NUTRIENT ANALYSIS OF A DRY TOILET COMPOST LEACHATE

Case Study of an Allotment Garden

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Environmental engineering

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ABSTRACT

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The aim of this thesis was to examine the concentrations of the nutrients nitrogen, phosphorus and potassium, as well as the amount of mixed liquor suspended solids in a sample of dry toilet leachate. This thesis was done for the Global Dry Toilet Association of Finland (Käymäläseura Huussi Ry) and the leachate came from the dry toilets of the Nekala Allotment Garden in Tampere, Finland. The leachate had been stored for six months prior to analysis.

Total nitrogen was analysed using the total Kjehdahl method; potassium was analysed using flame photometry and phosphorus was analysed by spectrophotometry. The concentrations of the nutrients in the leachate were on average 1 628 mg/L for nitrogen, 6 mg/L for phosphorus and 62 mg/L for potassium. This means that the concentration for nitrogen was 19 times higher than that found in untreated domestic wastewater. The concentration for potassium was also higher than the concentrations found in untreated domestic wastewater, approximately 4 times higher. The phosphorus concentration in the leachate was within the range of phosphorus found in untreated domestic wastewater. Total suspended solids in the leachate were close to the amount found in untreated domestic wastewater at19 mg/L. The nitrogen concentration of the leachate was close to the lowest values of nitrogen concentrations found in urine, 1 790 mg/L, but very small compared to nitrogen concentrations in dry toilet compost, 14 600 mg/kg.

Since the leachate was six months old when the analysis was done, it is possible that there had been evaporation of water during the storage of the leachate, which could have increased the concentrations of the nutrients analysed. It is also possible that some of the chemicals remained attached to the canister and could not be analysed, and that sludge formation during storage could have affected the nutrient concentrations in it. Perhaps future analysis on more fresh leachate would yield different results.
Because the leachate is so nutrient rich, it will aid in the process of composting and hence it can be added to a composting pile. The amount of seep liquid to be added to the compost depends on the carbon concentration in the compost, since the composting process depends on the balance of carbon and nitrogen as well as sufficient amounts of moisture and air. The liquid could also be diluted and used as a garden fertilizer once it is old enough; the process takes from one to two years depending on the temperature it is kept at and how it is stored. The leachate cannot be used as fertilizer for consumer crops as this is prohibited by Finnish law, due to health risks associated with pathogens that could be in the leachate.

Leachate, Seep liquid, Dry toilet, Ecological sanitation, Nitrogen, Phosphorus, Potassium, Wastewater, Compost, Urine, Faeces

CONTENTS

GLOSSARY

TAMK	Tampere University of Applied Sciences
Ecosan	Ecological sanitation
MLSS	Mixed liquour suspended solids
UHP water	Ultra High Purity water
TKN	Total Kjeldahl nitrogen.

KEYWORDS

Leachate, Seep liquid, Dry toilet, Ecological sanitation, Nitrogen, Phosphorus, Potassium, Wastewater, Compost, Urine, Faeces

1 INTRODUCTION

The aim of this thesis was to evaluate the organic components of the dry toilet leachate from the Nekala allotment gardens in Tampere, Finland. The concentrations analysed were those of nitrogen, phosphorus and potassium. The amount of mixed liquor suspended solids (MLSS) in the liquid was also analysed. The results of the analysis were to be compared to those of urine and domestic wastewater (more exactly black water, where human excreta is present). This thesis was commenced by the Global Dry Toilet Association of Finland (Käymäläseura Huussi Ry). The analysis was done in the environmental laboratory of Tampere University of Applied Sciences during the period of January – March 2014. Due to a six month practical training period in 2014, reporting began in November 2014.

Chapter 2 of this thesis explains the theory behind dry toilet leachate and nutrient recycling. Chapter 3 explains the methodology used in the analysis. Chapter 4 presents the results and Chapter 5 discusses the results and compares them with similar analysis done on untreated domestic wastewater, urine and dry toilet compost.

Dry toilets do not use water to flush waste into a sewage system but instead collect the waste for nutrient recycling. When maintained well, dry toilets are a sustainable and sanitary option to the water flush toilet which has become the norm in Western countries. Flush toilets are connected to a sewage system through which wastewater flows into a body of water. In many developed countries the water is treated before release, according to the laws of that country. However, there are countries where the water is either not treated or the treatment is inadequate to prevent eutrophication in water bodies that come into contact with the wastewater (UN-Habitat 2003).Whichever the case, flush toilets have proved over the years to be unsustainable due to the loss of nutrients from the human waste, as well as the obvious loss in volumes of possible drinking water. In Finland one person alone uses up to 40 liters of water a day for flushing the toilet (the Ministry of Environment, 2009). The emphasis from environmentalists is to adopt ecological sanitation (ecosan for short) through which nutrients from waste are retrieved and reused. Ecosan can particularly benefit Third World countries which have problems with inadequate sanitation.

