# Sludge accumulation in an anaerobic pond and viability of helminth eggs: a case study in Burkina Faso

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**Abstract**
Sludge accumulation and its pathogen content in pond are important to be known in developing countries for its management and to safeguard public health from its reuse. An anaerobic pond has been investigated for sludge accumulation and helminth eggs viability after four years operation in Burkina Faso. The rate of sludge accumulation was evaluated to averages of 18.4 cm/year, and 0.037 m3/capita year. Two equations describing vertical distribution of total solids and volatile solids in the accumulated sludge were found to be represented by the regressions equations adequately. Helminth eggs were reduced on average by 90% in the anaerobic pond. *Ascaris lumbricoides* and *Ancylostoma sp* were the most common eggs present in the sludge after four years operation. The average concentration of helminth eggs was 536 eggs/gTS and theirs rates of viability ranged from 10.8% (47 viable eggs/gTS) to 57.2 (1772 viable eggs/g TS, with an average rate of 36% (336 viable eggs/g TS). From a sludge depth and section study, eggs viability was found to be randomly distributed in the sludge layer.

**Keywords**
Anaerobic pond; egg viability; helminth; sahelian climate; sludge accumulation; sludge distribution.

## INTRODUCTION

Wastewater stabilization ponds are a simple, low-cost and low-maintenance process for treating wastewater. Their usage in developing countries is advised when sufficient land is available and where the temperature is most favourable for their operation (Mara, 2004; Nelson *et al.,* 2004). They comprise one or more series of different types of ponds in a system and usually, the first pond in the series is an anaerobic and serves as the primary treatment stage. The anaerobic pond's good performance for BOD and SS removal are often pronounced in warm climates such those of sub-Saharan. As others stabilisation ponds, the anaerobic pond generates a proportion of sludge that must be desludged in order to assure further sustainable operation of the pond. The wastewater and their subsequent sludge in developing countries particularly in Sub-Saharan Africa may contain significant concentration of helminth eggs due to their high prevalence related to the poor socio-economic conditions in these regions. The concentrations of these parasites must be known to estimate the risk they pose upon removal of the sludge (Nelson, 2003; Jiménez 2007).

Saqqar and Pescod (1995) studied sludge accumulation in Jordan, Gonçalves (2002) reported data on sludge accumulation in Brazil, Picot et al.(2003), Papadopoulos et al.(2003), studied sludge accumulation pattern in anaerobic pond under Mediterranean climatic conditions respectively in French and in Northern Greece. Nelson et al (2004) reported data on sludge accumulation, characteristics and pathogens inactivation in Mexico and stated that more regional data are needed to determine sludge rates accumulation, sludge distribution and sludge characteristics. In Burkina Faso, no information is available on sludge and helminth contents in anaerobic ponds. Owing to the scarcity of data, the goal of this research is to evaluate sludge production in an anaerobic pond and their functioning in sahelian tropical climate of Burkina Faso. The study comprises the following:

(i) Determining the accumulation rate and distribution of sludge in the anaerobic pond

(ii) Determining sludge characteristics

(iii) Determining helminth eggs concentration and viability for needs of risks associated in management for agriculture reuse which is often the preferred option of farmers.

## MATERIALS AND METHODS

### Description of the experimental pond system

This work was carried out at the pilot scale wastewater stabilization pond system (12°22' N, 1°30'W) of the International Institute for water and Environmental Engineering (2iE) of Ouagadougou. Its functioning was typical marked by the soudano-sahelien climate with a long dry season (from October to May) and a moderately favorable belt for solar energy that gets 2500 hours of solar energy per year with an intensity of 19.5 - 22.7 $MJm^{-2}d^{-1}$.The rainy season from June to September was characterized by an average pluviometer varying between 600 to 900 mm. The minimal monthly air temperatures varied from 16°C in January with 26.5°C in April and the maximum ones varied from 32°C in January with 42°C in April. The monthly average temperature of the coldest month of the year (January) varied between 25°C and 26°C.

