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# The utilization of human excreta and human urine in the agriculture as a fertilizer

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***Keywords***

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## Abstract

Human excreta contains all the macroelements which are important for the soil, for example nitrogen, phosphorus and potassium. Although there are many ways of treating human excreta, composting is often regarded as the best solution because the final result of this treatment is valuable humus. However, human urine contains the most of the nutrients, so it may be more reasonable to apply human urine alone as a fertilizer. Direct utilization of urine emerges a lot of problems, but there are several existing technologies which are able to recover the nutrients from urine. These technologies (stripping, absorption, struvite precipitation and membrane technologies) also capable to recover nutrients from wastewater. Our paper are focusing on the comparison of composting toilet and urine-diversion toilet by analysing the advantages and disadvantages of the two methods.

## 1. Introduction

Nowadays, one of the greatest problem of agriculture is running out of fertilizers. To replace the most important macroelments into the soil, alternative methods should be used. Using human excreta instead of artifical fertilizers may be a good choice. efore its application as a fertilizer, treatment of human excreta is needed. There are several existing methods. Human urine can be used without any treatment as a fertilizer, only some minor preparations has to be done before the application. However, people have to change their opinion regarding the application of flush toilets. Flush toilet based waste water infrastructure has a lot of harmful environmental effect, like eutrophication or water pollution in the case of unsufficient waste water treatment and wasting the nutrients (like nitrogen, phosphorus and potassium) of human excreta. Using dry toilets may eliminate a lot of environmental problems caused by flush toilets. There are many types of them, including composting toilets, urine-diversion toilets or incinerating toilet. By using composting toilet, the human excreta can be composted. Urine-diversion toilet separates human urine from faeces just after excreting. Incinerating toilet combusts the excreta, and also can generate electricity. It is also a good idea and possibility to use these types of dry toilets in developing countries.

### 1.1. The utilization of human excreta as a compost in the agriculture

The utilization of human excreta has been known since ancient times. According to some Latin sources, human excreta was considered extremely valuable. [4] [5] The successful application of human waste at the present time has been confirmed by several publications. [6] [7] [8] [9] [10]

There are four main methods of treating human excreta. The first is the well-known flush toilet based sewage water infrastructure, when excreta is transported by the sewage system to the waste water treatment plant (or without treatment to freshwater or oceans). The second is to apply raw human excreta directly in agricultural fields. This method is popular in Asia, where the raw human excreta is known as „night soil”. The problem is that it may be a vector for the disease organism. The third method of treating human excrement is to slowly compost it over an extended period of time. Most of the commercial composting toilets operates in this way. Slow composting generally takes place at temperatures below that of the human body which is 37°C or 98.60 F. This type of composting eliminates most disease organisms including human pathogens eventually in a matter of months.

The fourth method is thermophilic composting which involves thermophilic microorganisms in the composting process. Thermophilic microorganisms can create an environment in the compost which destroys disease organisms of human excreta, converting it into a friendly, pleasant-smelling humus, which is safe for food gardens. [1]

Composting human excreta can be implemented by composting toilets. There are several types; a general set-up can be seen on Figure 1. A simple, generally build-up composting toilet contains three elements: the underlaid of the toilet, the container, which can be a simple bucket too, and the cover material, which is plant strings, namely cellulose. Without cellulose composting process cannot happen. During the design of composting toilets the main goal is to lead human excreta into the soil by using the most effective humus making process. [1].

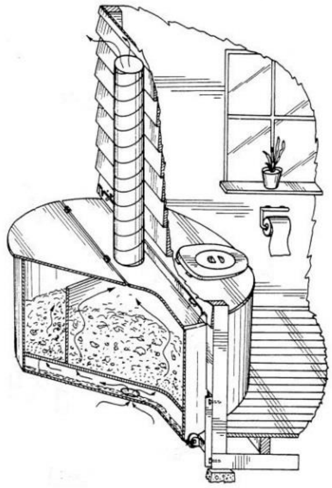

Figure 1: A typical composting toilet accepting kitchen waste and human excreta [2]

By using composting toilets, the human nutrient can remain in the nutrient cycle. The human nutrient cycle is an endless natural cycle, where food for humans must be grown on soil that is enriched by the continuous addition of organic materials recycled by humans. (Figure 2)