2. THEORY

2.1 Dry toilet nutrient recycling

The dry toilet differs from the flush toilet in the form that it does not use water to transport human waste, but instead collects the waste so that its nutrients can be obtained for nutrient recycling. There are different types of dry toilets; some separate urine from faeces, some have two levels while some are portable and made for public use. (Huussi ry, 2010). The main nutrients obtainable from sanitation waste are nitrogen (N), phosphorus (P) and potassium (K).They are essential for the growth of plants, animals and microorganisms and are known as nutrients, biostimulants and growth factors. They are needed especially in soil, as they are easily deplenished through agriculture. Apart from nitrogen, phosphorus and potassium, plants need smaller amounts of other elements such as sulphur (S), magnesium (Mg), calcium (Ca), iron (Fe) and chlorine (Cl), which are also growth factors. Growth factors cannot be synthesized from other carbon sources. (Metcalf & Eddy, 1991) When sanitation waste is composted its structure changes to humus, a nutrient-rich, pathogen-free matter from which plants obtain the nutrients needed for healthy growth. When practiced correctly ecosan can be a relatively easy and sustainable form of sanitation. (Jenkins, 1999)

2.2 Dry toilet leachate

According to Valve & Nuortie (2010), leachate is any liquid which goes through a mass, in this case urine going through a combination of faeces and drying material to rest on the bottom of a dry toilet container. When the vessel is a closed vessel with good dimensions, and enough drying material is used, there should not be, in theory, any leachate produced (Huussi Ry, 2010). Although dry toilet leachate is unhygienic due to the possible existence of pathogens in it, it is also full of nutrients. At this point there are no clear instructions on how to handle or dispose of dry toilet leachate. However, due to the prevalence of dry toilets in the countryside, Finland has a law prohibiting the disposal of dry toilet leachate into greywater (wastewater where no human excreta is present), in other words it can only be disposed of in the toilet. Humus from dry toilets is also only to be used for private farming and not for public distribution.

Leachate from a dry toilet is a good fertilizer once it is old enough; literature sources state that it is anywhere between one and two years (Valve & Nuortie, 2010; Jenkins, 1999). When diluted it can be used as fertilizer for non-consumable plants. (Valve & Nuortie, 2010) When handling any leachate, contact with skin, eyes and mouth should be avoided and appropriate equipment such as gloves, goggles and protective clothing should always be used.

2.3 NITROGEN

Nitrogen is an essential nutrient for plants and animals. Total nitrogen includes organic nitrogen, ammonia, nitrite and nitrate. Most common sources of these nitrogen compounds in wastewater are of plant and animal (including human) origin, such as runoff from animal manure, fertilized croplands and wastewater treatment plants. Atmospheric nitrogen is also a source of nitrogen in wastewater. (Metcalf & Eddy, 1991)

The nitrogen present in fresh wastewater contains protein rich matter and urea. Bacteria decomposes the organic nitrogen into ammonia (NH_3), and in an aerobic environment it is oxidized further to nitrates (NO_3^-) and nitrites (NO_2^-). One of the most typical forms of nitrogen found in wastewater is ammonia (NH_3). Other forms are its cation ammonium (NH_4^+) as well as anions nitrite (NO_2^-) and nitrate (NO_3^-) and nitrogen gas (N_{2}), which have oxidation states of -3, -3, +3 ,+5 and 0 respectively. (Metcalf & Eddy, 1991; EPA 2013)

According to Mamta (1999), nitrogen is said to be an indicator of water quality due to the fact that significant amounts of ammonia found in a water body suggests that the water has been contaminated with wastewater. This can be detrimental since research has shown that excess amounts of nitrogen in water bodies have the potential to alter aquatic organisms due to nitrogen's ability to deplete dissolved oxygen levels (Mara 2014).

2.4 PHOSPHORUS

Phosphorus is one of the three fundamental nutrients for plant growth. The existence of phosphorus in water bodies is crucial because it provides nutrients essential for organisms. The amount of phosphorus in natural waters is generally scarce and excess amounts of phosphorus in natural waters is mostly due to the discharge of man-generated wastes from wastewater treatment plants that, apart from human waste, also include fertilizers, detergents and laundering products. (Mamta, 1999)

In certain aquatic systems, phosphorus is the limiting reagent as its concentration limits the growth of algae and aquatic plants. Phosphorus concentrations of less than 10 ppb (parts per billion) do not support algae growth, while phosphorus levels of more than 100 ppb categorize lakes as highly eutrophic with high nutrient levels. (Minnesota Pollution Agency, 2007) It is important to control the release of phosphorus compounds from domestic and industrial waste discharges into surface waters in order to prevent eutrophication and the growth of poisonous algae blooms. (Metcalf & Eddy, 1991; Mamta, 1999) Common forms of phosphorus found in water bodies are polyphosphates, organic phosphates and orthophosphates such as PO_4^{3-}, HPO_4^{3-}, $H_2PO_4^{-}$, and H_3PO_4. Orthophosphates do not need to be broken down further for metabolism. (Metcalf & Eddy, 1991)

2.5 POTASSIUM

Potassium is found in many minerals and along with nitrogen and phosphorus, it is essential for both plants' and animals' growth. The lack of the potassium in the environment can limit plant growth. In living organisms, potassium plays a strong role in nerve functions and hence its deficiency can result in health problems such as cardial dysfunctions (Greenwood & Earnshaw, 1997). It has low leach ability because the potassium not absorbed by plants is bound to clay minerals in soils, from where it is readily taken up by plants again. This low leach ability makes it easy for potassium to accumulate in soil, but easily depleted if heavy crop production takes place. Potassium fertilizers (commonly from potash – the ashes of plants) are often added to agricultural soils (Lenntech; HACH manual). Most of commercially applied potassium (about 95% according to Lenntech) is added to synthetic fertilizers mainly in the form of potassium nitrates, potassium salts and mixtures of magnesium and calcium compounds (Lenntech; HACH manual).

