EU-SIDA GTZ EcoSan Promotion Project

Final sampling report for products from double-chamber UDDTs

(Faeces and urine)

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Summary

Kenya, as many other African countries, is confronted with serious problems in sanitation, water and food security. Urine diverting dehydrating toilets (UDDTs) recognized wastewater as sustainable source for fertilizing in agriculture and operate without water and are therefore a practical solution in areas with inadequate sewage disposal and limited amount of water.

To ensure a most effective treatment and reuse of the wastewater it is separated in two different streams (urine and faeces). The faecal waste is stored for a period of time under conditions that are intended to promote thermophilic microbial decomposition or desiccation for inactivation of faecal pathogens. As poor quality of the UDDT products have negative impacts on human health and the environment this study analysed microbiological quality and physicochemical parameters of faeces and urine from five households and one school frequently over a period of three month. The purpose of this study was to determine the amount of pathogen over time to observe if sufficient pathogen deactivation occurs during the six month of storage time and if the results fulfill the recommendations given by the WHO.

Methodology

Combined and mixed samples of 50 to 100g from different sites in the faeces heap were taken. Urine was taken directly from the storage container after stirring the urine inside the container. All samples are transported in sterile polyethylene containers which were stored in a cooled ice box and analysed for faecal coliforms within six hours after sampling.

The microbiological analysis was carried out in accordance with the Manual of Parasitological and Bacteriological Techniques (WHO, 1996). For the determination of faecal coliforms the MPN (most probable number) method with A1 medium was used. Five aliquots of each of three dilutions were examined to ensure a better estimate of faecal coliform counts. The helminth eggs concentrations were estimated using the Bailenger method where zinc sulphate is used for floating the eggs to the surface. For examination a microscope (10x or 40x magnification) and a McMaster Slide was used.

The soil moisture content is expressed by using dry weight measurements as percentage of wet weights. Therefore around 10 g composite sample is put in a drying oven for 24 hours at 105 ºC and weighed before and afterwards.

For the solid samples from the UDDTs pH is measured by adding distilled water until it is possible to measure a standard pH probe. For the urine sample the pH meter was placed directly in the sample.

Ambient temperature outside was measured outside the chamber while the ambient temperature in the chamber was measured outside the heap but inside the chamber as the door was closed. The temperature inside the heap was measured by placing the thermometer in the middle of the faeces pile.

For nutrients determination in the urine a photometric method was used were the concentration is estimated by using the light absorbance of the sample solution with a spectrophotometer. The method used for total phosphorous and ammonium-nitrogen determination was according to the manual of standard methods for the examination of water and wastewater (APHA, 1995).

Laboratory results

The table below shows the arithmetic mean and the median values for the 30 faecal samples of five households and one school taken frequently within the sampling period of three month. Furthermore it shows the recommendation for storage treatment of dry excreta before use at the household levels without adding new material.

Table 1: Summary of results for faeces samples (average and median values, n=30) and WHO recommendations

Parameter	**Unit**	**Average values (faeces)**	**Median values (faeces)**	**Recommendations WHO Guidelines** (Source: WHO Guidelines Executive Summary)
Ambient Temperature (outside)	**°C**	**25**	**25**	**-**
Ambient Temperature (in chamber)	**°C**	**25**	**25**	**> 20 – 35** (if storage >1year) **> 35** (if storage >6 month)
Temperature in heap	**°C**	**24**	**24**	**-**
pH		**9.95**	**9.99**	**> 9.00**

Moisture	**%**	**40.91**	**39.19**	**< 25 %** Comment: wetter material will prolong the time for absolute elimination of pathogens
Helminth Eggs	**eggs/ g**	**-**	**0**	**≤ 1**
FC	**MPN/g**	**-**	**0**	**< 1000**

The ambient temperature in the chamber in most cases is higher than the temperature inside the faeces pile. The difference in temperature between the chamber and the faeces pile can be related to variety of sun-exposure of the chambers and the outside ambient air temperature. This results disobey the recommendation of the WHO guidelines which require a temperature >35 °C for a storage time >6 month.

pH is in a range of 9.46 to 10.54 with an arithmetic mean of 9.95. Hence alkaline this is due to the fact that ash is used as additive. All samples meet the terms of a pH >9 which is required by the WHO guidelines for the alkaline treatment and the storage duration of >6 month of dry faeces at household levels.

There is a broad range from 16.21% to 89.86% moisture content. The extreme values can be explained as there was a broken chamber door frame which was damaged by termites hence rainwater got inside. Where moisture content was low the users added high amounts of ash furthermore the pile was small. For the other households the moisture content is in a range of 23.53 % to 66.05 % and the mean is 40.05% which is within the ideal range for aerobic biodegradation (40 to 60 %) (REDLINGER et al., 2001). The WHO recommendation for the storage time of six month requires moisture contents <25%.

In the beginning of the sampling period for three samples the amounts of coliforms were beyond the determination limit of the method thus the number is given as more than 1800 MPN/g. Faecal coliforms were high in the beginning but after the fourth sampling the numbers were under the determination limit of the method. The limits for FC according the WHO guidelines is <1000/g. Thus in the end of the sampling period this criteria was fulfilled for all sampled households.

In only one household the faecal samples were not containing helminth eggs while the other samples were all having eggs. The highest was 72 eggs/g sample and the lowest with 7 eggs/g as helminth eggs are less affected by biodegradation and desiccation and survive for a longer time (REDLINGER et al., 2001) it is very important to investigate their reduction.

For two households in Mumias a reduction of eggs up to 0/g was already shown after five samplings. The WHO safety guidelines for faecal material which is used for agricultural purpose is <1 helminth egg/g.

The table below shows the results (arithmetic mean and median) for the 30 urine samples taken frequently from three households and one school over a period of three month.

Table 2: Summary of results for urine samples (average and median values, n=30) and WHO recommendations for microbiological parameters

Parameter	Unit	Average values (urine)	Median values (urine)	Recommendations WHO Guidelines (Source: WHO Guidelines)
pH		**9.14**	**9.17**	**-**
TP	**mg/L**	**151**	**168**	**-**
NH_4	**mg/L**	**2678**	**2207**	**-**
Helminth Eggs	**eggs/L**	**-**	**0**	**< 1**
FC	**MPN/100ml**	**-**	**70**	**< 1000**

The pH in the urine samples range 8.36 to 9.80 so it is alkaline which will benefit the reduction of bacteria but might have a negative effect on plants. For total phosphorous the concentrations range from 21 mg/l to 251 mg/l with a mean of 151 mg/l for all collected urine samples. For ammonium nitrogen the concentrations range from 109 mg/l to 7406 mg/l with a mean of 2678 mg/l.

The urine samples from the household lacked eggs but were positive for faecal coliforms with a maximum of 430 MPN/100ml. This might be due to an infection of the users, a contamination of the urine channel (cross-contamination) and/or contamination of the urine storage container. High counts for helminth eggs with a maximum of 720 eggs/L and the maximum for faecal coliforms of 500 MPN/ 100ml in the urine samples of the school are very worrying as the urine is used directly without further treatment. The WHO safety guidelines have a limit of ≤1 egg/L.

Questionnaire

The amount of users ranged from 5 to 25 persons per UDDT with a median size of 15 people. Households reported using the toilet for 1 month up to 1 year.

The storage time for the biosolids collected in one chamber ranged from 1 month to 12 month (still in use up to sampling day) according to the report of the household. For urine it ranges from 1 to 7 days.

All users have ash as an additive because it is easy for them to get as they cook with firewood. All households visited reported that they use the urine for agricultural purpose around their home. Main crops which urine was used for fertilizing were maize, bananas, kales and mangos. Only the school has not yet reused the urine but it is fetched by a neighboring farmer. Dried faeces have not been used by any sampled households and school as the toilets are not long enough in use or the necessary drying time was not yet achieved.

There was a good overall satisfaction with the UDDT toilets, the main problems concerning the use were, blocked urine pipes and less amount of ash used. It was observed that there is a good knowledge about the use of UDDTs in most of the households. But there is a general lack of knowledge about the danger of pathogens in the dried faeces as observed people trust the products very much which could be a problem as they might not wait for the necessary storage time before reuse.

From the six sampling sides only in three households the hand wash facility was in use. Main problems were broken taps, tank stolen and no water. All interviewed people said there is water available throughout but as the tank is connected to a rain pipe of the toilet people hesitate to fill the tank. Hence there is still a lack of awareness about the importance of hand washing. Five of the sampling sites get their water from boreholes and only one household owner stated that water is coming from the river.

Conclusion and recommendation

According to the results it is shown that microbial inactivation takes place if temperature, pH, moisture and the length of storage time is obtained. Furthermore it is proved that the collected urine is rich in nutrients with average values of 151 mg/L total phosphorus and 2678 mg/L ammonium nitrogen and hence can help to increase crop production if used in agriculture.

Nevertheless there are also households where helminth egg concentrations are very high with a maximum of 304 eggs/g. Also the pathogens in urine with a maximum of 720 eggs/L and 500 MPN/L show that there is a problem concerning the proper use of the UDDTs.

As the new WHO guidelines promote the concept of health-based targets meaning they allow the use of excreta or wastewater which is not yet fully treated if the health risk can be reduced using a combination of risk-reducing options for example proceedings taken in agricultural practice and finally at the level of the consumer.

There is an urgent demand of support and training considering use, treatment, crop restriction, waste application and human exposer control to reduce the risk and maximizing the benefit for the users. Furthermore health and hygiene promotion is also required as there is a lack of awareness like handwashing after the toilet use. If the methods of combined risk reduction are applied by the users the products of the sampled UDDTs are safe to use for agricultural purpose.

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Abbreviations & Acronyms

Ecosan	Ecological sanitation
FC	Faecal Coliforms
MDG	Millennium Development Goals
MPN	Most Probable Number
TP	Total Phosphorus
UDDT	Urine Diverting Dehydrating Toilet
WHO	World Health Organization

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1. Introduction

2.6 billion people worldwide do not have access to any type of improved sanitation. Reducing these numbers by half, by the year 2015, is currently the focus of international efforts as part of the Millennium Development Goals (MDGs). Kenya, like many other African countries, is confronted by serious problems in sanitation, water and food security. Ecological sanitation offers an alternative to conventional sanitation and avoids its disadvantages like high costs and high water consumption. It is different from conventional approaches: human excreta, urine and greywater from households are recognised as a resource which should be reused mainly for irrigation and fertilizing in agriculture. Therefore waste water is separated in different streams (urine, faeces and greywater) to ensure most effective treatment and reuse.

To provide food for a growing world population it is necessary to enhance soil fertility and to enlarge irrigated farm land without tightening the water crisis. Therefore water resource development and providing organic fertilizer is crucial for food security and sustainable agricultural production. After pathogen reduction, human faeces and urine provide a low cost soil conditioner for agricultural use as they contain all nutrients essential for crops. For that reason recycling of nutrients from urine and faeces is one of the key benefits of ecosan.

2. Purpose of this study

Urine diverting dehydrating toilets (UDDTs) store faecal waste for a period of time under conditions that are intended to promote thermophilic microbial decomposition or desiccation for inactivation of faecal pathogens. The by the EcoSan Promotion Project (EPP) implemented toilets use a double vault system. When the first chamber has been filled, the faecal waste is allowed to stand for the period required for the second chamber to fill (approximately 6 month). Though the products from the UDDTs (faeces and urine) should be used as a fertilizer, it is fundamental to assess their microbiological quality, as poor quality has negative impacts on human health and the environment. Therefore the following microbiological and physicochemical parameters were analysed and compared to the WHO recommendations and safety guidelines (Table 3):

- Faecal coliforms
- Helminth Eggs
- Temperature: T (°C)
- pH
- moisture
- Nutrients for urine: TP(mg/l), NH_4-N (mg/l)

Table 3: Safety guidelines and recommendation for storage treatment of dry excreta and faecal sludge before use at the household and municipal levels without adding new material (Source: WHO Guideline Executive Summary)

	Helminth eggs (no. per gm total solids or per Liter)	*E. coli* (no. per 100 mL)
treated faeces and faecal sludge	<1/g total solids	<1000/g total solids
greywater for use in restricted irrigation	<1/Liter	$< 10^5$ (a) relaxed to $< 10^6$ when exposure is limited or re-growth is likely
greywater for use in unrestricted irrigation of crops eaten raw	<1/Liter	$< 10^3$ relaxed to $< 10^4$ for high-growing leaf crops or drip irrigation

(a)These values are acceptable due to the regrowth potential of E. coli and other faecal coliforms in greywater.

