Analysis of fecal sludge management in Ouagadougou: Kossodo and Zagtouli Fecal Sludge Treatment Plants

ENGINEER MASTER THESIS IN ENVIRONMENT AND WATER

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DEDICACES

I dedicate this report:

To JEHOVAH God who always help me to endure and overcome critical situations. His support allow me to achieve this report in the best condition. May your name always be sanctified.

To my father, my mother and my uncle for their financial, spiritual and emotional support. Without you I would not be here today. Thank you mom and dad and. God bless you.

To my best friend, my husband, the father of my children, my soulmate, who has always been available for me, Sweetheart, thank you very much for all your pieces of advice full of meaning for your love, for your financial support and also for your prayers.

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ABSTRACT

The objective of the study is to evaluate the stage of the FS treatments plants management in Ouagadougou, at Kossodo and Zagtouli FS treatment plants, in order to highlight the irregularity sectors in the operation of these Fecal Sludge Treatment plant. In order to reach our target, a collection and statistical analysis of data were conducted.

Data were collected from the database of the Sanitation Department of National Office for Water and Sanitation (ONEA) in Burkina Faso. The data obtained were the volume of FS and the number of trips, collected over a period of 22 months from September 2014 to June 2016 and the FS rotation on the drying beds, collected over the year 2015. The statistical tests used were ANOVA 2 - ways and t-test paired sample.

The statistical analysis of the volume of FS and the number of trips, showed that almost 140,000m^3 of FS was discharged during the period of operation, with 200m^{3}of daily, at both treatment plants. The total number of trips of vacuum trucks arrived at both FS treatment plants, was 14,000 and 19 was the daily average of trips. Knowing that the average production of FS per year per inhabitant varies between 0.10-0.15m^3, it means that 34% of FS produced by the population in Ouagadougou (2,741,000 inhabitants), was satisfactory treated in 2015. On the one hand, the statistical analysis showed that there is no significant difference between the months, the working days and the climatic seasons. On the other hand, there is a significant difference between Kossodo and Zagtouli FS treatment plants. Indeed, Kossodo treatment plant received (174m^3/day) almost two (2) times more volume of FS than Zagtouli (68m^3/day). Kossodo treatment plant received 40% more FS than its treatment capacity while Zagtouli received 45% less.

Base on the result obtained, some recommendations were suggested in order to improve the effectiveness of the FS treatment plants operation such as the construction of more FS treatment plants in Ouagadougou.

Keywords: Sanitation, Fecal sludge management, Treatment plant, Ouagadougou.

RESUME

L'objectif de cette étude est de faire l'état des lieux de la gestion des Stations de Traitement de Boue de Vidange (STBV) à Ouagadougou, plus précisément les stations de Kossodo et de Zagtouli, afin de relever les anomalies rencontrées dans le fonctionnement de ces stations et proposer des solutions. Pour cela, des données ont été collectées à partir de la base de données du Département de l'Assainissement de l'Office National de l'Eau et de l'Assainissement (ONEA) au Burkina Faso, pour lesquelles des analyses statistiques ont été effectuées utilisant les tests statistiques ANOVA 2-ways et t-test t d'échantillons appariés.

Les données obtenues sont : le volume de boues, le nombre de camions et la rotation des boues sur les lits de séchage, sur une période de 22 mois à partir de Septembre 2014 à Juin 2016.

L'analyse statistique du volume de boues et le nombre de camions, a montré que près de 140.000m^3 de boues de vidange ont été déchargés durant toute la période d'exploitation de la station, soit 200m^3 par jour, dans les deux STBV. Le nombre total de camions déchargeant dans les deux STBV était de 14.000 et 19 étant la moyenne journalière. Sachant que la production moyenne de boue par année par habitant varie entre 0,10-0,15m^3, cela signifie que 34% des boues produites par la population à Ouagadougou (2 741 000 habitants), ont reçu un traitement satisfaisant au cours de l'année 2015. L'analyse statistique a également montré qu'il n'y a pas de différence significative en termes de quantité de boues reçues du point de vue mensuelle, journalières et saisonnières. En revanche, il y a une différence significative en termes de quantité de boues reçues dans les STBV de Kossodo et de Zagtouli. En effet, la station de Kossodo a reçu 174m^3 / jour ce qui correspond au double de la quantité de boue de vidange reçu par la station de Zagtouli (68m^3 /jour). La station de Kossodo a reçu 40% plus de boue de vidange que sa capacité de traitement tandis que Zagtouli en a reçu 45% de moins.

A partir des résultats obtenus, quelques recommandations ont été suggérées afin d'améliorer l'efficacité de traitement des STBV, telles que l'agrandissement des STBV par la construction de nouveaux lits de séchages ainsi que la construction de nouvelles stations.

Mots clés : Assainissement, Gestion de Boue de Vidange, Station de Traitement, Ouagadougou.

ACRONYMS

%: Percentatge

ADF: French Development Agency

ANOVA: Analysis of Variance

DM: Dried Matter

EcoSan: Ecological Sanitation

FS: Fecal Sludge

FSTP: Fecal Sludge Treatment Plant

IWMI: International Water Management Institute

L/Pers/yr: Liter per person per year

L: Liter

M^3: Cubic meter

MAH: Ministry of Agriculture and Water Resources

MEDD: Ministry of Environment and Sustainable Development

MHU: Ministry of Housing and Urban Development

MS: Ministry of Health

ONEA: Water and Sanitation National Office

Pr: Probability of Reference

PSAO: Strategic Plan Sanitation of Ouagadougou

RRR: Resource Recovery of Reuse

SAS: Statistical Analysis Software

VIP: Very Important Personality

WLE: Water Land and Ecosystem

WWTP: Waste Water Treatment Plant

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INTRODUCTION

In the world, 2.4 billion of the population is in lack of improved sanitation facilities. In African cities, especially those in sub-Saharan Africa, waste management in general is a serious ecological problem. Indeed, 65 to almost 100% households in sub-Saharan Africa are not connected to a sewer system or have no sanitation system (WUP report 2014; EAA Ouaga 2014). In some areas in the urban cities of Africa, only 20% of households are equipped with a draining system for domestic wastewater by using latrines (traditional latrines, watertight tanks, and improved latrines) or septic tank.

Burkina Faso for instance, precisely in Ouagadougou, more than 60% of the population use simple pit latrines while less than 30% use VIP latrines or septic tanks (Bassan et *al*. 2013; INSD annuaire 2013).With a growth percentage of about 3% every year and an urban population annual rate of change of 6.1%, the management of FS, has become difficult to handle in Ouagadougou (WUP report, 2014).

In order to avoid a contamination risk of the environment by the uncontrolled release of FS into the environment, several projects have been implemented. In Burkina Faso, for instance, ONEA chose PÖYRY Company in order to realize a sanitation project in Ouagadougou. The project was financed by the French Development Agency (ADF), which appealed to the Department of Water and Sanitation in Developing countries (Sandec) and the Swiss Federal Institute for Research (Eawag) for an assistance mission, including scientific monitoring and strengthening the operation of wastewater treatment plants (WWTP) and the implementation of FS treatment plants. This project, instituted in 2010, contributed to the construction of three (3) FS treatment plants in Ouagadougou and two (2) others in Bobo Dioulasso and Dori (Hanspeter Zöllig et *al*, 2011).

Despite the existence of FS treatment plants in Ouagadougou, there is still 7% of the population who are engaged into open defecation, by releasing in the environment their FS without treatment (Mbéguéré, Dodane, and Koné , 2011; ONEA Ouaga, 2011). Moreover, according to the reports of operation and maintemnance of FS treatment plants by ONEA, many irregularities in the well functioning of the stations were observed. Irregularities about the treating and efficiency capacity of the stations, which can compromised the effectiveness of the stations.

The objective of the study is to evaluate the stage of the FS treatments plants management in Ouagadougou, at Kossodo and Zagtouli FS treatment plant, in order to reveal the irregularity sectors in the stations operation.

The specific objectives are:

- To conduct a literature review on the sanitation situation in Ouagadougou
- To analyze the number of trips and the volume of FS discharged at the stations of Kossodo and Zagtouli.

- To analyze the difference between the months, between the working days, between the climatic seasons and between the FS treatment plants.
- To analyze the correlation between the volume of FS and the number of trips.
- To compile, process and interpret data on the drying bed operation.

This report is divided into three (3) chapters:

- Chapter One: Generality. This chapter present a generality on the population's behavior in Ouagadougou and the characteristics of the FS treatment plants considered in the study.
- Chapter Two: Methodology. This chapter present the Study area considered, the Host institution where the internship was conducted, the collection and analysis of the data and the tools used in order to reach our goal.
- Chapter Three: Results and discussion. This chapter present the result of the analysis conducted with their interpretation by considering the other studies conducted in the same field.

1. GENERALITY

1.1 Sanitary situation in ouagadougou

1.1.1 The parties in charge of the sanitation in Ouagadougou

The self-ruling sanitary situation in Ouagadougou is controlled by two (2) main parties: Gouvernmental and non-gouvernmental. The gouvernmental actor include the city, ONEA (National Office for Water and Sanitation) and the ministries concerd with sanitation which are,The Ministry of Agriculture and Water Resources (MAH),The Ministry of Environment and Sustainable Development (MEDD),The Ministry of Health (MS) and The Ministry of Housing and Urban Development (MHU); they are in charge of the sanitation issues (ONEA Ouaga, 2011).

The non-gouvernmental parties, on the other hand, include the private sector, civil society, the technical and financial partners.

The city has signed a collaboration protocol with ONEA for the development of a strategic plan of wastewater and excreta in the city. Since 1992 the Sanitation Strategic Plan of Ouagadougou (PSAO) working concomitantly with ONEA, has remarkably improved the sanitary condition in Ouagadougou. Indeed, the construction of improved latrine being the main aim of PSAO, this allowed many of Ouagadougou residents to have independent and healthy latrines between 1992 and today in order to protect and preserve their health and the environment.It is estimated that in 2009, over 95% of the population in Ouagadougou benefited of independent sanitation facilities (Hanspeter Zöllig et *al.* , 2011).

In order to achieve his goal PSAO built not only improved latrines, but also create favorable conditions for the vulgarization of improved structures that can been used by everybody (ONEA Ouaga, 2011).

