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Characterisation of septage in partially sealed cesspit

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ABSTRACT

The alteration of wastewater from an individual home under anaerobic conditions in a partially sealed cesspit over the filling period of four months, and the pollution fluxes were assessed. The septage was much more concentrated than raw wastewater. A mass balance found percentage (%) removal rates for biological oxygen demand (BOD_5, 78%), chemical oxygen demand (COD, 62%), total nitrogen (TN, 52%), PO_4^{3-}-P (67%) and total suspended solids (TSS, 69%). The percentage (%) pollution loads of emptied septage were BOD_5 (22%), COD (38%), TN (48%), PO_4^{3-}-P (33%) and TSS (31%). The heavy metal content in septage was not complying with regulations for wadi disposal and effluent reuse in agriculture. Most of the TN removed, equal to 52% of the TN load to the cesspit, will most likely have infiltrated into the surrounding soil, and might reach the groundwater. Therefore, cesspits that are widely applied should be urgently replaced by proper on-site or off-site wastewater management systems.

Key words | anaerobic treatment, heavy metals, nitrogenous compounds, on-site sanitation, pollution, wastewater

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INTRODUCTION

The lack of proper on-site sanitation in unsewered low-income areas is becoming an important source of nutrient-rich wastewater leading to groundwater contamination (Munamati *et al.* 2015). In some developing countries, about 100% of the household wastewater is discharged untreated in water bodies or infiltrates to the groundwater. In these countries, simple systems are used for wastewater collection and treatment, with cesspits being among the most common ones. Cesspits are, therefore, considered as important non-point sources of pollution.

In the West Bank/Palestine, around 41 million cubic meters of sewage is collected in cesspits that serve 68% of the population (PWA 2012). Signals of groundwater pollution have been reported, e.g. nitrate (NO_3^-) concentrations exceeding 50 mg/L. The present practice of septage disposal is mainly via an uncontrolled discharge in nearby wadis, and to a much lesser extent in public sewerage networks (PWA 2012). Cesspits are not considered as a treatment technology, but are rather storage systems in which some sewage treatment occurs, used to solve the problem of lack of proper collection and treatment systems. During the retention in the cesspit, the wastewater quality changes and the final quality determines the way the produced septage is further handled.

At present, only a few technical data are available in Palestine, or elsewhere, on septage quantity and quality. The characteristics and the volume of septage data are essential for operational and design purposes of existing or newly planned urban sewage and/or septage treatment plants (Hithnawi 2004).

Moreover, these data are crucial to assess the environmental impact of cesspits as a consequence of septage infiltration and disposal in open areas. Lopez-Vazquez *et al.* (2014) reported that most planners forgot to include septage loads during the design phase, which later causes

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process failure especially in biological unit operations. For example, two activated sludge wastewater treatment plants (WWTP) located in eThekwini, South Africa experienced serious operational problems due to receiving faecal sludge from pit latrines (Wilson & Harrison 2012). A complete inactivation of the nitrification process was observed in one of the plants, which took several months to recover (Still & Foxon 2012). A hypothesis suggests that the excessive nitrogen load discharged into the plant was the main reason (Still & Foxon 2012), but the causes of the problem are unclear (Lopez-Vazquez *et al.* 2014). In addition to organic and nitrogenous compounds, heavy metals likely present in septage are of concern (Sorme & Lagerkvist 2002).

Cesspits are pits, such as pit latrines, that are without lining, so as to allow sewage infiltration into sub-soil to reduce the cost of frequent emptying. Knowledge on sewage 'treatment' in cesspits as anaerobic reactors is extremely limited. In Palestine, emphasis was given to characterize and quantify sewage collected in sewer networks (Mahmoud *et al.* 2003), but so far very little effort has been made to quantify the cesspits septage generation rate, characteristics and environmental impact in terms of pollutant fluxes to the surface and sub-surface environments. Household raw wastewater characteristics also need to be determined as they are likely to differ from sewage collected in sewer networks from large communities. Individual household wastewater characteristics have been barely reported in the literature. Although on the one hand, the cesspits are considered a major non-point source of pollution in the West Bank, on the other hand the cesspit is in essence a unique type of anaerobic reactor with specific reactor technology features as it is 'partially' continuous, 'partially' batch and 'partially' an accumulation system.