The anaerobic pond was built in 2004 as the first treatment pond of a series of ponds constituted by one anaerobic pond (AP), one facultative pond (FP) followed by one maturation pond (MP). The plant treats wastewater from the 2iE campus. With a hydraulic retention time of three days, the anaerobic pond was constructed in replacement of a primary settling tank that was revealed inefficient for the load applied. It receives screened raw wastewater which entered the pond at 1m depth and was drawn at 300 mm below the surface. The anaerobic pond has a geometry form of cylinder-cone trend egg-shaped, with the top surface of 103 $m^2$ and the bottom surface of 8 $m^2$. Its total depth is 3.1 m with 0.5 m free board and a wall slope of 2/3. Its effective depth is 2.6 m and the volume is 181 $m^3$.

During the four years of operation (from October 2004 to September 2008) the pond received different flow rates ranging from 40 to $66m^3d^{-1}$ with an average flow rate of $55m^3d^{-1}$. This flow rate variation corresponded to the volumetric organic loading of 104 to 225g BOD $m^{-3}d^{-1}$. The organic load was equivalent to 448 PE.

### Sampling Method

Sludge sampling was performed in September 2008 during the bathymetric surveys of the distribution of sludge in the anaerobic pond without empty it, after four years of continuous operation. The pond was divided in 12 bathymetric section spaced by 1m as shown in the figure 1. The sludge layers in the pond were measured for thickness and samples were collected to determine the accumulated properties and parasitological aspects of which helminths. The sludge depth was measured with the white towel test technique described by Mara (2004). With a pre-prepared grid representing the pond, five points (as illustrated in Figure 1) were chosen for full depth sludge samples and some grabs samples were taken along the sludge at different step of 10 cm, from the bottom (level zero) to the top of sludge depth.

The sludge cores were collected using a transparent plexiglas tube with a diameter 60 mm and 3.5m of length. The tube was opened at its basis and supplied with a movable faucet witch adheres well the basis of the tube preventing any flow when it is closed.

The faucet was tied at its two sides by a long robe going freely by the inside of the tube. The procedures of the sludge cores sampling constituted to lower the tube vertically into the pond (at point of sampling) until it reaches the bottom. Then, the robe was pulled and the faucet imprisons the column of sludge. The tube was then taken away in an upright position and the sludge was collected at the tube basis by opening the faucet and the overlaying water was removed. For the grab sampling at different depths, a device called “shaft syringe” was used (Figure 2). This was constituted by syringes of 50 ml attached at different levels around a shaft in iron. A robe was attached at the piston of the syringe and permitted to aspirate the sludge. Each robe attached at a syringe was indentified by a label where was marked the depth of sludge corresponding. Three shaft syringes were used simultaneously. The first shaft syringe was constituted by one first syringe fixed at the zero level for the bottom sampling collection and the next syringes and others were fixed at intervals of 30 cm. The second shaft syringe was constituted by one first syringe fixed at the distance of 10 cm level from the end on the shaft and the others were spaced with 30 cm intervals. The third shaft syringe was constituted by one first syringe fixed at 20cm level from the end of the shaft and the others ware spaced with 30 cm intervals. This procedure permitted to collect simultaneously sludge samples at different depths spaced with 10 cm interval.

Basic physico-chemical properties of the sludge were measured, including the pH, conductivity, total solid (TS), fixed (FS) and volatile solids (VS) according to Standard Methods (2005). Sludge density and percentage of water content (WC) were also deducted.