1.1.2 The population in Ouagadougou and their sanitation habits

The population in Burkina Faso has a growth percentage of about 3% every year and a urban population annual rate of change of 6.1%, that makes the management of the fecal sludge difficult to handle (WUP report, 2014). In 2006, the city of Ouagadougou with about 1.4 million inhabitants produced about 960 m^3 of solid waste and 600 m^3 of fecal sludge daily (Koanda, 2006; Ouedraogo Jules, 2006). In 2015 the estimated population is 2,741,000 inhabitants. In this case the quantity of fecal sludge produced by the city will be around 1,200m^3 per day, 0.4L/pers/day and 160Lper capita per year. In Ouagadougou, most homes are equipped with individual sanitation systems, namely traditional latrines, watertight tanks, septic tanks with a number of collective unit facilities that mostly do not work or work partially. The sewer system (with treatment plant) collects wastewater from some public services and the central market of Ouagadougou.

The distribution percentage of fecal sludge in the differents facilities is reperesentated on Figure1.

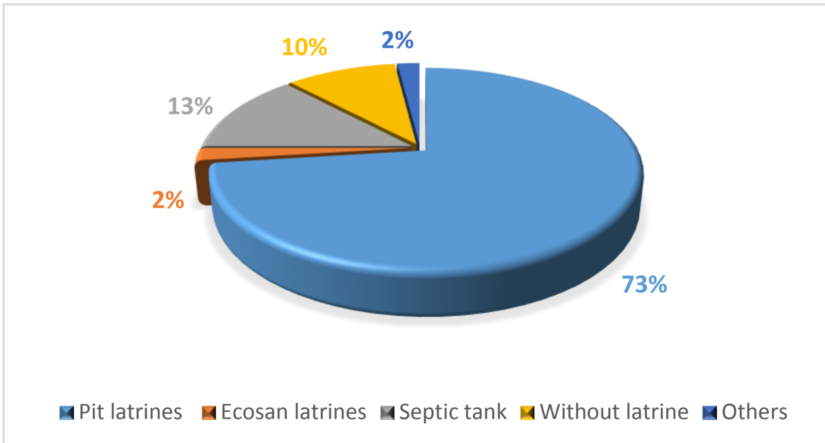

Figure 1: Distribution of FS in sanitary facilities. (Source (INSD annuaire, 2013)

The figure shows that almost 73% of the population are using pit latrines.

Behaviour of citizens in terms of sanitation pratices is affected by religion, culture and social living. Some people use water, paper or toilet paper for cleaning after toilet usage. In addition, waste material such as plastics bags, condoms, sanitary towels, newspapers, etc, are found in the sludge accumalated in houses. Moreover open defecation is still being in practice in some Ouagadougou surburb 7% of the population (Mbéguéré, Dodane, and Koné, 2011; EAA Ouaga, 2014).

1.1.3 Emptying and transportation of sludge

There are two methodes for emptying on site sanitation systems in Ouagadougou:

- Manual: It is done using basic tools such as buckets, shovel, peak and ropes.
- Mechanical:. It is carried out by suction using a vacuum truck.

It is noticed that 75% on the sanitary facilities have been emptied by a vacuum truck while 25% manually (Dgaeue, 2011).

❖ *Manual Emptying*

Manual scavenging is practiced often by households with low incomes and especially those with traditional facilities. It is also practiced for pits whose content is too compact and can not be emptied mechanically, which is very common in Ouagadougou.

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❖ *Mechanical Emptying*

The mechanical emptying is often restricted to households with middle and high income or with modern facilities (septic tanks, watertight tanks). Households therefore contact vacuum trucks drivers, which have the advantage of being faster and more efficient in the emptying process. The vacuum trucks can transport the sludge outside the city to illegal dumping sites or send it to the recognized treatment stations. With a volume capacity reaching $16m^3$, vacuum trucks can empty sanitation systems of several households before being filled (EAA Ouaga, 2014).

1.1.4 Ecological sanitation (Eco San)

Eco San is a type of ecological latrine that promote the reuse of the excreta and urine as fertilizers in agriculture (Figure 2). It is used in Burkina Faso precisely in the villages and the suburbs of Ouagadougou. Eco San latrines are different from the other latrines by their design and their simplicity. Eco San latrine conception allow the separation of urine and feces. The urine is stored for 45 days while the fecal material is stored for about 6 (six) months. In order to remove the odors and the pathogens, wood ash or charcoal are immediately added to the feces after defecation. The experience has shown that the vegetables and the fruit obtained from Eco San fertilizers (urine and fecal material) are of better quality and look bigger and nicer than those from chemical fertilizer ((Dagerskog, Kenfack and Jönsson, 2008; Ito et *al*. 2012).

Consequently, the use of Eco San fertilizers would offer food protection and security, resources conservation, sustainable agriculture, soil fertility conserved and health security(Savadogo, 2015).

A B

Figure 2: EcoSan latrines; A) interface for users B) Collected fecal sludge and urine stored for months and used as fertilizer (source: (Karim Savadogo 2015)

1.2 Characteristics of sludge and its treatment system

1.2.1 FS treatment plants in Burkina Faso

In order to solve the sanitation problem in Burkina Faso, several Fecal Sludge (FS) treatment plants have been set up recently, and are under construction in Ouagadougou, Bobo Dioulasso and Dori.

In Ouagadougou for example, two stations are in service (Zagtouli and Kossodo) since October 2014 and two more are under construction. In Dori, a fecal sludge treatment plant is in operation but is being managed by the municipality, while another is under construction. In Bobo Dioulasso one treatment plant is also under construction.

The plants of Zagtouli and Kossodo will be the subject of this study. It is important to emphasize that there is no recycling or reuse attached to the operation of the FS treatment facilities.

1.2.2 Types of sludge in FS treatment plants

Zagtouli and Kossodo stations are located in Ouagadougou but at different places. They receive the same types of sludge mechanically collected, i.e. domestic and public sludge coming from latrines and showers pit, single pit latrine (little water being used) and septic tanks. According to the study carried out by Hanspeter Zöllig (2011), it is demonstrated that sludge from single pit latrine are more concentrated in DM, BOD_5, COD, than those coming from septic tanks, latrines and showers (Figure 3).

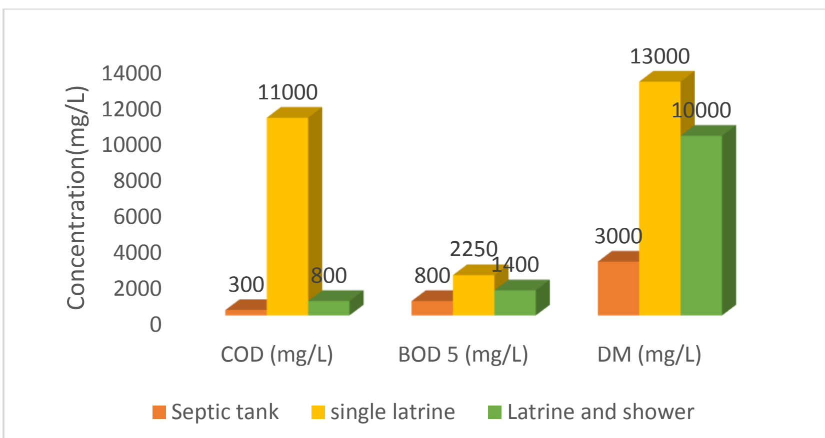


Figure 3: Comparison between the chemical properties and the types of sanitation facilities (Source:(Hanspeter Zöllig et al 2011))

1.2.3 Description of FS treatment

The chosen treatment process involves depositing the sludge directly on unplanted drying beds. The drying bed operates as a drying device, a filter and a bioreactor. The treatment process of the fecal sludge is detailed in the flow chart below (Figure 4). The different mechanisms of transformation and elimination which can operate in such a device are listed in Table 1 (EAA, Ouaga 2014).

The filtrate is delivered by pumping to the existing lagoons. In Kossodo for example there is a wastewater treatment plant (WWTP) where the filtrates coming from the FS are treated. This co-treatment is possible only if the fecal sludge does not exceed 15% of the total volume to be processed in the system. This is caused by the fact that the drying bed leachate does not have the same characteristics as the conventional waste water (Hanspeter Zöllig et al 2011; EAA Ouaga 2014).

Table 1: Mechanisms for processing and disposal in the drying beds (Source: EAA 2014)

Table 1: Constituents	Mechanisms processing and disposal
Suspended solids	Sedimentation Filtration
Soluble organic matter	Aerobic microbiological degradation Anaerobic microbiological degradation
Nitrogen	Ammonification nitrogen followed by nitrification and denitrification biological Adsorption on the gravel matrix Ammonia volatilization
Pathogens	Filtration Predation natural death UV irradiation and Sedimentation

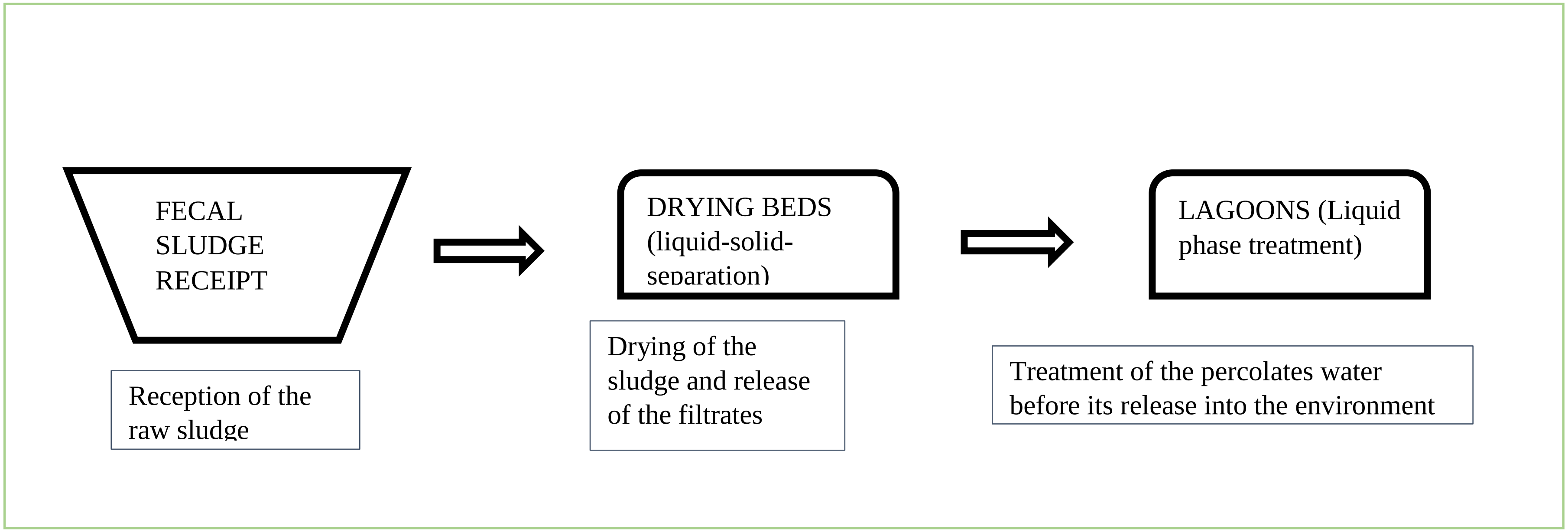


Figure 4: Treatment process of the station

1.2.4 Characteristics of the station of Kossodo and Zagtouli

Kossodo and Zagtouli stations have been designed the same. The only one difference observed is the way the FS leachates are treated. Several works are involved in the functioning of the station. These are respectively:

- **Weigh bridge and reception pond**

At their arrival and when they leave the station, the FS trucks are weighed using a weighbridge in order to have an accurate idea of the sludge weight being dumped (Figure 5).

