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Human Excreta as an Important Factor of Sustainable Water Management and Agriculture

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Abstract. The paper summarizes the results of the first stage of a research series. After the brief overview of the environmental effects caused by flush toilet the composition of human excreta is presented. To show how much valuable material is lost when regarding human excreta as waste the quantity of fertilizer used for enhance soil productivity and nutrient losses due to soil erosion is presented as well. Subsequently the benefits and necessity of composting of human excreta instead of using flush toilets is discussed.

Keywords: environmental effects of flush toilet, human excreta, composting of human excreta

1. Introduction

Collection and removal of human excreta dates back 4-5 thousands of years. Various methods and techniques were used according to historical times and places. Using human excreta in the past and in the present for agricultural purposes or industrial purposes (e.g. gunpowder from urine) was known, but not wide spread everywhere and at all times.

Joseph Bramah registered the invention of flush toilet tank in 1788. Initially the flush toilets served only the comfort of rich peoples and were not connected to the greywater sewage systems. Later, as a result of industrialization, connection of flush toilets to the drinking water and sewer system became widespread because of comfort and hygiene needs of the increased number of inhabitant of cities. Human excreta became waste which needs to be even faster clear away. After collection it has been usually emitted to surface water. The negative effects of unclean sewage on surface water and on human health focused attention to water. However it has not been considered how to avoid human excreta entering the water cycle. More and more advanced wastewater treatment technologies have been built and applied. The faecal nitrogen and phosphorus content is broken down and converted to nitrate and inorganic phosphate. These cause the eutrophication of water, so waste water treatment had to become more and more effective to avoid pollution of water. Instead, inorganic N and P is accumulated in the sludge and a small part gets into the atmosphere. However, the root of the problem is still not solved, in fact, it generates more and more serious environmental problems.

2. Environmental Effects Caused by Flush Toilets

Overall environmental effects caused by flush toilets can be classified in several well-known set of problem, however assessment of the impacts still focus on water:

- Changes in natural water cycle.
- Problems of water consumption (both quantity and quality aspects of it).
- Household-generated greywater must be treated like black water, unnecessarily.
- Energy demand of sewage drainage and waste water treatments is high.
- Organic matter of human excreta gets to water as inorganic N and P, which causes eutrophication.
- Inorganic N and P in the sludge get to the soil, which can pollute underground water bodies and accelerate the decomposition of humus.

- Burning of sludge: organic matter of human excreta become CO_2 and other gases.
- There is no way of humus forming from the organic matter content of the human excreta.
- Nutrients of human excreta are lost.

In Hungary, the water consumption is currently 34,1 m^3/year/person (in 2011), approximately 93,5 l/day/person [1]. Joint amounts of faeces and urine emitted by a person is about 1,5 l/day, so 550 l/year.

Distribution of pollution load of urban wastewater shows that 99% of bacteria originated from faeces; 11% of N-content originated from faeces, 87% from urine and 2% from greywater (GW); 40% of P-content originated from faeces, 50% from urine, 10% from GW; 47% of organic matter content originated from faeces, 12% from urine, 41% from GW [2]. So 99% of bacteria, 98% of N-content, 90% of P-content and the total amount of drug residues and hormones are in the human excreta, which is less than 2% of the total wastewater volume. We are diluting these 2% human excreta to 15-20% black water because of flush toilets, and after this 15-20% black water is mixed with 80-85% of greywater (exact quantities of greywater and blackwater depend on the types of toilet tanks and household water consumption habits).

And because of dilutions, the total amount of wastewater needs being treated by the well-known treatment technologies. Greywater would not require this degree of purification. Qualitative characterization (total solids, biochemical oxygen demand, dissolved organic carbon, nitrate, phosphate, potassium, calcium, sodium etc. anions, cations and microelements etc.) of household-generated GW streams (collected from bathing, laundry and cooking) of Hungary showed high variability for the analysed parameters [3], but have much more lower content than blackwater has. Nevertheless, black water and greywater are together in the sewage systems and in sewage treatment plants.

Once human excreta are removed by water from households, then we are not able to regain its original organic material compounds. During flow into the sewer system human excreta already begin to degrade. Urease enzymes hydrolyse the urea content of urine and this reaction generates ammonium ion (and CO_2). During waste water treatment the ammonium is oxidized to nitrate and the organic phosphorus compounds of human excreta are converted into inorganic phosphates. So we can say that the valuable organic N and P compounds of human excreta are converted into water pollutants by waste water treatment. And sadly most people are not aware of the fact that the greatest environmental harm is not this water load, but withdrawal of the very valuable organic matter content of human excreta from the cycle of biosphere.

