PHYSICAL AND CHEMICAL ASSESSMENT OF COMPOST DURING STABILIZATION IN A BIOREACTOR USING SHEA HUSKS AS COMPOSTING MATRIX

MEMOIR SUBMITTED FOR THE FULFILLMENT OF MASTER DEGREE IN WATER AND ENVIRONMENTAL ENGINEERING

OPTION: WATER AND SANITATION

Publicly defended on June, 22nd by

John Steve W. KABORE

Works directed by: Dr. Ryusei ITO

Panel members:

President: Dr. Mariam SOU

Members and correctors: Boukary SAWADOGO

Dr. Lydie Yiougo

Promotion (2011/2012)

DEDICATION

- To my beloved father, **KABORE Alphonse** and my mother **Sonia** who made so many sacrifices for me.

- To my dear Wushu Master, **KONE Mamadou** who taught me another part and philosophy of this life…

I dedicate this master thesis

ACKNOWLEDGEMENT

This work has been a great challenge to deal with and it would not have been possible without some help.

So, I would like to thank:

- The **J**apan **I**nternational **C**ooperation **A**gency **(JICA)** for finding capital for the Améli-Eaur project.
- The University of **Hokkaido** and **2iE** for the knowledge exchange.
- My supervisor Dr. Ryusei **ITO** for the theme proposal, his disponibility and support. Especially to him I say "*Arigatou Gozaimasu*".
- Dr. Mariam **SOU/DAKOURE** for her thrilling critics
- Dr. Inoussa **MAIGA** for his suggestions
- Mr. Seyram **SOSSOU** for the advices and documents he gave me.
- Mr Boukary **SAWADOGO** for his help on spectrophotometry and all lab-scale studies.
- Mr. David **MOYENGA** for helping me focus on important point of this work.
- Mr. Seydou **DICKO,** for his help on the social section of this work.
- PhD Students Drissa **SANGARE** and Armel **YAPI** for their advices.
- The 2iE ‘s Laboratory LEDES ‘’Laboratoire Eau Dépollution Ecosystème et Santé’ and it’s whole staff for their welcome and the support especially Mr. Moustapha **OUEDRAOGO** and Mr. Pierre **KABORE** for their assistance.

  Through these I thank all the teaching corps of 2iE.

I want to deeply thank the **workers of the 2iE’s construction site** without whom the project would have not taken place for their entire and kind participation.

To all my peers of master degree, thank you.

ABSTRACT

The assessment of the physical and chemical parameters occurring in compost made by the mix with Shea husks as matrix and human feces had been evaluated during one month. The job had been set in two steps. The first one was the performing of the compost and the second one was the assessment of the parameters. Relatively to the first step, every day, feces were properly mixed with an amount of Shea husks contained in a composting reactor. These parameters had been analyzed on the second step on samples taken from the reactor every (3) days. Oxygen Utilization Rate had been assessed by setting laboratory conditions of moisture content, temperature and organic load. Results show that there is an optimal combination of moisture content, temperature and organic load in which Oxygen Utilization Rate consumption is good. Relatively to temperature, moisture content, Nitrogen, Phosphorus and C/N ratio are irrelevant relatively to the standards. .
However, it is necessary to state that the experiments had been done during stabilization of the compost, meaning that this compost wasn't mature.

Keywords: Compost, human feces, Oxygen utilization rate, composting reactor, matrix.

RESUME

L'évaluation des paramètres physico-chimiques apparaissant dans un compost provenant du mélange entre une matière carbonée en l'occurrence la coquille de Karité et des fèces humaines, s'est déroulée sur une période d'un mois. Le travail général a été subdivisé en deux étapes. La première consistait à la réalisation du compost et la seconde consistait à l'évaluation des paramètres. Ainsi donc, durant la première étape, les fèces étaient correctement mélanger chaque jour avec les noix de Karité dans un bioréacteur. Ces paramètres ont été analysés durant la seconde étape sur des échantillons récupérés du bioréacteur tous les trois jours. Le taux de consommation d'oxygène par les microorganismes contenus dans le compost a été mesuré dans des conditions fixes de température, de taux d'humidité et de charge organique en laboratoire. Les résultats montrent qu'il existe une combinaison optimale entre la température, le taux d'humidité et la charge organique pour une bonne consommation en oxygène. Les résultats obtenus relativement à la température, au taux d'humidité, aux concentrations en azote et en phosphore ainsi que le rapport C/N sont en inadéquations avec les normes applicables à un bon compost. Cependant, les tests ont été réalisés sur des échantillons provenant d'un compost en phase de stabilisation et non encore mature.