After being weighted, the trucks are guided to the drying beds where the FS will be discharged. Between two (2) consecutive drying beds there are two (2) rakes positioned by an orientation angle in order to eliminate the maximum of coarse elements.

Figure 5: Weigh Bridge at Kossodo FS treatment plant

- **Drying beds**

The platform drying beds is consisting of beds, as well as access roads for trucks (Figure 6). As stated in the pre-feasibility report, drying beds were designed assuming the following assumptions:

- Loading is 150 kg of total solids per m^2 per year.
- Effective drying area of 128 m^2 per bed with specific dimensions of 16 x 8 m;
- A bed feeding for 4 consecutive days at a rate of 2 discharges per bed per day (i.e. on average 20 m^3 per day for four (4) days).

The station has 48 beds, arranged in 6 rows of 8 beds. The thickness of dried sludge to the surface of the bed is expected to remain below 30 cm maximum.

Figure 6: Drying beds at Kossodo FS treatment plant

- **Disposal of the filtrate**

The filtrates are disposed through PVC manifolds located inside the drying beds. The receptacle (chamber) is connected to a pumping station where the filtrates will be deliver to the lagoons (Figure 7). The flow of leachate representing between 50 and 80% of the flow of raw sludge, the value of 65% was used (Rapport ADP, Volet 2 STBV, 2010).

Leachate treatment is done in different ways depending on the stations.

Kossodo: The leachates are directly discharged into a nearby Waste Water Treatment Plant (WWTP) where it undergoes treatment. This addition of leachate to the WWTP influent is not expected to affect the performance of treatment since the flow and additional daily charge from the FSTP is in principle less than 2% of the flow of the WWTP.

Zagtouli: A lagoon system dedicated exclusively to the treatment of leachate bed is provided with gravity feed.

Figure 7: Lagoon system at Zagtouli FS treatment plant

1.3 The Host Institution and the study area

1.3.1 IWMI presentation

The International Water Management Institute (IWMI), member of the CGIAR System Organization, is a non-profit, scientific research organization focusing on the sustainable use of water and land resources in developing countries. It is headquartered in Colombo, Sri Lanka, with regional offices across Asia and Africa. IWMI works in partnership with governments, civil society and the private sector since 1984, to develop scalable agricultural water management solutions that have a real impact on poverty reduction, food security and ecosystem health. In West Africa, IWMI is located in Accra, Ghana, and was established since 2002. I have done my internship at IWMI Ghana for a period of six (6) months, where I got a lot of professional skills and experiences.

Indeed, as an intern at IWMI Ghana, I worked in the Resource Recovery and Reuse (R.R.R.) department supervised by Josiane Nikiema, PhD Sub-theme leader, Water quality, and safe water reuse. The management of all sort of waste, solid and liquid, and their recovery, are the main activities leads by R.R.R department. It is in this context that, during my stay at IWMI, I have contributed to the collection of baseline information on Fecal Sludge (FS) management, in order to support the RRR activities in Burkina Faso and Ghana. The main activities that I conducted being at IWMI are:

- To collect data in FS management (volume of FS and number of trips) from Ouagadougou and greater Accra FS treatment plants
- To analyze the data collected and interpret them
- To travel to Burkina Faso and collect raw FS samples in Ouagadougou (Zagtouli and Kossodo FS treatment plants)
- To send the samples collected to laboratories in order analyzed them (chemical parameters)
- To collect co compost samples (made from solid wastes and EcoSan latrines) in Ouagadougou
- To interview truck drivers in Ouagadougou
- To meet the sanitation stakeholders in Burkina Faso (ONEA)
- To do a power point presentation at IWMI Ghana office on my project
- To participate to the logistic of WLE (Water Land and Ecosystem) conference in Accra

My internship at IWMI made my educational training more perfect and skillful for an employment.

2. METHODOLOGY

2.1.1 Generality on the study area

The area chosen for the study is located in Burkina Faso specifically in the city of Ouagadougou. The estimated population in Burkina Faso in 2015 is 17,915,000 inhabitants with 30% residing in urban agglomeration. Ouagadougou is located in the province of Kadiogo at 12° 20 'North and 58 1° 30' West with an area of 220 km^2 and a population of 2,741,000 inhabitants in 2015(WUP report, 2014). Ouagadougou is also the administrative, economic communication and cultural center of the country. There are 12 districts in Ouagadougou with 55 sectors (INSD annuaire, 2013).

Figure 8: Geographic location of the study

Ouagadougou climate is chracterised by two seasons, dry and rainy season. In dry season, the depth level of the ground water table varies between 5 and 10 m while in rainy seasons it varies between 1 and 3 m (EAA Ouaga, 2014). The dry season start from October to May with a North East wind harmattan, and the rainy one start from June to September with a South wind, the Mousson.

The hotest months in Ouagadougou are March and April with a maximum average temperature of 36°C while the lowest ones are December and January with a minimum temperature of 23°C. During the rainy season the average height of rainy fall is about 795mm. The maximum amounts of rainfall usually occur in August (Figure 9) (Bassan et *al*., 2013; INSD annuaire, 2013).

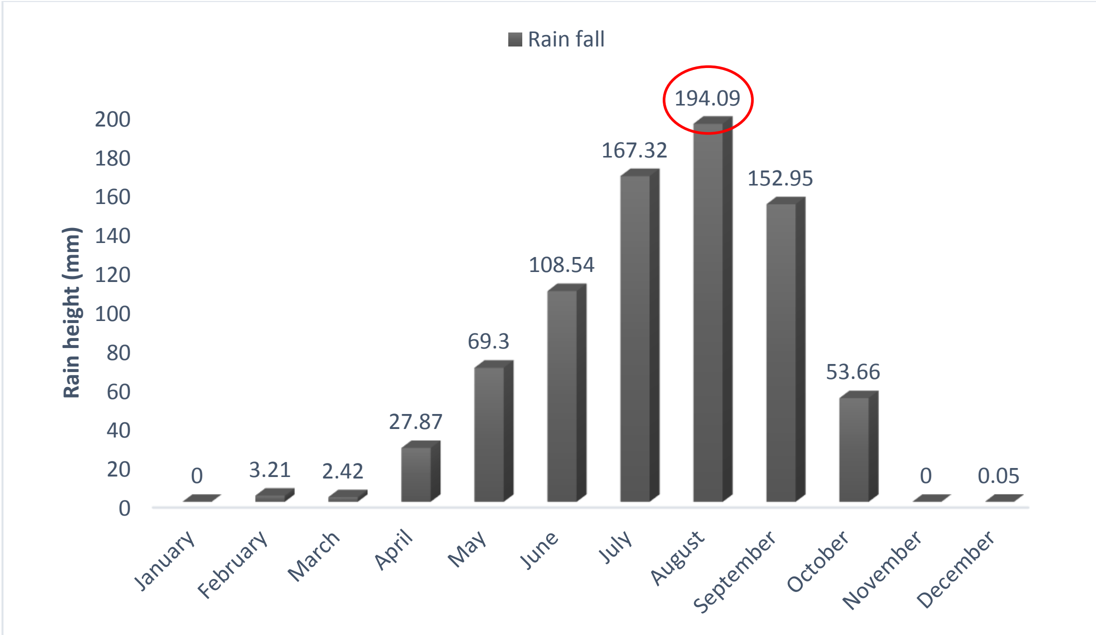


Figure 9: Monthly average of rain fall (source: database from IWMI from 2000 to 2010)

2.2 Collection of data

The data used in the study were collected from the database of the Sanitation Department of the Water and Sanitation National Office (ONEA) in Burkina Faso. ONEA is a governmental structure which aim is the creation, improvement and management of sanitation facilities for drainage of wastewater and excreta. Since 1985, ONEA, collect taxes from the users through water bills for the sanitation management. In 2003 a cooperation agreement was signed between the city of Ouagadougou and ONEA in order to work out strategic waste and excreta remediation plans.

The data extracted were:

- Volume of Fecal Sludge (FS)
- Number of trips
- FS rotation on the drying beds

The volume of FS and the number of trips, were obtained after recounting the monthly and daily reports of operating and monitoring of the FS treatment plants (Zagtouli and Kossodo). At Zagtouli the data were collected over a period of 20 months of operation from October 2014 (opening of the station) to May 2016. At Kossodo the data were collected over a period of 19 months of operation from September 2014 (opening of the station) to July 2015 and from November 2015 to June 2016. Kossodo Plant was closed from August 2015 to October 2015 for restoration works of the access road to the station (see Annex I and II).

The FS rotation on the drying bed, were obtained from the monitoring the reports of operating of the FSTP (Kossodo and Zagtouli) from January 2015 to December 2015. The reports show the number of drying beds over the 48 drying beds in operation on which the different steps of rotation were conducted. The different rotation activities are:

- To full the drying bed
- To empty the drying bed
- To Scrape the drying bed

2.3 Methodology adopted

In order to analyze the data, three (3) methods were used:

- Statistical analysis of the volume of FS and the number of trips
- Assess the drying bed operation

2.3.1 Statistical analysis

The Tests used for the statistical analysis in our study are ANOVA two-ways and t-test for paired sample.

- **Analyze of variance two-ways (ANOVA 2-ways)**

Analyze of variance (ANOVA) is a statistical method used to test differences between two or more means (Hines, Montgomery, and Borror 2008). The analysis of variance, by means of a Statistical Analysis System (SAS), allowed to analyze the difference between the months, the days, the stations and the climatic seasons on the volume of FS collected at both station. The tests used by the SAS for interpretation were Duncan range Test and Tukey's Student Range (HSD) with a confidence of 95% (i.e. $\alpha=0.05$).