The main objectives of this research were to characterize the septage of a partially sealed household cesspit over the filling period, with emphasis on organic matter (biological oxygen demand (BOD5), chemical oxygen demand (COD)), nitrogenous compounds (Total Kjeldahl-nitrogen (TKN) and nitrate (NO_3^-)) heavy metals (Zn, Cu, Ni, Pb, Mn, Fe, Cr) and pathogens, in a partially sealed house onsite cesspit during the filling period; and to determine the specific pollution loads (g/capita d) and fluxes from the cesspit percolating into the surrounding soil through a mass balance for a single household.

MATERIAL AND METHODS

Experimental set-up; cesspit and raw wastewater collection tank

An actual operating and representative household cesspit of about 10 m^3 volume, which was partially sealed, with a filling period of 120 days, was selected in the unsewered village of Beit Dajan in Palestine. A raw wastewater collection tank of 500 L working volume was installed in the yard of the selected study house to collect the daily produced raw wastewater. The tank was equipped with all of the polyvinyl chloride pipelines needed for filling with raw wastewater and subsequent emptying in the cesspit. The tank was provided with a water stopcock and measuring tape to measure the volume of collected wastewater daily.

Measurements of water consumption and raw wastewater production and sampling

The research was carried out during the period March–July 2012. At the beginning of the research, the home water supply meter was recorded daily for 30 days, and the volume of produced household total wastewater was measured. This allows calculation of the specific water consumption and wastewater production. After the first month, raw wastewater collection and sampling continued for 14 consecutive days. The tank was allowed to be filled over 24 hours, and then a representative sample was taken after thoroughly mixing the tank content. After that, the volume of collected wastewater was measured. Then, the tank was emptied to allow the cycle of daily collection and sampling to be repeated. The wastewater temperature, electrical conductivity (EC) and pH were measured *in situ*. The collected samples were stored in a cooling box at 4 °C, and directly transferred to the lab for analysis in less than 1 h.

Cesspit start-up, operation and monitoring

At the onset of this experiment, the cesspit content was emptied until reaching the rather thick sludge layer at the bottom. The dimensions of the cesspit were measured, using a tape and a long stick, but the thickness of the sludge layer could not be measured. The reading of the water supply meter was recorded to allow for a mass balance calculation over the cesspit once becoming completely full. A first sludge sample from the cesspit bottom was collected for analysis. Afterwards, septage samples from the cesspit were collected biweekly over the whole four months filling period. The samples were collected from different random horizontal and vertical locations in the cesspit, after carefully scraping the very thin floating scum layer of a few millimetres. The samples were preserved at 4 °C in a special insulated cooling box, and directly transferred to the lab, where they were analysed for BOD_5, COD, TKN, NO_3^-, PO_4^{3-}-P, TS, total suspended solids (TSS), total dissolved solids (TDS) and thermotolerant coliforms (TtC). The septage pH, EC and temperature were measured *in situ*.

The pollution fluxes from the cesspit were assessed based on the mass balance by calculating the total volume of influent sewage over the filling period of four months and the volume of emptied septage when the cesspit was full.

Analytical methods

The raw wastewater and septage samples were analysed for pH, temperature, EC, TSS, TDS, TKN, COD, BOD_5, PO_4^{3-}-P, TtC and heavy metals according to standard methods (APHA 2005). Heavy metals were determined in duplicate samples that were subjected to acid digestion, and then analysed by ICP (ICP OPTIMA 3000 Perkin Elemer).