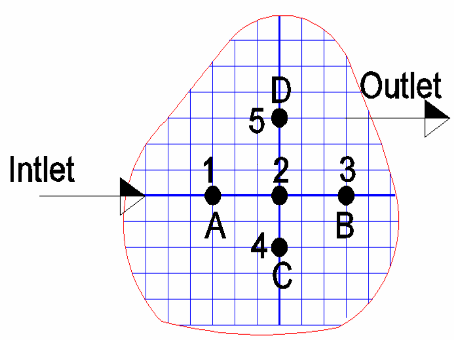


**Figure 1** Pre-prepared grid of the anaerobic pond

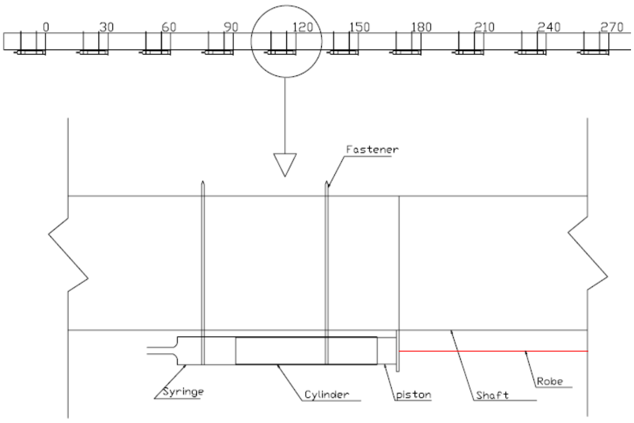


**Figure 2** Device of shaft syringe

**Helminth eggs concentration and viability test**

There are different analytical procedures to recover and detect viable and non viable helminth eggs. For this study, the helminth eggs and their viability were determined by combining the US EPA protocol (1999) modified by Schwartzbrod (2003) with adapted safranine O (2.5% in $H_20$) dying method developed by de Victoria and Galvan (2003). This method permit an accuracy of recovered eggs amounts to 75.5% when applied biosolid analysis (Bowman et al., 2003).

## RESULTS

**Sludge distribution and accumulation**

Figure 3 shows the distribution of sludge measured in the anaerobic pond after four years operation.

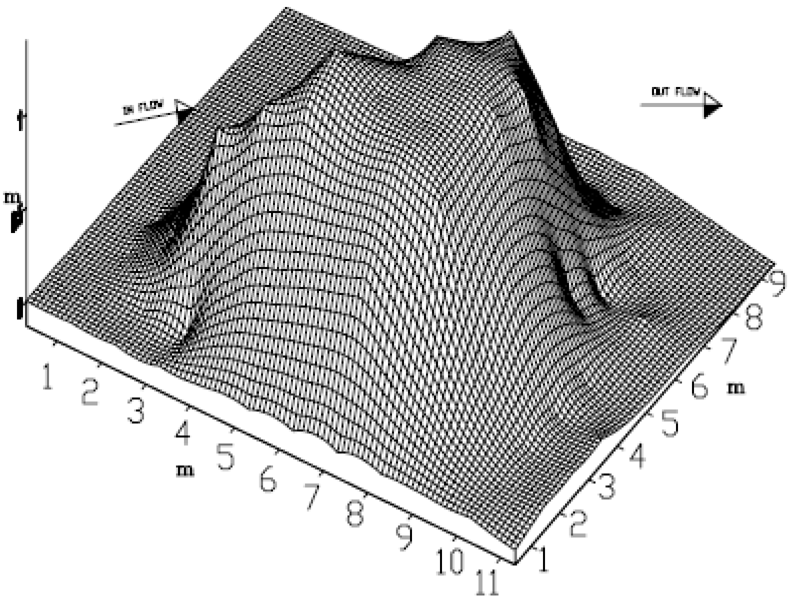

Figure 3 Sludge distribution in the anaerobic pond

In the pond, the height of sludge accumulation varied ranging from 12.3 cm to 139 cm with an average of 74 cm. We estimate the accumulation rate to 18.4 cm/ year. The weak heights were measured near the inlet while the high ones were measured in the middle of the pond. This distribution is similar to those reported by Papadopoulos et al (2003) regarding the geometric shape of the pond (i.e an inverted truncated pyramid comprising of steep slopes at the sidewalls (2:3)). In term of volume, the total sludge accumulation was 66 $m^3$, representing 36.5% of the pond volume. This rate is slightly higher than that (one-third full of sludge) recommended by Mara *et al* (2004) for anaerobic pond desludging. With an organic load of 448 Equivalent-Inhabitant, the sludge accumulation rate for anaerobic pond studied was calculated to be 0.037 $m^3$/capita year. This rate is greater than those reported by Picot et al (2003) in French (0.017 $m^3$/capita year), Nelson et al (2004) in central Mexico (0.022 $m^3$/capita year). The rate obtained in this study is relatively similar to the value of 0.04 $m^3$/capita year reported by Mara *et al* 2004 in warm climate, the value of 0.05 $m^3$/capita year reported by Pena *et al* (2000) in Columbia and the value of 0.0519 $m^3$/capita year reported by Gonçalves et al (2002) in Brazil.