- **Analyze of paired sample (t-Test)**

The analysis of paired sample is a test that applies two different samples whose the interests are collected in pairs. The test procedure would then consist of analyzing the differences between the averages volumes of FS per truck discharged at Kossodo and Zagtouli for the same period of time. The formula applied in order to determinate the t-Test is:

$$\boxed{t_D = \frac{\overline{D}}{S_D / \sqrt{n}}}$$

t_D= t distribution;

D=the average of the X-Y differences (unlike non-paired test where the difference in the average is calculated)

S_D= standard deviation of the differences

n=number of sample

The different hypotheses are then:

If $\boxed{|t_D| > t_{\alpha/2,\, n-1}}$ the hypotheses H_0: $\mu_D=0$ is rejected means that $\mu_1 \neq \mu_2$

(α=0.05; $t_{\alpha/2,\, n-1}$is determined from a table of percentage points of the t distribution)

2.3.2 Assessment of the drying bed operation

In order to assess the situation of the drying beds, we counted, for each step of FS rotation, the number of drying beds affected. After counting the drying beds, we arranged the number into percentage by considering the total number of drying beds (48 drying bed) in operation at the station.

2.4 Tools and treatment of data

The data is processed using four (4) software: EXCEL, ZOTERO, ARC GIS and SAS.

- The Excel software was used to capture the data collected and to the achievement of different graphics;
- The SAS the software enables a complete statically analysis for any variable that is available digital data. It is designed to simplify the tasks related to the adjustment of a distribution to a random sample;
- The ARC GIS software was used to create the map of the study area;
- The ZOTERO is a personal research assistant and tool that automatically helps to gather, organize, and analyze sources and then share the results of the research.

3. RESULTS AND DISCUSSION

3.1 Fecal sludge management

The table 2 present the volumes of fecal sludge collected on a monthly basis from September 2014 to June 2016 at Kossodo FSTP and from October 2014 to May 2016 Zagtouli FSTP. The total volume of FS collected in both facilities is 139,912 m^3 with 13,981 trips of vacuum trucks in total. A Zagtouli the average volume of FS per truck is $9.8m^3$ while in Kossodo is $10.2m^3$.

Table 2: Monthly volumes of fecal sludge collected at each station

	KOSSODO		ZAGTOULI	
Months	FS Volume (m^3)	Number of trips	FS Volume (m^3)	Number of trips
Sep-14[b]	2,971	292		
Oct-14	5,514	542	1,591	170
Nov-14	5,407	502	2,331	255
Dec-14	3,330	342	1,513	166
Jan-15	5,370	560	1,712	212
Feb-15	4,066	405	1,992.5	213
Mar-15	4,935	473	2,105.5	226
Apr-15	7,413	736	1,949.5	223
May-15	7,737	799	2,178	249
Jun-15	8,952	497	2,077	236
Jul-15	4,459	435	2,216.5	251
Aug-15[a]			2,510	295
Sep-15[a]			2,092	235
Oct-15[a]			2,533	286
Nov-15	816	77	1,842.5	201
Dec-15	2,373	222	1,943.5	239
Jan-16	3,176	299	1,712	212
Feb-16	4,876	471	2,443	292
Mar-16	5,787	578	2,171	255
Apr-16	7,041	672	2,130	235
May-16	7,173	695	1,877	208
Jun-16[b1]	7,596.4	725		
Total	**98,992**	**9,322**	**40,920**	**4,659**
Average	**5,210**	**491**	**2,046**	**233**
Stand deviation	**2118**	**190**	**288**	**35**
Coef variation (%)	**41**	**39**	**14**	**15**

[a] The plant of Kossodo was closed during these months because of the restoration works of the access road to the station, road damaged by the weight of the truck and rain. Consequently no FS was delivered at the treatment facility during that period.

[b] The station was not operating

[b1] The data at Zagtouli plant was not yet available

The trucks that are in use in Burkina Faso have capacities comprised between 3.5 and 16 m^3. It is therefore needed to investigate and identify the average truck size. This will also inform on the logistics required for FS management in the country.

3.1.1 Correlation between the volume of FS and the number of trips of FS trucks

Figure 10 shows the correlation between the volumes of FS at both stations as a function of the number of trips undertaken by FS trucks. The slope of this curve corresponds to the average truck size in Ouagadougou, i.e. 9.7m^3/truck. This average truck size seems to be a good indicator of the situation on the ground since the overall regression coefficient (R^2) is = 0.98 (close to 1) and the Root Mean Square Error (RMSE) =21.

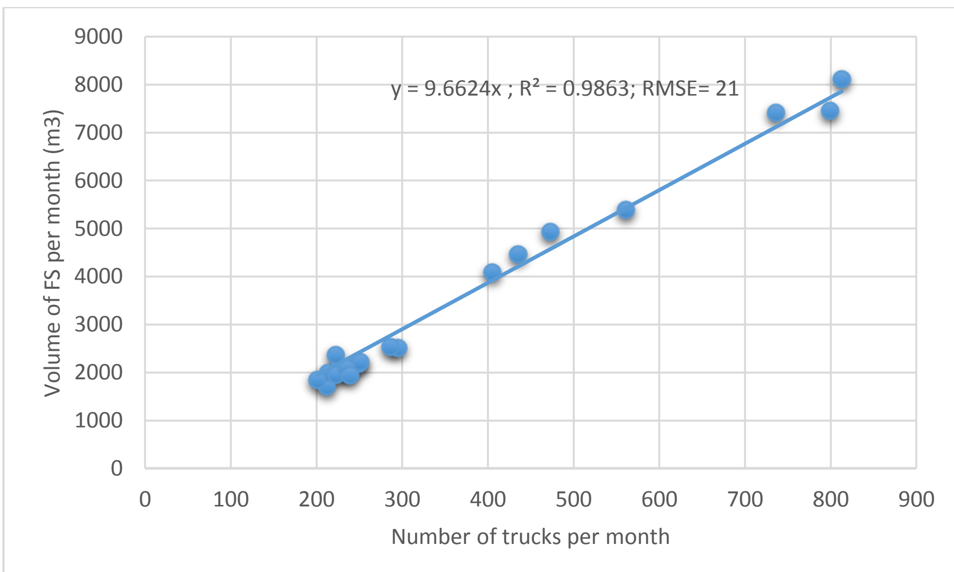


Figure 10: Correlation between the volume of FS and the trucks in Ouagadougou

Looking individually at each station, the figure 12 highlights the average volume of trucks for the two (2) stations, Kossodo and Zagtouli.

3.1.2 Difference between the FS treatment plants, Kossodo and Zagtouli stations

The difference between the stations was obtained by means of two (2) methods:

- The t-test paired sample by considering the volume of FS collected per truck
- ANOVA two-ways by considering the volume of FS discharged at both facilities

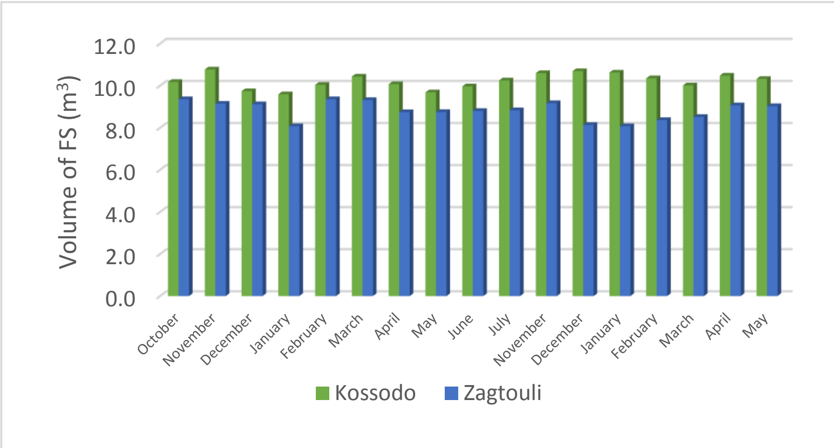
3.1.2.1 Volume of FS collected per truck

The table 3 present the average volume of trip at each station for a period of 17 months, from October 2014 to May 2016 except the months during which the stations did not operate. At Zagtouli the average volume of FS per truck is 8.8m^3, while at Kossodo, the average volume of FS per truck 10.2m^3. The average number of trip per working days is 19 trips for both facilities.

Table 3: Average volume of FS per trip

	Average volume of FS per trucks	
Months	Kossodo	Zagtouli
October 14	10.2	9.4
November 14	10.8	9.1
December 14	9.7	9.1
January 15	9.6	8.1
February 15	10.0	9.4
March 15	10.4	9.3
April 15	10.1	8.7
May 15	9.7	8.7
June 15	10.0	8.8
July 15	10.3	8.8
November 15	10.6	9.2
December 15	10.7	8.1
January 16	10.6	8.1
February 16	10.4	8.4
March 16	10.0	8.5
April 16	10.5	9.1
May 16	10.3	9.0
Overall average	**10.2**	**8.8**

To asses if the difference between Zagtouli and Kossodo was significant, a test for paired sample was conducted (Figure 11). The result of t Test ($t_D = 10.5$) > ($t_{\alpha/2,\, n-1} = 2.2$) shows that the difference between the stations is statistically significant.



t distribution(t_D)	10.5
standard deviation (S_D)	0.6
n	17
t 0.05/2, 16	2.201

Figure 11: Result of t-test for paired sample

3.1.2.2 Volume of FS collected per facility

Kossodo and Zagtouli plants received different amount of FS. A quick statistical comparison between Zagtouli and Kossodo plants, as shown in Figure 12 and 13, emphasize the major difference between the two plants with regards to the quantity of FS received by showing that Kossodo plant received about two times more sludge than Zagtouli plant, although kossodo station did not work the whole year of 2015.

Indeed, Kossodo plant received about 99,000 m^3 of FS during the 19 months of operation, and 174m^3 per day in average, i.e. 40% more FS than expected by the station (125m^3 /day, the expected volume of FS). The average of volume of FS is 5,210m^3, the standard deviation is 2,117m^3 with a coefficient of variation of 40%. The monthly volumes raised from about 3,000-5,000m^3 at launch to 8,952 m^3 in June 2015. Thereafter, amounts reduced as a result of difficulties experienced at the treatment site which further resulted in the shutting down of the plant for four (4) consecutive months. The station was able to resume operation in December at a lower regime and raised from 2,373m^3 in January 2016 to 7,600m^3 in June 2016.

Zagtouli plant for its part, received 40,920m^3 of FS during the 21 months of operation and 65m^3 of FS per day in average. The average of volume of FS is 2,046m^3, the standard deviation is 288m^3 with a coefficient of variation of 14%. The monthly volumes varied between 1,592 m^3 (recorded in October 2014, when the operation formally started) and 2,533 m^3 (in October 2015). This maximum was also recorded at a time whereby the 2nd station was not functional. But it is not possible to establish any causal link.

