PENTINGNYA PEMULIHAN URIN DARI AIR LIMBAH PERKOTAAN

THE IMPORTANCE OF URINE RECOVERY FROM MUNICIPAL WASTEWATER

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Abstrak

Urin mengandung konsentrasi nutrien yang tinggi yang dapat meningkatkan polusi air dan korosi pada sistem pembuangan limbah. Seiring dengan menurunnya cadangan fosfor global, kondisi ini dapat memperburuk kerentanan populasi dunia dalam hal ketahanan pangan, air minum, sanitasi, dan kebersihan. Penelitian ini bertujuan untuk mendapatkan lebih banyak pengetahuan tentang pentingnya pemulihan urin dari air limbah perkotaan. Implementasi sistem pemisahan urin sebelumnya, pentingnya pengalihan urin, produk potensial dan teknologi untuk pemulihan urin dijelaskan secara singkat. Secara keseluruhan, pengalihan urin diharapkan dapat mengatasi masalah lingkungan tersebut dengan mengurangi polusi air dan muatan organik di instalasi pengolahan air limbah, menyediakan nutrien yang berharga untuk produksi pertanian, dan mengurangi biaya ekonomi dari sanitasi yang tidak tepat.

Kata kunci: Air limbah perkotaan, Pemulihan *nutrient*, Sanitasi, Sistem air limbah, Urin.

Abstract

Urine contains a high concentration of nutrients that could increase water pollution and corrosion in the sewerage system. Along with the decrease in global phosphorus reserves, this condition may aggravate the worldwide population's vulnerability in food security, drinking water, sanitation, and hygiene. This paper aims to gain more knowledge on the importance of urine recovery from municipal wastewater. The previous implementation of the urine separation system, the importance of urine diversion, the potential product, and technologies for urine recovery was briefly described. Overall, urine diversion is expected to address those environmental problems by reducing water pollution and organic loading in wastewater treatment plants, providing valuable nutrients for agricultural production, and lessening the economic cost of improper sanitation.

Keyword: *Municipal wastewater, Nutrient recovery, Sanitation, Urine, Wastewater system.*

1. INTRODUCTION

The recent report on sustainable development goals (United Nations, 2021) highlighted that in 2020, 3.6 billion global populations have lack access to safely managed sanitation. Approximately 56% of worldwide domestic wastewater was safely treated, and the rest remained improperly treated or disposed. Domestic wastewater typically consists of a mixture of black water (i.e., feces, urine, and flush water) and grey water (i.e., wastewater from cooking, washing, and cleaning) from the household level. Among those mixtures, urine contributes to approximately 1% (v/v) of total domestic wastewater flow (Govindan *et al.*, 2021; Mihelcic *et al.*, 2011; Wilsenach & Van Loosdrecht, 2003), 79% of overall nitrogen (N), 47% of overall phosphorus (P), and 71% of overall potassium (K) in the sewage (Ostermeyer *et al.*, 2022). Each person could release around 1.2–1.4 L of urine per day (Rose *et al.*, 2015; Schouw *et al.*, 2002). However, this composition may vary according to physical exercise, environmental conditions, water consumption, local diet, and calorie intake.

The continuous leaching of nutrients from domestic wastewater and agricultural sources substantially accelerates algal blooms and increases water pollution (Werner *et al.*, 2009). Added to the rapid depletion of phosphate sources around the globe (Cordell *et al.*, 2009), it can leave some of the worldwide population with high vulnerability in food security, drinking water, sanitation, and hygiene.

Another problem with untreated urine was increasing odor and corrosion in the sewerage system due to ~70% sulphate concentration in the urine and volatile fatty acid build-up (Freguia *et al.*, 2021). Nutrient recovery from urine may address those problems by closing the loop of the nutrient cycle in the environment. It could reduce water pollution and provide enough nutrients for agricultural production (Kvarnström & Emilsson, 2006; Maurer *et al.*, 2006).

Nonetheless, to optimally recovered the nutrients, urine has to be source-separated. The urine diversion system has some benefits, including decreasing Total Kjedahl Nitrogen (TKN) in the sewage, reducing the anoxic tank requirement, bioreactor volume, power, and electricity consumption (Freguia *et al.*, 2021). A previous study (Malisie *et al.*, 2007) also showed that plants fertilized with urine have tremendous growth and described the increasing height and number of leaves compared to feces-based vermicomposting fertilizer.