Treatment	Duration	Comment
Storage; ambient temperature 2–20°C	1.5–2 years	will eliminate bacterial pathogens; regrowth of *E. coli* and *Salmonella* may need to be considered if rewetted; will reduce viruses and parasitic protozoa below risk levels. Some soil-borne ova may persist in low numbers.
Storage; ambient temperature >20–35 °C	>1 year	substantial to total inactivation of viruses, bacteria and protozoa; inactivation of schistosome eggs (<1 month); inactivation of nematode (roundworm) eggs, e.g. hookworm (*Ancylostoma/Necator*) and whipworm (*Trichuris*); survival of a certain percentage (10–30%) of *Ascaris* eggs (≥4 months), whereas a more or less complete inactivation of *Ascaris* eggs will occur within 1 year.
Alkaline treatment: pH >9	>6 months	if temperature >35 °C and moisture <25%, lower pH and/or wetter material will prolong the time for absolute elimination.

3. Sampling

Sampling period:

15.12.2009 – 31.3.2010

3.1 Sampling sites

Total of 24 faeces and 24 urine samples were taken since the first sampling. The samples were taken from five UDDTs in households and one in a primary school. Three of the chosen sampling sites were in Western Province of Kenya, near Mumias and the other three were in Nyanza, near Ugunja.

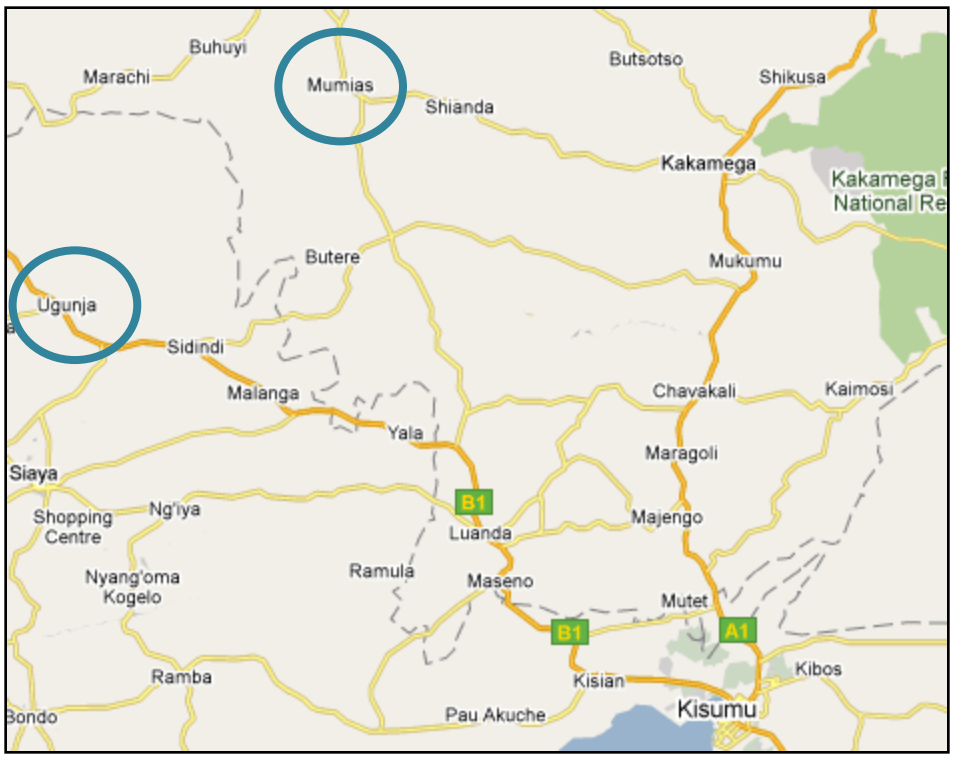

Figure 1: Map of sampling area

The three households in Western Province have not yet stopped using the first chamber but they stopped from the first sampling date so during the sampling period the changing of parameter for the first three month can be documented. For Nyanza Province one household had already stopped using the first chamber for three month so the monitoring is up to the end of storage time of six month. The school in Nyanza stopped using the second chamber three weeks ago due to Christmas holidays. All users were told to stop using the sampling chamber for the time of the sampling period. A new household was chosen for Ugunja from the sixth sampling as there were heavy rains and too much water was going into the sampling chamber of the old household as the door frame was destroyed.

3.2 Sample procedure

The day before sampling the sites were visited to interview the head of each household in order to collect information on demographics, water supply, toilet use and maintenance behaviour (see results questionnaire).

Figure 2: Sampling of household UDDT in Mumias

In the morning of the sampling day, combined and mixed samples of 50 to 100g from 5 different sites in the faeces heap were taken. Urine was taken directly from the storage container after stirring the urine inside the container. All samples are transported in sterile polyethylene containers which were stored in a cooled ice box and analysed for faecal coliforms within 6 hours after sampling.

In the laboratory samples were stored in the fridge and all parameters were measured within 48 hours. Analyses have been carried out at the laboratory of the Biological Sciences Department at Egerton University- Njoro, Kenya. Contact person is Dr. Steve Omondi (Mobile: +254721831059).

4. Material and Methods

4.1 Microbiological analysis

The microbiological analysis was carried out in accordance with the Manual of Parasitological and Bacteriological Techniques published by the World Health Organisation, 1996 (WHO, 1996).

Preparation:

For the faecal coliforms 1g of the faecal material was suspended in 10ml of sterile potassium phosphate buffer (10% suspension) and for the Helminth eggs 2.5g were suspended in 250 ml of the buffer. With the help of a vortex mixer, the suspension is homogenized.

4.1.1 Faecal coliforms

MPN method

MPN (most probable number) counts are statistically the best estimates obtained by culturing a number (usually five) of sample volumes and/or dilutions of such samples. In the MPN method used, five 1ml aliquots of each of three dilutions were examined, so that a better estimate of faecal coliform numbers was obtained.

The Medium used was dispensed in 5ml quantities into test-tubes each of which contains an inverted Durham tube. The test-tubes were closed with a screw cab and then sterilized. During sterilization, the air in the Durham tube is expelled and it becomes completely full of medium.

Consumables

- Non-absorbent cotton wool
- Lactose
- Tryptone
- Salicin
- NaCl
- Triton X-100
- Distilled water
- Ethanol
- Sterile laboratory gloves
- Aluminium foil

Equipment

- 100ml screw-capped bottles
- Test-tubes (100 mm × 12 mm) or half-ounce (14ml) screw-capped bottles
- 1ml serological “blow-out” pipettes
- Bunsen burner
- Test-tube rack
- Incubator
- Autoclave or pressure cooker
- Balance (± 0.01 g)

Procedure:

Using a sterile pipette, 1.0ml of the suspension was transferred to a test tube containing 9ml of quarter strength Ringer's solution and shaken vigorously. One millilitre of this suspension contained 0.01g of the original sample (1:10 dilution). The dilution procedure was repeated to dilute the sample to 1:100. Afterwards by using a fresh sterile 1ml pipette, 1ml of the 1:100 dilutions was added to each of the five sterile test tubes. Using the same pipette 1ml of the 1:10 dilution was added to each of the second set of five test-tubes. Again using the same pipette, 1ml of the undiluted sample to each of the third set of five test-tubes was added.

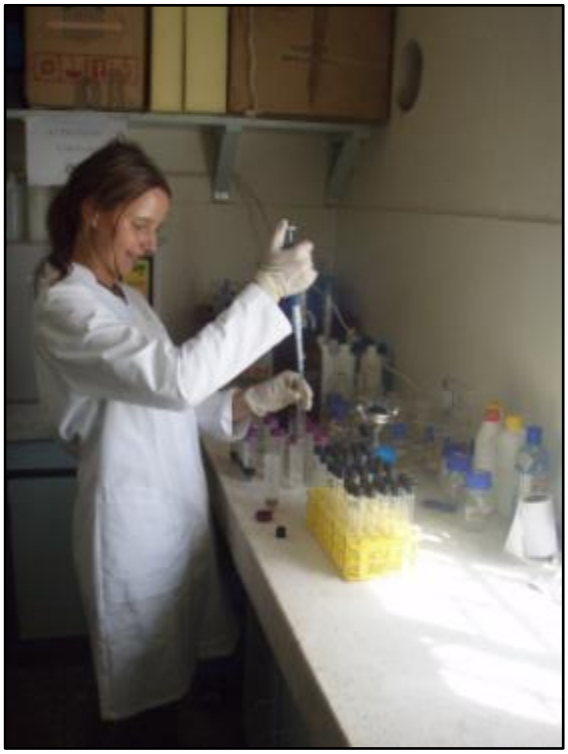

Figure 3: Preparation for MPN method

The 15 tubes were put in a rack and transferred to an incubator maintained at 44°C.

Figure 4: Incubator with test tubes

After incubation for 24hrs, the numbers of positive tubes (those with gas production) at each dilution were counted and from this the faecal coliform MPN was determined with the help of table 16.

Figure 5: After incubation at 44°C for 24 h, four of the five tubes show gas production

4.1.2 Helminth eggs

The modified Bailenger method

The main advantages of this method are that, it requires relatively inexpensive reagents and covers the full range of species routinely found in wastewater.

Reagents

- Zinc sulphate solution (33%, relative density 1.18)
- Ethyl acetate
- Sodium acetate trihydrate
- Glacial acetic acid
- Detergent solution

Equipment

- Plastic containers for sample collection
- Centrifuge
- Centrifuge Tubes
- Pasteur pipettes
- Mc Master counting slide
- Vortex mixer
- Siphon
- 10ml measuring cylinder

50ml of sample suspension was sedimented for 1-2 hours afterwards 90% of supernatant was removed and the sediment was carefully transferred to the centrifuge tube. The sample was centrifuged at 1000g for 15 minutes and then the supernatant was removed. The pellet was suspended in an equal volume of acetocetic buffer and two volumes of ethyl acetate were added. After mixing the solution with the vortex mixer, the sample was centrifuged again for 15 min at 1000g. The sample now is separated in three distinct phases. All the non-fatty, heavier debris, including helminth eggs, larvae and protozoa will be in the bottom layer, the rest was poured and the pellet including the eggs was resuspended in five volumes of zinc sulphate solution. The sample was mixed and put into a McMaster slide for examination. After waiting for 5 minutes the eggs float to the surface and can be examined under the microscope (10x or 40x magnification).

Figure 6: Helminth eggs examination under the microscope

4.2 Physicochemical parameters

4.2.1 Temperature and pH

Ambient temperature outside was measured outside the chamber while the ambient temperature in the chamber was measured outside the heap but inside the chamber while the door was closed. The temperature inside the heap was measured by placing the thermometer in the middle of the faeces pile.

Figure 7: Thermometer in faeces pile

For the solid samples from the UDDTs, pH was measured by adding distilled water until it was possible to measure with a standard pH probe. For the urine sample the pH meter was placed directly in the sample.

Figure 8: pH meter for measuring pH in urine sample

4.2.2 Moisture

The soil moisture content was expressed by using dry weight measurements as percentage of wet weights. Therefore around 10 g composite sample was put in a drying oven for 24 hours at 105 ºC and weighed before and afterwards.

Material

- Oven with 100 –110 ºC temperature
- Balance of precision of ±0.001 g.
- Weigh tins

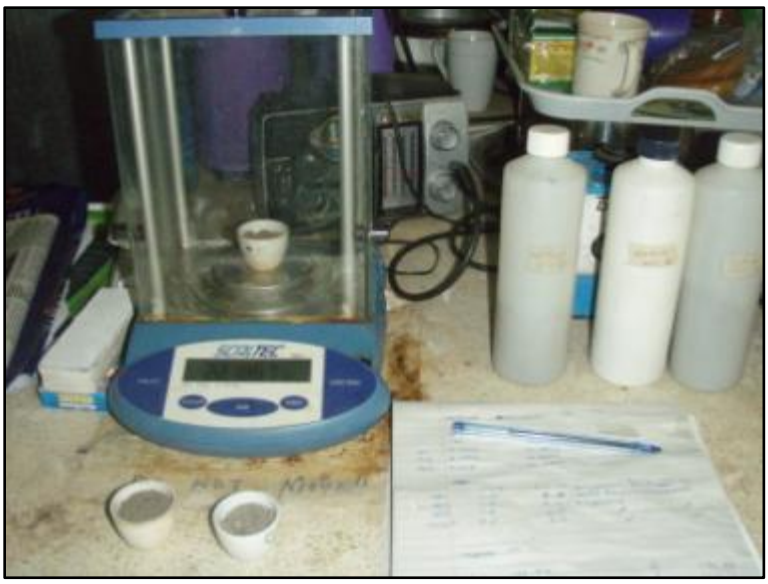

Figure 9: Balance for moisture determination

4.2.3 Nutrients

Photometry is a method of estimating concentrations by using the light absorbance of the sample solution. The sample absorbance was determined with a spectrophotometer where the sample was placed in a cuvette and then penetrated by monochromatic light. Monochromatic light is light of a separated wavelength for example 578 nm. The light beam is partly absorbed by the substances in the solution hence the intensity of the emergent light is lower than that of the incident light. The reduced radiation is measured by a detector. Thus the light absorption can be determinate and this is related to the concentration of the absorbent material in the solution. This relation is shown with a calibration curve where the extinction of standard series of known concentrations is measured and plotted against concentration on a millimetre graph paper. The concentration of the sample is then estimated graphically through linear regression.