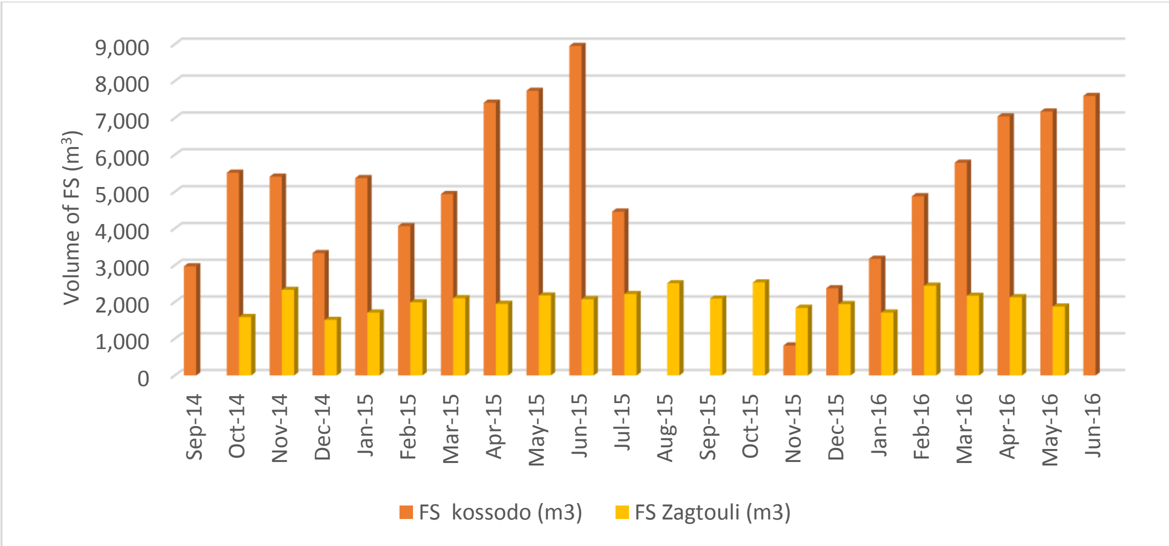
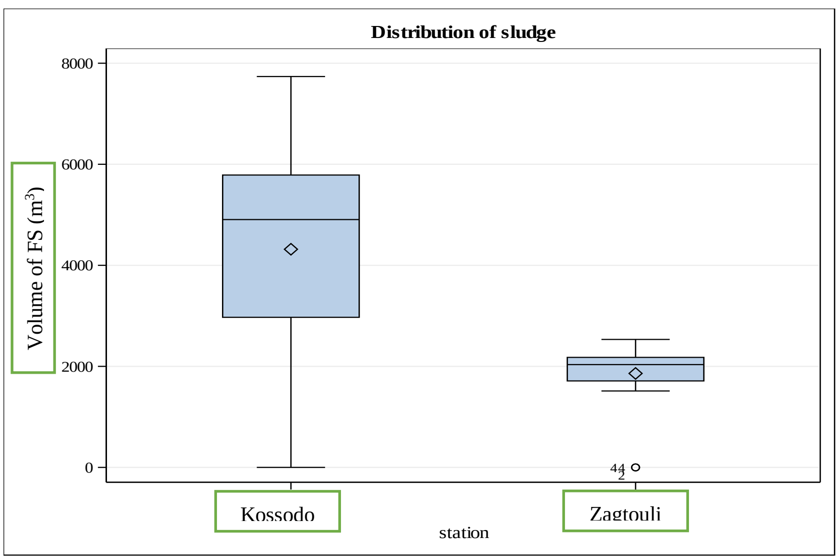


Figure 12: Representative differences between Kossodo and Zagtouli plants



Means with the same letter are not significantly different.			
Duncan	**Mean**	**N**	**station**
A	4317	22	1
B	1860	22	2

Figure 13: Statistically difference between Kossodo and Zagtouli treatment plant by using SAS

Considering to the volume of FS received throughout the period of operation, it is necessary to do a statically analysis in order to define if there is any difference between the operating months, the working days and climatic season on the amount of FS for both FSTP.

3.1.3 Differences between the month, weekdays and climatic season for both FSTP

In order to know if there is a significant difference between the months, the weekdays, the Tukey's Studentized Range (HSD) test as well as the Duncan's multiple Range test have been applied for a confidence of 95% (i.e. α=0.05). The Duncan's multiple Range test has been chosen for the interpretation of the result (Annex III and IV).

3.1.3.1 Differences of the months at both facilities

The months considered for the analysis are from September 2014 to June2016 and are numbered 1-22 as we can observe on the Figure 14.

The amount of FS received at both facilities is not significantly affected by the months for the period of operation. The Probability of Reference (Pr = 0.65) is higher than Alpha (α=0.05) and they are represented by the same grouping letter (Annex V). The lowest volume of FS discharged in Ouagadougou at both facilities was in September 2015 (mean FS=1,046m^3) and the highest volume of FS was in May 2015 (mean FS=4,958m^3).

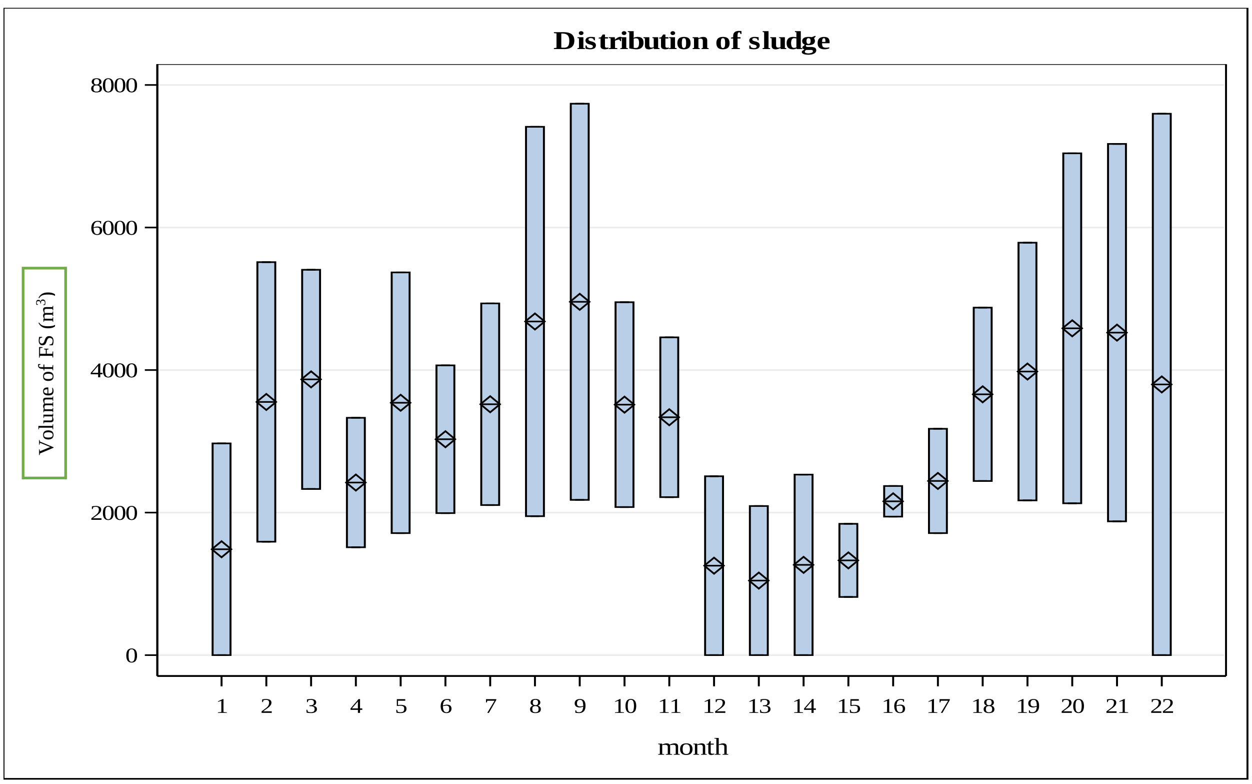


Figure 14: Statically Result of the distribution of the FS by month in Ouagadougou

3.1.3.2 Differences of the working days at both facilities

The days considered for the distribution of the sludge are Monday to Saturday and are numbered 1-6 (see Figure 15).

When applying the Duncan Range test, no significant change in the daily FS rate collected was observed. Indeed, the Probability of Reference is higher than Alpha (P_r=0.41>α=0.05). The distribution of the sludge is also represented by the two (2) different letters (A, B) by using Duncan grouping (Annex VI). In fact there are only two (2) days (Monday and Friday), represented by two different letters, where the average volume of FS is slightly different. The other days are significantly similar. On Monday the stations received the largest volume of FS (Mean=144.59m^3) while on Friday they received the lowest one on average (Mean=112.96m^3).