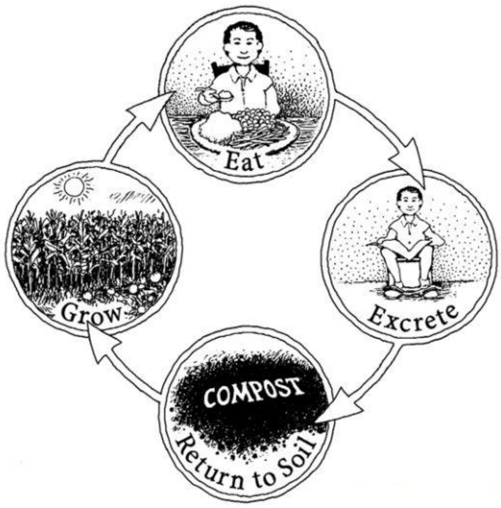


Figure 2: The human nutrient cycle, using human excreta in the agriculture as a natural fertilizer [1]

Since the paper is about the utilization of human excreta in the agriculture, it is important to note, that human urine contains the most of the nutrients out of human waste.

## 1.2. The utilization of human urine in the agriculture

The amount of human urine is only 0,4-1% out of the daily amount of sewage water, but 88% of the wastewater's nitrogen content, 67% of the wastewater's phosphorus content and 73% of the wastewater's potassium content contained in the urine. [11] [12] [13] That is why most of the practical and technological researches about utilization of human excreta are focusing on human urine. [14] [15] [16] [17] [18, 19] For the separate collection of urine, urine-diversion toilet have to be applied.

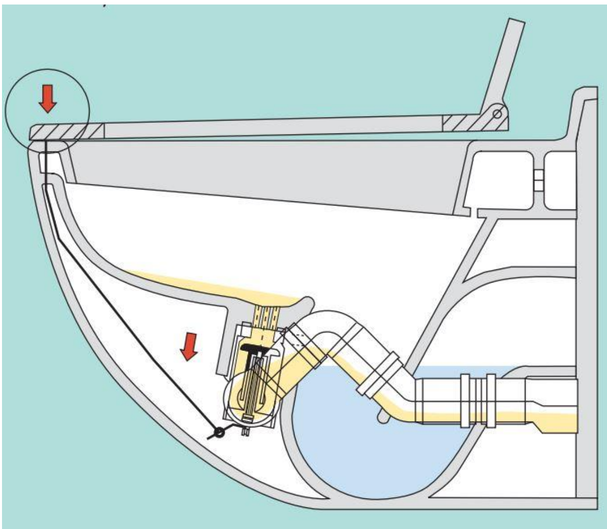

Figure 3: Urine-diversion toilet set-up [3]

The operation of this toilet can be seen on Figure 3. When the toilet lid is lifted, a valve opens a chamber, where the urine will flow and it will be separated from the faeces. So valuable nutrients can be collected and utilized as fertilizer.

Nitrogen in the urine is mainly in the form of urea, while phosphorus is in the form of superphosphate and potassium is in ionic form, with a ratio of 18:2:5 NPK [20], which is extremely useful for plants. A typical NPK ratio in normal commercial fertilizer can be 9:6:17 [21]. Moreover, human urine contains not only essential macro- but micronutrients as well. The nitrogen content of fresh human urine is up to 9 gN/l [22]. However, urine is not allowed to be used as fertilizer in the EU, therefore we have to seek for technics which allow the legal utilisation of urine or its nutrients.

The incinerating toilet, which is other type of dry toilets, can produce also electrical energy. During the combustion process, a significant amount of valuable nutrients are lost, although elemental analysis of sewage sludge ash showed that it comprised 6-10% P and 7-18% Ca [23].

## 2. Comparison of composting toilet to urine-diversion toilet

Still, there are some problems concerning the utilization of compost or urine in the agricultural fields. To see these issues, the comparison of these toilet types are introduced in Table 1 and Table 2 by highlighting the advantages and disadvantages of these toilets.