Mass balance calculations

The mass balance calculations of water and the measured parameters were carried out based on the following equations:

$$\text{Volume of percolated wastewater from the cesspit to the surrounding soil} = \text{volume of sewage produced over the filling period} - \text{emptied septage volume} \quad (1)$$

Evaporation was neglected as the cesspit was a closed system, and evaporation was estimated to be less than 1% of the collected wastewater, calculated based on 1 mm/d evaporation.

$$\text{Specific raw pollutant production}\left(\frac{g}{c}/d\right) = \frac{Q_{in}\ X\ C_{in}}{\text{number of household inhabitants}} \quad (2)$$

$$\text{Specific septage pollutant production}\left(\frac{g}{c}/d\right) = \frac{Q_{out}\ X\ C_{out}}{\text{number of household inhabitants}} \quad (3)$$

$$\text{Specific mass removed}\left(\frac{g}{c}/d\right) = \frac{Q_{in}XC_{in} - Q_{out}XC_{out}}{\text{number of household inhabitants}} \quad (4)$$

$$\text{Removal rate (\%)} = \frac{Q_{in}XC_{in} - Q_{out}XC_{out}}{Q_{in}XC_{in}} \times 100 \quad (5)$$

where: mass removed = mass of a certain influent element that is removed in the cesspit (g/d); removal is the sum of accumulated, degraded and infiltrated, which equals the influent load minus the load removed via septage; Q_{in} and Q_{out} = average daily volume of raw wastewater and emptied septage (L/d); C_{in} and C_{out} = concentration of a given parameter in the influent raw wastewater and in septage once the cesspit is filled and emptied (g/L).

Statistical data analysis

Statistical comparisons of means was followed by 'Paired samples *t*-test' in order to compare if the differences of a parameter are significantly different in raw wastewater from septage using the Statistical Package for the Social Sciences, version 20.0 (IBM 2011), with *p* value <0.05 considered significantly different. In the text, the mean values and standard deviations are given in this form: mean value (standard deviation).

RESULTS AND DISCUSSION

Water balance

The household water balance reveals a relatively low specific water consumption of 59 L/c d. The specific wastewater production is 51.5 L/c d representing 87% of the consumed water, which is higher than expected due to limited gardening activities that are in turn limited as a result of water scarcity. On the other hand, the emptied septage from the cesspit is 11 L/c d (19% of the consumed water) which implies that the total percolated wastewater to surrounding soil was 40 L/c day (68% of the consumed water). This substantial amount of septage that infiltrates into the sub-soil will affect the chemical and microbial groundwater quality. The fate of the pollutants through vertical or horizontal percolation into the soil and groundwater was not investigated in this research and requires further studies using, for example, isotopically labelled compounds coupled to hydrological modelling. Evapotranspiration is not expected to have a role because trees are not planted near the cesspit.

Individual home sewage characteristics

General characteristics

In terms of COD, the results presented in Table 1 reveal that raw wastewater characteristics of an individual home in Beit Dajan was of medium strength and was significantly less concentrated than Al Bireh municipal wastewater 1,586 (125) mg/L ($p < 0.05$). An opposite trend was noticed for TN.

The large range of total solids concentrations shows that the samples sometimes contained some sludge. This likely happened as a result of the occurrence of pulse-like eruptions of the biogas from the sludge bed (Mahmoud *et al.* 2003).

The Beit Dajan raw wastewater was more concentrated in terms of COD than the sewage in the Egyptian rural areas, Turkey, the Netherlands, Brazil and Columbia (Table 1). However, it was less concentrated than the sewage of the cities of Al Bireh and Amman, and still can be considered as medium strength according to the sewage strength classification proposed by Henze & Comeau (2008) and Metcalf & Eddy (2013). This is only for COD,