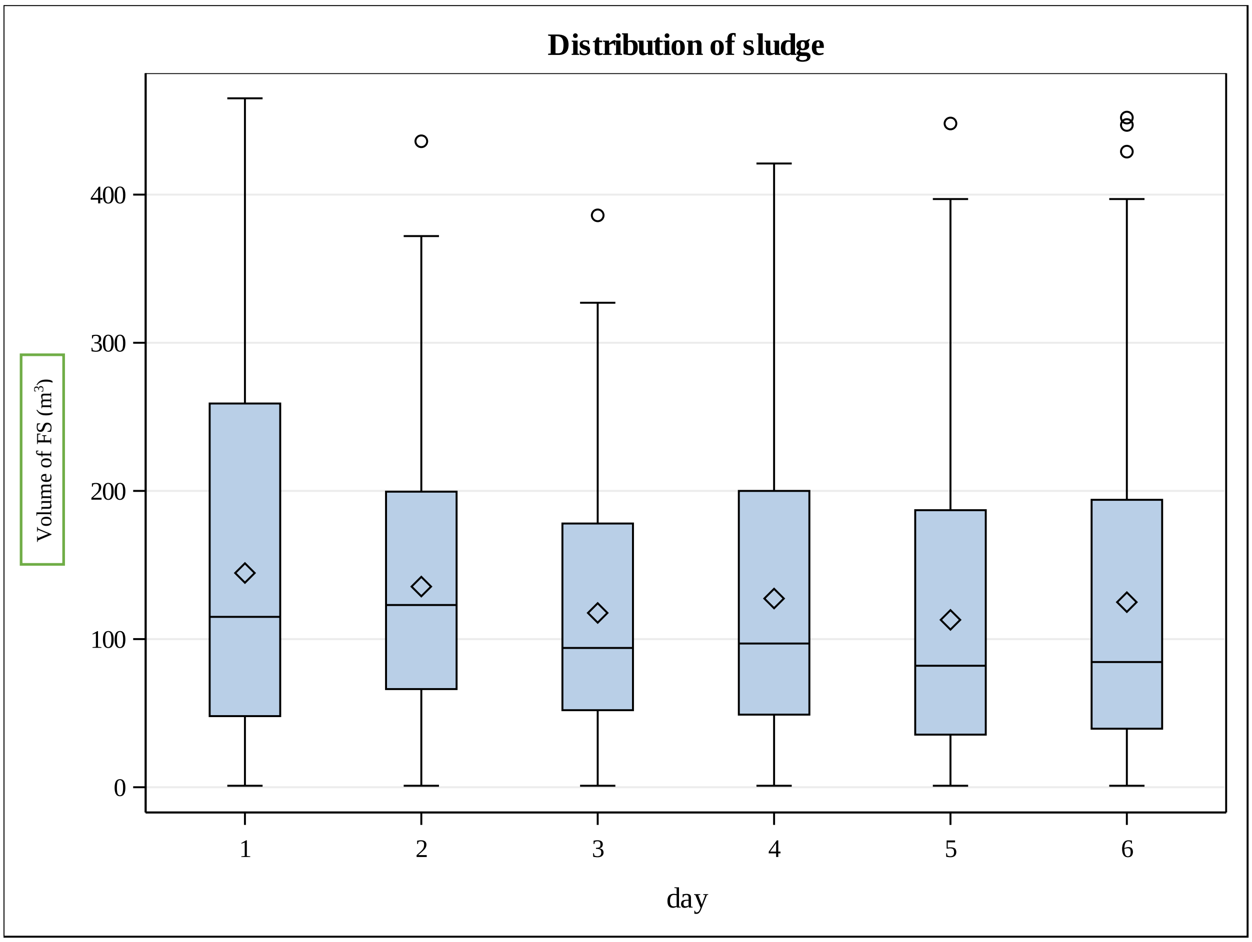


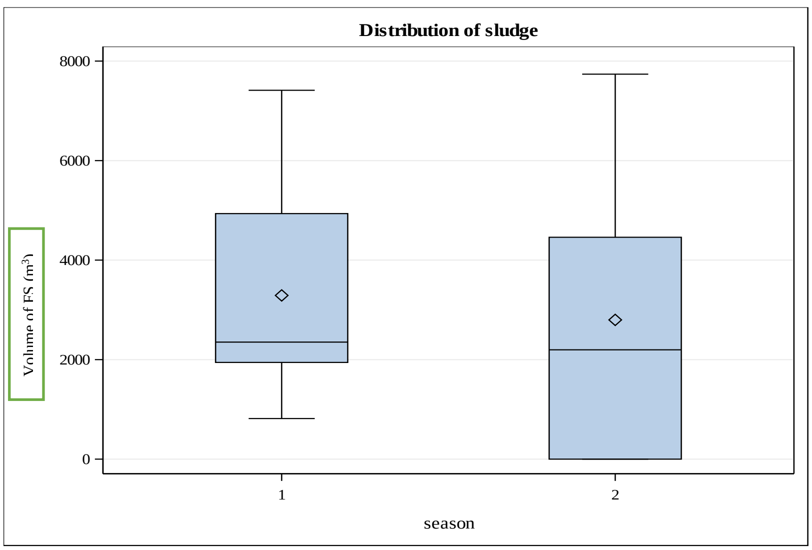
Figure 15: Statically Result of the distribution of FS by working day in Ouagadougou

3.1.3.3 Differences of climatic season

Based on several reports published previously, it could be anticipated that FS collection rates during rainy season would increase compared to data in the dry season. We wanted to confirm whether this was still the case in Ouagadougou for the two operated plants.

The seasons considered are dry season numbered by 1 and rainy season numbered by 2. The dry season start from November to April with a North East wind harmattan, and the rainy one start from May to October with a South wind, the Mousson.

According to Duncan's Multiple Range Test, Figure 16, the climatic season, are not significantly different because the Probability of Reference (P_r= 0.41) is superior to Alpha (α =0.05), and the two (2) seasons have the same Duncan grouping letter. The mean of the volume of FS discharged at both Treatment Plants during the dry season (3,290 m^3) is statically superior than the one discharged during the rainy season (2,798m^3). Base on the result obtained, it seems like the climatic season do not have an impact on the volume of FS.



Means with the same letter are not significantly different.			
Duncan	**Mean**	**N**	**season**
A	3290	26	1
A			
A	2798	18	2

Figure 16: Statistical difference between the dry and the rainy season (number 1= dry season; number 2= rainy season)

3.1.4 Discussion

The total volume of FS collected in both facilities for a period of 22 months, is 139,912 m^3 and is less than the amount of sludge produced by the estimated population of Ouagadougou. According to Bassam et al (2013), the estimated volume of FS produce per year is about 265,720m^3 in Ouagadougou and the average production of FS is in principle between 0.10-0.15m^3 per inhabitant per year and 1,200m^3 per day (Bassan et *al.*, 2013; Koanda, 2006; Ouedraogo, 2006). It means that 34% of the FS produced in Ouagadougou is treated satisfactorily. The reasons that can explain this difference between the quantities of FS produced and the ones treated are:

- Almost 68% of the population in Ouagadougou are using pit latrines which may be emptied by using manual means, while 26% are using VIP latrines connected to septic tank which are often emptied by using vacuum trucks (Bassan et *al.*, 2013).Because the $FSTP_s$

receive and treat FS discharged by the vacuum trucks, the numbers reporting here are reasonable.

- The retention time of FS in the septic tank also influences the availability of FS to be removed or treated in the fecal sludge treatment plant. The retention time varies between 2 to 4 years according to the type of latrine considered.
- The real collection rates may be higher as uncontrolled dumping areas were probably in existence prior to the operation of these two treatment facilities, and may still be in use in the meantime. Travel distances and tipping fees are incentives for some trucks drivers to empty indiscriminately the FS into the environment and not at the designated sites. There are in Ouagadougou seven (7) uncontrolled sites where FS are dumping without treatment and with little control (Ouedraogo, 2006).

The total number of trips for both facilities is 13,981 which corresponds to a daily average of 19 trips. The overall average volume of sludge collected per trip is $9.5m^3$ and the daily travel frequency per truck is 2. According to Tarradellas et *al*. (2004), the average number of truck rotation in some developing countries varies between 2-3 rotations per working days.

According to the results obtained there is a significant difference between the stations. Kossodo plant received about two (2) times more volume of FS than Zagtouli. The volumes collected at Kossodo were the highest, because of the geographic location mostly favorable, easy to access, well equipped, well known, compared to that of the second plant. Indeed, Kossodo FSTP is located in the city center where most household, have high incomes and luxury houses with VIP latrines connected to septic tank. They empty their septic tanks more often because of their larger water consumption. The truck drivers prefer discharging the trucks not far from where they collected the FS because of the transportation cost that corresponds to 50% of the charge cost. This is in line with the study by Tarradellas et *al*. (2004) in Ouahigouya, where it was confirmed that there are almost 15 dumping sites located throughout the main road. On them there is at least one dumping site located within three (3) Km from the district hall where the truck drivers can easily discharge the FS. The frequency of emptying the septic tank and the truck rotation depend on the population the travel distance and the living standard according to Hawkins and Muxímpua (2015). Moreover, the high variability of the volume of FS discharged, 40%, can been explain by the fact that the station was closed for almost four (4) months.

On the other hand Zagtouli is located in the outskirts of Ouagadougou, so hardly reachable and not well known by the truck drivers as Kossodo plant is. Moreover, most households around Zagtouli plant do not have high incomes and are equipped of pit latrines that may be manually emptied. The service charge for septic tanks emptying by the vacuum trucks, depends on the financial conditions of the household and varies between 6,000-18,000XOF (12-36 USD). These results support a study made in Maputo (Mozambique) by Hawkins and Muxímpua (2015) about one third (43%) of the on-site sanitation facilities are almost impossible to empty, mostly due to poor pit lining, or none at all. Most of the latrine in Maputo is a household responsibility and cost US$ 35 for pit latrines and septic tanks US$ 220.

Concerning the influence of climatic season on the volume of sludge the result obtained from our study shows that there is no difference between the climatic seasons, so no impact on the volume of FS. This result is different from the ones reported in the literature review related to the impact of the climatic season on the volume of FS. Indeed according to Bassan et *al*. (2013) and Zöllig et *al* (2011) in the rainy season there is opportunity of intrusion of rain water or groundwater into the septic tanks/ pits. Many septic tanks and pits do not have adequate cover or are not well constructed. Consequently, after a heavy rain there is a groundwater or direct infiltration of the rain water into the septic tanks causing their rapid filling. This situation therefore leads the households to empty their systems more often during the rainy season and not at all in the dry season.

We cannot conclude from these results that the climatic season does not have any impact of the volume of FS because the data received were not sufficient. At Kossodo plant for example the station was closed for two (2) months part of the rainy season. Also during the rainy season the truck drivers prefer discharging their FS into the farms with the farmer's agreement, because it is during the rainy season that the farm works are much intense. Our result may also be explained by the fact that access challenges may have also impeded collection during the rainy season, even if the reverse should have been observed.

3.2 Assessment of the drying beds operation

The drying bed operation shows how the rotation of the FS is done on the bed. Indeed before having the sludge dried, the fecal sludge must pass through rotation processes from bed to bed. The annual drying cycles is estimated to 15 considering up to 4 days of feeding, 2 days handling and 19 days of drying. These settings can be adjusted during operation depending on local weather conditions and the type of the actually sludge receiving. At Kossodo and Zagtouli plants the rotation is done as follow:

- To fill the drying bed
- To scrape the drying bed
- To empty the drying bed

According to the problems occurs, or situation on the drying bed, it can happen that the beds are clogged and need to be scrapped. Let's consider how the drying beds are operating (see Annex VII and VIII).

❖ **Drying bed operation at Zagtouli FSTP**

Figure 17 shows the annual drying bed operation from January to December 2015 (Annex IX for annual analysis at Kossodo plant). We observed that during the three (3) first months of the year there are more scraped drying beds (about 70%) and empty drying beds (40%) than drying beds to scrape (20%). As time passes, the drying beds are clogged (70% in July) and scraped (60% in May). On the other hand, during the months of August and September we observed over 50% of dried beds with 80% of scraped bed in December.