Table 1.: The advantages and disadvantages of composting toilets [1] [24] [25]

| Advantages | Disadvantages |
|---|---|
| low odour levels in case of proper use | some model need ventilation |
| no need for sewage system | the eligible moisture for composting process has to be ensured |
| easy to install | it is hard to implement in urban areas |
| water free toilet system | need to know the materials that can be get into the compost |
| chemical free | need to know the utilization method of final compost product |
| low maintenance costs | composting process needs oxygen |
| it generates compost | in case of improper use, odour and flies may appearance |
| it can process kitchen waste too, which decrease our everyday waste | existing prejudices and misconceptions in the agriculture concerning the application of human excreta |
| hormones and pharmaceuticals degrade during composting process | |
| ensure the nutrient cycle | |
| it is easy to use in villages and rural areas | |
| it is already used also in developing and developed countries | |
| the product is manageable and can be processed in several different ways | |
| the product can be used as a natural fertilizer | |
| various formation is possible | |
| by selecting proper wastes, the quality of composting process can be affected favorable | |

Table 2: Advantages and disadvantages of urine-diversion toilets [26] [27]

| Advantages | Disadvantages |
|---|---|
| low odour levels | the separation of urine and faeces is not suitable for real humus-forming process |
| no need for sewage system | using artificial fertilizers in agriculture is more common and well-known, while human urine utilization has to confront with prejudice, misconceptions, lack of information and unawareness |
| easy to install | using flush toilets is more common and well-known, while urine diversion toilet has to confront with lack of information and unawareness |
| water free toilet system | during improper storage and transportation, several spontaneous process, for example excretion and |

| | |
|---|---|
| | evaporation can change significantly the composition of human urine |
| chemical free | |
| low maintenance costs | |
| it is already used also in developed and developing countries | |
| utilization of human urine as a liquid fertilizer in the agriculture | |
| from human urine we can recover the nutrients which are the most important for plants | |
| various methods can be applicable in practice for nutrient recovery from human urine | |

## 3. Conclusions

Composting toilet is a type of dry toilets which has low odour levels, low maintenance costs and which is a water and chemical free system. Its end product is humus rich compost. To get good compost quality, the composting process have to be controlled by ensuring the sufficient oxygen quantity for the composting process, as well the eligible moisture level.

Urine can be collected and managed separately by using urine-diversion dry toilets. These toilets are commercially available, like composting toilets. The storage of urine should last at least one month when it is used as fertilizer for food crops that are not consumed untreated and even six months when it is used for all plants.

To conclude, we may state that although composting toilet has a lot of favorable attributes, it is more reasonable to apply only human urine as a fertilizer. To eliminate the disadvantages, some technologies can be applied to recover the nutrients from urine. These main technologies are struvite precipitation, stripping and absorption and membrane technologies [28] [29] [30] [31] [32] [33] [34].

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**References**

1. Jenkins, J., *The humanure handbook - A guide to composting human manure 2nd edition.* 1999.
2. Ylösjoki, M.J., *Composting device for toilet and kitchen waste.* https://patentimages.storage.googleapis.com/dd/d9/c9/4ecd267df410e6/US5171690.pdf, 1992.
3. Larsen, T.A., et al., *Peer Reviewed: Re-engineering the toilet for sustainable wastewater management*. Environmental Science & Technology, 2001. **35**(9): p. 192A-197A.
4. Duncker, L.C., G.N. Matsebe, and N. Moilwa, *The social/cultural acceptability of using human excreta (faeces and urine) for food production in rural settlements in South Africa.* Water Reseach Commission, 2007. **WRC Report No TT 310/7**: p. 102.
5. Machline, V. and C. Machline, *Urban sanitaion and the use of human waste as manure in Ancient Rome*. 2014.
6. Shiming, L., *The utilization of human excreta in Chinese agriculture and the challenge faced.* EcoSanRes, 2002: p. 4.