Figure 10: Spectrophotometer for nutrient determination

Blanks and references:

To consider the impurities of glassware and reagents it is important to use blanks to get a correction factor. Blanks are only containing distilled water and all the used reagents but no sample. The light extinction of the blanks was measured and then the extinction of the sample was corrected by this value. Only distilled water is used as reference which is taken as the zero value.

Material:

- Spectrophotometer

- Filtration unit

- Glass-fibre filters

- Reagents

To avoid particle interference wastewater samples were diluted. Analyses have to be done as soon as possible and the samples were stored in the fridge (4°C in the dark). Glassware which was used for the analyses were washed with 10 % sulphuric acid (H_2SO_4) and rinsed with distilled water.

Total Phosphorus (TP)

To measure TP unfiltered samples were used. TP was measured via the ascorbic acid method (APHA, 1995). It is necessary to reduce the phosphorus in the water samples into free ortho-phosphate (SRP) by using persulphate digestion.

Standard calibration curve:

For the calibration curve 5.623g of dried (24h, 70 °C) potassium hydrogen phosphate (K2HPO4) salt was dissolved in 1 litre of distilled water to get a stock solution with a concentration of 1 g/l. 10ml of this stock solution were diluted furthermore to 1 litre with distilled water to get an intermediate solution of 10 mg/l. To get a working solution with a concentration of 0.5 mg/l, 25 ml intermediate solution were diluted to 500 ml with distilled water. The standard series was prepared by taking the volumes shown on the table below. Triplicate samples were taken for each concentration.

Conc. (mg/l)	0.00	0.01	0.02	0.05	0.10	0.20	0.40	0.50
Working solution (ml)	0.0	0.5	1.0	2.5	5.0	10.0	20.0	25.0
Vol.dist. water (ml)	25.0	24.5	24.0	22.5	20.0	15.0	5.0	0.0

The standard solutions used for the TP calibration curve have to undergo the persulphate digestion first before measured.

Reagents:

A) Ammonium molybdate solution: 15 g (NH4)6MO7O24 x 4 H2O) in 500 ml distilled water

B) Sulphuric acid: 140 ml concentrated sulphuric acid is diluted up to 1000 ml with distilled water

C) Ascorbic acid: 2.7 g ascorbic acid is dissolved in 50 ml distilled water. This is freshly prepared since the acidic solution is highly unstable and must be used within 24 hrs.

D) Potassium-Antimonyltartrate-Solution: 0.34 g K-Antimonyltartrate is dissolved in 250 ml distilled water

E) Potassium persulphate K2S2O8

Procedure:

For the persulphate solution 12g of $K_2S_2O_8$ was dissolved in 100 ml of distilled water under heating for about half an hour. 1 ml of this solution was added to 25 ml of all samples. Afterwards the weight of all bottles was noted then the bottles were closed (not too tightly) and autoclaved for 90 minutes (120 °C, 1.2 atm.). Further on the bottles were weighed again after cooling and the amount of water lost through evaporation was replaced by distilled water. The four reagents (A,B,C,D) were mixed according to these ratios:

A: B: C: D = 2: 5: 2: 1

To 25 ml of each filtered samples 2.5 ml of the mixed reagents were added and after 15 minutes the absorbance of the samples was measured at a wavelength of 885 nm with distilled water as a reference.

Ammonium- nitrogen (NH_4-N):

For the standard calibration curve ammonium chloride (NH_4Cl) with molecular weight of 53.492g was dissolved in 250 ml distilled water to get a solution with a concentration of 1 g/l. 10 ml of this dilution was diluted with distilled water to 1 litre to get a concentration of 10 mg/l. By taking 25 ml of this solution and diluting it up to 1 litre a concentration of 0.25 mg/l was achieved. To get the standard series the volumes of the table below were used. Triplicate samples for each concentration were used to determine the calibration curve.

Conc. (mg/l)	0.00	0.01	0.02	0.05	0.10	0.25
Working solution (ml)	0.0	10	2.0	5.0	10.0	25.0
Vol.dist. water (ml)	25.0	24.0	23.0	20.0	15.0	0.0

Reagents

A) Sodium salicylate solution:

130 g of sodium salicylate and 130 g of trisodium–dihydrate were mixed in 800 ml of distilled water. 0.97 g of sodium nitroprussid was then added to this solution. The solution was filled up to 1000 ml using distilled water. This solution has a bench life of two months.

B) Hypochlorid solution

0.2 g of sodium dichloroisocynurate which should always be freshly prepared was added and mixed with 100 ml of NaOH solution. The NaOH solution, made by dissolving 32 g NaOH in 1000 ml distilled water can be prepared in advance because it has a bench life of two months.

Procedure:

2.5 ml of reagent A were added to 25 ml of the urine samples, followed immediately by adding reagent B. After this the samples were placed in the dark at a temperature of 25°C for 90 minutes. The absorbance was determined at a wavelength of 655 nm.

5. Results and Discussion

5.1 Dried faeces

Figure 11: Sampling of dried faeces

5.1.1 Temperature

Temperature is a crucial parameter to determine if any kind of biodegradation is taking place in the drying chamber of the UDDT as microbiological activities are strongly influenced by temperature. It is as well an important indicator of the drying process.

Table 4: Ambient temperature outside

Sample	Area	sampling 1 T [°C]	sampling 2 T [°C]	sampling 3 T [°C]	sampling 4 T [°C]	sampling 5 T [°C]	sampling 6 T [°C]	sampling 7 T [°C]	sampling 8 T [°C]	sampling 9 T [°C]	sampling 10 T [°C]
HH1	Mumias (Western)	-		25		20		24		22	
HH2	Mumias (Western)	-		28		21		26		25	
HH3	Mumias (Western)	-		26		21		25		23	
HH4	Ugunja (Nyanza)		-		35						

HH4new	Ugunja (Nyanza)		-				23		23		24
HH5	Ugunja (Nyanza)		-		35		28		28		28
SCHOOL	Ugunja (Nyanza)		-		29		23		21		26

Table 5: Results ambient temperature inside the chamber

Sample	Area	sampling 1 T [°C]	sampling 2 T [°C]	sampling 3 T [°C]	sampling 4 T [°C]	sampling 5 T [°C]	sampling 6 T [°C]	sampling 7 T [°C]	sampling 8 T [°C]	sampling 9 T [°C]	sampling 10 T [°C]
HH1	Mumias (Western)	22		28		21		22		22	
HH2	Mumias (Western)	33		29		22		27		25	
HH3	Mumias (Western)	32		23		22		23		23	
HH4	Ugunja (Nyanza)		25		36						
HH4new	Ugunja (Nyanza)						23		23		25
HH5	Ugunja (Nyanza)		28		34		28		27		25
SCHOOL	Ugunja (Nyanza)		25		24		22		21		22

Table 6: Temperature in the heap

Sample	Area	sampling 1 T [°C]	sampling 2 T [°C]	sampling 3 T [°C]	sampling 4 T [°C]	sampling 5 T [°C]	sampling 6 T [°C]	sampling 7 T [°C]	sampling 8 T [°C]	sampling 9 T [°C]	sampling 10 T [°C]
HH1	Mumias (Western)	24		26		20		23		22	
HH2	Mumias (Western)	23		26		22		25		25	

HH3	Mumias (Western)	22		25		23		24		24	
HH4	Ugunja (Nyanza)		25		36						
HH4new	Ugunja (Nyanza)						25		24		22
HH5	Ugunja (Nyanza)		30		29		26		28		25
SCHOOL	Ugunja (Nyanza)		30		24		23.5		22		25

Table 7: Mean maximum, minimum values for temperature

	Ambient Temperature outside [°C]	Ambient Temperature in chamber [°C]	Temperature in heap [°C]
MEAN	**25**	**25**	**24**
MAX	**35**	**36**	**30**
MIN	**20**	**21**	**20**

The ambient temperature outside the chamber is in a range of 20 to 35 °C and almost the same like the ambient temperature in the chamber (21 to 36°C). The ambient temperature in the chamber in most cases is higher than the temperature inside the faeces pile. The difference in temperature between the chamber and the faeces pile can be related to variety of sun-exposure of the chambers and the outside ambient air temperature. As stated by DEL PORTO and STEINFFELD (1998) the temperature inside a composting pile increases due to microbic aerobic metabolism and might reach 70°C. However in this study the temperature of the heap was mainly equal to the ambient temperature and never reached a temperature above 30°C. Hence the data show that there was no heat production inside the pile by thermophilic bacteria. This results disobey the recommendation of the WHO guidelines which require a temperature >35 °C for a storage time >6 month.

5.1.2 pH

The pH scale ranges from 0 to 14 with pH 7 as the neutral point. From pH 7 to 0 the sample becomes increasingly acidic and from pH 7 to 14 it is turning more alkaline (DEPARTMENT OF WATER AFFAIRS AND FORESTRY, 1996). For microbiological activities pH is an important parameter as it is toxic to pathogens if the pH is over 9.5 (EcoSanRes, 2005).

On the other side extreme values of pH can have negative effects on plants if the products of UDDTs are used in agriculture. Most effects of pH on plants are indirect through availability of certain plant nutrients and heavy metals in the soil. The majority of micro-nutrients and heavy metals are unavailable for plant uptake at high soil pH and available at lower pH levels. Therefore they can be absorbed by crops and contaminate water bodies (WHO, 2006b). Before a nutrient can be used by plants it must be dissolved in the soil solution. As it is shown in figure 12, plant nutrients generally show the highest availability in the pH range from 5.5 to 7. 0, which is also a good range for beneficial soil bacteria (CSBE, 2003). This figure also presents that nutrients such as nitrates, phosphates and potassium become less available to plants below a pH of 5. When the pH is 8 or higher, iron magnesium and zinc become less available to plants.

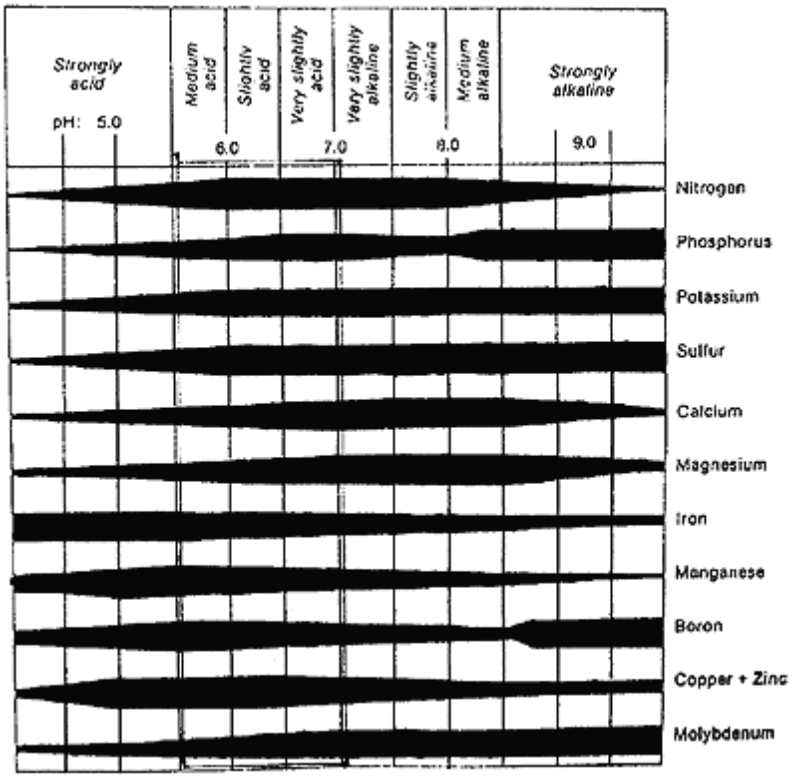

Figure 12: The effect of soil pH on availability of plant nutrients (SPRAGUE, 1964)

Table 8: pH of dried faeces

Sample	Area	sampling 1 Ph	sampling 2 pH	sampling 3 pH	sampling 4 pH	sampling 5 pH	sampling 6 pH	sampling 7 pH	sampling 8 pH	sampling 9 pH	sampling 10 pH
HH1	Mumias (Western)	9.90		9.94		9.80		10.02		9.70	
HH2	Mumias (Western)	9.58		9.99		10.02		9.72		9.65	
HH3	Mumias (Western)	9.60		10.10		9.91		9.88		9.64	
HH4	Ugunja (Nyanza)		9.46		9.67						
HH4new	Ugunja (Nyanza)						9.84		10.07		10.00
HH5	Ugunja (Nyanza)		10.00		10.02		10.06		10.21		9.82
SCHOOL	Ugunja (Nyanza)		10.35		10.54		10.32		10.31		10.24

The pH is in a range of 9.46 to 10.54 with an arithmetic mean of 9.95. Hence alkaline this is due to the fact that ash is used as additive. Hence all samples meet the terms of a pH >9 which is required by the WHO guidelines for the alkaline treatment and the storage duration of >6 month of dry faeces at household levels.