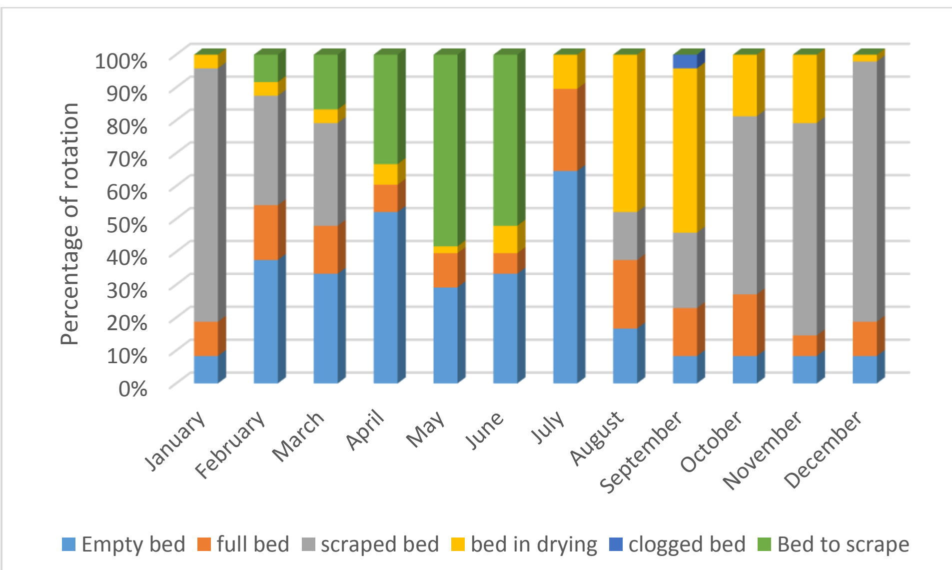


Figure 17: Annual analysis of drying beds operation at Zagtouli

- **Discussion**

The purpose of a drying bed is to stabilize the FS and release the percolates that are treated by means of lagoon system. The treatment of the percolate can be done only when the drying beds are able to release them. In the case of Zagtouli and Kossodo FS treatment plants, the disposal of percolate is not well done because of bad percolation process of the drying beds (Rapport ADP 2 STBV,2010).

The clogging of the drying beds is the main reason of their bad percolation. According to the Rapport ADP1 STBV Grand-Nokoue, Benin, (Abiola, 2015), the establishment of a sandblasting is necessary at the beginning of the treatment in order to remove the maximum of sand and then avoid the clogging of the drying beds.

Moreover, we observed that the time of rotation was not respected during the year of exploitation. Clogged drying beds, is the activity that used more than 50% of the beds while the other activities (scrapped and dry drying beds) are sharing the remained percentage. The rotation is not respected because the percolation process of the filtrates takes a longer time than expected due to clogging drying beds. The rotation frequency of the different activities on the drying bed determine also the efficiency of the FS treatment. Also the time of percolation of the filtrate is not respected because of regular scrapping than can lead to the damage of gravels.

In addition, the overexploitation of the treatment plant can also explain the high percentage of full beds. When the drying beds receive more sludge that it may contain or stabilize, the treatment process cannot be satisfying.

CONCLUSION AND RECOMMENDATIONS

This study offers a state of art of the FS treatment plants management in Ouagadougou mainly the plants of Kossodo and zagtouli.

It reveals that, according to the FS production of the population of Ouagadougou, only 34% of the FS produced is treated satisfactorily.

The analysis also showed that there is a good correlation between the volume of FS and the number of trips. There is no significant difference between the quantities of FS receive monthly, daily and seasonal at both facilities. This means that whatever the day, the month or the climatic season at which the FS is discharged, no impact is observed on the volume of FS.

Therefore, the FS treatment plant of Kossodo due to its location in town center, received more volume of FS than Zagtouli. It received almost 30% of FS more that it is able to stabilize and treat.

On the other hand, the analysis of the drying beds operation showed that the time of FS rotation was not respected due to a problem of percolation of the filtrates and also due to an overexploitation of the drying beds especially at Kossodo plant.

At this point of the study, we can conclude that Kosodo FS treatment plant is facing a lot of operation problems, such as overexploitation of the station and the clogging of the drying beds. Nevertheless, according to the results obtained, some recommendations are done:

- To build more FS treatment plants in order to avoid an over exploitation of one station as it was observed at Kossodo FS treatment plant
- To improve the infiltration process of the drying beds in order to avoid many clogged drying beds
- To employ more technicians in order to insured a good maintenance of the station
- To improve the filtration of FS before discharging into the drying beds.
- To build a storage area for the dried FS and reuse them for agriculture

As perspectives, we suggest to extend the study for more years in order to have more data, before giving a broadly conclusion about the effectiveness of the FS treatment plants in Ouagadougou.

BIBLIOGRAPHICAL REFERENCES

Abiola. F, Rapport ADP, Volet 1 SDBV. 2 "Maitrise d'œuvre pour les Etudes d'amélioration de la collecte et du traitement des boues de vidange dans le grand Nokoue y compris les études techniques détaillées d'exécution de la station d'épuration d'Ekpe" 2015.

Bassan M, Tchonda T, Yiougo L, Zoellig H, I Mahamane, M Mbéguéré, and L Strande. "Characterization of faecal sludge during dry and rainy seasons in Ouagadougou, Burkina Faso," 1–5, 2013.

Chowdhry S, and Kone D. "Business analysis of fecal sludge management: emptying and transportation services in Africa and Asia." *Draft Report). The Bill and Melinda Gates Foundation,* 2012.

Dagerskog L, , KenfacS k, and Jönsson H. "ECOSAN Fertilisers with potential to increase yields in West Africa." *Urban Agriculture Magazine* 20 (2008): 41–43.

Defo C, , Fonkou T, Mabou P, Nana P, and Manjeli Y. "Collecte et évacuation des boues de vidange dans la ville de Bafoussam, cameroun (Afrique Centrale)." *VertigO-La Revue électronique En Sciences de L'environnement* 15, no. 1 (2015).

DGAEUE. "Enquête nationale sur l'accès des ménages aux ouvrages d'assainissement familial 2010 - monographie nationale. Ouagadougou, Burkina Faso," 2011.

Dodane P, , Mbéguéré M, Sow O, and Strande L. "Capital and operating costs of full-scale fecal sludge management and wastewater treatment systems in Dakar, Senegal." *Environmental Science & Technology* 46, no. 7 (2012): 3705–11.

Eau et Assainissement en Afrique, Ouaga (EAA), Centre Regional pour l'eau potable et de l'assainissement. "Gestion des boues de vidange au Burkina Faso: Cas de Ouagadougou," 2014.

Hawkins P and Muxímpua O. "Developing business models for fecal sludge management in Maputo," June 2015.

Hines W, Douglas W, Montgomery C, Goldman M and BorroM r. Probability and Statistics in Engineering. John Wiley & Sons, 2008.

Ingallinella AM, , Sanguinetti G, Koottatep T, Montangero A, Strauss M, Jimenez B, Spinosa L, Odegaard H, and Lee DJ. "The challenge of faecal sludge management in urban areas- strategies, regulations and treatment options." *Water Science & Technology* 46, no. 10 (2002): 285–94.

Institut National de la Statistique et de la Démographie (INSD) annuaire. "Recensement generaux de la population et l'habitation 1985, 1996, 2006," 2013.

Kayaga S, Godfrey A, Cotton A, and Barros C. "Improving on-plot sanitation management in low-income settlements of cities of developing countries: case study from Maputo, Mozambique." *International Journal of Environment and Waste Management* 16, no. 2 (2015): 112–32.

Keraita B, Drechsel P, and Amoah P. "Influence of urban wastewater on stream water quality and agriculture in and around Kumasi, Ghana." *Environment and Urbanization* 15, no. 2 (2003): 171–78.

Koanda H, "Vers Un assainissement urbain durable en Afrique subsaharienne: Approche innovante de planification de la gestion des boues de vidange," 2006.

Koné D, and Strauss M. "Low-Cost Options for treating faecal sludges (FS) in developing countries–challenges and performance," Vol. 27, 2004.

Matejka G, Bouvet Y, Emmanuel E, Koulidiati J, Ngnikam E, Tanawa E, and Vermande P. "Gestion maîtrisée des déchets solides urbains et de l'assainissement dans les pays en voie de développement, les besoins en études scientifiques et techniques spécifiques et en outils méthodologiques adaptés in." *L'étalement Urbain En Afrique: Défis et Paradoxes*, 2004.

Mbéguéré M, , Dodane P, and Koné D. "Gestion Des Boues de Vidange," 2011.

Office National de l'Eau et de l'Assainissement (ONEA) Ouaga. "Plan Stratégique d'Assainissement Des Eaux Usées de Ouagadougou (PSAO)," 2011.

Ouedraogo J "Atelier sur la politique de la gestion des boues de vidange," 2006.

Rapport ADP, volet 2 SDBV. "Services de consultants pour les études détaillées d'exécution, l'élaboration des dossiers d'appel d'offres, la supervision et le contrôle des travaux d'assainissement collectif de la ville de Ouagadougou," 2010.

Ryusei I, Ushijima K, Hijikata N, and Funamizu N. "Survey of sanitation conditions in Burkina Faso for design of toilet," 2012.

Savadogo K. "ECOSAN Burkina Faso : Scale and Learnings," 2015.

Tarradellas J, , Klutsé A, Encadrement SANDEC-EPFL, and D Koné. "La collecte et le transport mécanisés des boues de vidange dans la ville de Ouahigouya (Burkina Faso)," 2004.

WUP report. United Nations Department of Economic and Social Affairs/Population World Urbanization Prospects*:* The 2014 Revision, 2014i

Zöllig H "Caractérisation physico-chimique des boues de vidange dans la ville de Ouagadougou," 2011.