Table 1 | Sewage characteristics of individual homes and sewered communities

	Individual household wastewater				
	This study Beit Dajan village/ Palestine				
Parameters	Range	Average	U.S. EPA (2002)	WERF (2007)	Crites & Tchobanoglous (1998)
BOD_5	407–512	471 (38)	155–286	112–1,101	110–400
COD	863–1,240	995 (99)			
TN	111–322	199 (54)	26–75	139–4,584	20–85
TSS	304–4,952	1,290 (1,314)	155–330	22–1,690	100–350
TDS	265–552	383 (87)			
pH	5.8–8.3	7.8 (0.7)			
PO_4^{3-}–P	5.8–15.2	10.5 (2.7)	6–12	0.2–32	12–20
EC	554–1,143	819			
T	15–28	22 (5)			

	Sewered communities' wastewater						
	Al Bireh /Palestine	Amman/ Jordan	Rural areas/ Egypt	Istanbul/ Turkey	Bennekom/ Netherlands	Campina Grande/ Brazil	Cali/ Columbia
COD	1,586	1,183	824.9	410	528	727	267
TKN	104	109	33.8	43	70	44	24
Total P		–	8.9	7.2	18	11	1.3
PO_4^{3-}–P	13	–	3.87	4.5	14	8	–
TSS	736	420	310	210	–	492	215
T	12–27	16–24	–	–	20–8	24–26	24–25

Compiled in Mahmoud *et al.* (2003). All parameters are in (mg/L), except pH(–), EC in μS/cm and T in °C.

for TKN it is the other way around. The TSS, BOD_5 and total nitrogen (TN) values in Beit Dajan's sewage are higher than the values reported by Crites & Tchobanoglous (1998) and U.S. EPA (2002) for individual homes. However, the WERF (2007) study of individual homes has ranges of values that include the values in Beit Dajan sewage. The PO_4^{3-}-P values are within the ranges presented by other studies. The total phosphate is approximately equal to *ortho*-phosphate in domestic sewage (Mahmoud *et al.* 2003). The BOD_5 and COD concentrations did not show large daily variations over the measuring period, but TN and PO_4^{3-}-P did, which may show that anthropogenic sources of TN and PO_4^{3-}-P are more subjective to changes due to changes in occupancy of the house. The COD:BOD_5 ratios of the raw wastewater in this study are comparable to the typical COD:BOD_5 ratios of domestic wastewaters, with a range of 1.5–3.3 (Metcalf & Eddy 2013) (Table 2).

The nitrogen concentration in the household raw wastewater was very high as compared to the TN content of municipal sewage of the whole city of Al Bireh in Palestine, which is clearly due to the very low water consumption (Table 1). The nitrate concentration in the raw wastewater was negligible, thus TN is equivalent to TKN (Metcalf & Eddy 2013).

Heavy metals

The heavy metals (Cu, Ni, Pb, Mn, Fe, Cr, Zn) concentrations in Beit Dajan individual household raw wastewater reveal that iron (Fe) and zinc (Zn) have the highest concentrations (Table 3). Unfortunately, it was not possible to carry out a mass balance for the heavy metals, which is due to the very low concentration of these metals and the degree of sensitivity of the analysis.

Specific waste production

The specific organic matter production in terms of BOD_5 and COD in Beit Dajan individual household wastewater were almost half of the reference wastewaters of the Netherlands (Kujawa-Roeleveld *et al.* 2000) and of the Al Bireh City in Palestine (Mahmoud *et al.* 2003) (Table 4). This is attributed, based on interviews, to the socio-cultural-economical habit of very careful discarding of any remaining food in the dish washing sink in small towns and rural areas. In the major towns and cities of Palestine, however, discarding the remaining food and used cooking oil in kitchen sinks is believed to play a central role in increasing sewage strength. Henze & Comeau (2008) showed that the application of 'clean tech cooking' can reduce the COD load of grey water from 55 to 32 gCOD/c d. Henze & Comeau (2008) reported that kitchen waste contributes around 35% to the COD content of the traditional household waterborne wastes, and can even be much higher in cases where more solid waste is directed to the sewer system. Likewise for organic content, the specific P production is very low, which reflects low use of detergents, since