2.6 MIXED LIQUOR SUSPENDED SOLIDS

MLSS is the concentration of non-soluble suspended solids in mixed liquor, composed of biomass, non-biodegradable volatile suspended solids and inert inorganic total suspended solids (Metcalf & Eddy, 1991). The value for MLSS is the direct correlation between the suspended solids concentration and the size of the microbe population; the larger the value for MLSS, the larger the microbe population size. It is calculated as mass of solids divided by the volume and expressed as milligrams per litre, mg/l (Viskari, 2010). MLSS analysis is done in wastewater treatment plants, where its monitoring is critical for plant efficiency. (Viskari,2010; HACH, Mixed liquor…, 2004)

3. METHODOLOGY

3.1 The leachate

According to the Janitor of the allotment garden of Nekala, Taavi Seppälä, (2014) the drytoilet in the allotment garden is an old storage building converted into a dry toilet. There are altogether nine dry toilets on the allotment garden area. The vessel used as the dry toilet is the Green Toilet 330, a 330 L tank with wheels with a sheet on the bottom through which the leachate can seep into a tube, where it is then directed into a 20 L canister. Peat is used as the drying material in the dry toilets. During peak seasons the vessel becomes full within one week, in which approximately 4 kg of peat is used. The vessel is changed when there is approximately 200 L of waste so when 2/3 of it is full. It is changed when it is 2/3 full to make it easier to handle. There are 3 canisters of 20 L volume in the garden that hold the leachete. The full canister is sent to the storage as is the dry toilet waste, where it is kept closed and in the shade. The allotment garden uses the leachete to wet the green compost when the compost gets dry. (Seppälä, 2014).

3.1.2 Pretreatment of leachate

The samples for the analysis are all from the same origin, collected in Nekala on January of 2014 and stored in the refridgerator in the TAMK laboratories. One litre of the leachate was filtered with a vacuum flask and both the filtered and unfiltered leachate were preserved with 4M of H_2SO_4.

3.2 Total Kjeldahl Nitrogen analysis

Total Kjedahl Nitrogen is the total of organic and ammonia nitrogen and includes protein nitrogen as well as non-protein nitrogen. In this work the modified Kjeldahl method was used, according to the Finnish standard SFS 5505. The method consisted of reducing the nitrite and nitrate with Devarda's alloy and digesting organic matter with suphuric acid (H_2SO_4) in the presence of a copper catalyst. The reactions form ammonium sulphate ($[NH_4]_2SO_4$) from which ammonia is then released by adding sodium hydroxide NaOH. The solution is then distilled in boric acid ($H_3BO_{3)}$ solution and titrated with H_2SO_4 in order to determine the amount of ammonium present.
The materials used in the analysis can be found in Eeva-Liisa Viskari's Waste Laboratories Exercise handout. (2010)

3.2.1 Procedure

There were three steps in the Total Kjedahl Nitrogen analysis procedure; wet digestion, where the organic nitrogen is converted to ammonium; distillation, where the ammonium salts are converted to ammonia; and titration, where the amount of ammonia is found out using H_2SO_4.
There were all together 14 samples and 6 blanks used in the procedure. Out of the 14 samples, 8 samples were of volume of 25 ml and 6 samples of 50 ml. The 6 blanks had 3 samples of 25 ml volume and 3 samples of 50 ml volume.

3.2.2 Wet digestion

50 ml of sample was put into six tubes and 25 ml of sample into eight tubes. There were six blank samples, three of which had 50 ml of sample and three of which had 25 ml of sample. 2 ml of concentrated sulphuric acid (H_2SO_4) was added into each tube, as well as 2 Kjeldahl tablets. The wet digest unit, Büchi Digest system K-437, was switched on and the digestion time was one hour.

3.2.3 Distillation

After the wet digestion and letting the samples cool, 2 ml of UHP water was added into the tubes. 20 ml of NaOH solution and a mix of 20 ml H_3BO_3 and a share indicator were then added into the samples, and distilled for four minutes by the Distillation unit K-314 manufactured by Büchi.

3.2.4 Titration

After taking them from the distillation unit, the distilled samples were titrated one by one with diluted H_2SO_4 with the Metrohm 775 Dosimat titrator. The equivalent point was observed as the point when the colour turned from blue to a brownish gray.

The concentration of total nitrogen can then be calculated using the following formula

$$X = 2\ x\ c_{H2SO4} \frac{V_{H2S04} - V_{Blank}}{V_{Sample}}\ x\ 14\ x\ 1000\ ml \qquad (1)$$

where the concentration of acid is multiplied with the number of moles in the solution used for titration.