**Sludge characteristics**

Data on sludge characteristics were shown in Table 1. Temperature and pH showed weak variation in the sludge even if the global trend slightly decreased with sludge depth (from the top to the bottom) whereas the conductivity increased from the bottom to the top. The ranging values of WC (86.9%- 99.7%) and TS (0.2% – 13%) explained that the sludge were in liquid to pasty forms; the last ones were observed in the first five centimeters depths at the bottom of the pond. Considering the solids, the average values found for VS less than 50% indicated the digested stage of the sludge.

The solids concentration (TS and VS) were found to be correlated with depth in the sludge with coefficients of determination $R^2$ respectively 0.82 and 0.69 (Figure 4). Nelson *et al.* (2004) have found similar correlation of TS with depth ($R^2$= 0.84) in anaerobic and facultative pond sludge layers. In accordance to authors, these regression equations can be used to estimate the solids concentration of the sludge if the thickness of sludge layer is known. This information is useful to develop more accurate methods for sludge accumulation and biodegradation estimation and can help for predicting appropriate method for sludge removal.

**Table 1** Sludge characteristics

| Parameters | Mean | Min | Max | σ |
|---|---|---|---|---|
| Temperature °C | **26.5** | 22.3 | 31.2 | 2.8 |
| pH | **6.4** | 6.4 | 6.5 | 0.01 |
| Conductivity μ$Scm^{-1}$ | **2988** | 1862 | 4480 | 865 |
| Density | **1.1** | 11 | 1.13 | 0.02 |
| Water content % | **93.9** | 86.9 | 99.7 | 2.4 |
| Total solids (TS) % | **6.1** | 0.2 | 13 | 2.4 |
| Fixed solids (%TS) | **50.6** | 28.3 | 80.5 | 7.4 |
| Volatile solids (%TS) | **49.4** | 19.5 | 71.7 | 7.4 |

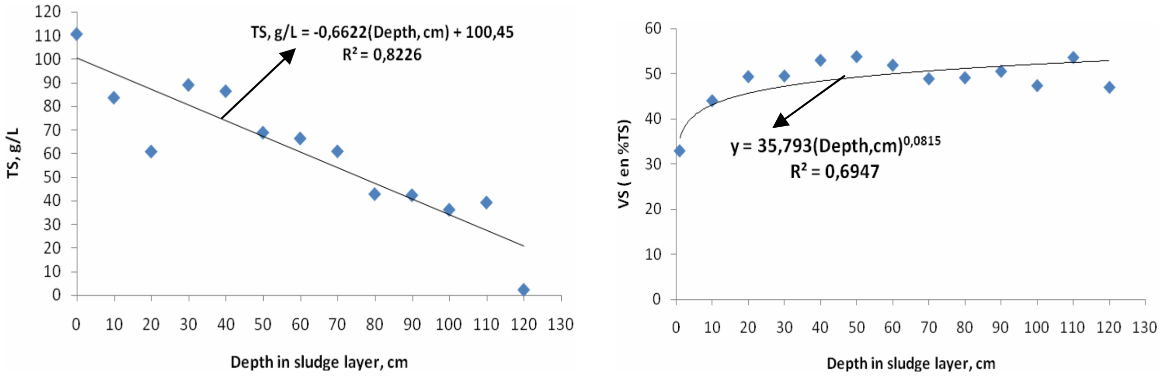


**Figure 4** Total solids (left) and volatil solids (right) as a function of depth in sludge layer

**Helminth removal in the anaerobic pond**

The composition of influent in term of helminth eggs concentrations were variable ranging from Zero to 15 helminth eggs per litre with an average of 5 eggs/l. The helminth eggs detected in raw wastewater were those of *Ascaris lumbricoides* (0 to 10 eggs/l), *Ancylostoma sp* (0 to 4 eggs/l), *Trichuris trichiura* (0 to 1 egg/l), and *Trichostrongylus sp* (0 to 1 egg/l). The four genera of helminth eggs identified in raw sewage presented the following composition: *Ascaris lumbricoides* (45.5%), *Ancylostoma sp* (37%), *Trichuris trichiura* (9%) and *Trichostrongylus sp* (8.5%). The concentrations of helminth eggs obtained in this study were representative for the campus wastewater of 2iE. They would be less than that can be founded in urban area wastewaters in Africa and others developing countries where high concentrations of pathogens are currently reported in literature reviews. The concentration of eggs in wastewater and in sludge is likely to reflect prevalence in the community (Llyod and Frederick, 2000). The findings in this study would attest the consideration that the campus of 2iE regroups students and staff supposed to have a hygiene education and integrated interventions such as de-worming to reduce the risk of helminth contamination.