Table 2 | The COD, BOD_5, N and P ratios in raw wastewater and cesspit septage in Beit Dajan, Al Bireh wastewater and effluent UASB-septic tank treating wastewater in Al Bireh city

Locality	Beit Dajan				Al-Bireh	
Wastewater type	Raw household wastewater		Septage		Raw sewered wastewater	Effluent of a UASB septic tank
Reference	This study		This study		Mahmoud *et al.* (2003)	Al-Shayah & Mahmoud (2008)
Parameter	Average	Range	Average	Range	Average	Average
COD:BOD_5	2.12 (0.2)	1.75–2.47	3.35 (0.34)	2.95–3.88	2.05	2.13
N:BOD_5	0.4 (0.11)	0.22–0.64	0.67 (0.05)	0.59–0.79	0.13	0.28
N:COD	0.2 (0.05)	0.11–0.3	0.20 (0.01)	0.19–0.23	0.07	0.15
N:P	19.6 (4.6)	10.5–25.9	22.8 (4.02)	19–30	6.23	4.21

Table 3 | Heavy metals in raw wastewater and septage of a household in Beit Dajan during the filling period, Al Bireh City septage and raw and treated sewage in an extended aeration system compared with standards and guidelines

	Cu	Ni	Pb	Mn	Fe	Cr	Zn	Reference
Raw household wastewater (Beit Dajan)								
Avg	0.213 (0.081)	0.000 (0.000)	0.007 (0.019)	0.115(0.059)	1.567(1.284)	0.005 (0.014)	0.711 (0.947)	This study
Range	0.047–0.328	0.000–0.000	0.000–0.060	0.050–0.242	0.460–4.600	0.000–0.042	0.228–4.080	This study
Septage (Beit Dajan)								
Avg	0.399 (0.170)	0.038 (0.023)	0.18 (0.077)	0.790 (0.386)	23.685 (8.980)	0.055 (0.018)	2.937 (0.962)	This study
Range	0.172–0.652	0–0.068	0.096–0.286	0.388–1.454	12.48–36.4	0.032–0.08	1.64–4.26	This study
Concentration factor[a]								
Avg	1.87	≥2.5	≥3.6	6.9	15	≥3.66	4.13	This study
Septage (Palestinian rural areas)	0.24	0.03	0.01	0.47	12.56	0.04	1.23	Amous (2014)
Al Bireh city raw sewage								
Avg	0.221	0.075	N/A	N/A	N/A	0.163	1.364	Samara (2009)
Max	0.72	0.117	N/A	N/A	N/A	0.227	3.496	Samara (2009)
Al Bireh city treated effluent								
Avg	0.11	0.03	N/A	N/A	N/A	0.057	0.478	Samara (2009)
Max	0.207	0.047	N/A	N/A	N/A	0.089	1.480	Samara (2009)
Palestinian standards/treated sewage discharge to wadis	0.200	0.200	0.100	0.200	2.000	0.500	5.000	PSI (2003)
Palestinian lowest specifications for agricultural use	0.200	0.200	0.200	0.200	5.000	0.100	2.000	PSI (2012)
Max. HMs to be discharged in the public sewers	1.000	1.000	0.400	1.000	N/A	0.500	50.000	Sewerage municipal by-law/Al Bireh
FAO guidelines for max. HMs	0.200	0.200	5.000	0.200	5.000	0.100	2.000	FAO (1992)

All parameters are in ppm; N/A: not available.
Raw wastewater: monitored over 15 consecutive days of 24 hours composite samples each (number of samples 15); Septage monitored over the whole filling period of 120 days (number of samples 6).
[a]Concentration factor = (heavy metal concentration in septage/heavy metal concentration in raw wastewater), and when heavy metal concentration in raw wastewater was below detection limit, the detection limit was considered, as in the case of Ni, Pb and Cr.

washing machines and wash basins are significant contributors of orthophosphate in domestic wastewater. The specific N production is close to the reference wastes because the source of N remains unchanged (Table 4). It is estimated that around 85 and 47% of the waterborne waste N and P content originates from urine (Henze & Comeau (2008). The wastes that people put in the sink in large cities have COD, but only a low content of N (Henze & Comeau 2008).