X= Nitrogen content of the sample (mg/l)

2= The multiplication factor of H_2SO_4 (N=2)

c_{H2SO4}= the concentration of sulphuric used in the sample titration (mol/l)

V_{H2SO4}= Volume of H_2SO_4 used in the sample titration (ml)

V_{Blank} = The volume of H_2SO_4 used in the titration of the blank sample (ml)
V_{Sample}= The sample volume digested (ml)
14= The molar mass of nitrogen (g/mol)
1000= The multiplication factor (mg/g)

3.3 Determination of total phosphorus

The orthophosphate concentrations were determined using the Acid Persulfate Digestion Method 8190 followed with the ascorbic acid (PhosVer3) method 8048 suitable for ranges of 0,02 to2,50 mg/l PO_4^{3-}. The analysis was done according to the Standard Methods for the examination of water and wastewater 4500-P B & E. During the Acid Persulfate Digestion the samples were treated with an acid and an oxidizer, and left to boil for 30 minutes to change all the phosphates into orthophosphates. The orthophosphates were then determined using the reactive phosphorus (Ascorbic Acid) Method 8048 with the HACH DR 2800 Spectrophotometer. The results were shown in mg/l PO_4^{3-}. After receiving the orthophosphate results total phosphorus was calculated using the known molar mass of phosphorus and the number of moles of orthophosphates.

3.3.1 Materials

Materials for the Acid Persulfate Digestion Method for determining Total phosphorus can be found from the HACH manual, method 8190. Materials for the Ascorbic Acid Method, for the analysis of orthophosphates can be found from the HACH manual, method 8048.

3.3.2 Procedure

For the analysis six samples and three blanks were analysed. 25 ml of sample was poured into a 125 ml Erlenmeyer flask, then one Potassium Persulfate Powder Pillow was added. 2,0 ml of sulphuric acid (H_2SO_4) solution of concentration 10,5 mol/l was added then the flask was boiled on a hot plate for 30 minutes. After it had cooled, 2,0 ml of sodium hydroxide (NaOH) of concentration 5 mol/l was added then swirled well. The sample was then poured into a 25 ml graduated cylinder, and distilled water was added until it filled up to 25 ml. After that, the reactive phosphorus test was done using the 490 P React PV programme from the HACH method 8190. (HACH manual)

3.4 Potassium analysis

For the potassium analysis flame photometry was used, using the using the Thermo Scientific - SOLAAR S Series (710633 v1,19) AA spectrometer to determine potassium (K) concentrations.

3.4.1 Procedure

For the analysis 20 ml of 1/10 diluted sample was taken and filtered, as were 10 ml of non-diluted and non-filtered samples. The sample was digested before centrifuging it in order to remove suspensions using the Thermal Scientific IES CL30R Centrifuge
The samples were then diluted to different dilutions to increase the chances of being in the correct range. The dilutions were ¼, 1/10, 1/50 and 1/100, of which the original sample had 10 ml of seep liquid. Lanthanum(III) chloride ($LaCl_3$) and Hydrochloric acid (HCl) were then added into the samples. The Thermo Scientific - SOLAAR S Series (710633 v1,19) AA spectrometer was used to determine the Potassium concentrations in mg/L.

3.5.Mixed Liquor Suspended Solids

MLSS was determined according to the standard SFS-EN 872. The filter was washed with distilled water and dried in the oven on a Petri dish with a known weight for one hour in 110 ˚C. Once the filter was completely dry it was weighed then placed onto the funnel on top of the suction bottle. 20 ml of original, non-filtered sample was then filtered through the funnel. The filter was removed and placed into the oven to dry for one hour in 105 ˚C, stabilized in the desiccators then weighed.
The mixed liquor suspended solids can be calculated using the following formula.

$$\frac{a-b}{c} \qquad (2)$$

where

a = mass of the filter and residue, mg/L

b= mass of the filter before filtration, mg

c= sample volume, l

4. RESULTS

4.1 Total Kjehdahl nitrogen results

Below in Table 1 are the results from the Total Kjehdahl Nitrogen analysis. From the table we can observe that Sample 25 ml #1, Sample 25 #2 and sample 25 ml #7 as well as Blank 25 ml #1 are possible outliers in the data, since they differ significantly from the other titration results. It is important to note that significantly less volume of H_2SO_4 was used in samples 25 ml #1 (0,574 ml) and 25 ml #7 (0,480 ml) than in the other samples and a significantly larger amount was used in the titration of Sample 25 ml #2 (206,56 ml). Hence they are outliers in the experiment and can be omitted from further analysis of the results. When calculating concentrations for the blank samples the results for all except one blank were negative and close to zero, which in theory is not possible. Hence their values will be regarded as zero. The sample Blank 25 ml #1 was the only blank sample with a positive nitrogen concentration of 5,6 mg/L, hence it can also be concluded as an outlier and can be omitted from further analysis. For the calculations the volume of H_2SO_4 used to titrate the blank samples was the average volume of 0,9 ml.