Mots-clés: Compost, fèces humaines, Taux d'utilisation d'oxygène, bioréacteur, matière carbonée.

ABREVIATIONS AND ACRONYMS

2iE: International Institute for Water and Environmental Engineering

T-P: Total Phosphorus

T-N: Total Nitrogen

MC : Moisture Content

COD: Chemical Oxygen Demand

TOC : Total Organic Carbon

C/N: Carbon-Nitrogen ratio

F/S: Organic load: feces volume on Shea volume

OUR : Oxygen Utilzation Rate

LEDES : Laboratoire Eau Dépollution Ecosystèmes et Santé

LIST OF CONTENTS

DEDICATION i

ACKNOWLEDGEMENT ii

ABSTRACT iii

RESUME iv

ABREVIATIONS AND ACRONYMS v

LIST OF CONTENTS vi

LIST OF TABLES viii

LIST OF FIGURES ix

PART I: PRESENTATION AND CONTEXT 1

I.1 - STATEMENT OF THE PROBLEM 1

I.2- Améli-EAUR PROJECT 2

PART II: SYNTHESIS AND GENERALITIES 4

II.1 - DEFINITION AND UTILITY OF A DRY TOILET 4

II.1-1 ECOSAN toilet 8

II.1-2 Model of the projected composting toilet 9

II.2 -ABOUT USUAL COMPOST 10

PART III: MATERIALS AND METHODS 13

III.1- METHODOLOGICAL APPROACH 13

III.2- THE EXPERIMENTAL DEVICES 13

III.2-1 Description and purpose of the toilet 13

III.2-2- The composting reactor 14

III.3- LAB-SCALE STUDIES: Physical and chemical analysis 16

PART IV: RESULTS AND DISCUSSION 21

IV- PRESENTATION OF THE RESULTS 21

IV.1.1 - Evolution of the temperature 21

IV.1.2 - pH 22

IV.1.3 - Electric conductivity 22

IV.1.4 – Moisture content 23

IV.1.5 – Chemical Oxygen Demand 23

IV.1.6 – Total Nitrogen 24

IV.1.7– Total Phosphorus 24

IV.1.8– Oxygen Utilization Rate (OUR) 25

IV.1.9 – C/N ratio 27

IV.2 - DISCUSSION 28

CONCLUSION AND RECOMMENDATION 31

BIBLIOGRAPHY 36

APPENDICES 38

LIST OF TABLES

Table 1-Daily weight of feces put into the reactor 16

Table 2-Experimental conditions set up for evaluating temperature effect on OUR 19

Table 3-Experimental conditions set up for evaluating moisture effect on OUR........ 19

Table 4-Experimental conditions set up for evaluating F/S effect on OUR 20

LIST OF FIGURES

Figure 1 Améli-EAUR's model regarding human excreta treatment 2
Figure 2 Améli-EAUR operating areas in Burkina Faso 3
Figure 3-Models of dry toilet (RAE, 2010) 6
Figure 4- Domestic wastewater components 7
Figure 5-Pollution distribution (Toilette du monde, 2009) 8
Figure 6-Transversal projection of an ECOSAN toilet model (Toilette du monde 2007) 9
Figure 7-Ameli-EAUR's composting toilet 10
Figure 8-Model with separation at the source 13
Figure 9-The diverting toilet 14
Figure 10-The composting reactor 15
Figure 11-OUR measurement device 18
Figure 12-Evolution of temperature during the composting process 21
Figure 13-Evolution of pH during the composting process 22
Figure 14-Evolution of EC during the composting process 22
Figure 15-Evolution of Moisture content during the composting process 23
Figure 16-Evolution of COD during the composting process 23
Figure 17-Evolution of T-N during the composting process 24
Figure 18-Evolution of T-P during the composting process 24
Figure 19-Evolution of OUR at 40°C and various MC and F/S 25
Figure 20-Evolution of OUR at 50 °C and various MC and F/S ratio 26
Figure 21-Evolution of OUR at 60 °C MC 50% and F/S ratio 10 % 27
Figure 22-Evolution of C/N ratio during composting process 27
Figure 23-Couples of evolution of TOC and TN during composting process 28