Cesspit septage characteristics

General characteristics

The overall septage characteristics assessed over the whole filling period (from March to July 2012) reveal that septage is more concentrated as compared to raw wastewater ($p < 0.05$) (Tables 1 and 5). The septage quality parameters were stable over the entire filling period, with the exception

Table 4 | Specific pollutants production rate (g/c d) in raw wastewater from an individual home in Beit Dajan as compared with household and sewered sewage from literature, and emptied septage and percentage removal in cesspit and emptied septage

References Parameters	Beit Dajan/ Palestine Raw wastewater (household) This study g/c d	Emptied septage This study g/c d	%	Removal in cesspit This study g/c d	%	Al-Bireh/Palestine Raw sewage (sewered) Mahmoud et al. (2003) g/c d	The Netherlands Raw sewage (sewered) Kujawa-Roeleveld et al. (2000) g/c d	USA Raw sewage (household) WERF (2007) g/c d
BOD_5	25	5.6	22	19.4	78	60	–	50–70
COD	51	19	38	32	62	170	102	–
TN	10	4.8	48	5.2	52	11	12.9	10.3
PO_4^{3-}-P	0.51	0.17	33	0.34	66	1.4	1.7	1.7
TSS	83	26	31	57	69	–	–	–

of COD and TS that increased with time due to accumulation.

The general quality values of septage from the studied cesspit are low or in the lower range when compared to the septage values from other sources (U.S. EPA 2002). That is because the septage quality presented by the U.S. EPA is for septage from septic tanks, which are popular in the United States, and which is basically settled, accumulated and digested sludge. The slightly high COD/BOD_5 ratio indicates that septage is of less biodegradability as compared to raw wastewater since it increased from 2.12 to 3.35. The increase in the COD/BOD ratio is due to removal of easily biodegradable organic matter through anaerobic processes in the cesspit, and accumulation of non-biodegradable or slowly biodegradable organic matter (Table 4).

The nitrogen concentration inside the cesspit is quite high as compared to nitrogen concentration in the influent raw wastewater due to ammonification processes of the particulate nitrogenous compounds that accumulate there

Table 5 | Septage characteristics of individual household septage cesspit in Beit Dajan and in the USA

Locality/Country Reference Parameters	Beit Dajan/Palestine This study	Range	Average	Al Bireh City /Palestine wastewater Hithnawi (2004)	USA septage[a] U.S. EPA (2002)
BOD_5		448–527	504 (29)	–	440–78,600
COD	863–1,240	1,533–1,793	1,681 (107)	1,034	1,500–703,000
TN	111–322	308–378	340 (27)		66–1,060
NH_4^+-N				83	
TSS	304–4,952	352–2,495	1,491(998)	3,068	310–93,378
TDS		427–580	499 (49)	–	353–71,402
pH		6.7–7.0	6.85 (0.1)	7.2	1.5–12.6
PO_4^{3-}-P	5.8–15.2	11.3–16.5	15.1 (2)	12	20–760
EC	(1,143)	891–1,422	1,141 (170)	–	–
T		19.8–25.6	24.4 (2.3)		

All parameters are in (mg/L), except pH (–), EC in μS/cm and T in °C; # of raw wastewater samples is 15, and # of septage samples is 6; Standard deviations are presented between brackets.
[a]Source: U.S. EPA (2002).

(Tables 1 and 5). The nitrogen load from a cesspit either to nature, once disposed in open areas, or to a treatment plant, is clearly of serious concern. The oxygen demand to oxidize this nitrogen load is around 1,500 mg/L.