TABLE 1. TOTAL NITROGEN CONCENTRATIONS IN SAMPLES

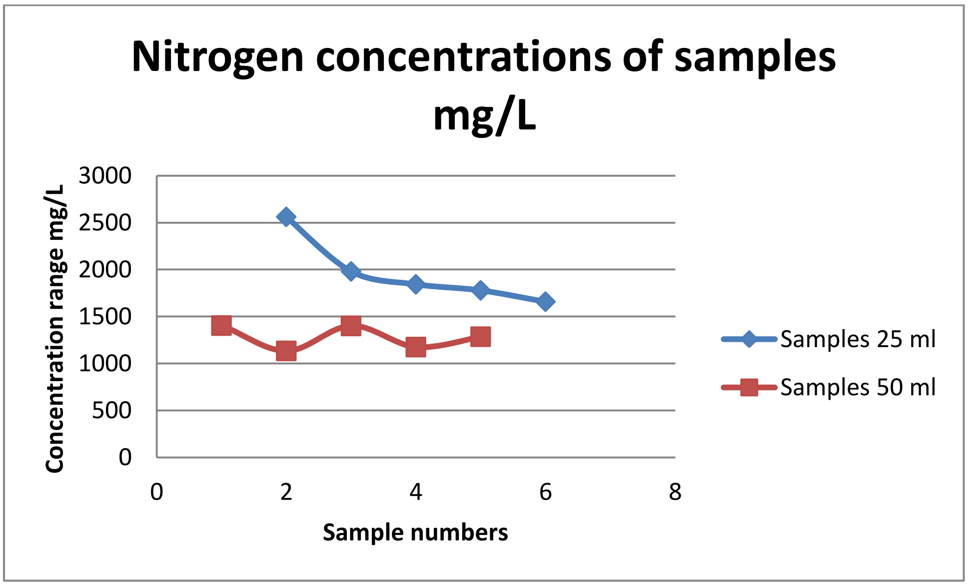
Type of sample	Concentration of H_2SO_4	Volume of H_2SO_4 used	Total Nitrogen (TN) concentration mg/L	Average Total Nitrogen (TN) concentration mg/L
Blank 50 ml #1	0,5 M	0,084 ml	0,00	0,00
Blank 50 ml #2	0,5 M	0,088 ml	0,00	0,00
Blank 50 ml #3	0,5 M	0,086 ml	0,00	0,00
Blank 25 ml #1	0,5 M	0,100 ml	5,6	0,00
Blank 25 ml #2	0,5 M	0,084 ml	0,00	0,00
Blank 25 ml #3	0,5 M	0,086 ml	0,00	0,00
Sample 50 ml #1	0,5 M	4,88 ml	1 342,32	1 290,33
Sample 50 ml #2	0,5 M	5,106 ml	1 405,6	1 290,33
Sample 50 ml #3	0,5 M	4,142 ml	1 135,68	1 290,33
Sample 50 ml #4	0,5 M	5,092 ml	1 401,68	1 290,33
Sample 50 ml #5	0,5 M	4,288 ml	1 176,56	1 290,33
Sample 50 ml #6	0,5 M	4,682 ml	1 286, 88	1 290,33
Sample 25 ml #1	0,05 M	0,574 ml	27,1	
Sample 25 ml #2	0,05 M	206,552 ml	11 562	
Sample 25 ml #3	0,5 M	4,666 ml	2 562	1 965,15
Sample 25 ml #4	0,5 M	3,628 ml	1 981	1 965,15
Sample 25 ml #5	0,5 M	3,382 ml	1 843	1 965,15
Sample 25 ml #6	0,5 M	3,268 ml	1 779	1 965,15
Sample 25 ml #7	0,5 M	0,480 ml	218,4	
Sample 25 ml #8	0,5 M	2,962 ml	1658,72	1 965,15

The range of the nitrogen concentration in the samples was 1 134,56 mg/L to 2 562 mg/L. The average was 1 290,33 mg/L for the samples having 50 ml of the leachate and

1 965, 15 mg/L for the 25 ml samples. Their combined average was 1 627,74 mg/L. The complete data for the Total Kjehdal Nitrogen analysis can be found as an attachment in Appendix 1.

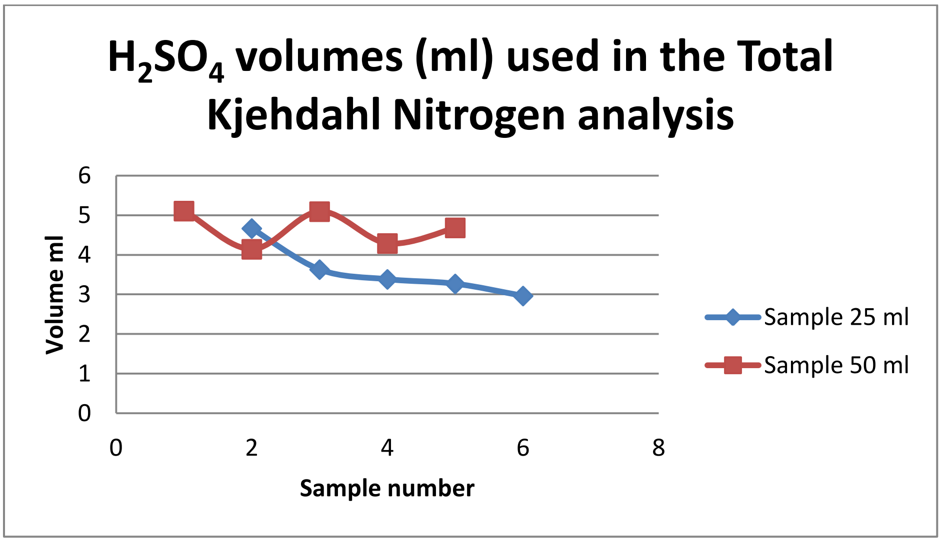
Below in Graph 1 is an illustration of Total Kjehdahl Nitrogen results found from the two sets of samples (25 ml and 50 ml). The illustration shows that the concentrations obtained from the samples of 25 ml volume were higher than the nitrogen concentrations in the samples of 50 ml volume. Theoretically the 50 ml samples should have had twice the concentration of nitrogen in them than the samples of 25 ml volume. It is possible that there was some human error in the distillation or titration phase which could have contributed to the 50 ml samples having smaller nitrogen values than the 25 ml samples.