5.1.3 Moisture

Moisture is a critical parameter for the kind of biodegradation taking place in a UDDT drying chamber. When moisture is low microorganism cannot survive as there is too less water for metabolic processes, when there is enough water and oxygen, aerobic biodegrading is taking place and if oxygen levels are low but water is enough anaerobic

Table 9: Moisture content of drying faeces

Sample	Area	sampling 1 moisture [%]	sampling 2 moisture [%]	sampling 3 moisture [%]	sampling 4 moisture [%]	sampling 5 moisture [%]	sampling 6 moisture [%]	sampling 7 moisture [%]	sampling 8 moisture [%]	sampling 9 moisture [%]	sampling 10 moisture [%]
HH1	Mumias (Western)	66.05		34.49		31.33		41.13		28.73	
HH2	Mumias (Western)	54.85		39.19		23.53		30.22		24.17	
HH3	Mumias (Western)	53.44		41.02		44.92		43.04		44.13	
HH4	Ugunja (Nyanza)		89.86		85.72						
HH4new	Ugunja (Nyanza)						40.94		42.10		56.67
HH5	Ugunja (Nyanza)		50.13		34.70		27.94		26.17		56.36
SCHOOL	Ugunja (Nyanza)		19.92		27.08		34.02		16.21		19.29

There is a broad range from 16.21% to 89.86% moisture content. In all sampling sites ash was used as soak material. The high moisture content of HH1 in Ugunja can be explained by the broken chamber door frame which was damaged by termites hence rainwater got inside. In the school where moisture content was low the users added high amounts of ash furthermore the pile was small and the students stopped using the toilet already three weeks before the sampling day. This low moisture content is too low for bacteria to survive hence reduction of faecal coliforms takes place through drying and desiccation (REDLINGER et al., 2001). For the other households the moisture content is in a range of 23.53 % to 66.05 % and the mean is 40.05% which is within the ideal range for aerobic biodegradation (40 to 60 %) (REDLINGER et al., 2001). Thus there are samples exposed aerobic or anaerobic biodegradation leading also to reduction of faecal coliforms REDLINGER et al., 2001). It was expected that with prolonged storage time the moisture content reduces and biodegradation is taken over by desiccation processes. But as shown in the chart below, for the Mumias area the moisture content raised again after reduction. This is due to the fact that the rainy seasons started and during heavy rains water got into the drying chambers as the doors are not completely waterproof. The WHO recommendation for the storage time of six month requires moisture contents <25%.

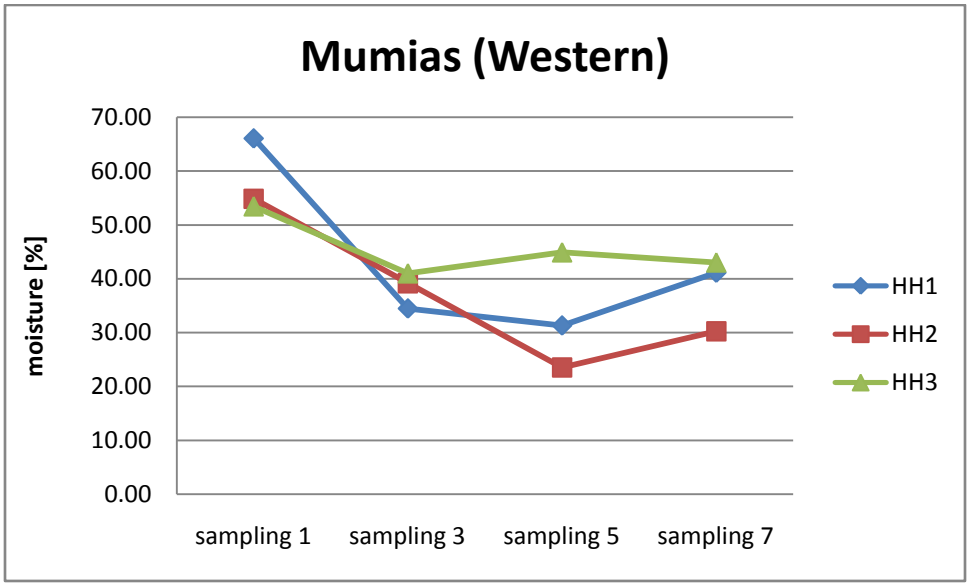

Figure 13: Moisture content Mumias (Western)

5.1.4 Faecal coliforms

The direct detection of pathogens is difficult, time-consuming and expensive. Therefore indicator organisms are commonly used to determine pathogens and faecal cross-contamination (DEPARTMENT OF WATER AND FORESTRY, 1996). Faecal coliforms are harmless and characteristic for the intestines of warm-blooded animals including humans and therefore also found in faeces (MURPHY, 2006). That is the reason why these bacteria are commonly used as an indicator for the presence of faecal pathogens and to evaluate microbial quality.

The risk of getting ill from pathogens is correlated to the concentrations of faecal coliforms in the sample, hence the higher the amount of pathogens in higher the health risk (DEPARTMENT OF WATER AND FORESTRY, 1996).

Table 10: Faecal coliforms in dried faeces

sample	area	sampling 1 FC [MPN/g]	sampling 2 FC [MPN/g]	sampling 3 FC [MPN/g]	sampling 4 FC [MPN/g]	sampling 5 FC [MPN/g]	sampling 6 FC [MPN/g]	sampling 7 FC [MPN/g]	sampling 8 FC [MPN/g]	sampling 9 FC [MPN/g]	sampling 10 FC [MPN/g]
HH1	Mumias (Western)	>1800		>1800		13		0		0	
HH2	Mumias (Western)	16		2		5		2		0	
HH3	Mumias (Western)	0		13		0		0		0	
HH4	Ugunja (Nyanza)		>1800		2						
HH4new	Ugunja (Nyanza)						0		0		0
HH5	Ugunja (Nyanza)		50		5		130		0		0
SCHOOL	Ugunja (Nyanza)		75		13		40		0		0

In the beginning of the sampling period for three samples the amounts of coliforms were beyond the determination limit of the method thus the number is given as more than 1800 MPN/g. There were two households (HH3, HH4new) were coliforms were low from the first sampling. In all other samples faecal coliforms were high but after the fourth sampling the numbers were under the determination limit of the method. The limits for FC according the WHO guidelines is <1000/g. Thus in the end of the sampling period this criteria was fulfilled for all sampled households.

As faecal coliforms are more sensitive organisms so the results might be influenced by transport time as well. Hence the low numbers of coliforms does not mean that there are not more resistant pathogens which can also cause health problems when products of UDDTS are used in agriculture.

5.1.5 Helminth eggs

Helminths are worms and the source for different infections called helminthiases. The helminth eggs are very resistant due to their shell and are discharged in the environment in faeces, they are microscopic and the main spreading of the disease is through oral faecal path (CISNEROS and RENDON, 2007).

Table 11: Helminth eggs in dried faeces

sample	area	sampling 1 Helminth Eggs [eggs/g]	sampling 2 Helminth Eggs [eggs/g]	sampling 3 Helminth Eggs [eggs/g]	sampling 4 Helminth Eggs [eggs/g]	sampling 5 Helminth Eggs [eggs/g]	sampling 6 Helminth Eggs [eggs/g]	sampling 7 Helminth Eggs [eggs/g]	sampling 8 Helminth Eggs [eggs/g]	sampling 9 Helminth Eggs [eggs/g]	sampling 10 Helminth Eggs [eggs/g]
HH1	Mumias (Western)	65		16		12		16		48	
HH2	Mumias (Western)	0		16		0		0		0	
HH3	Mumias (Western)	7		0		0		0		0	
HH4	Ugunja (Nyanza)		50		8						
HH4new	Ugunja (Nyanza)						68		72		304
HH5	Ugunja (Nyanza)		0		0		0		0		0
SCHOOL	Ugunja (Nyanza)		33		16		0		0		32

In only one household the faecal samples were not containing helminth eggs while the other samples were all having eggs. The highest was 72 eggs/g sample and the lowest with 7 eggs/g as helminth eggs are less affected by biodegradation and desiccation and survive for a longer time (REDLINGER et al., 2001) it is very important to investigate their reduction. For two households in Mumias a reduction of eggs up to 0/g was already shown after five samplings. To prove this results it would be necessary to do further samplings. The WHO safety guidelines for faecal material which is used for agricultural purpose is <1 helminth egg/g.

<u>Identified helminth eggs in faeces</u>

- Hymenolepis diminuta
- Hookworm
- Trichuris trichiura
- Enterobius vernicularis
- Ascaris lumbricoides

5.2 Urine

Figure 14: Urine sampling (Mumias)

5.2.1 pH

Table 12: pH in urine samples

Sample	Area	sampling 1 pH	sampling 2 pH]	sampling 3 pH	sampling 4 pH	sampling 5 pH	sampling 6 pH	sampling 7 pH	sampling 8 pH	sampling 9 pH	sampling 10 pH
HH1	Mumias (Western)	9.25		9.17		9.43		9.15		8.97	
HH2	Mumias (Western)	8.96		8.79		9.24		8.85		8.36	
HH3	Mumias (Western)	9.30		8.45		8.88		8.70		8.89	
HH4	Ugunja (Nyanza)		9.37		9.52						
HH4new	Ugunja (Nyanza)						9.40		8.89		8.80
HH5	Ugunja (Nyanza)		9.35		9.36		9.12		9.36		9.29
SCHOOL	Ugunja (Nyanza)		8.67		9.69		9.71		9.80		9.55

The pH in the urine samples range 8.36 to 9.80 so it is alkaline which will benefit the reduction of bacteria but might have a negative effect on plants (see under pH dried faeces).

5.2.2 Nutrients

Total phosphorus (TP (mg/l)) consists of dissolved and particulate phosphorus. Phosphorus is essential for plant growth and mined phosphates are commonly used as fertilizer to increase agricultural productivity (WHO 2006). High phosphorus levels generally are no problem for plants (US.EPA, 2004). However, phosphorus is bound to soil and therefore may accumulate especially near the soil surface where it might be easily washed in aquatic environments due to runoff and soil erosion (WHO, 2006). In aquatic environment, phosphorus leads to eutrophication, algae growth and oxygen depletion (MURPHY, 2006). Nitrifying bacteria in the humus and soil converts the ammonia in urine into nitrate ions which can be taken up by the plants (MORGAN, 2005). On the other side, high concentrations of ammonium-nitrogen may cause negative effects on crop yield and quality as well as on ground- and surface water as ammonia may turn into ammoniac which is highly toxic to aquatic life (KLEE, 1998).

Table 13: Concentration of total phosphorous in urine samples

Sample	area	sampling 1 TP [mg/L]]	sampling 2 TP [mg/L]]	sampling 3 TP [mg/L]]	sampling 4 TP [mg/L]]	sampling 5 TP [mg/L]]	sampling 6 TP [mg/L]]	sampling 7 TP [mg/L]]	sampling 8 TP [mg/L]]	sampling 9 TP [mg/L]]	sampling 10 TP [mg/L]]
HH1	Mumias (Western)	189		191		180		209		168	
HH2	Mumias (Western)	221		121		159		70		133	
HH3	Mumias (Western)	204		191		129		222		143	
HH4	Ugunja (Nyanza)		225		170						
HH4new	Ugunja (Nyanza)						195		110		66
HH5	Ugunja (Nyanza)		251		176		146		243		112
SCHOOL	Ugunja (Nyanza)		181		24		21		57		37

For total phosphorous the concentrations range from 21 mg/l to 251 mg/l with a mean of 151 mg/l for all collected urine samples.

Table 14: Ammonium nitrogen concentrations for urine samples

Sample	Area	sampling 1 NH_4 [mg/L]]	sampling 2 NH_4 [mg/L]]	sampling 3 NH_4 [mg/L]]	sampling 4 NH_4 [mg/L]]	sampling 5 NH_4 [mg/L]]	sampling 6 NH_4 [mg/L]]	sampling 7 NH_4 [mg/L]]	sampling 8 NH_4 [mg/L]]	sampling 9 NH_4 [mg/L]]	sampling 10 NH_4 [mg/L]]
HH1	Mumias (Western)	1091		7406		5104		2246		6071	
HH2	Mumias (Western)	2029		3274		2515		1153		1885	
HH3	Mumias (Western)	2207		5769		2822		986		109	
HH4	Ugunja (Nyanza)		1568		3552						
HH4new	Ugunja (Nyanza)						967		2242		2455
HH5	Ugunja (Nyanza)		1139		6419		2004		1151		6498
SCHOOL	Ugunja (Nyanza)		404		1870		4251		982		179

For ammonium nitrogen the concentrations range from 109 mg/l to 7406 mg/l with a mean of 2678 mg/l.

5.2.3 Microbiological parameters

There were only two samples of urine analysed for the microbiological parameters. One was from a household UDDT the other one from the school. Helminth eggs and faecal coliforms were determined direly in the urine samples. For the coliforms five 1ml aliquots of three dilutions were examined, so that a better estimate of faecal coliform numbers is obtained. For the eggs a volume of 250ml sample was used.