PART I: PRESENTATION AND CONTEXT

I.1 - STATEMENT OF THE PROBLEM

In Sub-Saharan Africa, 24% of population in rural area and 44 % in urban area have an improved sanitation facility in 2008 (Millennium development goals report, 2010). For the drinking water, the report says the coverage of the improved water source is 47% in rural area and 83% in urban area. This coverage is related to the poorness; poor people don't have improved toilet, in contrast, rich people has. This fact shows that the main target to benefit the sanitation system is poor people and in rural area. Therefore, some cheap but improved sanitation systems designed are required.

Situated in West Africa, Burkina Faso is a country without sight on the sea, and its capital is Ouagadougou. This country shares borders with Mali (North), Niger (East), Benin (South-East), Cote d'Ivoire (South-West), Togo and Ghana (South). In 2009, the population was estimated around 15.746.232 inhabitants (INSD, 2009). The climate is in average warm and the seasons' repartition is unequal between the rainy one (3 months from June to September) and the dry one (8 or 9 months from October to June). Such situation often rarefies water for people, precisely for rural communities' inhabitants. For instance the year 2011 in Burkina Faso had been marked by an important dryness. At the end of 2011 year, 58.5% of rural population did not have access to drinkable water and around 114 townships had an access to drinking water under 50% (Assainissement et Eau pour tous, 2012). Only 3.1% of the population have an adequate system of sanitation. Defecation at free air is practiced by 62.8% of people (Assainissement et Eau pour tous, 2012) leading to many diseases.

Several systems of feces treatment already exist in the country. One of the well-known is the ECOSAN toilet, which one by using human's feces produces compost (Muellegger, 2004). However most of the existing systems has some deficiencies. For instance lime is used in ECOSAN toilet, thus contributing to the increasing of pH from acid to basic while the average for a good composting process is around 6 or 8.

Regarding such situations, Améli-Eaur project tries to bring some help, by doing researches in water and sanitation in order to provide some useful devices, efficient and above all, easily reachable by the population.

The main objective of the performed studies is to find the appropriate design of an efficient composting reactor, by:

- Assessing the physical and chemical interplays during the composting process
- Bringing out the influence of the matrix on this composting process
- Optimizing the operating condition with a local matrix

I.2- Améli-EAUR PROJECT

The **I**nternational **I**nstitute for **W**ater and **E**nvironmental **E**ngineering (2ie), in collaboration with Hokkaido's university and the **J**apan **I**nternational **C**ooperation **A**gency (**JICA**) instigated the Améli-EAUR project. It is a research project which aims to develop the model of water supply and sanitation for sustainable sanitation in Burkina Faso. **Figure 1** shows the plan of the project concerning human excreta management. More precisely, it consists on following five research groups:

-Feces and urine treatment (in order to make fertilizer)

-Gray water treatment

-Reuse of compost, treated gray water and urine in agriculture

-Drinking water supply

- Socialization and economics.

