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Abstract

The agronomic potential of wastewaters in general and faecal sludge in particular is now recognized by the scientific community as well as farmers. Indeed, in Dakar these products are used in urban agriculture, with satisfactory results in terms of productivity. At the Faecal Sludge Treatment Plant (FSTP) of Camberene, the gardeners and florists are showing more and more interests for the dried sludge from drying beds. However, these practices of reuse pose environmental and health risks because they facilitate the transmission channels of different forms of pollution.

To remedy to this and take more advantage of the agronomic potential of sludge, many treatment options have been tried. These are simple, hygienic, low cost and adapted to climate conditions of developing countries. Vertical Flow Constructed Wetlands (VFCW) are, to date, recognized as capable to reduce faecal sludge pollutant content and transform sludge into a stable humus which can be safely used as agricultural amendments. In this process of transformation, a number of factors are involved in different ways.

The overall objective of this study was to evaluate the impact of these factors on the process of humification and the inactivation of helminth eggs. The scientific approach to be adopted will be to shed light on the influence of residual moisture, the nature of plants and the nature of the incoming sludge to develop ideas on how to use VFCW in an optimal way that allow the the production of safe humus.

Keywords

Faecal sludge, VFCW, Humification, Residual moisture, Nature of plants, Nature of sludge, Helminth eggs inactivation.

INRODUCTION

Enrolled in the Goal n° 7 of the MDG's, sanitation has been known for a renewed interest in both governments and NGOs which are spending more and more funding. This new approach was embodied in the countries of sub-Saharan Africa by increasing the sanitation coverage from 26% in 1990 to 31% in 2006 (UN 2008). This increase is due to the consolidation of a multitude of sanitation policies initiated by the government of each country with support of development partners. It is in this context that ONAS has set up, under the Long Term Water Project (Projet Eau à Long Terme : PELT) and the Sanitation Program of Peri Urban Districts of Dakar (Programme d'Assainissement des Quartiers Péri Urbains de Dakar : PAQPUD). These projects funded by the World Bank aims to provide 60 000 individual wastewater 270 000, 160 semicollective systems 130 000 persons, 10 public lavatories and 70 school toilet blocks. Following the PELT, the National Drinking Water and Sanitation Program of the Millennium (Programme national d'Eau Potable et d'Assainissement du Millénaire : 2005-2015) is the instrument by which the government of Senegal aspect to achieve until 2015 the Millennium Development Goals on water and sanitation in urban and rural areas. The objectives of this program for sanitation in rural areas are to raise the access rate in sanitation from 17% in 2004 to 59% in 2015 and to ensure sanitation of public places in rural communities. In urban areas, this Program aims to increase the access rate of 56.7% in 2002 to 78% in 2015.

In these different consolidation policies, emphasis is placed on one-site sanitation systems which are left stranded by the makers. So many systems have been constructed. This new built facilities cause a sharp increase in the coverage of sewerage allowing a good management of liquid waste at the concession. Unfortunately, the MDGs advocate the need to extend the coverage of improved sanitation, but fail to recognize the importance of maintenance of latrines for sanitary conditions (Parkinson and Quader 2008). Indeed, the good coverage on-site sanitation has resulted in the production of large amounts of septic sludge whose amount increases gradually each year.

Contrary to wastewater management, development of faecal sludge management strategies tailored to conditions of developing has been neglected. The faecal sludge collected by these systems are usually discharged untreated into the urban and suburban areas, which poses great risks to water resources and public health. (Ingallinella et al. 2002). The city of Dakar is not immune to this reality. Indeed, the sludge drawn off the septic tanks are routinely discharged into the wild areas of stripping, the network of urban sewage or in holes drilled in the streets or in backyards. These illegal practices may have, because of the different forms of pollution contained in the sludge, harmful effects on the environment and health. Thus, the 2002's health statistics of the Ministry of Health ranked diarrhoeal and parasitic diseases, all linked to water, to the fourth most cases of disease and diarrhoeal diseases rank second among cases of death after malaria.

However, the lack of sanitation can not be the only factor to consider when we are trying to establish a relationship between the removal of excreta and the transmission of diseases and other environmental damage. These risks may be related to the reuse of wastewater and human excreta in peri urban agriculture. Indeed, the use of wastewater and excreta in agriculture is a major source of spread of salmonella and other infectious protozoa in the environment (Melloul et al. 2002). This practice is known in Dakar in *Niayes* valley. It is strengthened more and more because according to gardeners, it saves water and inputs.