We got into a vicious circle discharging human excreta to freshwater: waste water treatment convert human excreta to water pollutant, while we replace missing nutrients to soils artificially, which lead to the exploitation of soils in the long run.

3. Benefits of Composting Human Excreta

Plant and animal biomass are essential components of material and energy flows of ecosystems. Getting them out from the natural cycles, or transportation to an inappropriate environmental media in an inappropriate chemical form causes a lot of long time environmental problems and upsets natural circulation of carbon, nitrogen, phosphorus and water.

The nitrogen management of soils depends not only on the total amount of nitrogen, but also on the C/N ratio. If $C/N < 20$, then nitrogen is released from the organic bonds, and become easily soluble. If $C/N > 30$ then nitrogen bonds to organic compounds. Therefore plant and animal biomass must take part in the processes of soil humus formation together. This means that human excreta must be composted with added vegetable cellulose. Vegetable cellulose has other, great importance as well. According to laboratory test, the enzymatic degradation rate of urea decreases in the presence of cellulose an order of magnitude [4]. So the enzymatic degradation of urea in urine will be blocked, if directly after getting out from body, vegetable cellulose is added to urine.

Drug residues and hormones are completely degraded by composting human excreta [5], while wastewater treatment is not able to remove these from water. Human excreta does not consist heavy metals, while these can be accumulated in waste water sludge because of common treatment of industrial and household waste water. The content of faecal bacteria is insignificant of properly composted human excreta, even the helminthic eggs are destroyed during the long period of composting [5]. In contrast, it is to be noted, that animal and human excreta without prior treatment was/is often used in agriculture: like non-composted manure and slurry, and sucked liquid municipal waste. The bacterial and helminthic eggs content of these are very high. (However, plants do not take up the bacteria, but bacteria may get to their surface.) Utilization of human excreta by composting is not self-evident for people, especially in the developed world – primary because of cultural and psychological reasons.

The overall environmental effects of utilization of human excreta by composting instead of using flush toilets can be summarized as follows:

- It does not intervene in the natural water cycle.
- Water consumption is reducing.
- Inorganic N and P load of surface water caused by human excreta is stopped, eutrophication will be reduced significantly.
- The amount of waste water sludge is reducing significantly.
- The household waste water does not contain human excreta, so on-site wastewater treatment of grey water could be used.
- Energy and cost demand of sewage drainage and waste water treatments is reducing significantly.
- The nutrient content of human excreta goes back to the natural biological cycles.
- Use of fertilizer and slurry is reducing significantly, so their unfavourable environmental effects and use of energy and mineral resources are reducing also.
- Exploitation of soils and soil erosion is reducing.
- Food production becomes more sustainable.

4. Nutrients in Human Excreta

Mass and composition of excreta highly depend on the nutrition habits of people. Because of this, literature on the components does not contain the mean value, but extremes (*Table 1*). The minimum value indicates the amount and composition of faeces and urine of a typical little eater, vegetarian man. The maximum value is characteristic for a meat eater who eats a lot. Based on these bibliography data calculated quantity of nitrogen, phosphorus, potassium, calcium and carbon get out from people by faeces and urine separately and together are shown in *Table 2*. Not only the amounts produced by a single individual, but also the amounts produced in a year by 10 million people (population of Hungary) and by 7 billion people (population of Earth) were calculated.

Table 1: Average composition of human faeces and urine (Source: [7]).

	Faeces	**Urine**
Amount	150-300 g/person/day	1-1,3 l/person/day
Moisture content	66-80%	93-96%
Dry matter	40-81 g/person/day	50-70 g/person/day
in the dry matter:		
Organic compounds	88-97%	65-85%
N	5-7%	15-19%
P (as P_2O_5)	3-5,4%	2,5-5%
K (as K_2O)	1-2,5%	3,0-4,5%
C	40-55%	11-17%
Ca (as CaO)	4-5%	4,5-6%

Table 2: Calculated amount of nutrients in human excreta.