GRAPH 1 . NITROGEN CONCENTRATIONS OF SAMPLES



Graph 2 illustrates that higher volumes of H_2SO_4 were used in the nitrogen analysis for the samples with volumes of 50 ml, as would be expected since those samples should, in theory, have twice the nitrogen concentration than the samples of 25 ml volume.

GRAPH 2 . H_2SO_4 VOLUMES USED IN TOTAL NITROGEN ANALYSIS



4.2 Total phosphorus results

The results for total phosphorus are presented in Table 2. The HACH Spectrophotometer presented the results as phosphate concentrations in mg/L. The total phosphorus mass was then calculated by finding the number of moles of phosphorus and then multiplying it with the molar mass of phosphorus (30,973 g/mol) by using the following formula.

$$m = nM \tag{3}$$

The range of the concentrations of the phosphates were 14,7 – 21,6 mg/L. From these results the total phosphorus was calculated, and it ranged from **4,80 – 7,05** mg/L. The average result for the total phosphorus concentration for the samples was **6,37 mg/L**. The calculations for total phosphorus can be found in Appendix 3.

TABLE 2. PHOSPHATE (PO_4^{3-}) & TOTAL PHOSPHORUS CONCENTRATIONS

Sample name	PO_4^{3-} result mg/L	Result mg/L	Dilution factor	Total phosphorus concentration mg/L
Sample 1	2,03	20,3	10	6,62
Sample 2	2,00	20,0	10	6,52
Sample 3	1,97	19,7	10	6,43
Sample 4	2,08	20,8	10	6,78
Sample 5	1,47	14,7	10	4,80
Sample 6	2,16	21,6	10	7,05
Blank 1	0,01	0,1	10	0,03
Blank 2	0,01	0,1	10	0,03
Blank 3	0,01	0,1	10	0,03

4.3 Potassium results

The results from the potassium concentration analysis are presented in Table 3. The samples were diluted ¼, 1/10, 1/50 and 1/100. The results were multiplied with the dilution factors to obtain the potassium concentrations. The samples that were diluted ¼ and 1/10 were too concentrated for the range of testing. Hence the samples that were diluted to 1/50 and 1/100 will be the ones analysed. The results obtained for sample 1/50 and 1/100 were 0,9215 mg/L and 0,7703 mg/L respectively. After multiplying with the dilution factor the potassium concentrations **46,075 mg/L** and **77,03 mg/L** were obtained. The average value of the two samples left for the concentration of potassium was **61,55 K mg/L**.

TABLE 3. POTASSIUM CONCENTRATIONS

Sample	Signal	Rsd %	Conc of K mg/L in mg/L in diluted solution	Dilution factor	Conc mg/L
Blank 1	0,009	1,6	0,0000		
Blank 2	0,008	1,6	0,0000		
Blank 3	0,008	1,6	0,0000		
¼ orig	1,784	1,0	4,6105 CX (Outside range)		
1/10 orig	1,556	0,4	3,6936 CX (Outside range)		
1/50 orig	0,648	0,0	0,9215	50	**46,075**
1/100 origf	0,540	0,4	0,7703	100	**77,03**

4. 4 Mixed liquor suspended solids results

The following results were calculated using formula (2) for MLSS determination.

Mass of filter after filtration, mg = 353,7 mg
Mass of filter before filtration, mg = 334,4 mg
Sample volume, L = 0,020 L
Using the MLSS equation, the concentration for mixed liquor suspended solids is **19,28 mg/L**.

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5. DISCUSSION

No previous data was found on the nutrient composition of a dry toilet leachate, however, the values obtained from the Nekala dry toilet leachate can be compared with those of black water and urine, as both have large concentrations of organic nutrients in them. The typical concentration of nitrogen in black water is between 20 to 85 mg/L, depending on the composition of it. The average concentration of phosphorus in household wastewater is between 4 to 15 mg/l and the concentration of potassium between 7 and 15 mg/l. (Metcalf & Eddy, 1991). The comparison of the concentrations of the nutrients found in the leachate with the nutrients found in untreated black water can be found in Table 4 below.

TABLE 4
COMPARISON OF NUTRIENT CONCENTRATIONS FOUND IN UNTREATED DOMESTIC WASTEWATER WITH NUTRIENT ANALYSIS MADE ON THE NEKALA DRY TOILET LEACHATE.

Nutrient	Range of nutrient concentrations (mg/L) found in black water in literature	**Nutrient in dry toilet leachate analysis mg/L**	**Percentage of dry toilet leachate value compared to maximum value found in literature**
N	20 – 85	**1 628**	**1915 %**
P	4 – 15	**6,4**	**42 %**
K	7 – 15	**62**	**410 %**

(source: Liu & Lipták, 2000, according to Metcalf & Eddy, 1991)

Comparing the results from the leachate nutrient analysis to nutrient analysis done on untreated domestic wastewater, it can be concluded that the sample leachate had nitrogen concentration 19 times stronger than the strongest concentration found in untreated domestic wastewater (Metcalf & Eddy, 1991). This can most likely be explained by the fact that average domestic household wastewater is diluted with an abundant amount of water. This means that the urine and faeces in it would be much more diluted compared to the urine and faeces in the dry toilet. Hence the dry toilet leachate would have more concentrated nutrient values since there is no additional water added to it. For example in Finland one person alone uses up to 40 litres of water a day for flushing the toilet, according to the Ministry of Environment's research on household's water consumption (Huoneistokohtaisten vesimittareiden käyttö…, 2009). Multiplying it with the population to a town the size of Tampere (220 446 in 2014 according to Tampere city), that would mean that approximately 8 817 840 litres of toilet water is flushed each day, diluting urine and faeces in the domestic household wastewater significantly.