ANNEXES

ANNEX I: Daily, monthly and climatic season data (volume of FS) at Kossodo from 2015-2016

Days (sludge m³) / Months	Mondays	Tuesdays	Wednesdays	Thursdays	Fridays	Saturdays	Climatic seasons
January 2015	189	302	213	215	44	107	Dry season
	211	298	317	233	146	185	
	189	162	152	200	230	219	
	307	337	269	196	240	219	
				215			
February 2015	312	10	10	209	126	205	
	181	237	181	194	166	159	
	147	119	139	113	233	164	
	274	144	169	273	126	194	
March 2015	283	194	0	0	0	64	
	180	119	101	202	185	163	
	396	262	112	273	188	201	
	278	436	249	300	237	308	
		205					
April 2015	244	318	315	382	281	325	
	286	223	279	261	224	192	
	338	372	386	421	240	429	
		336	319	280	265	254	
			238	209			

ANNEX I: Daily, monthly and climatic season data (volume of FS) at Kossodo from 2015-2016

Days (Sludge m³) / Months	Mondays	Tuesdays	Wednesdays	Thursdays	Fridays	Saturdays	Climatic seasons
May 2015	311	273	339	361	189	288	Dry season
	425	326	298	280	285	360	
	425	348	292	361	213	32	
	299	293	147	303	243	264	
					216	287	
June 2015	387	254	191	257	258	358	Rainy season
	374	297	248	277	448	380	
	334	325	327	237	248	337	
	317	279	198	342	377	343	
	375	353					
July 2015	511	564	472	417	499	636	
			416	364	325	256	
Dec 2015	144	78	94	87	108	79	
	131	133	100	168	29	49	
	119	81	88	97	93	29	
	128	133	118	49		9	
		41	96	92			
January 2016						19	Dry season
	30	139	219	84	118	165	
	56	140	113	164	88	94	
	87	113	134	185	175	73	
	137	141	205	211	142	144	

ANNEX I: Daily, monthly and climatic season data (volume of FS) at Kossodo from 2015-2016

Days (Sludge m^3) / Months	Mondays	Tuesdays	Wednesdays	Thursdays	Fridays	Saturdays	Climatic seasons
February 2016	185	209	217	173	211	195	Dry season
	224	150	172	218	238	218	
	267	164	249	162	144	194	
	267	127	164	150	176	215	
	187						
March 2016		230	147	109	141	230	
	277	164	152	184	201	268	
	275	173	218	192	232	135	
	210	213	178	219	333	271	
	259	237	196	313			
April 2016					288	229	Rainy season
	217	290	302	267	228	191	
	353	270	271	279	278	220	
	465	214	206	184	221	334	
	287	194	286	290	230	447	
May 2016	290	187	206	265	219	307	
	280	281	289	261	204	258	
	331	249	192	286	193	352	
	324	313	258	358	180	452	
	391	247					
June 2016			281	270	330	368	
	336	287	223	237	323	397	
	413	260	300	191	397	342	
	320	224	276	72	133	329	
	350	318	318	301			

ANNEX II: Daily, monthly and climatic season data (volume of FS) at Zagtouli from 2015-2016

Days (Sludge m^3) / Months	Mondays	Tuesdays	Wednesdays	Thursdays	Fridays	Saturdays	Climatic seasons
January 2015	85	73	85	27	56		Dry season
	72	165	25	48	67		
	92	67	35	36	60		
	167	73	107	63	69		
					103		
February 2015	90.5	119	72	58	101	57	
	143	75	64	147	44	63	
	54	53	135	116	122	67	
	76	35	113	52	136		
March 2015	131	69	71	66	44	74	
	138	92	62.5	86.5	60.5	54	
	82	130	111	65	33	165	
	53	64	130	77.5	84	125.5	
		37					
April 2015	66	121	111	91	53.5	95.5	
	83	66	54.5	97.5	42	91.5	
	81	164	74.5	74.5	54	55	
		66.5	87	60	70	55	
			64	71.5			
June 2015	47	43	65	71	102	101	Rainy season
	48	132	48	67	61	112	
	81	154	76	63	43	61	
	116	102	59	97	58	94	
	99	79					

ANNEX II: Daily, monthly and climatic season data (volume of FS) at Zagtouli from 2015-2016

Days (sludge m) / Months	Mondays	Tuesdays	Wednesdays	Thursdays	Fridays	Saturdays	Climatic seasons
July 2015	128	34	28	46	126	40	
	138	148	52	91	82	47	Rainy season
	84	95	50	101	64	90	
	90	106	149	70	127	82	
			71	80			
August 2015	69	135	100.5	131.5	89	182.5	
	83	155	52	123	95	81	
	112	138	99	82	108		
	68	132.5		135	108	65	
	117					50	
September 2015	201	163	123	77	105	59	
	143	103	110	144	104	85	
	181	139	90				
		125	144				
October 2015	96	76	56	131	156	27	Dry season
	143	93	69	92	55	80	
	117	54	87	119	187	56	
	110	99	105	97	82	122	
				102	54	71	
November 2015	84	140	118	103	63	98	
	29	61	73	84	51	56	
	37	74	68	44	139	138	

	55	113	47	28	59	82	

ANNEX II: Daily, monthly and climatic season data (volume of FS) at Zagtouli from 2015-2016

Days (sludge m) / Months	Mondays	Tuesdays	Wednesdays	Thursdays	Fridays	Saturdays	Climatic seasons
December 2015	94	54	45	63	110	66	
	80	78	69	144	51	101	
	104	73	77	93		47	
	140	53	130	69		47	Dry season
		70	87				
January 2016						56	
		85	73	85	27	67	
	60	72	165	25	48	60	
	33	92	67	35	36	69	
	48	167	73	107	63	103	
February 2016	188	76	154	56	51	100	
	63	80	123	58	61	70	
	184	134	63	115	94	84	
	42	127	59	154	96	96	
	115						
April 2016							
					50	111	
	77	36	126	69	52	60	
	120	126	89	133	61	85	
	122	42	58	87	29	137	
	103	83	69	59	63	86	
May 2016		138	76	35	64	55	
	34	155	94	98	17	64	
	50	85	130	36	55	98	
	32	114	85	85	45	84	
	60	90					

ANNEX III: Recapitulative table of daily data into SAS

Class Level Information		
Class	**Levels**	**Values**
station	2	1 2 (Kossodo (1), Zagtouli (2))
season	2	1 2 (Dry season (1), rainy season (2))
month	18	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 (from January 2015 to June 2016)
day	6	1 2 3 4 5 6 (From Monday to Saturday)
sludge	292	1 2 9 17 25 27 28 29 32 33 35 35.5 36 37 41 41.5 42 43 44 44.5 45 46 47 47.5 48 49 50 51 52 53 53.5 54 54.5 55 56 57.5 58 59 59.5 60 60.5 61 62.5 63 64 65 66 66.5 67 68 68.5 69 70 71 71.5 72 72.5 73 74 74.5 75 76 77 77.5 78 79 80 81 82 82.5 83 84 85 86 86.5 87 88 88.5 90 91 91.5 92 93 94 95 96 97 97.5 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 125 125.5 126 127 128 129.5 130 131 131.5 132 132.5 133 134 135 136 137 138 139 140 141 142 143 144 146 147 148 149 150 152 154 155 156 159 162 163 164 165 166 166.5 167 168 169 172 173 175 176 178 180 181 184 185 187 188 189 191 192 193 194 196 198 200 201 202 204 205 206 209 210 211 213 214 215 216 218 219 220 221 223 224 224.4 228 229 230 232 233 237 238 240 243 247 248 249 254 258 259 260 261 262 264 265 267 268 269 270 271 273 274 275 276 277 278 279 280 281 283 285 286 287 288 289 290 292 293 297 298 299 300 301 303 307 308 313 317 318 319 320 323 324 325 326 327 329 330 331 333 334 336 337 338 342 343 348 350 352 353 358 360 361 372 374 375 377 380 382 386 387 391 396 397 413 421 425 429 436 447 448 452 465
repno	5	1 2 3 4 5

ANNEX IV: SAS results

Source	DF	Type I SS	Mean Square	F Value	Pr > F
station	1	66450555.49	66450555.49	18.22	0.0003
season	1	2570290.38	2570290.38	0.70	0.4106
month	20	60756560.35	3037828.02	0.83	0.6569

Source	DF	Type I SS	Mean Square	F Value	Pr > F
station	1	2732617.794	2732617.794	382.76	<.0001
season	1	164582.213	164582.213	23.05	<.0001
month	17	537237.324	31602.196	4.43	<.0001
day	5	83203.626	16640.725	2.33	0.0410

ANNEX V: Recapitulative table of differences between the months

Means with the same letter are not significantly different.			
Duncan Grouping	**Mean**	**N**	**month**
A	4958	2	9
A			
A	4681	2	8
A			
A	4586	2	20
A			
A	4525	2	21
A			
A	3979	2	19
A			
A	3869	2	3
A			
A	3798	2	22
A			
A	3660	2	18
A			
A	3553	2	2
A			
A	3541	2	5
A			
A	3520	2	7
A			
A	3515	2	10
A			
A	3338	2	11
A			
A	3029	2	6
A			
A	2444	2	17
A			

Means with the same letter are not significantly different.			
Duncan Grouping	**Mean**	**N**	**month**
A	2422	2	4
A			
A	2158	2	16
A			
A	1486	2	1
A			
A	1329	2	15
A			
A	1267	2	14
A			
A	1255	2	12
A			
A	1046	2	13

ANNEX VI: Recapitulative table of differences between the days

Means with the same letter are not significantly different.				
Duncan Grouping		**Mean**	**N**	**day**
	A	144.59	117	1
	A			
B	A	135.45	120	2
B	A			
B	A	127.37	119	4
B	A			
B	A	124.92	112	6
B				
B		117.63	119	3
B				
B		112.96	117	5

ANNEX VII Situation of drying bed operation at Zatouli FSTP in 2015

Months	**Empty bed**	**full bed**	**scraped bed**	**bed in drying**	**Bed to scrape**
January	0%	33%	0%	17%	50%
February	0%	17%	0%	4%	79%
March	0%	48%	23%	13%	17%
May	0%	29%	0%	4%	67%
June	0%	92%	0%	4%	4%
July	0%	90%	2%	6%	2%
August	2%	0%	4%	88%	6%
September	6%	0%	10%	75%	8%
October	17%	0%	56%	0%	27%
November	90%	10%	0%	0%	0%
December	58%	2%	6%	25%	8%

ANNEX VII: Situation of drying bed operation at Zatouli FSTP in 2015

Months	**Empty bed**	**full bed**	**scraped bed**	**bed in drying**	**clogged bed**	**Bed to scrape**
January	8%	10%	77%	4%	0%	0%
February	38%	17%	33%	4%	0%	8%
March	33%	15%	31%	4%	0%	17%
April	52%	8%	0%	6%	0%	33%
May	29%	10%	0%	2%	0%	58%
June	33%	6%	0%	8%	0%	52%
July	65%	25%	0%	10%	0%	0%
August	17%	21%	15%	48%	0%	0%
September	8%	15%	23%	50%	4%	0%
October	8%	19%	54%	19%	0%	0%
November	8%	6%	65%	21%	0%	0%
December	8%	10%	79%	2%	0%	0%

ANNEX IX: Annual analysis of drying bed operation at Kososdo