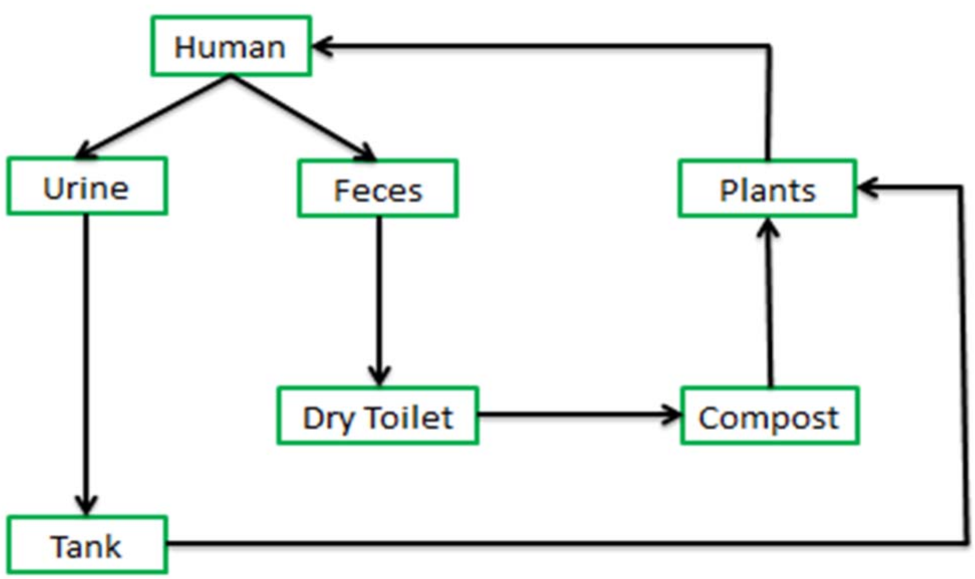


Figure 1 Améli-EAUR's model regarding human excreta treatment

The center of the project is in the laboratories on 2iE in Ouagadougou. All the studies and analysis are made there. The project has 6 pilots in 3 villages near the capital, which are Barcoundba, Kologondiessé and Kamboinsé (Figure 2). Regarding these pilots, the developed models are tested by some selected families. Reactions, opinions and experience from the families will constitute a feedback to develop the model. The results of the project will be used to improve the quality of human life in the region.

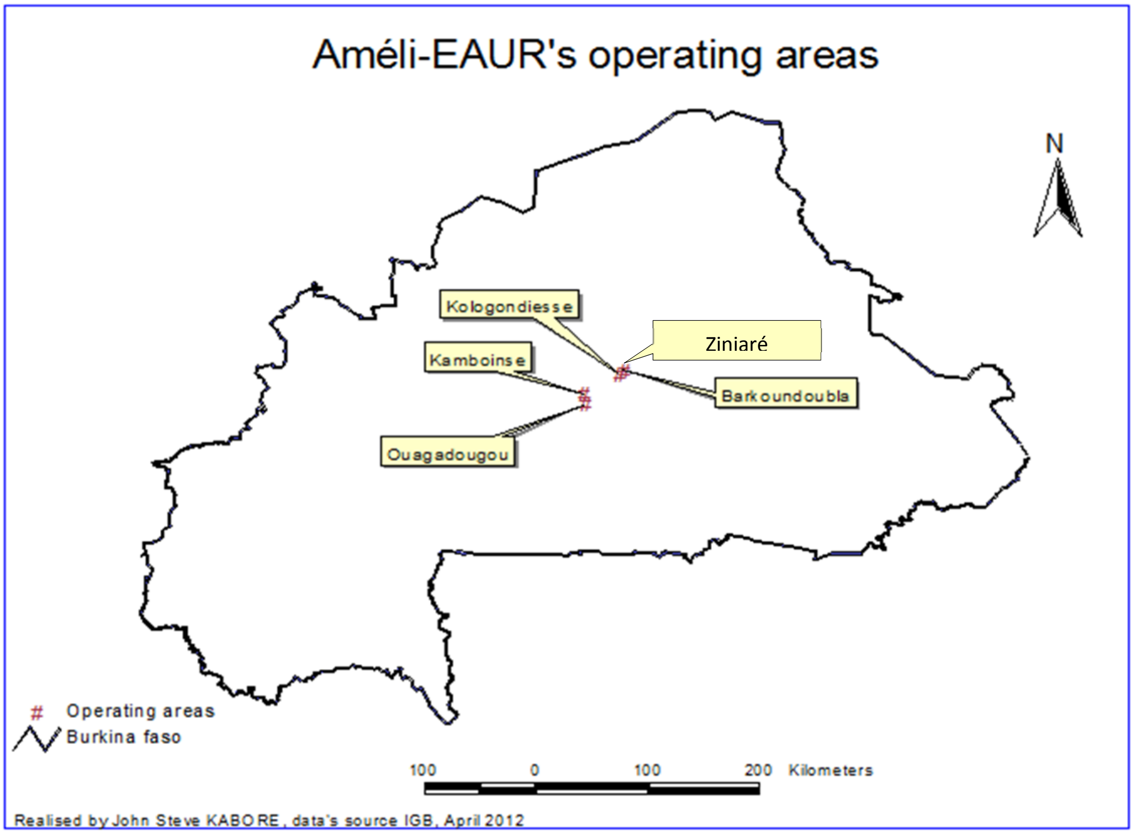


Figure 2 Améli-EAUR operating areas in Burkina Faso

PART II: SYNTHESIS AND GENERALITIES

II.1 - DEFINITION AND UTILITY OF A DRY TOILET

A dry toilet is a kind of toilet that collects human feces without water. Two types of dry toilet exist. One with feces and urine mixed and the other one in which they are separated. However, each type possesses several models like shown in Figure 3.