Municipal wastewaters, according to Metcalf & Eddy (1991), may contain 7-15 mg/L potassium. The potassium concentration of the leachate, 62 mg/L, was 4 – 9 times higher than this. The typical values for phosphorus concentrations in domestic wastewater is 4 – 15 mg/L. The tested samples had phosphorus concentrations of 6,4 mg/L which was wigthin the range of the untreated domestic wastewater. Compared to nitrogen and potassium (which were approximately 19 and 4 times higher respectively), the phosphorus concentration in the leachate was the only nutrient concentration within the range found in untreated domestic wastewater.

Nitrogen values in urine can vary from person to person depending on an individual's diet (Schönning). Research done in Sweden showed that on average urine collected in Sweden had nitrogen levels of 7 000 mg/L, while samples collected in Kenya had nitrogen levels of 3 800 mg/L (Schönning, 2001). Huussi Ry's 2013 research on nitrogen concentrations in urine found that the nitrogen concentrations can be anywhere between 1 790 mg/L and 8 200 mg/L. The leachate from the dry toilets of Nekala had nitrogen concentration of 1 628 mg/L, which means that the nitrogen concentration of the leachate is almost similar to the lowest values of nitrogen concentrations in urine. Theoretically it is possible to use diluted urine as a fertilizer, but at the moment EU legislation forbids this in commercial food production.

Nutrient analysis was done in 2014 on a dry toilet compost owned by Finnish environmental organization Dodo ry. According to research done by TAMK students it was found that the dry toilet compost of Dodo ry had nitrogen levels of 14 600 mg/kg (Chernyaev, A. Pylänäinen, I. & Taipale, T. 2014). Comparing nitrogen values of the leachete from Nekala to Dodo ry's dry toilet compost, it can be seen that the leachate had much smaller nitrogen values than those of the dry toilet compost. It is important to remember that nitrogen concentrations decrease as the compost matures due to ammonium levels decreasing.

Possible evaporation of water during the storing period of the leachate could have been the reason why nitrogen and potassium concentrations in the leachate were higher than the concentration values found in wastewater. Alternatively it is also possible that nitrogen concentrations could have been higher in the leachate while it was still fresh, since, according to UNESCO (2003), there is always a risk of losing nitrogen in the form of ammonia through evaporation.

According to Metcalf & Eddy, the typical composition for fixed suspended solids in untreated domestic wastewater is between 20 mg/l to 75 mg/l. The value obtained from the analysis of the Nekala leachate was 19 mg/l. This result is close to the lower concentration of 20 mg/l found in literature. However, the MLSS value could have also changed during the storage process because sludge tends to accumulate when urine stands for a long period of time (UNESCO, 2003), meaning that the MLSS value could have been lower during the period when the leachate was more fresh.

Based on the results obtained from the nitrogen, phosphorus and potassium analyses, it can be concluded that the leachate has high potential to eutrophy water bodies. This is because it has higher concentrations of eutrophying nutrients than found in aquatic ecosystems. The concentrations of nitrogen and potassium in the leachate were also much higher than the concentrations of nitrogen and potassium found in average domestic wastewater (Metcalf & Eddy, 1991). Care should be taken that the leachate does not enter any water bodies, as this would potentially decrease the quality of the water.

The fact that the nutrient concentrations were higher than those in the average untreated domestic wastewater goes along with what is found in literature about dry toilet leachate being very concentrated in nutrients. Because it is so nutrient rich, it will aid in the process of composting as a source of nitrogen, phosphorus and potassium. The amount of leachate added to the compost will depend on the characteristics of the compost since the composting process depends on the balance of carbon and nitrogen, as well as sufficient moisture and aeration (Jenkins, 1999) . The leachate can also be diluted and used as a garden fertilizer in one’s own garden once it is old enough, varying from one to two years depending on the temperature it is kept in and how it is stored. The usage of humus from sanitation waste for fertilizing commercial products is prohibited by Finnish law. Future analysis on how to make fertilizers from human waste safe enough for commercial purposes is needed.

The leachate can be home to certain pathogens, which are disease carrying microorganisms. Pathogens in the leachate are those which are likely to be found in domestic wastewater as well, normally originating from human faeces. (George, 2008). Bacteria in faeces such as *Escherichia coli, Vibrio cholera* and *Salmonella typhi* can cause diseases of the gastrointestinal tract, such as typhoid and paratyphoid fever, dysentery, diarrhea and cholera. In Finland there is little risk to contract these diseases as they tend to exist in warmer climates. However, certain pathogens such as whipworms and ringworms are present worldwide. The best way to eliminate pathogens in composting is to use time and high temperatures, between 37˚C and 50 ˚C. (Jenkins, 1999).

It is not recommended for the leachate to be used directly on crops due to the pathogens it may contain. Different pathogens can survive on the surfaces of vegetables for several months (Jenkins, 1999), so it is recommended for the leachate to be properly composted before it is used for agriculture, or then used solely as fertilizers for non-consumable plants. Adding the leachate to the compost will speed up biological activity in it, aiding in making the compost turn into fertilizer faster. Consequently the composting activity will raise the temperature, eliminating dangerous pathogens.