According to Ayers et al (1993), the primary removal mechanism for parasite eggs is thought to be sedimentation facilitated by suspended solids removal. The results obtained in the routine monitoring of helminth eggs removal in the anaerobic pond studied seems to be in accordance to this assertion with the best average removals observed of 90% for helminth eggs.

**Accumulation of helminths eggs in the sludge**

All the species observed in raw sewage were found present in sludge layer: *Ascaris lumbricoides*, *Ancylostoma sp*, *Trichuris trichiura and Trichstrongylus sp*. The vertical distribution of helminth eggs was studied at five locations (Figure 1) along the length section A-B including near the inlet (location 1), middle (2), outlet (3), and the crosswise section C-D including the right side (4) and the left side (5). At the sampling points, the thicknesses of sludge layer were: **1** (48 cm), **2** (126 cm), **3** (57 cm), **4** (67 cm), **5** (56 cm).

The concentration of total helminth eggs showed (Figure 5) higher values in the middle side (location 2) with 807 eggs/g TS than near the inlet (538 eggs/g TS) and near the outlet 343 eggs/g TS. At the right side (point 4) and the left one (point 5), these concentrations were respectively 504 eggs/g TS and 489 eggs/g TS. The average concentration was 536 eggs/g TS. Regarding the distribution of eggs at the five locations, it is likely the concentration of eggs was a function of the height of accumulated sludge with a maximum observed in the middle of the pond. The results on column sludge measured show the following species composition (%) of helminths eggs per g/TS: *Ascaris lumbricoides* 38.5%, *Ancylostoma sp* 55.8%, *Trichuris trichiura* 0.5%, and *Trichstrongylus sp* 5.2%. *Ascaris lumbricoides* and *Ancylostoma sp* were the most common eggs present in the sludge after four years operation.

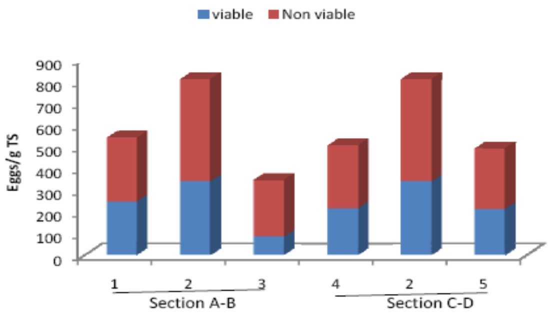


**Figure 5** Distribution of helminth eggs in slugde along the length and width of the pond

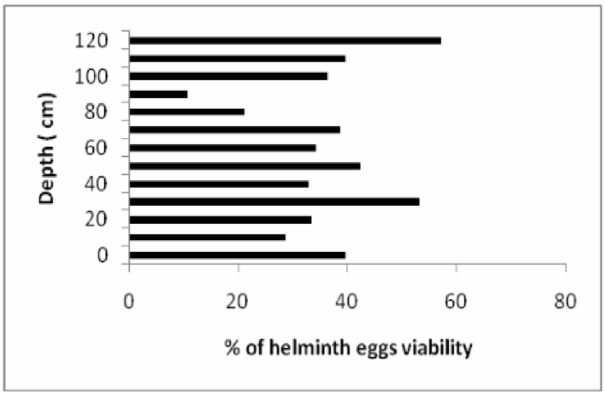


**Figure 6** Eggs viability along the depth profile

**Viability of helminth eggs in the sludge**

The main risk in sludge management in term of public health is the viable fraction bound to its potential infection (Zerbini and Chermicharo, 2001 in Sperling et al., 2003). The sludge, after four years operation, showed a percentage of viable eggs along the section A-B of 46 percent near the inlet (1), 42 percent at the middle (2), and 24 percent near the outlet (3). The rate viability was similar at the two sides on the pond along the section C-D with 42 percent of helminth eggs viability. The viabilities observed were less than 50% at each sample location with a slightly decrease from near the inlet to near the outlet along the length (section A-B) of pond. Along the width section C-D none significant trend was observed.