This paper aims to gain more knowledge on the importance of urine recovery from municipal wastewater. It describes the previous implementation of the urine separation system, the potential product, and technologies for urine recovery. Literature reviews were conducted by searching high-quality scientific articles published in the ScienceDirect and Crossref databases. Furthermore, other published reports related to the Ecosan project were also considered.

2. PREVIOUS IMPLEMENTATION OF URINE DIVERSION

The approach in the no-mix toilet was already visualized in the Ecological sanitation (Ecosan) system. Ecosan follows a sustainable closed-loop sanitation system that could minimize environmental pollution and provide valuable nutrients for agriculture by turning human excreta into fertilizer (Winblad *et al.*, 2004). Moreover, it also can be described that implementing Ecosan may decrease health risks in sanitation, prevent deterioration of soil fertility, optimize water usage (Langergraber & Muellegger, 2005), and reduce greenhouse gas emissions (Ryals *et al.*, 2019). In this system, human excreta are mainly stored and treated on-site or off-site for a few periods to remove all pathogens before the nutrients can be recovered or recycled.

2.1 Eco-toilet implementation of the Ecosan project in South-East Asia

In general, the proposed eco-toilet in the Ecosan project can be divided into three basic types, i.e., (i) urine-diverting toilet systems (UDTs) which use a small amount of water for flushing; (ii) urine-diverting dehydration toilet systems (UDDTs) which can be defined as a dry toilet; and (iii) mixing urine with feces (mix-toilet) (Karak and Bhattacharyya, 2011; Winblad *et al.*, 2004). In the UDTs and UDDTs systems, the toilet has two outlets and two collection systems to separate urine from feces and may come in a pedestal or squatter model (Kvarnström & Emilsson, 2006). Conversely, at the mix-toilet, there is only one outlet for urine, feces, and a small amount of flushing water. The additional perforated floor facilitated liquid separation inside the collection chamber (Winblad et al., 2004). In this system, urine that has been in contact with feces has to be evaporated and sterilized before being recycled into fertilizer (Winblad *et al.*, 2004).

Compared to mix-toilet, UDTs and UDDTs are more favorable for urine recovery because they have less odor and low pathogenic content. Moreover, the contamination with fecal matter is limited to none, making it an excellent fertilizer for agriculture (Kvarnström & Emilsson, 2006). This system collects urine in a non-metal container or tank to prevent ammonia corrosion. Once the volume is two to three full, the container must be sealed right away to minimize the evaporation of ammonia and the loss of nitrogen during storage and avoid possible contact of humans and animals with the urine. Generally, urine collected from UDTs and UDT is safe to be used directly in a home garden. However, at a communal level, it is recommended to store urine for at least 6- months and at 20º C to minimize the loss of nitrogen and ensure safe handling of urine before application (in case there was fecal cross-contamination), along with 1-month interval after the last urine application to harvest the crop product (Karak & Bhattacharyya, 2011; Kvarnström & Emilsson, 2006).

2.2 The obstacle to Ecosan projects

Based on the previous surveys (Albrecht *et al.*, 2010; 2021), the acceptance of using excreta (particularly urine) is relatively high. The results revealed that about 62% of respondents understand that human urine can be used as fertilizer and are willing to eat food fertilized. Another survey also found 80% of positive attitudes apart from a diverse religious background. Most farmers in those studies commonly used animal excreta as fertilizer and did not resist using human urine as another source of fertilizer as long as it had been processed to minimize its health risk. However, the respondents were mostly unsure whether the public would eat food grown with human excreta-based fertilizer (Barton *et al.*, 2021). Using human excreta as a crop fertilizer was considered a taboo or sensitive issue for some people. The hesitancy to use the recovery product remains high due to a lack of information about its benefit on soil fertility and crop production (Albrecht *et al.*, 2010; Center for Advanced Philippine Studies (CAPS), 2011a).