Table 15: Helminth eggs urine samples

sample	Area	sampling 1 Helminth Eggs [eggs/L]	sampling 2 Helminth Eggs [eggs/L]	sampling 3 Helminth Eggs [eggs/L]	sampling 4 Helminth Eggs [eggs/L]	sampling 5 Helminth Eggs [eggs/L]	sampling 6 Helminth Eggs [eggs/L]	sampling 7 Helminth Eggs [eggs/L]	sampling 8 Helminth Eggs [eggs/L]	sampling 9 Helminth Eggs [eggs/L]	sampling 10 Helminth Eggs [eggs/L]
HH3	Mumias (Western)	0		0		0		0		0	
SCHOOL	Ugunja (Nyanza)		0		80		160		720		120

Table 16: Faecal coliforms in urine samples

sample	area	sampling 1 FC [MPN/100ml]	sampling 2 FC [MPN/100 ml]	sampling 3 FC [MPN/100 ml]	sampling 4 FC [MPN/100 ml]	sampling 5 FC [MPN/100 ml]	sampling 6 FC [MPN/100 ml]	sampling 7 FC [MPN/100 ml]	sampling 8 FC [MPN/100 ml]	sampling 9 FC [MPN/100 ml]	sampling 10 FC [MPN/100 ml]
HH3	Mumias (Western)	430		110		40		50		50	
SCHOOL	Ugunja (Nyanza)		0		90		0		500		380

The urine samples from the household lacked eggs but were positive for faecal coliforms with a maximum of 430 MPN/100ml. This might be due to an infection of the users, a contamination of the urine channel (cross-contamination) and/or contamination of the urine storage container. High counts for helminth eggs with a maximum of 720 eggs/L and the maximum for faecal coliforms of 500 MPN/ 100ml in the urine samples of the school are very worrying as the urine is used directly without further treatment. The WHO safety guidelines have a limit of ≤1 egg/L.

<u>Identified helminth eggs in urine sample</u>

- Enterobius vernicularis
- Ascaris lumbricoides

For further information on Helminth eggs and faecal coliforms see under results for the dried faeces.

5.3 Questionnaire

Figure 15: Women answers questions about use and maintenance behaviour

The amount of users ranged from 5 to 25 persons per UDDT with a median size of 15 people. Households reported using the toilet for 1 month up to 1 year. The storage time for the biosolids collected in one chamber ranged from 1 month to 12 month (still in use up to sampling day) according to the report of the household. For urine it ranges from 1 to 7 days. Only one household stopped using the first chamber for three month and the sampled school stopped using the toilet for three weeks as there were Christmas holidays.

Table 17: Amount of people using UDDT, time of use and storage time of sampled product

sample	Owner	date	area	Amount of people using the toilet	UDDT in use since	Storage time urine	Storage time of faeces
HH1	Emily Walubengo	16/12/09	Mumias (Western)	21	2 month	3-7 days	2 month but still in use up to sampling day
HH2	Wilfred Kuyabu Okwani	16/12/09	Mumias (Western)	15	6 month	7 days	6 month but still in use up to sampling day
HH3	James Makau Mkenya	16/12/09	Mumias (Western)	9	1 month	7 days	1 month but still in use up to sampling day
HH4	Ismael Ouma	20/01/10	Ugunja (Nyanza)	25	12 month	5-6 days	12 month but still in use up to sampling day
HH4new	Penina Owno	23/02/10	Ugunja (Nyanza)	10	4 month	7 days	4 month but still in use up to sampling day
HH5	Helena Aketch	20/01/10	Ugunja (Nyanza)	5	6 month	7 days	3 month (not in use)
SCHOOL	Uriya Primary School	20/01/10	Ugunja (Nyanza)	150	3 month	3 weeks (not in use)	3 weeks (not in use)

All users have ash as an additive because it is easy for them to get as they cook with firewood. All households visited reported that they use the urine for agricultural purpose around their home. Main crops which urine was used for were maize, bananas, kales and mangoes. Only the school has not yet reused the urine but it is fetched by a neighbouring farmer. Dried faeces have not been used by any sampled households and school as the toilets are not long enough in use or the necessary drying time was not yet achieved.

Operation and maintenance (O&M)

The toilets visited for sampling were all functioning. All toilets were in use, but there was a difference in the maintenance behaviour as shown in the table below.

Table 18: Operation and maintenance

Sample	Area	sampling 1 O&M	sampling 2 O&M	sampling 3 O&M	sampling 4 O&M	sampling 5 O&M	sampling 6 O&M	sampling 7 O&M	sampling 8 O&M	sampling 9 O&M	sampling 10 O&M
HH1	Mumias (Western)	++		+		+-		++		++	
HH2	Mumias (Western)	++		++		++		++		++	
HH3	Mumias (Western)	+		--		+-		+-		+-	
HH4	Ugunja (Nyanza)		+-		--						
HH4new	Ugunja (Nyanza)						+-		--		+
HH5	Ugunja (Nyanza)		+		+		++		++		++
SCHOOL	Ugunja (Nyanza)		+		---		---		---		+

++: very clean (no smell, whole toilet absolutely clean, stairs clean)

+: clean (no smell, dirt on the floor or stairs)

+ -: not very clean (smell as urine part not clean, dirt or ash but no faeces on the floor)

--: dirty (smell, faeces, urine on the floor)

---: very dirty (signs of cross contamination e.g. faeces, ash block urine part)

It was observed that generally the UDDTs in Mumias are better maintained and very clean. For these sites the users were very satisfied with the toilets and there were no signs of cross contamination or bad smells. Ash was always there, the faeces were drying as sufficient amounts of ash were used. For the toilets in Ugunja there was one household (HH5) were the toilet was clean, ash was always there, faeces were also dry. For the other toilets the users were challenged with the right use. There were signs of cross contamination like faeces or urine on the floor and often not enough ash was used. Therefore faecal material was wet and also counts for helminth eggs were high (table 8).

Figure 16: Cross contamination, faeces and ash in the urine part

Figure 17: Blocked urine pipe

There were three household toilets in Ugunja with technical problems. One had a broken wooden chamber frame which was destroyed by termites, the other one had a hole in the chamber were the concrete broke and the third had a hole next to the toilet slap (Figure18). The problem is that faeces cannot dry properly as rain water gets inside the chamber. It was also observed that during the rainy season water enters the chambers even if there is no technical problem. This is because the chamber door is slanting and the door frame is never completely water proof.

Figure 18: Technical problems in household UDDTs:

Above left: Hole in the chamber next to the door frame
Above right: chamber frame destroyed by termites
Down: Hole in concrete next to the toilet slap

There was a good overall satisfaction with the UDDT toilets and the main problems concerning the use were blocked urine pipes and less amount of ash used. It was observed that there is a good knowledge about the use of UDDTs in most of the households.

For the household there are sometimes problems with the proper use by visitors and for the school, pupils had problems with the use (cross contamination). There was one household in Ugunja (HH4new) were the toilet owners complained about insufficient training about the correct use. There is a general lack of knowledge about the danger of pathogens in the dried faeces as observed people trust the products very much which could be a problem as they might not wait for the necessary storage time before reuse.

From the six sampling sides only in three households the hand wash facility was in use. Main problems were broken taps, tank stolen and no water. All interviewed people said there is water available throughout but as the tank is connected to a rain pipe of the toilet people hesitate to fill the tank. Hence there is still a lack of awareness about the importance of hand washing. Five of the sampling sites get their water from boreholes and only one household owner stated that water is coming from the river.

6. Conclusion and recommendation

As shown by this study the products of UDDTs are an important source of nutrients in agriculture. The average values of 151 mg/L phosphorus and 2678 mg/L ammonium nitrogen prove that urine contains high amounts of important plant nutrients. Hence the reuse of urine in agriculture can help to increase crop production and will have a significant impact on nutrition and household food security. Furthermore it can help substitute the use of chemical fertiliser and limits its negative impacts on the environment.

According to the faecal coliform and helminth eggs counts it is shown that microbial inactivation takes place in the dried faeces if temperature, pH, moisture and the length of storage time is obtained. Faecal coliforms concentrations in faeces were beyond the determination limit of the method (>1800 MPN/g) in the beginning but after the fourth sampling already the numbers were under the determination limit. Even if helminth eggs are less affected by the biodegradation and desiccation and survive for a longer time for two households in Mumias a reduction of eggs up to 0/g was already shown after five samplings.

Nevertheless there are also households where helminth egg concentrations are very high with a maximum of 304 eggs/g. Therefore it is also demonstrate that it is necessary to ensure that the health risk is reduced later on in the agriculture, food production and consumption chain if pathogen reduction fails in the system. Also the pathogens in urine with a maximum of 720 eggs/L and 500 MPN/L show that there is a problem concerning the proper use of the UDDTs. This results in a higher health risk as faeces and urine might still contain dangerous amount of pathogens even after the recommended storage time.

The new WHO guidelines promote the concept of health-based targets meaning they allow the use of excreta or wastewater which is not yet fully treated if the health risk can be reduced using a combination of risk-reducing options for example proceedings taken in agricultural practice and finally at the level of the consumer. There is an urgent demand of support and training considering use, treatment, crop restriction, waste application and human exposer control to reduce the risk and maximizing the benefit for the users.

Health and hygiene promotion is also required as there is a lack of awareness like handwashing after the toilet use. Only three households out of the six sampling sites use the handwash facility. One main reason is the rainwater tank disappears as the users do not see it benefit so they use it for a “better” purpose e.g. storing water in the kitchen.

Furthermore after the first use of the faeces people should be trained in hygienic food handling and food preparation practice like produce washing and cooking to reduce negative health effects. If the methods of combined risk reduction are applied by the users the products of the sampled UDDTs are safe to use for agricultural purpose.

More photos:

http://www.flickr.com/photos/gtzecosan/sets/72157623342153157/

http://www.flickr.com/photos/gtzecosan/

SuSanA case studies for the EcoSan Promotion Project in Kenya:

http://www.susana.org/lang-en/case-studies/region/ssa

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URL: http://www.who.int/water_sanitation_health/wastewater/labmanual.pdf

8. APPENDIX

8.1 Excel Data

8.1.1 Summarised data

DATA URINE

sample	Owner	date	Area	storage time	pH	TP [mg/L]	NH_4 [mg/L]	Helminth Eggs [eggs/L]	FC [MPN/100mL]
HH1	Emily Walubengo	16/12/09 (sampling1)	Mumias (Western)	3-7 days	9.25	189	1091	not measured	not measured
HH2	Wilfred Kuyabu Okwani	16/12/09 (sampling1)	Mumias (Western)	7 days	8.96	221	2029	not measured	not measured
HH3	James Makau Mkenya	16/12/09 (sampling1)	Mumias (Western)	7 days	9.3	204	2207	0	430
HH4	Ismael Ouma	20/01/10 (sampling2)	Ugunja (Nyanza)	5-6 days	9.37	225	1568	not measured	not measured
HH5	Helena Aketch	20/01/10 (sampling2)	Ugunja (Nyanza)	7 days	9.35	251	1139	not measured	not measured
SCHOOL	Uriya Primary School	20/01/10 (sampling2)	Ugunja (Nyanza)	3 weeks (not in use)	8.67	181	404	0	0
HH1	Emily Walubengo	3/2/2010 (sampling3)	Mumias (Western)	7 days	9.17	191	7406	not measured	not measured
HH2	Wilfred Kuyabu Okwani	3/2/2010 (sampling3)	Mumias (Western)	7 days	8.79	121	3274	not measured	not measured
HH3	James Makau Mkenya	3/2/2010 (sampling3)	Mumias (Western)	2 days	8.45	191	5769	0	110
HH4	Ismael Ouma	10/02/2010 (sampling4)	Ugunja (Nyanza)	5-6 days	9.52	170	3552	not measured	not measured
HH5	Helena Aketch	10/02/2010 (sampling4)	Ugunja (Nyanza)	7 days	9.36	176	6419	not measured	not measured
SCHOOL	Uriya Primary School	10/02/2010 (sampling4)	Ugunja (Nyanza)	1-2 days	9.69	24	1870	80	90