Table 2 presents the vertical distribution of the species of helminth eggs/g TS found in the sludge at regular intervals from the bottom (level zero) to the top layer (120 cm) corresponding to recent deposited sediment. All the samples (100%) analysed at different depth location were positive in viable helminth eggs. This could mean that there is not yet a safe sludge depth in the vertical distribution of helminth eggs in this study. The rate of the helminth eggs viability (Figure 6) varied widely from a minimum 10.8% (47 viable eggs/g TS) measured at the level 90cm from the bottom to a maximum of 57.2% (1772 viable eggs/g TS) measured at the level 120 cm from the bottom (i.e in the surface sediment). The average percentage viability was 36% (336 viable eggs/g TS). The rates of viable helminth observed at different depths in sludge layer (Figure 6) were found randomly distributed without a clear trend. The expected distributions of viable eggs were that they would decrease with depth in sludge layer. In contrary, in our study, the randomly distribution could be explained by spatial heterogeneity and re-suspension of sediment induced by gas production in anaerobic sludge layer. The presence of viable helminth eggs at the deepest sludge layer confirm that public health issues must be considered for desludging and agriculture reuse.

**Table 2** Vertical distribution of the species of helminths eggs found in sludge layer

| | ***Ascaris Lumbricoides*** | | ***Ancylostoma sp*** | | ***Trichuris trichiura*** | | ***Trichostrongylus sp*** | | **Total count** | |
|---|---|---|---|---|---|---|---|---|---|---|
| Depth (cm) | **V** | **NV** | **V** | **NV** | **V** | **NV** | **V** | **NV** | **V** | **NV** |
| 0 | 11 | 36 | 90 | 109 | 0 | 4 | 18 | 34 | 119 | 183 |
| 10 | 31 | 114 | 33 | 45 | 0 | 1 | 0 | 0 | 64 | 161 |
| 20 | 38 | 116 | 35 | 42 | 0 | 0 | 8 | 3 | 81 | 161 |
| 30 | 95 | 202 | 258 | 157 | 0 | 0 | 67 | 11 | 421 | 371 |
| 40 | 58 | 150 | 150 | 313 | 0 | 0 | 35 | 35 | 243 | 497 |
| 50 | 116 | 138 | 29 | 65 | 0 | 0 | 15 | 15 | 160 | 218 |
| 60 | 60 | 181 | 72 | 108 | 0 | 0 | 24 | 12 | 157 | 301 |
| 70 | 65 | 158 | 328 | 486 | 0 | 13 | 53 | 53 | 446 | 709 |
| 80 | 37 | 137 | 131 | 561 | 0 | 0 | 19 | 0 | 187 | 698 |
| 90 | 19 | 152 | 9 | 222 | 0 | 9 | 19 | 5 | 47 | 388 |
| 100 | 120 | 88 | 133 | 387 | 0 | 0 | 44 | 44 | 297 | 519 |
| 110 | 114 | 31 | 265 | 500 | 1 | 20 | 0 | 31 | 380 | 581 |
| 120 | 1327 | 442 | 442 | 885 | 2 | 0 | 0 | 0 | 1772 | 1327 |

V= Viable; NV Non Viable

## CONCLUSION

In this study, the rate of sludge accumulation in anaerobic pond in sahelian climate was evaluated to be 0,036 m3/ capita year. Water content and the rates of total solids found showed that the sludge were in liquid to pasty form. The vertical distributions of TS and VS were found to be adequately describe by regression equations and indicate a consolidation and a mineralization of sludge with depth

The removal efficiency of helminth eggs from the wastewater was 90% in the anaerobic pond with an hydraulic residence time of 3days. The prevailing helminth species found in the sludge were *Ancylostoma sp* and *Ascaris lumbricoides*. The higher percentage of viable helminth eggs are found in surface sludge. Although the destruction of helminth eggs appeared in the sludge layer, the remained rates of eggs viability found after 4 years of operation demonstrate the needs for further treatment before its disposal and reuse for land application. This treatment must be done in low cost way taking into account the financial constraint prevailing in sub-Saharan Africa regions. Co-composting and drying bed methods for sludge treatment will be our next investigations for sludge management.

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