synthetic fertilizers, especially when used indirectly.

Psychological reasons were indicated as the main drawback for this application. In general, the answers implied that health concerns were also to be noted.

All in all, the investigation regarding perception of environmental engineers, who recommend and set the fundamentals of this practice for valorizing a wastewater stream whilst controlling pollution, and farmers, who are the immediate group to apply UBF for producing crops, provided encouraging results for the use source separated urine in agriculture as fertilizer.

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