To take better advantage of the agronomic potential of sewage sludge and at the same time protect people from risks related to the reuse of sludge, their hygienic treatment seems inevitable. The processing technologies applied to sewage sludge can be used to treat faecal sludge. However, their application in developing countries is limited by the costs of construction, implementation and lack of jurisdiction. The challenge this poses is to develop low cost treatment options which are simple to operate and to ensure satisfactory performance.

A natural treatment system, useful for the treatment and dewatering of sludge is formed by VFCWs (Koottatep et al. 2005). This processing technology of sludge has the double advantage of providing adequate clearance rate and a course final product (biosolids). The VFCW uses biological treatment process in which a number of biochemical changes occur as a result of the activity of plants, microbes and other physical factors (Koottatep et al. 2005). These processes convert the organic matter to stable organic matter during the process of humification in situ. The biosolids generated are comparable to those of other mature composts (Kengne et al. 2009).

To date in a world characterized by an unprecedented food crisis, a generalized impoverishment of the peasantry in developing countries and global warming with serious consequences, planted drying beds, by their ability to transform faecal sludge into humus may be a successful alternative. Indeed, this practice can help to reduce emissions of greenhouse gases (limiting incineration operations), to promote environmentally sustainable of agriculture through the reduction of chemical inputs and is likely to become increasingly important in the overall management of the environment (Senesi and Plaza 2007).

Despite the unanimity of the scientific community about the ability of VFCWs to mineralize bed filters and humifier biosolids, the action of the main factors influencing this system is not well known. Most studies on the transformation of organic matter in natural systems refer to the transformation of litter in the forest or composting.

This thesis aims to first follow the purification performance but also to explain the mechanisms responsible for the humidification and the inactivation of helminth eggs in biosolids. It includes the following specific objectives

SO1: follow the purification performance during the different experiments;
SO2: monitor the influence of residual moisture on the process of humification;
SO3: follow the influence of plant type on the process of humification;
SO4: follow the influence of the type of sludge on the process of humification;
SO5: follow the inactivation of helminth eggs in the different experiments during the maturation phase.

MATERIAL & METHODS

1-Experimental design

The first device consists of 3 beds, each with an area of 4 m2. They have a depth of 85 cm occupied upwards by 5 cm of coarse gravel size from 10 to 40 mm, 15 cm of fine gravel of size 5 to 10 mm and 15 cm of beach sand. The base of the filtration device is occupied by a central drain which runs through the bed. The PVC drain has a diameter of 5 cm. It is also equipped with several holes in the top uncovered. It has a slope of 2.5% and communicates with an outlet.

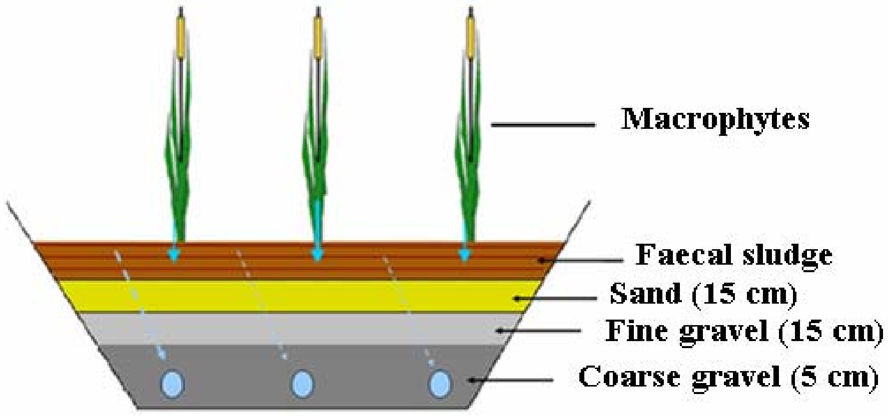

Figure 1: Diagram of a planted drying bed

Unfortunately, these three beds can not allow us to multiply experiences in order to be able to do statistical analysis. For that, currently, nine experimental beds (photo 1) with 50 cm diameter and 90 cm depth are in place.

Photo 1 : Experimental scale drying beds

These beds are composed in the same way as previous these last beds will be used in all the experiments we have undertaken in this study.