6. CONCLUSION

In this work the concentrations of the nutrients in the leachate were on average 1 628 mg/L for nitrogen, 6mg/L for phosphorus and 62 mg/L for potassium. Comparing the values obtained from the analysis to values found in untreated domestic wastewater, it can be seen that nitrogen concentrations in the leachate were around 19 times higher, and potassium concentrations 4 times higher than those found in untreated domestic wastewater. The phosphorus concentrations were within the range found in literature and the MLSS, 19 mg/L was close to the range for suspended solids found in untreated domestic waste water.

Nitrogen values in urine have been found to range between 1 790 mg/L and 8 200 mg/L depending on the individual’s diet (Huussi ry, 2013). The leachate from the dry toilets of Nekala had nitrogen concentration of 1 628 mg/L, which means that the nitrogen concentration of the leachate is almost similar to the lowest value of the nitrogen concentration in urine. Dry toilet compost was found to have a nitrogen concentration of

14 600 mg/kg (Chernyaev, Pylvänäinen & Taipale, 2014). The leachate from Nekala had a much smaller nitrogen concentration than that of the dry compost. This could be due to nitrogen concentrations in the dry toilet compost decreasing as the compost matured due to decreasing ammonium levels.

Since the leachate was six months old when the analysis was done, it is possible that evaporation changed the concentrations of nutrients. It is also possible that some of the nutrients were in solid form and remained attached to the canister in which the leachate was stored in. There is also a possibility that the solids filtered during the pretreament phase contained some insoluble nitrogen, phosphorus or potassium compounds, which were then filtered and could not be analysed. These are factors that should be taken into account, and it is recommended that future analysis be made on more fresh leachate.

Future analysis should also be made on the pathogen types in the leachate. Pathogens are known to exist in sanitary waste throughout the world and their presence make it unfavourable for fresh leachate to be used as a fertilizer on crops due to the possible spread of disease. When the leachate is added to a compost, the heat produced (over 37˚C) over a period of time is sufficient to eliminate harmful pathogens. The period of time varies according to the temperature present in the compost pile, but in colder climates such as in Finland, it is recommended for the compost containing human waste to compost for at least one year before it is safe to be used on one’s crops.

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APPENDICES

APPENDIX 1. Total Kjehdahl nitrogen data

Sample	H2SO4	c of H2S04V of total N	V sample	c of N				
B 50 ml #1	0,084	0,5	50	-1,68	V Blank	Max	11561,76	S 25 ml#2
B 50 ml #2	0,088	0,5	50	-0,56	0,09	Min	27,104	S 25 ml#1
B 50 ml #3	0,086	0,5	50	-1,12	0,09			
B 25 ml #1	0,1	0,5	25	5,6	0,09	Max 2	2562,56	S 25 ml #3
B 25 ml #2	0,084	0,5	25	-3,36	0,09	Min 2	1134,56	S 50 ml
B 25 ml #3	0,086	0,5	25	-2,24	0,09			
S 50 ml #1	4,88	0,5	50	1341,2	0,09	Average 50 ml		1290,333
S 50 ml #2	5,106	0,5	50	1404,48	0,09	Average 25 ml		1965,152
S 50 ml #3	4,142	0,5	50	1134,56	0,09			
S 50 ml #4	5,092	0,5	50	1400,56	0,09			
S 50 ml #5	4,288	0,5	50	1175,44	0,09			
S 50 ml #6	4,682	0,5	50	1285,76	0,09			
S 25 ml #1	0,574	0,05	25	27,104	0,09			
S 25 ml #2	206,55	0,05	25	11561,76	0,09			
S 25 ml #3	4,666	0,5	25	2562,56	0,09			
S 25 ml #4	3,628	0,5	25	1981,28	0,09			
S 25 ml #5	3,382	0,5	25	1843,52	0,09			
S 25 ml #6	3,268	0,5	25	1779,68	0,09			
S 25 ml #7	0,48	0,5	25	218,4	0,09			
S 25 ml #8	2,962	0,5	25	1658,72	0,09			

APPENDIX 2. Orthophosphate and total phosphorus results

	mg/L	n	mP	mP mg	PO4	P	O4	Avg
0,0203	20,3	0,00021379	0,006621717	6,621717	94,953	30,973	63,96	6,366199
0,02	20	0,000210631	0,006523859	6,523859				
0,0197	19,7	0,000207471	0,006426001	6,426001				
0,0208	20,8	0,000219056	0,006784814	6,784814				
0,0147	14,7	0,000154813	0,004795036	4,795036				
0,0216	21,6	0,000227481	0,007045768	7,045768				
0,0001	0,1	1,05315E-06	3,26193E-05	0,032619				
0,0001	0,1	1,05315E-06	3,26193E-05	0,032619				
0,0001	0,1	1,05315E-06	3,26193E-05	0,032619				

APPENDIX 3. Photographs of the Nekala allotment garden's dry toilets.

Photograph source: Taavi Seppälä, 2014

Photograph 1 A dry toilet from Nekala with the Green Toilet 330 and ventilation pipe in sight

Photograph 2 Canisters in which the dry toilet leachate is directed

Photograph 3 A Nekala dry toilet from inside