Mixing system:

1 **Toilet with litter (T.L.B):** A litter is added by the user after relieving himself. This type of toilet has a small volume leading to some early emptying periodicities (1 or 2 times in a week). It is adequate for lack of space problems in some areas. (Morgan, 2007)

2 **Compact composting toilet with single pit**: In this concept, the pit is shallow, about 1.0 to 1.5 m deep, and the toilet site is temporary. Excreta, soil, ash, leaves are added to the pit. The toilet consisting of a ring beam, slab and structure; moves from one site to the next at 6 to 12 months intervals. The old site (the one which sheltered the toilet) is covered with soil and left to compost and a tree is planted there preferably during the rainy season. (Morgan, 2007)

3 **Composting toilet with large volume or double alternating pits:** In this concept, there are two permanently sited shallow pits, about 1.5m deep and dug close to each other for alternate using. For a medium sized family (about 5 persons) the pit takes about 12 months to fill up and this same period allows sufficient time for the mix of excreta, soil, ash and leaves to form compost which can be excavated. Every one year pit is excavated while the other becomes full. (Morgan, 2007)

Separating system:

4 **Compact model:** In the first case, the separation can be made by gravitation when feces, mixed with urine fall on a porous textile. In the second case, where urine is diverted, the separation can be made at the source and the collected volume can be evacuated towards an outlet (**Figure 3**) or a treatment station. This system is not indicated for urines re-use because they could be contaminated by feces during gravitational separation. The emptying period is about 1 or 2 times in a month. (Morgan, 2007)

5 **Linked model:** The concept is almost the same than compact model, nevertheless this model has dug pits and the emptying periodicity is longer (more than one year). (Morgan, 2007)