2- Experimental procedure

2-1 Macrophyte choice

In this study, Echinochloa pyramidalis and Typha australis are the two macrophytes that will be used. The choice of these two plants is motivated by their good adaptation to the sludge conditions. Indeed, in beds that are now operating in full-scale (unpublished results), these two plant species showed good growth behaviour and good performance of removing common pollutants (SS, MS, COD, N). Other units, Echinochloa pyramidalis has shown real potential to humifier biosolids accumulated on the surface of the bed (Kengne et al. 2009).

2-2 Planting and acclimatization

The planting will be done with cuttings long from 15 to 20 cm with at least two internodes. Cuttings are placed in a hole not to exceed 5 cm depth with a density of 9 plants / m2. The period of acclimatization should last 1 to 2 months depending on the growth rate of regrowth of plants. During this period, the cuttings are watered every day with tap water, the supernatant or raw sludge having a concentration of less than 3 g / l (Abiola, 2009 unpublished results).

2-3 Scalability

This phase take place immediately after the acclimation. It takes 1 to 2 months. This phase will gradually accustom plants to charge more and higher. This can avoid plants mortalities..

2-4 Mass loading rate

In all the experiments to be conducted in this study, the beds are supplied with a nominal load of 200 kg TS/m2/year. This charge has been described by Kengne et al. (2009) as the optimum for Echinochloa pyramidalis. Also in planted beds which are operated at full scale, Typha australis (unpublished results) showed a good performance on similar charges. The beds will be operated at rated load for one year. A maturation period of 6 months will be observed (Kengne 2009

3 Procedure

3-1 Influence of humidity

To elucidate the influence of this parameter on the process of humification, we will vary the moisture in the sludge dewatering by varying the supply frequency. The experimental protocol is summarized in the diagram below

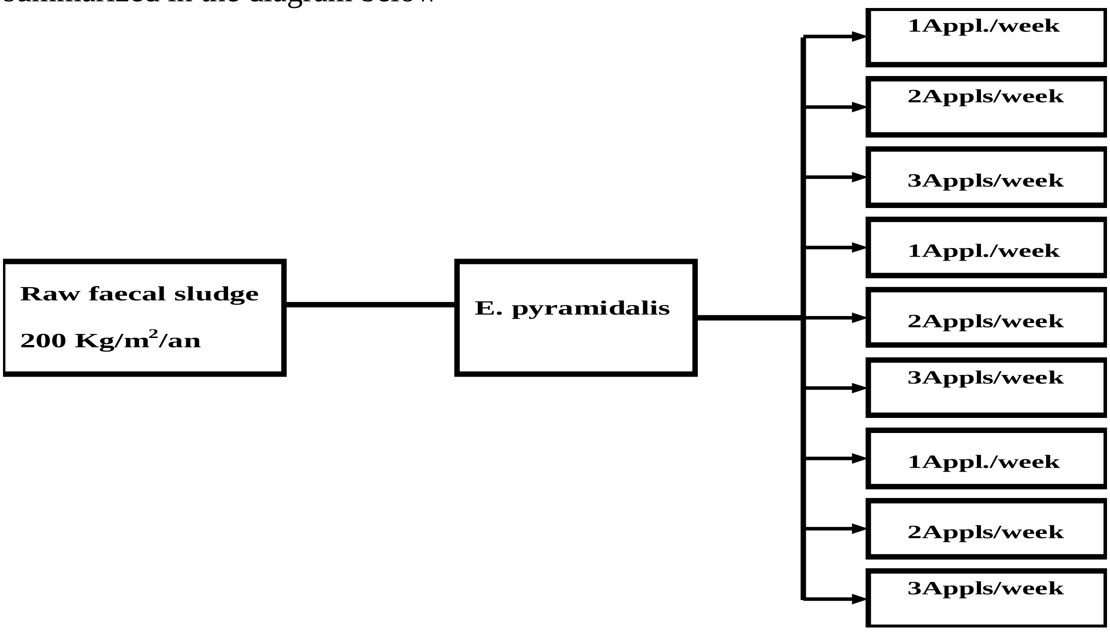

Figure 2: Procedure for determining the influence of moisture

3-2 Determination of the influence of the type of plant

To see the influence of plant type on the humification process, we will use two different types of plants. These plants (Typha australis and Echinochloa pyramidalis) will be planted with the same density and acclimated to their new environment in the same conditions. In the third reads the two plant species will be mixed with the same density as before. The procedure is summarized in the diagram below.