HH1	Emily Walubengo	17/2/2010 (sampling5)	Mumias (Western)	2 days	9.43	180	5104	not measured	not measured
sample	Owner	date	Area	storage time	pH	159	2515	Helminth Eggs [eggs/L]	FC [MPN/100mL]
HH2	Wilfred Kuyabu Okwani	17/2/2010 (sampling5)	Mumias (Western)	2 days	9.24	129	2822	not measured	not measured
HH3	James Makau Mkenya	17/2/2010 (sampling5)	Mumias (Western)	7 days	8.88	195	967	0	40
HH4new	Penina Owno	24/02/10 (sampling6)	Ugunja (Nyanza)	7 days	9.40	146	2004	not measured	not measured
HH5	Helena Aketch	24/02/10 (sampling6)	Ugunja (Nyanza)	5 days	9.12	21	4251	not measured	not measured
SCHOOL	Uriya Primary School	24/02/10 (sampling6)	Ugunja (Nyanza)	3 weeks (not in use)	9.71	209	2246	160	0
HH1	Emily Walubengo	10/3/2010 (sampling7)	Mumias (Western)	2 days	9.15	70	1153	not measured	not measured
HH2	Wilfred Kuyabu Okwani	10/3/2010 (sampling7)	Mumias (Western)	3 days	8.85	222	986	not measured	not measured
HH3	James Makau Mkenya	10/3/2010 (sampling7)	Mumias (Western)	5 days	8.70	110	2242	0	50
HH4new	Penina Owno	17/03/10 (sampling8)	Ugunja (Nyanza)	5 days	8.89	243	1151	not measured	not measured
HH5	Helena Aketch	17/03/10 (sampling8)	Ugunja (Nyanza)	3 days	9.36	57	982	not measured	not measured
SCHOOL	Uriya Primary School	17/03/10 (sampling8)	Ugunja (Nyanza)	2 days	9.80	168	6071	720	500
HH1	Emily Walubengo	26/3/2010 (sampling9)	Mumias (Western)	2 days	9.15	133	1885	not measured	not measured
HH2	Wilfred Kuyabu Okwani	26/3/2010 (sampling9)	Mumias (Western)	3 days	8.85	143	109	not measured	not measured
HH3	James Makau Mkenya	26/3/2010 (sampling9)	Mumias (Western)	4 days	8.97	66	2455	not mesured	not measured
HH4new	Penina Owno	31/03/10 (sampling10)	Ugunja (Nyanza)	2 days	8.36	112	6498	not mesured	not measured
HH5	Helena Aketch	31/03/10 (sampling10)	Ugunja (Nyanza)	7 days	8.89	37	179	0	50

SCHOOL	Uriya Primary School	31/03/10 (sampling10)	Ugunja (Nyanza)	5 days	8.80	189	1091	not mesured	not mesured
					pH	TP [mg/L]	NH_4 [mg/L]	Helminth Eggs [eggs/L]	FC [MPN/100mL]
MEAN					**9.14**	**151**	**2678**	**-**	**-**
MEDIAN					**9.17**	**168**	**2207**	**0**	**70**
MAX					**9.80**	**251**	**7406**	**720**	**500**
MIN					**8.36**	**21**	**109**	**0**	**0**

DATA FAECES

sample	Owner	Date	area	Ambient Temperature outside [°C]	Ambient Temperature in chamber [°C]	Temperature in heap [°C]	pH	moisture [%]	Helminth Eggs [eggs/g]	FC [MPN/g]
HH1	Emily Walubengo	16/12/09 (sampling1)	Mumias (Western)	-	22	24	9.90	66.05	65	>1800
HH2	Wilfred Kuyabu Okwani	16/12/09 (sampling1)	Mumias (Western)	-	33	23	9.58	54.85	0	16
HH3	James Makau Mkenya	16/12/09 (sampling1)	Mumias (Western)	-	32	22	9.60	53.44	7	0
HH4	Ismael Ouma	20/01/10 (sampling2)	Ugunja (Nyanza)	-	25	22	9.46	89.86	50	>1800
HH5	Helena Aketch	20/01/10 (sampling2)	Ugunja (Nyanza)	-	28	30	10.00	50.13	0	50
SCHOOL	Uriya Primary School	20/01/10 (sampling2)	Ugunja (Nyanza)	-	25	30	10.35	19.92	33	75

sample	Owner	Date	area	Ambient Temperature outside [°C]	Ambient Temperature in chamber [°C]	Temperature in heap [°C]	pH	moisture [%]	Helminth Eggs [eggs/g]	FC [MPN/g]
HH1	Emily Walubengo	3/2/2010 (sampling3)	Mumias (Western)	25	28	26	9.94	34.49	16	>1800
HH2	Wilfred Kuyabu Okwani	3/2/2010 (sampling3)	Mumias (Western)	28	29	26	9.99	39.19	16	2
HH3	James Makau Mkenya	3/2/2010 (sampling3)	Mumias (Western)	26	23	25	10.10	41.02	0	13
HH4	Ismael Ouma	10/02/2010 (sampling4)	Ugunja (Nyanza)	35	36	25	9.67	85.72	8	2
HH5	Helena Aketch	10/02/2010 (sampling4)	Ugunja (Nyanza)	35	34	29	10.02	34.70	0	5
SCHOOL	Uriya Primary School	10/02/2010 (sampling4)	Ugunja (Nyanza)	29	24	24	10.54	27.08	16	13
HH1	Emily Walubengo	17/2/2010 (sampling5)	Mumias (Western)	20	21	20	9.80	31.33	12	13
HH2	Wilfred Kuyabu Okwani	17/2/2010 (sampling5)	Mumias (Western)	21	22	22	10.02	23.53	0	5
HH3	James Makau Mkenya	17/2/2010 (sampling5)	Mumias (Western)	21	22	23	9.91	44.92	0	0
HH4new	Penina Owno	24/02/10 (sampling6)	Ugunja (Nyanza)	23	23	25	9.84	40.94	68	0
HH5	Helena Aketch	24/02/10 (sampling6)	Ugunja (Nyanza)	28	28	26	10.06	27.94	0	130
SCHOOL	Uriya Primary School	24/02/10 (sampling6)	Ugunja (Nyanza)	23	22	23.5	10.32	34.02	0	40
HH1	Emily Walubengo	10/3/2010 (sampling7)	Mumias (Western)	24	22	23	10.02	41.13	16	0
HH2	Wilfred Kuyabu Okwani	10/3/2010 (sampling7)	Mumias (Western)	26	27	25	9.72	30.22	0	2

sample	Owner	Date	Area	Ambient Temperature outside [°C]	Ambient Temperature in chamber [°C]	Temperature in heap [°C]	pH	moisture [%]	Helminth Eggs [eggs/g]	FC [MPN/g]
HH3	James Makau Mkenya	10/3/2010 (sampling7)	Mumias (Western)	25	23	24	9.88	43.04	0	0
HH4new	Penina Owno	17/03/10 (sampling8)	Ugunja (Nyanza)	23	23	24	10.07	42.10	72	0
HH5	Helena Aketch	17/03/10 (sampling8)	Ugunja (Nyanza)	28	27	28	10.21	26.17	0	0
SCHOOL	Uriya Primary School	17/03/10 (sampling8)	Ugunja (Nyanza)	21	21	22	10.31	16.21	0	0
HH1	Emily Walubengo	26/3/2010 (sampling9)	Mumias (Western)	22	22	22	9.70	28.73	48	0
HH2	Wilfred Kuyabu Okwani	26/3/2010 (sampling9)	Mumias (Western)	25	25	25	9.65	24.17	0	0
HH3	James Makau Mkenya	26/3/2010 (sampling9)	Mumias (Western)	23	23	24	9.64	44.13	0	0
HH4new	Penina Owno	31/03/10 (sampling10)	Ugunja (Nyanza)	24	25	22	10.00	56.67	304	0
HH5	Helena Aketch	31/03/10 (sampling10)	Ugunja (Nyanza)	28	25	25	9.82	56.36	0	0
SCHOOL	Uriya Primary School	31/03/10 (sampling10)	Ugunja (Nyanza)	26	22	25	10.24	19.29	32	0
MEAN				**25**	**25**	**24**	**9.95**	**40.91**	**-**	**-**
MEDIAN				**25**	**25**	**24**	**9.99**	**39.19**	**0**	**0**
MAX				**35**	**36**	**30**	**10.54**	**89.86**	**304**	**130**
MIN				**20**	**21**	**20**	**9.46**	**16.21**	**0**	**0**

8.1.2 Moisture

Sample	Date	Area	W1	W2	W3	MC [%]
HH1	16/12/09 (sampling1)	Mumias (Western)	14.6007	25.2013	20.9848	66.05
HH2	16/12/09 (sampling1)	Mumias (Western)	16.6820	25.4497	22.3439	54.85
HH3	16/12/09 (sampling1)	Mumias (Western)	14.6230	23.8523	20.6380	53.44
HH4	20/01/10 (sampling2)	Ugunja (Nyanza)	14.5998	22.6454	18.8375	89.86
HH5	20/01/10 (sampling2)	Ugunja (Nyanza)	16.6867	25.6407	22.6507	50.13
SCHOOL	20/01/10 (sampling2)	Ugunja (Nyanza)	14.6233	22.0810	20.8421	19.92
HH1	3/2/2010 (sampling3)	Mumias (Western)	14.5940	24.4701	21.9374	34.49
HH2	3/2/2010 (sampling3)	Mumias (Western)	16.6836	26.2476	23.5546	39.19
HH3	3/2/2010 (sampling3)	Mumias (Western)	14.6232	24.6303	21.7192	41.02
HH4	10/02/2010 (sampling4)	Ugunja (Nyanza)	14.6129	24.0072	19.6711	85.72
HH5	10/02/2010 (sampling4)	Ugunja (Nyanza)	16.6916	26.0150	23.6134	34.70
SCHOOL	10/02/2010 (sampling4)	Ugunja (Nyanza)	14.6318	24.3146	22.2510	27.08
HH1	17/2/2010 (sampling5)	Mumias (Western)	14.5932	24.5692	22.1891	31.33
HH2	17/2/2010 (sampling5)	Mumias (Western)	16.6816	26.2665	24.4409	23.53
HH3	17/2/2010 (sampling5)	Mumias (Western)	14.5969	24.6078	21.6421	42.10

$$MC = \frac{W2 - W3}{W3 - W1} \cdot 100$$

MC: moisture content in %

W1: weight of tin in g

W2: weight of moist soil+tin in g

W3: weight of dried soil+tin in g

HH4new	24/02/10 (sampling6)	Ugunja (Nyanza)	16.6837	26.3776	24.3667	26.17
HH5	24/02/10 (sampling6)	Ugunja (Nyanza)	14.3574	24.0841	22.7270	16.21
SCHOOL	24/02/10 (sampling6)	Ugunja (Nyanza)	14.6299	24.8438	22.2510	34.02
HH1	10/3/2010 (sampling7)	Mumias (Western)	14.5971	25.0113	21.9765	41.13
HH2	10/3/2010 (sampling7)	Mumias (Western)	16.6819	26.9458	24.5637	30.22
HH3	10/3/2010 (sampling7)	Mumias (Western)	14.6243	24.4514	21.4943	43.04
HH4new	17/03/10 (sampling8)	Ugunja (Nyanza)	14.5998	22.6454	18.8375	89.86
HH2	17/03/10 (sampling8)	Ugunja (Nyanza)	16.6867	25.6407	22.6507	50.13
SCHOOL	17/03/10 (sampling8)	Ugunja (Nyanza)	14.6233	22.0810	20.8421	19.92
HH1	26/3/2010 (sampling9)	Mumias (Western)	14.5915	24.0743	21.9577	28.73
HH2	26/3/2010 (sampling9)	Mumias (Western)	16.6771	27.0103	24.9987	24.17
HH3	26/3/2010 (sampling9)	Mumias (Western)	14.3493	24.3316	21.2750	44.13
HH4new	31/03/10 (sampling10)	Ugunja (Nyanza)	14.5904	27.8414	23.0484	56.67
HH2	31/03/10 (sampling10)	Ugunja (Nyanza)	16.6764	26.2762	22.8158	56.36
SCHOOL	31/03/10 (sampling10)	Ugunja (Nyanza)	14.3470	24.3057	22.6952	19.29

8.1.3 Helminth eggs

sample	date	Area	Product	orig. sample V [l]	vol. pellet [ml]	vol. final [ml]	Chamber I	Identification	Chamber II	identification	number of eggs/l	weight [g]	amount water [ml]	number of eggs/ water	number of eggs/ g
HH1	16/12/09 (sampling1)	Mumias (Western)	Faeces	0.24	2	12	18	Hymenolepis diminuta	21	Hymenolepis diminuta	6500	25	250	1625	65
HH2	16/12/09 (sampling1)	Mumias (Western)	Faeces	0.24	2	12	0	-	0	-	0	25	250	0	0
HH3	16/12/09 (sampling1)	Mumias (Western)	Faeces	0.24	2	12	3	2x Ascaris spp./ 1x Hookworm	4	3x Hymenolepis diminuta/ 1x Hookworm	1166	25	250	292	7
HH3	16/12/09 (sampling1)	Ugunja (Nyanza)	Urine	0.24	2	12	0		0		0	25	250	0	0
HH4	20/01/10 (sampling2)	Ugunja (Nyanza)	Faeces	0.24	2	12	2	Trichuris trichiura	1	Trichuris trichiura	500	2.5	250	125	50
HH5	20/01/10 (sampling2)	Ugunja (Nyanza)	Faeces	0.24	2	12	0	-	0	-	0	2.5	250	0	0
SCHOOL	20/01/10 (sampling2)	Mumias (Western)	Faeces	0.24	2	12	1	Enterobius vernicularis	1	Enterobius vernicularis	333	2.5	250	83	33
SCHOOL	20/01/10 (sampling2)	Mumias (Western)	Urine	0.24	1	6	0	-	0	-	0	2.5	250	0	0
HH1	3/2/2010 (sampling3)	Mumias (Western)	Faeces	0.25	1	6	1	Hookworm	1	Hookworm	160	2.5	250	40	16
HH2	3/2/2010 (sampling3)	Mumias (Western)	Faeces	0.25	1	6	2	Hookworm	0	-	160	2.5	250	40	16
HH3	3/2/2010 (sampling3)	Mumias (Western)	Faeces	0.25	1	6	0	-	0	-	0	2.5	250	0	0
HH3	3/2/2010 (sampling3)	Ugunja (Nyanza)	Urine	0.25	1	6	0	-	0	-	0	-	-	-	-
HH4	10/02/2010 (sampling4)	Ugunja (Nyanza)	Faeces	0.25	1	6	1	Enterobius vernicularis	0	-	80	2.5	250	20	8
HH5	10/02/2010 (sampling4)	Ugunja (Nyanza)	Faeces	0.25	1	6	0	-	0	-	0	2.5	250	0	0