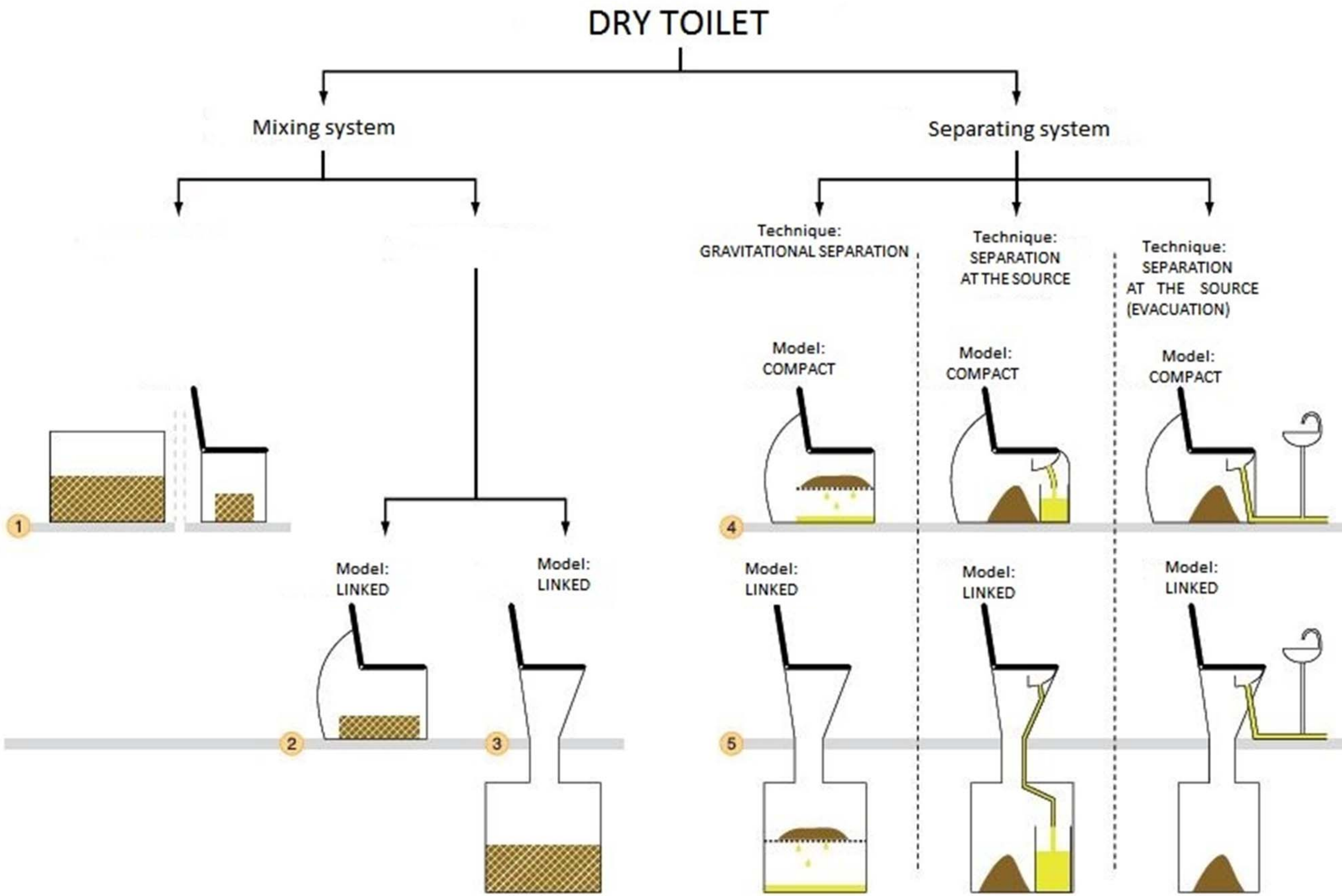


Figure 3-Models of dry toilet (RAE, 2010)

In general, when people don't have dries toilets, they use water closet and water for cleaning. These practices increase households' water consumption. Indeed, in the general context, 25 to 35% of households' wastewater is due to water closet. (Joseph ORSAGH, 2000). Using dry toilet will considerably reduce the volume of domestic wastewater.

Moreover, separate excrements from water is the best way to reduce its pollution. **Figure 4** shows that domestic wastewater are rejected in the environment, ground waters, rivers… after their treatment while more than 98% (**Figure 5**) of pathogens (viruses, parasitic protozoa, helminths) present in wastewater come from feces (Toilette du Monde, 2009).