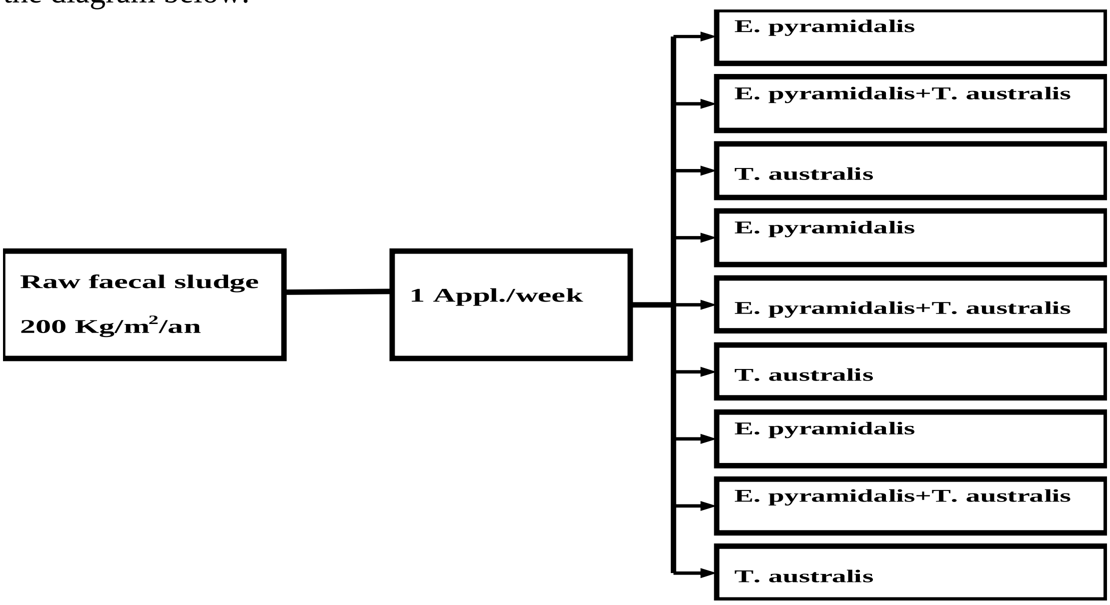

Figure 3: Procedure for determining the influence of the nature of plants

3-3 Determination of the influence of the type of sludge

In this part of the study we will use raw sludge from septic tanks, thickening sludge and sludge from the digesters (sewage sludge).

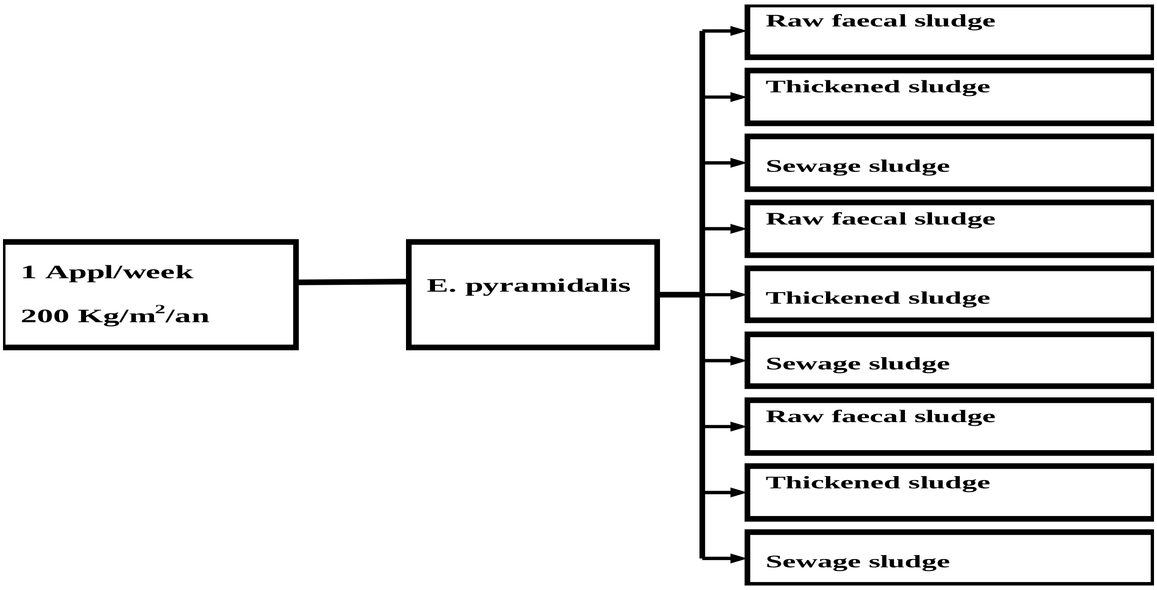

Figure 4: Procedure for determining the influence of the nature of the incoming sludge