Together in faeces and urine	g/person/day	kg/person/year	Hungary/year (10 million person) (thousand t)	Earth/year (7 billion person) (million t)
mass	1000-1500	365-548	3700-5500	2600-3800
dry matter	90-151	32,9-55,1	330-550	230-385
organic compounds	67,7-138,2	24,7-50,4	250-500	175-350
N	9,5-19,0	3,5-6,9	35-70	25-50
P	1,1-3,45	0,4-1,26	4-13	2,8-9
K	1,9-5,2	0,7-1,9	7-19	5-13
C	21,5-56,9	7,8-20,8	78-208	55-146
Ca	3,9-8,3	1,4-3,0	14-30	10-21

In *Table 3* the active ingredient content of N, P, K fertilizers used in Hungary and in the world is summarised. Let us not forget that 2/3 of utilized nitrogen fertilizer comes to ground-water and surface water [6]. Keep in mind also, that fertilization causes more rapid decomposition of soil humus content, which worsen structure, water management property, chelating, adsorption and puffer capacity of soils as well – opposite to nutrient supply in form of organic compost. The excreta of 7 billion people contains 25-50 million tonnes of nitrogen, 2,8-9 million tonnes of phosphorus, 5-13 million tonnes of potassium. This is definitely a huge amount. In particular, if we take into account that human excreta must be composted mixed with plant biomass (this is the right way of composting human excreta) – so nutrients of plant biomass would increase the nutrient content of the composted human excreta. If all domestic animal excreta would be composted also, then these together likely cover nutrient demand of the soils.

Table 3: Total quantity of active ingredient content of fertilizers used in Hungary (Source: [8]) and on the Earth (Source: [9]) and nutrient loss due to soil loss in Hungary and on the Earth.

Nutrient	Active ingredient content of fertilizers used in Hungary (2012) (thousand t)	Active ingredient content of fertilizers produced on the Earth together (2012) (million t)	Nutrient loss due to soil loss in Hungary (thousand t)	Nutrient loss due to soil loss on the Earth (million t)
total mass			70 000	30 000-75 000
N	310	122	200	90-218
P	58	23,5	44	20-47
K	72,5	26,5	183	82-195

Soil loss in Hungary caused by soil erosion is about 80-110 million m^3 soil in a year, which means 1,5 million tonnes of organic matter, 0,2 million tonnes of N, 0,1 million tonnes of P_2O_5 and 0,22 million tonnes of K_2O loss per year [10]). This is 200.000 tonnes of N, 44.000 tonnes of P and 183.000 tonnes of K loss per year (*Table 3*).

1,3% of the arable land of the Earth is lost annually due to water, wind and ice erosion and salinization. This means 1000 tonnes of soil per second [6]. Calculated for a year: 31,5 billion tonnes of soil is lost. Other sources say 75 billion tonnes of soil is lost per year. The average N, P and K content of the Hungarian soils was used as estimation of the total N, P and K loss of soils on the Earth. The result is: 90-218 million tonnes of N, 20-47 million tonnes of P and 82-195 million tonnes of K loss of soil annually (*Table 3*).

5. Summary

Human excreta are considered – especially in the developed world – as a waste which must be clear away as fast as possible by water. Operation and maintain of flush toilet based water infrastructure has high environmental price. However, the remediation of harmful environmental effects is still concentrated to water pollution. Analysing of really preventive options for stopping water load is overshadowed. During waste water treatment the valuable organic components of the human excreta are transformed into water loading inorganic N and P compounds. The improvement of end of pipe – waste water treatment – technologies is believed for perfect solution in solving the problem. However this loading is not the most harmful environmental effect of flush toilets. The greatest environmental harm of flush toilets is the withdrawal of the very valuable organic matter content of human excreta from the cycle of biosphere. We should realize that our general and wide spread accepted view, namely “the better we clean waste water consisting human excreta, the better we protect our environment” is incorrect and misleading.

According to my approximate calculation 2,6-3,8 billion tonnes of human excreta are produced in every year on the Earth. This means 175-350 million tonnes of organic matter. It consist of 25-50 million tonnes of N, 2,8-9 million tonnes of P and 5-13 million tonnes of K. Portion of this huge mass is withdraw from humus circulation because of the collection and treatment of waste water and treatment of waste water treatment sludge, and is converted into water pollutants. Nevertheless human excreta are also a part of the biosphere, and its leading back into natural cycles is the essential basis for future food production.

More widespread agricultural utilization of human excreta is needed in any case in the future, regarding the annually loss of soil mass and soil fertility on the Earth, and the cost, material and energy demand of fertilizer production and utilization. Because of the freshwater pollution, the decreasing amount of good quality water resources and the effects of global warming we need to shift to using such methods which reducing water consumption and preventing water pollution.

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