7. Mackie Jensen, P.K., et al., *Hygiene versus fertiliser: The use of human excreta in agriculture – A Vietnamese example.* International Journal of Hygiene and Environmental Health, 2008. **211**(3): p. 432-439.
8. G Knudsen, L., et al., *The fear of awful smell: Risk perceptions among farmers in Vietnam using wastewater and human excreta in agriculture*. Vol. 39. 2008. 341-52.
9. Mara, D. and S. Cairncross, *Guidelines for the safe use of wastewater and excreta in agriculture and aquaculture : measures for public health protection.* World Health Organization & United Nations Environment Programme, 1989: p. 207.
10. Spångberg, J., P. Tidåker, and H. Jönsson, *Environmental impact of recycling nutrients in human excreta to agriculture compared with enhanced wastewater treatment.* Science of The Total Environment, 2014. **493**: p. 209-219.
11. Larsen, T.A. and W. Gujer, *Separate management of anthropogenic nutrient solutions (human urine).* Water Science and Technology, 1996. **34**(3): p. 87-94.
12. Jönsson, H., et al., *Source separated urine-nutrient and heavy metal content, water saving and faecal contamination.* Water Science and Technology, 1997. **35**(9): p. 145-152.
13. Larsen*, T.A., et al., *Source Separation: Will We See a Paradigm Shift in Wastewater Handling?* Environmental Science & Technology, 2009. **43**(16): p. 6121-6125.
14. Maurer, M., W. Pronk, and T.A. Larsen, *Treatment processes for source-separated urine.* Water Research, 2006. **40**(17): p. 3151-3166.
15. Niwagaba, C.B., *Treatment Technologies for Human Faeces and Urine.* 2009.
16. Pradhan, S.K., et al., *Human Urine and Wood Ash as Plant Nutrients for Red Beet (Beta vulgaris) Cultivation: Impacts on Yield Quality.* Journal of Agricultural and Food Chemistry, 2010. **58**(3): p. 2034-2039.
17. A, R., et al., *Practical Guidance on the Use of Urine in Crop Production*. 2010.
18. Semalulu, O., et al. *Potential for Reuse of Human Urine in Peri-urban Farming*. in *Innovations as Key to the Green Revolution in Africa*. 2011. Dordrecht: Springer Netherlands.
19. Wohlsager, S., et al., *Urine - A Valuable Fertilizer with Low Risk after Storage in the Tropics*. Vol. 82. 2010. 840-7.
20. Linden, B., *Human urine as a nitrogen fertilizer applied during crop growth to winter wheat and oats in organic farming.* 1997.
21. Pradhan, S.K., et al., *Use of Human Urine Fertilizer in Cultivation of Cabbage (Brassica oleracea)—Impacts on Chemical, Microbial, and Flavor Quality.* Journal of Agricultural and Food Chemistry, 2007. **55**(21): p. 8657-8663.
22. Jaatinen, S., *Characterization and Potential Use of Source-Separated Urine*. Tampere University of Technology. Publication. 2016: Tampere University of Technology.
23. Cohen, Y., *Phosphorus dissolution from ash of incinerated sewage sludge and animal carcasses using sulphuric acid.* Environmental Technology, 2009. **30**(11): p. 1215-1226.
24. Ho, Y.B., et al., *Degradation of veterinary antibiotics and hormone during broiler manure composting.* Bioresource Technology, 2013. **131**: p. 476-484.
25. Kocsis, I.D., *Komposztálás, biogáztermelés.* www.tankonyvtar.hu, 2011.
26. Mnkeni, P. and L.M. Austin, *Fertiliser value of human manure from pilot urine-diversion toilets*. Vol. 35. 2009.
27. Karak, T. and P. Bhattacharyya, *Human Urine as a Source of Alternative Natural Fertilizer in Agriculture: A Flight of Fancy or an Achievable Reality*. Vol. 55. 2011. 400-408.
28. Zhang, L., Y.-W. Lee, and D. Jahng, *Ammonia stripping for enhanced biomethanization of piggery wastewater.* Journal of Hazardous Materials, 2012. **199-200**: p. 36-42.
29. Quan, X., et al., *Simultaneous removal of ammonia, P and COD from anaerobically digested piggery wastewater using an integrated process of chemical precipitation and air stripping.* Journal of Hazardous Materials, 2010. **178**(1): p. 326-332.
30. Zhang, L. and D. Jahng, *Enhanced anaerobic digestion of piggery wastewater by ammonia stripping: Effects of alkali types.* Journal of Hazardous Materials, 2010. **182**(1): p. 536-543.
31. Le Corre, K.S., et al., *Phosphorus Recovery from Wastewater by Struvite Crystallization: A Review.* Critical Reviews in Environmental Science and Technology, 2009. **39**(6): p. 433-477.
32. Warmadewanthi and J.C. Liu, *Recovery of phosphate and ammonium as struvite from semiconductor wastewater.* Separation and Purification Technology, 2009. **64**(3): p. 368-373.
33. Ichihashi, O. and K. Hirooka, *Removal and recovery of phosphorus as struvite from swine wastewater using microbial fuel cell.* Bioresource Technology, 2012. **114**: p. 303-307.
34. Xie, M., et al., *Membrane-based processes for wastewater nutrient recovery: Technology, challenges, and future direction.* Water Research, 2016. **89**: p. 210-221.