3-4 Monitoring of purification performance

Along with monitoring the process of humification, we will monitor the purification performance of beds following the different procedures. For this, a sample of leachate will be collected at the end of the percolation and brought to the lab for analysis. The parameters followed are Total Suspended Solids (TSS), Total Solids (TS), Total Volatile Solids (TVS), Total Kjeldahl Nitrogen (TKN), Total Phosphorus (TP), Chemical Oxygen Demand (COD), Ammonia (NH4 +), pH, ORP, conductivity, nitrates Temperature and Coliform and faecal content.

3-5 Monitoring the process of humification and helminth eggs inactivation

The objective of this study is to follow the factors influencing the process of humification and inactivation of helminths, we will then keep track of the evolution of these two parameters during feeding phases (6 months) and during the maturation phase (3 months)

3-5-1 Parameters for monitoring humification

The monitoring parameters include criteria of a chemical, biological and analytical.

- **Chemical criteria** : C / N ratio, cation exchange capacity (CEC), NO3-, NO 2 -, report NO3-/NH4+, pH, ORP, conductivity, loss of ignition, analysis of easily biodegradable substances (sugars, amino acids, phenols, etc..) and readily biodegradable substances (fiber, lignin, tannins, etc..)
- **Microbiological and enzymatic measurement**: biomass and diversity, microbial metabolism evaluated by the rate of respiration, measurement of enzyme activity
- **Germination test:** evaluation of residual phytotoxicity (rate of seed germination, root length) of *Lepidium sativum L.* or other test plants.
- **Criteria for analytical and spectroscopic:** amount of humic or fulvics acids humification indices (humification index, humification rate, rate of polymerization), spectroscopy: visible (E4/E6 ratio, infrared and UV

3-5-2 Monitoring of helminth eggs inactivation

To follow the inactivation of helminths, their quantity will be evaluated first in raw sludge in order to have an idea about the concentration of helminth eggs. After this step, the concentration of eggs in biosolids will be assessed every 3 months from the first month entering the beginning of the maturation period. The samples will be provided on the top 5 cm, 5 cm in the middle layer of biosolids and the last 5 cm.

3-6 Morphological characteristics of plants

Plants play an important role in the operation of drying beds by their density but also by their morphological characteristics. This may affect the mechanisms involved in the process of humification. For this, we will regularly monitor the status of plants that are in beds. This monitoring will involve measuring the maximum length and average diameter of the leaves or stems (releases), the average number of leaves per plant or rejection, the renewal rate and mortality, the root distribution. This monitoring will also follow plant parasitic infections that may have adverse effects on plants. Root density will be monitored at the end of the experience.

RESULTS AND DISCUSSION

1-Results

1-1-Characteristics of raw sludge

Table 1: Characteristics of sludge in Dakar in comparison with those of other developing countries

Parameter	TS (mg/l)	TSS (mg/g)	COD (mg/l)	TKN (mg/l)	NH4+ (mg/l)	NO3- (mg/l)	TP (mg/l)	pH	Sal (g/l)	Cond (ms/cm)	Eh (mV)
Average	4109	3186.8	6807.3	325.2	352.8	2.8	79.8	7.6	1.9	4.1	-162.8
Max	6264	5544	8456	626	845	5.7	118.7	7.8	3.5	6.82	-45
Min	2932	1200	4546	318	141	0.6	32	7.3	1.1	2.77	-295
Cameroon[1]	33400	33400	29900	1200	600			7.6		3	-59
Accra (Ghana)[2]	12000		7800	330							
Ouagadougou (Burkina Fasso)[2]	19000		13500								
Bangkok (Tailand)[2]	15350		15700	415							

[1] Kengne et al, 2009
[2] Strauss, 2006

The sludge produced in Dakar are less concentrated in Total Solids (TS) than those of most developing countries. Thus, the volume of sludge to be treated for the same mass load will be more important. This can affect plants (asphyxia, length of percolation largest...)