Sample	date	Area	Product	orig. sample V [l]	vol. pellet [ml]	vol. final [ml]	Chamber I	Identification	Chamber II	identification	number of eggs/l	weight [g]	amount water [ml]	number of eggs/ water	number of eggs/ g
SCHOOL	10/02/2010 (sampling4)	Mumias (Western)	Faeces	0.25	1	6	0	Enterobius vernicularis	2	Enterobius vernicularis	160	2.5	250	40	16
SCHOOL	10/02/2010 (sampling4)	Mumias (Western)	Urine	0.25	0.5	3	1	Enterobius vernicularis	1	Ascaris lumbricoides (infertile)	80	-	-	-	-
HH1	17/2/2010 (sampling5)	Mumias (Western)	Faeces	0.25	1.5	9	0	-	1	Ascaris lumbricoides (infertile)	120	2.5	250	30	12
HH2	17/2/2010 (sampling5)	Mumias (Western)	Faeces	0.25	1.5	9	0	-	0	-	0	2.5	250	0	0
HH3	17/2/2010 (sampling5)	Mumias (Western)	Faeces	0.25	1	6	0	-	0	-	0	2.5	250	0	0
HH3	17/2/2010 (sampling5)	Ugunja (Nyanza)	Urine	0.25	0.5	3	0	-	0	-	0	-	-	-	-
HH4new	24/02/10 (sampling6)	Ugunja (Nyanza)	Faeces	0.25	0.5	3	10	Ascaris lumbricoides	7	Ascaris lumbricoides	680	2.5	250	170	68
HH5	24/02/10 (sampling6)	Ugunja (Nyanza)	Faeces	0.25	0.5	3	0	-	0	-	0	2.5	250	0	0
SCHOOL	24/02/10 (sampling6)	Mumias (Western)	Faeces	0.25	2	12	0	-	0	-	0	2.5	250	0	0
SCHOOL	24/02/10 (sampling6)	Mumias (Western)	Urine	0.25	0.5	3	3	Enterobius vernicularis	1	Enterobius vernicularis	160	-	-	-	-
HH1	10/3/2010 (sampling7)	Mumias (Western)	Faeces	0.25	2	12	1	Hookworm	0	-	160	2.5	250	40	16
HH2	10/3/2010 (sampling7)	Mumias (Western)	Faeces	0.25	2	12	0	-	0	-	0	2.5	250	0	0
HH3	10/3/2010 (sampling7)	Mumias (Western)	Faeces	0.25	2	12	0	-	0	-	0	2.5	250	0	0

Sample	date	Area	Product	orig. sample V [l]	vol. pellet [ml]	vol. final [ml]	Chamber I	Identification	Chamber II	identification	number of eggs/l	weight [g]	amount water [ml]	number of eggs/ water	number of eggs/ g
HH3	10/3/2010 (sampling7)	Ugunja (Nyanza)	Urine	0.25	1	6	0	-	0	-	0	-	-	-	-
HH4new	17/03/10 (sampling8)	Ugunja (Nyanza)	Faeces	0.25	1	6	5	Ascaris lumbricoides	4	2 Hookworm, 2 Ascaris lumbricoides	720	2.5	250	180	72
HH5	17/03/10 (sampling8)	Ugunja (Nyanza)	Faeces	0.25	2	12	0	-	0	-	0	2.5	250	0	0
SCHOOL	17/03/10 (sampling8)	Mumias (Western)	Faeces	0.25	2	12	0	-	0	-	0	2.5	250	0	0
SCHOOL	17/03/10 (sampling8)	Mumias (Western)	Urine	0.25	1	6	4	2 Enterobius vernicularis, 2 Ascaris lumbricoides	5	2 Enterobius vernicularis, 3 Ascaris lumbricoides	720	-	-	-	-
HH1	26/3/2010 (sampling9)	Mumias (Western)	Faeces	0.25	2	12	2	Ascaris lumbricoides	1	Enetrobius vernicularis	480	2.5	250	120	48
HH2	26/3/2010 (sampling9)	Mumias (Western)	Faeces	0.25	1	6	0	-	0	-	0	2.5	250	0	0
HH3	26/3/2010 (sampling9)	Mumias (Western)	Faeces	0.25	2	12	0	-	0	-	0	2.5	250	0	0
HH3	26/03/10 (sampling10)	Ugunja (Nyanza)	Urine	0.25	0.5	3	0	-	0	-	0	-	-	-	-
HH4new	31/03/10 (sampling10)	Ugunja (Nyanza)	Faeces	0.25	2	12	10	5 Ascaris lumbricoides, 5 Hookworm	9	Ascaris lumbricoides	3040	2.5	250	760	304
HH5	31/03/10 (sampling10)	Ugunja (Nyanza)	Faeces	0.25	1	6	0	-	0	-	0	2.5	250	0	0
SCHOOL	31/3/2010 (sampling9)	Mumias (Western)	Faeces	0.25	2	12	2	Ascaris lumbricoides	0	-	320	2.5	250	80	32

Sample	date	Area	Product	orig. sample V [l]	vol. pellet [ml]	vol. final [ml]	Chamber I	Identification	Chamber II	identification	number of eggs/l	weight [g]	amount water [ml]	number of eggs/ water	number of eggs/ g
SCHOOL	31/3/10 (sampling6)	Mumias (Western)	Urine	0.25	0.5	3	0	-	3	Ascaris lumbricoides	120	-	-	-	-

$$N = \frac{A \cdot X}{P \cdot V}$$

N= number of eggs per liter of sample

A= number of eggs counted in the McMaster slide

X= volume of the final product [ml]

P= volume of the McMaster slide

8.1.4 Faecal coliforms

MPN

number of positive tubes

If 1ml contains 0.1g

sample	date	area	product	1ml	0.1ml	0.01 ml	MPN/100 ml	MPN/g
HH1	16/12/09 (sampling1)	Mumias (Western)	faeces	5	5	5	>18000	>1800
HH2	16/12/09 (sampling1)	Mumias (Western)	faeces	3	0	0	160	16
HH3	16/12/09 (sampling1)	Mumias (Western)	faeces	0	0	0	0	0
HH3	16/12/09 (sampling1)	Ugunja (Nyanza)	Urine	5	1	1	430	-
HH4	20/01/10 (sampling2)	Ugunja (Nyanza)	faeces	5	5	5	>18000	>1800
HH5	20/01/10 (sampling2)	Ugunja (Nyanza)	faeces	5	2	0	500	50
SCHOOL	20/01/10 (sampling2)	Mumias (Western)	faeces	5	3	0	750	75
SCHOOL	20/01/10 (sampling2)	Mumias (Western)	Urine	0	0	0	0	-
HH1	3/2/2010 (sampling3)	Mumias (Western)	faeces	5	5	5	>18000	>1800
HH2	3/2/2010 (sampling3)	Mumias (Western)	faeces	1	0	0	20	2
HH3	3/2/2010 (sampling3)	Mumias (Western)	faeces	3	2	0	130	13
HH3	3/2/2010 (sampling3)	Ugunja (Nyanza)	Urine	2	3	0	110	-
HH4	10/02/2010 (sampling4)	Ugunja (Nyanza)	faeces	1	1	0	20	2
HH5	10/02/2010 (sampling4)	Ugunja (Nyanza)	faeces	2	1	0	50	5
SCHOOL	10/02/2010 (sampling4)	Mumias (Western)	faeces	5	3	0	130	13

sample	date	area	product	1ml	0.1ml	0.01 ml	MPN/100 ml	MPN/g
SCHOOL	10/02/2010 (sampling4)	Mumias (Western)	urine	3	0	1	90	-
HH1	17/2/2010 (sampling5)	Mumias (Western)	faeces	3	2	0	130	13
HH2	17/2/2010 (sampling5)	Mumias (Western)	faeces	2	1	0	50	5
HH3	17/2/2010 (sampling5)	Mumias (Western)	faeces	0	0	0	0	0
HH3	17/2/2010 (sampling5)	Ugunja (Nyanza)	urine	1	1	0	40	-
HH4	24/02/10 (sampling6)	Ugunja (Nyanza)	faeces	0	0	0	0	0
HH5	24/02/10 (sampling6)	Ugunja (Nyanza)	faeces	3	2	0	130	13
SCHOOL	24/02/10 (sampling6)	Mumias (Western)	faeces	2	0	0	40	4
SCHOOL	24/02/10 (sampling6)	Mumias (Western)	urine	0	0	0	0	-
HH1	10/3/2010 (sampling7)	Mumias (Western)	faeces	0	0	0	0	0
HH2	10/3/2010 (sampling7)	Mumias (Western)	faeces	1	0	0	20	2
HH3	10/3/2010 (sampling7)	Mumias (Western)	faeces	0	0	0	0	0
HH3	10/3/2010 (sampling7)	Ugunja (Nyanza)	urine	1	2	0	50	-
HH4	17/03/10 (sampling8)	Ugunja (Nyanza)	faeces	0	0	0	0	0
HH5	17/03/10 (sampling8)	Ugunja (Nyanza)	faeces	0	0	0	0	0
SCHOOL	17/03/10 (sampling8)	Mumias (Western)	faeces	0	0	0	0	0
SCHOOL	17/03/10 (sampling8)	Mumias (Western)	urine	5	2	0	500	-
HH1	26/3/2010 (sampling9)	Mumias (Western)	faeces	0	0	0	0	0

sample	date	area	product	1ml	0.1ml	0.01 ml	MPN/100 ml	MPN/g
HH2	26/3/2010 (sampling9)	Mumias (Western)	faeces	1	0	0	20	2
HH3	26/3/2010 (sampling9)	Mumias (Western)	faeces	0	0	0	0	0
HH3	26/3/2010 (sampling9)	Ugunja (Nyanza)	Urine	1	2	0	50	-
HH4	31/03/10 (sampling10)	Ugunja (Nyanza)	faeces	0	0	0	0	0
HH5	31/03/10 (sampling10)	Ugunja (Nyanza)	faeces	0	0	0	0	0
SCHOOL	31/03/10 (sampling10)	Mumias (Western)	faeces	0	0	0	0	0
SCHOOL	31/03/10 (sampling10)	Mumias (Western)	Urine	5	2	0	500	-

Table 19: Table for calculating MPN of faecal coliforms

Faecal coliform MPN per 100 ml of sample for three sets of five tubes containing 1 ml, 0.1 ml and 0.01 ml of sample respectively[a]

Number of positive tubes			MPN
1 ml	0.1 ml	0.01 ml	per 100 ml
0	0	0	0
0	0	0	20
0	1	0	20
1	0	0	20
1	0	1	40
1	1	0	40
1	2	0	50
2	0	0	40
2	0	1	50
2	1	0	50
2	1	1	70
2	2	0	70
2	3	0	110
3	0	0	70
3	0	1	90
3	1	0	90
3	1	1	130
3	2	0	130
3	2	1	160
3	3	0	160
4	0	0	110
4	0	1	140
4	1	0	160
4	1	1	200
4	2	0	200
4	2	1	250
4	3	0	250
4	3	1	310
4	4	0	320
4	4	1	380
5	0	0	220
5	0	1	290
5	0	2	410
5	1	0	310
5	1	1	430
5	1	2	600
5	1	3	850
5	2	0	500
5	2	1	700
5	2	2	950
5	2	3	1 200
5	3	0	750
5	3	1	1 100
5	3	2	1 400
5	3	3	1 750
5	3	4	2 100
5	4	0	1 300
5	4	1	1 700
5	4	2	2 200
5	4	3	2 800
5	4	4	3 450
5	5	0	2 400
5	5	1	3 500
5	5	2	5 400
5	5	3	9 100
5	5	4	16 000
5	5	5	>18 000