Moreover, some obstacles arose frequently in the EcoSan implementation, i.e., (i) technical issues (e.g., poor infrastructure design, lack of ash supply, lack of maintenance) and (WaterAid Australia & International WaterCentre, 2008); (ii) social issues (e.g., improper sanitation habits; the hesitancy to use excreta derived fertilizer, toilet preferences, etc.) (Center for Advanced Philippine Studies (CAPS), 2012, 2011a, 2011b; Okem & Odindo, 2020; WaterAid Australia & International WaterCentre, 2008). About 34% of new toilets have 81% of damaged infrastructure caused by strong winds in Vietnam. Moreover, after some period of installation, most people (78%) were not eager to use DVC latrines and preferred to use septic tanks toilets instead (Center for Advanced Philippine Studies (CAPS), 2011a; WaterAid Australia & International WaterCentre, 2008). The foul smell and the existence of maggots increased to 14 and 12%, respectively, by 39 months of installation compared to the first four months due to improper practice after urination and defecation (i.e., inaccurate use of ash). The study also revealed that 58.8% of fecal matter and 65.4% of urine were never used in agriculture for hygienic reasons (Harada & Fujii, 2020). Elsewhere in the Philippines, the obstacles that arose from the project were mainly related to foul smell, cockroaches, lack of ash supply to dry the fecal matter, and continuous open urination in the fields (Center for Advanced Philippine Studies (CAPS), 2011b). Furthermore, since the urine pipe was connected to the washbowl, the possibility of pathogen contamination and greywater dilution was extremely high. Meanwhile, In Indonesia, the typical diet of plant-based protein in low-income populations has resulted in a lack of phosphorus and potassium content in the urine (i.e., 90% N, 4% P, and 6% K), which hindrance the target to meet good quality fertilizer (Malisie *et al.*, 2007). In general, some Ecosan projects failed to sustain due to the lack of good planning and support from the community and the municipal governments.

3. NUTRIENT RECOVERY FROM SOURCE-SEPARATED URINE

The development of urine recovery has gained much interest in the last decade. Several technologies for nutrient removal (N, P, K) and urine recovery involve crystallization, electrolysis, fluidized bed, and microwave-activated carbon (**Table 1**).

Table 1. Potentially available technology for nutrient recovery

Technology	Recovered product	Remarks	Ref.
Crystallization	Struvite = 0.99 g/L Average size 110 μm	Efficiency recovery = 87%	(Aguado et al., 2019)
Electrolysis	K-struvite	P = 85% K = 35.4%	(Shan et al., 2021)
Fluidized bed homogenous crystallization	K-struvite purity = 95 ± 3% Average size 0.85 mm	Removal P = 98.4% Removal K = 70.5%	(Le et al., 2020)
Microwave-activated carbon	Struvite > 90%		(Ganesapillai et al., 2016)
Crystallization+ CO_2	Struvite = 1.7 kg/m^3 processed urine $(NH_4)_2SO4$ production = 3.7 kg/m^3 processed urine	Recovery P = 55%, N = 85%	(Wei et al., 2018)

4. STRUVITE AS A POTENTIAL PRODUCT OF NUTRIENT RECOVERY

Struvite (**Figure 1**) has been known as one of the potential products of nutrient recovery. Struvite is a slow-release fertilizer that can provide long-lasting nutrients for the plant (Bridger *et al.*, 1962). It has a white orthorhombic crystal structure composed of Mg^{2+}, NH_4^+, and PO_4^{3-} at a molar ratio of 1:1:1 (Le Corre et al., 2009). A previous study revealed that struvite application on cucumber, coriander, tomato, parsley, rocket, cress, valerian, dill, and basil had increased approximately 67–857% of total plant fresh weight and 52–656% of total dry weight (Yetilmezsoy *et al.*, 2020).

5. CONCLUSION

Untreated urine has created major problems for sewerage and surface water. Their high nutrient composition (N, P, K) promotes the increase of algal blooms and decreases surface water quality. The effort to recover nutrients from urine has been carried out in the last two decades, i.e., implementing a no-mix toilet in the Ecosan project or conducting research involving technologies that can optimally recover nutrients. About 55-98% phosphorus and 35-75% potassium can be recovered. In general, struvite was the best possible outcome from urine recovery due to its characteristics and composition, which could provide long-lasting nutrients for the plant.

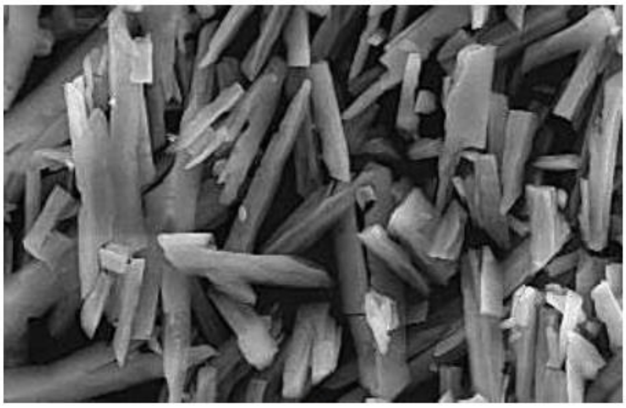

Figure 1. SEM image of struvite crystal (Ariyanto *et al.*, 2019)

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