Moreover, it is estimated that for complete nitrification of the 340 mg N/L in the septage, the alkalinity will decrease by around 2,430 mg $CaCO_3$/L (considering that for every 1 mg N to be nitrified, 7.14 mg alkalinity as $CaCO_3$ is consumed to accommodate the produced H^+). But this amount of alkalinity is far more than the alkalinity present in septage, based on septage alkalinity of 547 mg $CaCO_3$/L presented by Hithnawi (2004) for random septage samples analysed in Al Bireh City (Palestine). Therefore, the treatment of septage from localities with low water consumption in septage biological treatment systems will require the addition of external alkalinity. This is because alkalinity in wastewater comes mainly from the carbonate species that already exist in the used drinking water. Consequently, when water consumption is low, the alkalinity in wastewater will also be low.

The high N:P ratio might be due to socio-cultural reasons, such as low use of detergents, as well as wastewater disposal methods, viz. partly disposal of dish washing water in the garden. Although lower income means usually less consumption of meat protein, plant protein such as lentils are very popular in Palestinian traditional food which increase the N in wastewater as well.

Heavy metals present in cesspit septage

It was found that Fe in septage had the highest concentration followed by Zn as compared to other metals ($p < 0.05$) (Table 3). The high Fe concentration is most likely due to solubilisation of iron from the ferric to ferrous form under completely anaerobic conditions in the cesspit. The dissolved oxygen in the very upper part of septage inside the cesspits was zero (data not shown).

The reference guiding and standard values presented in Table 3 reveal that the heavy metals (Cu, Pb, Mn, Fe and Zn) content is not in compliance with the heavy metals concentration limits according to the Palestinian regulations for wadi disposal and effluent reuse in agriculture. This entails that septage disposal in wadi and agricultural fields is not safe.

The sewerage by-law of the Al-Bireh municipality (for the year 2000) has specified obligatory guidelines for industrial effluent quality. According to this by-law, pollutant concentrations in this effluent shall not exceed the identified limits (Table 3). As per these regulations, septage heavy metals concentrations allow the disposal of septage in the septage receiving unit of the Al-Bireh WWTP to be further treated in the aerobic system.

Thermotolerant coliforms

Thermotolerant coliforms were found in both raw wastewater and septage samples with high counts of 6.7×10^7 (8.9×10^4) CFU/100 mL and 8.4×10^6 (3.6×10^6) CFU/100 mL, respectively. This shows that the number of thermotolerant coliforms had decreased significantly ($p < 0.05$) in the cesspit. Most likely this was due to the long retention time. The survival time of thermotolerant coliforms is less than 60 days and usually less than 30 days at 20–30 °C (Westcot 1997). Sedimentation may be one method of pathogen reduction, but this does not preclude soil infiltration, survival and propagation. The main message relayed by the results of this research is that current practices are inadequate from an environmental perspective, and the thermotolerant coliforms, indicating pathogens, behaviour in a system like a cesspit do strengthen this argument.

CONCLUSIONS

- The cesspit's septage is much more concentrated than raw wastewater.
- The percentage (%) removal rates in gram per capita per day (g/c d) are: BOD_5 (78%), COD (62%), TN (52%), PO_4^{3-}-P (67%) and TSS (69%).
- The percentage (%) pollution loads of emptied septage are: BOD_5 (22%), COD (38%), TN (48%), PO_4^{3-}-P (33%) and TSS (31%).
- The heavy metals content in septage do not comply with regulations for wadi disposal and effluent reuse in agriculture. However, septage HM concentrations allow the septage disposal in municipal WWTPs.

- Most of the TN removed, equal to 52% of the TN load to the cesspit, will most likely infiltrate into the surrounding soil, and may reach the groundwater.
- The thermotolerant coliforms removal in the cesspit is inadequate from an environmental perspective.
- The septage quality parameters were stable over the entire filling period, with the exception of COD and TS that increased with time due to accumulation.
- The cesspits should be replaced by proper on-site or off-site wastewater management systems.

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