8.1.5 Nutrients urine

Date: 16.12.2009 (sampling 1)

Total Phosphorus (TP)

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		Y	x
Blank	0.006	0.009	0.008	1	0.008	0.01
1	1.188	1.195	1.192	100	118.400	189.47
2	1.387	1.391	1.389	100	138.150	221.07
3	1.282	1.281	1.282	100	127.400	203.87
Std. [conc. 0,50mg/l]	0.304	0.305	0.305	1	0.297	0.47

f(x) = 0.6249x + 0.0018

R2= 0.9998

x=(y-0.0018)/ 0.6249

Ammonium-nitrogen (NH_4-N)

Samples	extinction (655nm)			dilution	extinction (655nm)	concentration [mg/l]
	1	2	mean		Y	x
Blank	0.025	0.024	0.025	1	0.025	0.01
1	0.138	0.131	0.135	10000	1100.000	1091.26
2	0.223	0.235	0.229	10000	2045.000	2028.76
3	0.247	0.247	0.247	10000	2225.000	2207.33
Std. [conc. 0,25mg/l]	0.283	0.279	0.281	1	0.257	0.24

f(x) =1.0080x + 0.0149

R2= 0.9998

x=(y-0.0149))/ 1.0080

Date: 20.01.2010 (sampling 2)

Total Phosphorus (TP)

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.005	0.001	0.003	1	0.003	0.00
1	1.415	1.403	1.409	100	140.600	224.99
2	1.568	1.570	1.569	100	156.600	250.60
3	1.134	1.131	1.133	100	112.950	180.75
Std. [conc. 0,50mg/l]	0.310	0.309	0.310	1	0.307	0.49

f(x) = 0.6249x + 0.0018

R2= 0.9998

x=(y-0.0018)/ 0.6249

Ammonium-nitrogen (NH_4-N)

Samples	extinction (655nm)			dilution	extinction (655nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.025	0.027	0.026	1	0.026	0.01
1	1.607	1.607	1.607	1000	1581.000	1568.44
2	1.175	1.173	1.174	1000	1148.000	1138.87
3	0.431	0.435	0.433	1000	407.000	403.76
Std. [conc. 0,25mg/l]	0.281	0.285	0.283	1	0.257	0.24

f(x)= 1.0080x + 0.0149

R2= 0.9998

x=(y-0.0149))/ 1.0080

Date: 3.02.2010 (sampling 3)

Total Phosphorus (TP)

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		Y	x
Blank	0.004	0.004	0.004	1	0.004	0.00
1	1.194	1.196	1.195	100	119.100	190.59
2	0.757	0.759	0.758	100	75.400	120.66
3	1.203	1.198	1.201	100	119.650	191.47
Std. [conc. 0,50mg/l]	0.317	0.319	0.318	1	0.314	0.50

f(x) = 0.6249x + 0.0018

R2= 0.9998

x=(y-0.0018)/ 0.6249

Ammonium-nitrogen (NH_4-N)

Samples	extinction (655nm)			dilution	extinction (655nm)	concentration [mg/l]
	1	2	mean		Y	x
Blank	0.028	0.030	0.029	1	0.029	0.01
1	0.773	0.778	0.776	10000	7465.000	7405.74
2	0.357	0.361	0.359	10000	3300.000	3273.79
3	0.611	0.610	0.611	10000	5815.000	5768.83
Std. [conc. 0,25mg/l]	0.283	0.279	0.281	1	0.252	0.24

f(x)= 1.0080x + 0.0149

R2= 0.9998

x=(y-0.0149))/ 1.0080

Date: 10.02.2010 (sampling 4)

Total Phosphorus (TP)

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.001	0.002	0.002	1	0.002	0.00
1	1.064	1.067	1.066	100	106.400	170.26
2	1.101	1.101	1.101	100	109.950	175.95
3	0.151	0.153	0.152	100	15.050	24.08
Std. [conc. 0,50mg/l]	0.309	0.310	0.310	1	0.308	0.49

f(x) = 0.6249x + 0.0018

R2= 0.9998

x=(y-0.0018)/ 0.6249

Ammonium-nitrogen (NH_4-N)

Samples	extinction (655nm)			dilution	extinction (655nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.031	0.029	0.030	1	0.030	0.01
1	0.386	0.390	0.388	10000	3580.000	3551.57
2	0.674	0.680	0.677	10000	6470.000	6418.64
3	0.219	0.218	0.219	10000	1885.000	1870.02
Std. [conc. 0,25mg/l]	0.284	0.287	0.286	1	0.256	0.24

f(x)= 1.0080x + 0.0149

R2= 0.9998

x=(y-0.0149))/ 1.0080

Date: 17.02.2010 (sampling 5)

Total Phosphorus (TP)

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		Y	x
Blank	0.005	0.001	0.003	1	0.003	0.00
1	1.126	1.126	1.126	100	112.300	179.71
2	0.995	0.994	0.995	100	99.150	158.66
3	0.815	0.805	0.810	100	80.700	129.14
Std. [conc. 0,50mg/l]	0.314	0.310	0.312	1	0.309	0.49

f(x) = 0.6249x + 0.0018

R2= 0.9998

x=(y-0.0018)/ 0.6249

Ammonium-nitrogen (NH_4-N)

Samples	extinction (655nm)			dilution	extinction (655nm)	concentration [mg/l]
	1	2	mean		Y	x
Blank	0.021	0.022	0.022	1	0.022	0.01
1	0.532	0.540	0.536	10000	5145.000	5104.15
2	0.272	0.278	0.275	10000	2535.000	2514.87
3	0.307	0.305	0.306	10000	2845.000	2822.41
Std. [conc. 0,25mg/l]	0.300	0.305	0.303	1	0.281	0.26

f(x)= 1.0080x + 0.0149

R2= 0.9998

x=(y-0.0149))/ 1.0080

Date: 24.02.2010 (sampling 6)

Total Phosphorus (TP)

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.001	0.001	0.001	1	0.001	0.00
1	1.224	1.220	1.222	100	122.100	195.39
2	0.911	0.915	0.913	100	91.200	145.94
3	0.129	0.130	0.130	100	12.850	20.56
Std. [conc. 0,50mg/l]	0.304	0.302	0.303	1	0.302	0.48

f(x) = 0.6249x + 0.0018

R2= 0.9998

x=(y-0.0018)/ 0.6249

Ammonium-nitrogen (NH_4-N)

Samples	extinction (655nm)			dilution	extinction (655nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.026	0.026	0.026	1	0.026	0.01
1	0.123	0.124	0.124	10000	975.000	967.25
2	0.227	0.229	0.228	10000	2020.000	2003.95
3	0.453	0.456	0.455	10000	4285.000	4250.98
Std. [conc. 0,25mg/l]	0.294	0.295	0.295	1	0.269	0.25

f(x)= 1.0080x + 0.0149

R2= 0.9998

x=(y-0.0149))/ 1.0080

Date: 10.03.2010 (sampling 7)

Total Phosphorus (TP)

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		Y	x
Blank	0.001	0.000	0.001	1	0.001	0.00
1	1.308	1.301	1.305	100	130.400	208.67
2	0.433	0.439	0.436	100	43.550	69.69
3	1.382	1.389	1.386	100	138.500	221.63
Std. [conc. 0,50mg/l]	0.308	0.306	0.307	1	0.307	0.49

f(x) = 0.6249x + 0.0018

R2= 0.9998

x=(y-0.0018)/ 0.6249

Ammonium-nitrogen (NH_4-N)

Samples	extinction (655nm)			dilution	extinction (655nm)	concentration [mg/l]
	1	2	mean		Y	x
Blank	0.048	0.045	0.047	1	0.047	0.03
1	0.272	0.273	0.273	10000	2260.000	2242.05
2	0.162	0.163	0.163	10000	1160.000	1150.78
3	0.146	0.145	0.146	10000	990.000	982.13
Std. [conc. 0,25mg/l]	0.315	0.317	0.316	1	0.270	0.25

f(x)= 1.0080x + 0.0149

R2= 0.9998

x=(y-0.0149))/ 1.0080

Date: 17.03.2010 (sampling 8)

Total Phosphorus (TP)

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.002	0.002	0.002	1	0.002	0.00
1	0.690	0.690	0.690	100	68.800	110.09
2	1.520	1.521	1.521	100	151.850	243.00
3	0.355	0.358	0.357	100	35.450	56.73
Std. [conc. 0,50mg/l]	0.308	0.312	0.310	1	0.308	0.49

f(x) = 0.6249x + 0.0018

R2= 0.9998

x=(y-0.0018)/ 0.6249

Ammonium-nitrogen (NH_4-N)

Samples	extinction (655nm)			dilution	extinction (655nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.022	0.023	0.023	1	0.023	0.01
1	0.260	0.258	0.259	10000	2365.000	2346.22
2	0.570	0.568	0.569	10000	5465.000	5421.61
3	0.128	0.130	0.129	10000	1065.000	1056.53
Std. [conc. 0,25mg/l]	0.310	0.308	0.309	1	0.287	0.27

f(x)= 1.0080x + 0.0149

R2= 0.9998

x=(y-0.0149))/ 1.0080

Date: 26.03.2010 (sampling 9)

Total Phosphorus (TP)

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		Y	x
Blank	0.002	0.003	0.003	1	0.003	0.00
1	1.050	1.051	1.051	100	104.800	167.70
2	0.833	0.830	0.832	100	82.900	132.66
3	0.899	0.895	0.897	100	89.450	143.14
Std. [conc. 0,50mg/l]	0.308	0.310	0.309	1	0.307	0.49

f(x) = 0.6249x + 0.0018

R2= 0.9998

x=(y-0.0018)/ 0.6249

Ammonium-nitrogen (NH_4-N)

Samples	extinction (655nm)			dilution	extinction (655nm)	concentration [mg/l]
	1	2	mean		Y	x
Blank	0.036	0.037	0.037	1	0.037	0.02
1	0.649	0.648	0.649	10000	6120.000	6071.41
2	0.225	0.228	0.227	10000	1900.000	1884.91
3	0.046	0.049	0.048	10000	110.000	109.11
Std. [conc. 0,25mg/l]	0.304	0.305	0.305	1	0.268	0.25

f(x)= 1.0080x + 0.0149

R2= 0.9998

x=(y-0.0149))/ 1.0080

Date: 31.03.2010 (sampling 10)

Total Phosphorus (TP)

Samples	extinction (885nm)			dilution	extinction (885nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.004	0.001	0.003	1	0.003	0.00
1	0.411	0.413	0.412	100	40.950	65.53
2	0.706	0.704	0.705	100	70.250	112.42
3	0.237	0.232	0.235	100	23.200	37.12
Std. [conc. 0,50mg/l]	0.316	0.319	0.318	1	0.315	0.50

f(x) = 0.6249x + 0.0018

R2= 0.9998

x=(y-0.0018)/ 0.6249

Ammonium-nitrogen (NH_4-N)

Samples	extinction (655nm)			dilution	extinction (655nm)	concentration [mg/l]
	1	2	mean		y	x
Blank	0.029	0.026	0.028	1	0.028	0.01
1	0.276	0.274	0.275	10000	2475.000	2455.34
2	0.680	0.685	0.683	10000	6550.000	6498.00
3	0.045	0.046	0.046	10000	180.000	178.56
Std. [conc. 0,25mg/l]	0.288	0.287	0.288	1	0.260	0.24

f(x)= 1.0080x + 0.0149

R2= 0.9998

x=(y-0.0149))/ 1.0080

8.2 WHO guidelines and recommendations

Table 20: WHO recommendation on microbiological quality guidelines for treated wastewater used for crop irrigation (WHO,1996)

Category	Reuse conditions	Exposed group	Intestinal nematodes[b] (arithmetic mean no. of eggs per litre[c])	Faecal conforms (geometric mean no. per 100 ml[c])	Wastewater treatment expected to achieve the required microbiological quality
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks	Workers, consumers, public	≤1	≤1000[d]	A series of stabilization ponds designed to achieve the microbiological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees[e]	Workers	≤1	No standard recommended	Retention in stabilization ponds for 8-10 days or equivalent helminth and faecal coliform removal
C	Localized irrigation[f] of crops in category B if exposure of workers and the public does not occur	None	Not applicable	Not applicable	Pretreatment as required by the irrigation technology, but not less than primary sedimentation

Source: World Health Organization (1989).

[a] In specific cases, local epidemiological, sociocultural and environmental factors should be taken into account, and the guidelines modified accordingly.
[b] *Ascaris* and *Trichuris* species and hookworms.
[c] During the irrigation period.
[d] A more stringent guideline (≤200 faecal coliforms per 100 ml) is appropriate for public lawns, such as hotel lawns, with which the public may come into direct contact.
[e] In the case of fruit trees, irrigation should cease two weeks before fruit is picked, and no fruit should be picked off the ground. Sprinkler irrigation should not be used.
[f] Also called drip or trickle irrigation.