1-2-Morphological characteristics of plants

This monitoring was done in the three beds currently in use (Photo 2 and 3). These parameters were measured before the start of changes in the feeding frequency that is currently underway.

Table 2: Morphological characteristics of plants

Periods	Beginning		Month 1		Month 2		Month 3		Month 4	
Parameter	Density (Nb/m2)	Height (cm)	Density (Nb/m2)	Height (cm)	Density (Nb/m2)	Height (cm)	Density (Nb/m2)	Height (cm)	Density (Nb/m2)	Height (cm)
Bed 1	9	15	77.6	45.8	118.3	81.3	347,5	121	426.2	136.3
Bed 2	9	15	76.5	43.8	113.2	80.6	379,2	119.7	453.5	142
Bed 3	9	15	80.2	56.4	120.6	98.4	380,7	129.2	470	151.8

Two months after planting, the plants had a height of over 80 m. This helped to shorten the stages of acclimatization and scalability.

Photo 2 and 3: Macrophytes at the beginning and after 4 months

3 Purification performances

As the three beds are operated under same conditions, the purification performances summarized in this figure represent averages of these three beds.

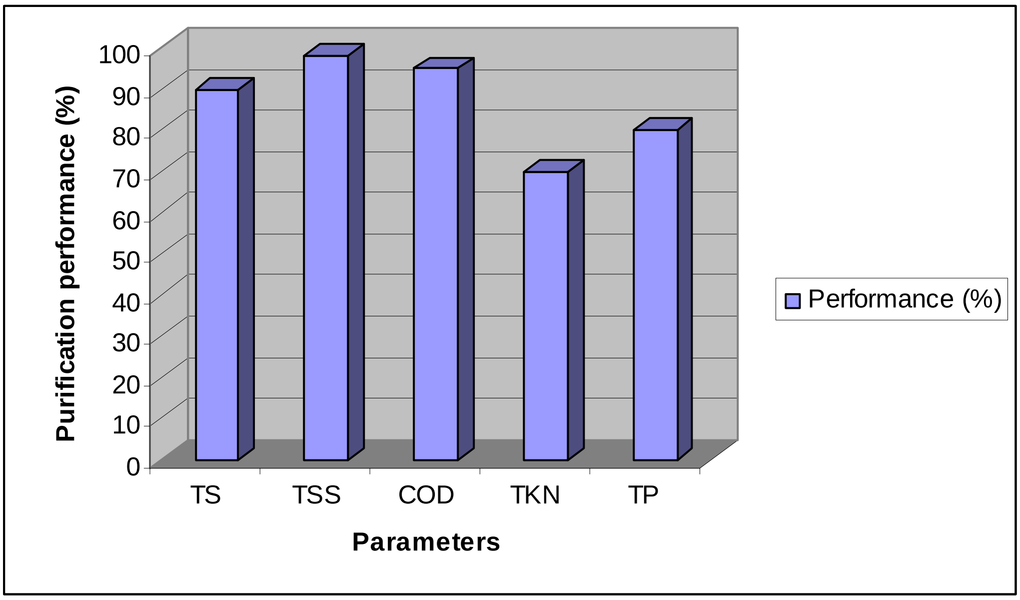

Figure 5: Performance purifying beds

Despite the high levels of depollution, leachate content loads of pollutant higher than Senegalese standards to discharge or reuse.

4 Expected Results

- Good knowledge of supply frequency, plants choice and the method of sludge pre-treatment that allow an efficient purification
- Determining the best supply frequency for sludge dehydration and mineralization
- Selection of the appropriate plant or plant association for proper sludge drying and mineralization
- Selection of the best quality of sludge, which offers a better quality of humus
- Determination of time required to inactivate helminth eggs
- Development of design criteria of planted drying beds in sub-Saharan Africa

CONCLUSIONS

In these experiences, planted beds treat sludge volumes larger than those of other developing countries. But the performance is satisfactory. The outstanding experiments will determine the best purification performance but also to will determine the influence of these three factors, selected in this study, in sludge dewatering and mineralization. The maturation period chosen will determine the speed helminths inactivation. Finally, all these experiences will enrich the database of the essential criteria which can use for the design of this type of faecal sludge treatment technologies in sub-Saharan Africa.

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