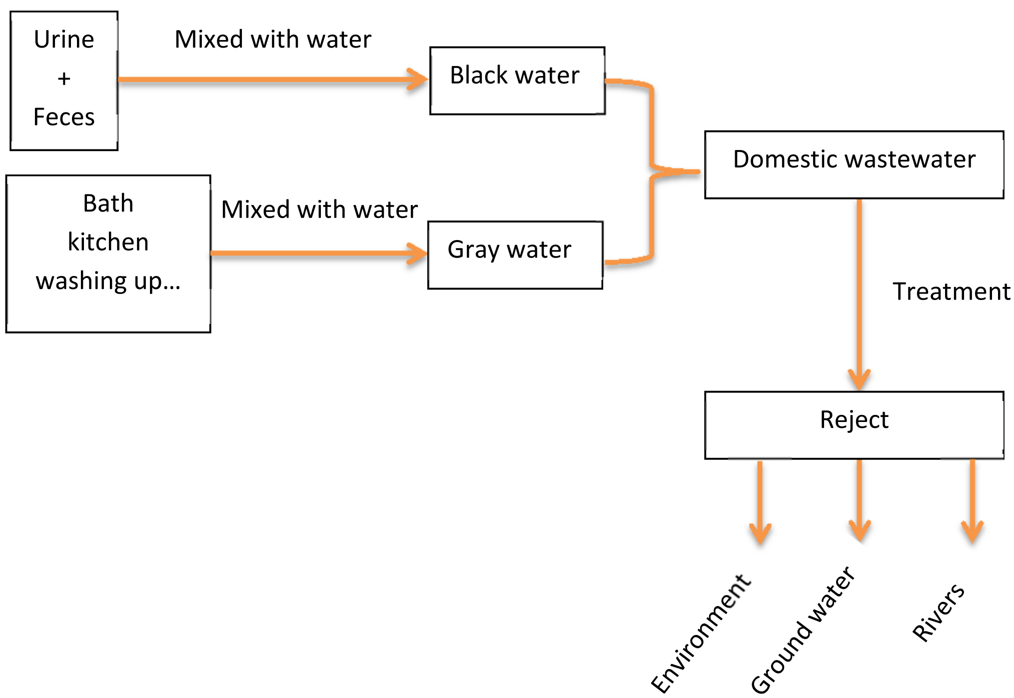


Figure 4- Domestic wastewater components

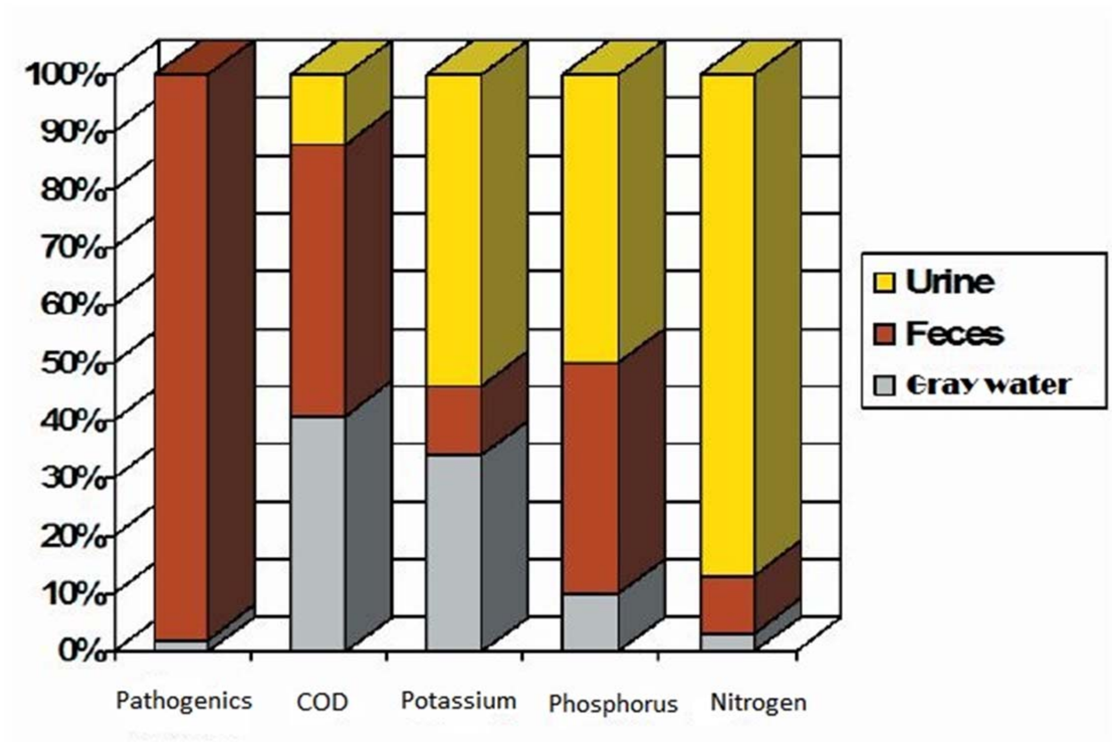


Figure 5-Pollution distribution (Toilette du monde, 2009)

Another purpose of the dry toilet is the re-use of the matters. Indeed, feces and urine can be reuse for agricultural intents, after following some processes to be harmless for crops and human health. For instance urine contains between 60 and 80% of nitrogen produced by the human body and requisite for the growth of plants.

II.1-1 ECOSAN toilet

Shorten form of the word Ecological Sanitation, ECOSAN is another approach of the integrated management of solid and liquid wastes. It tries to bring a solution to sanitation problems by improving environment care and human health. This type of toilet is for instance appropriated for areas where ground water shows on surface.

ECOSAN latrine is constituted by two waterproof pits having warming plates used for feces dessication. Inside the cabin, there are two defecation holes, one per pit, used alternatively to permit complete dehydration of feces within the pit out of order. Feces and urine are collected apart, meaning that that it is also a separating system. However, for dessication process, lime or cinder is used, thus increasing pH level because of their basic condition, while we know that most of bacteria involved in composting have their optimum growth between pH 6 and 8.

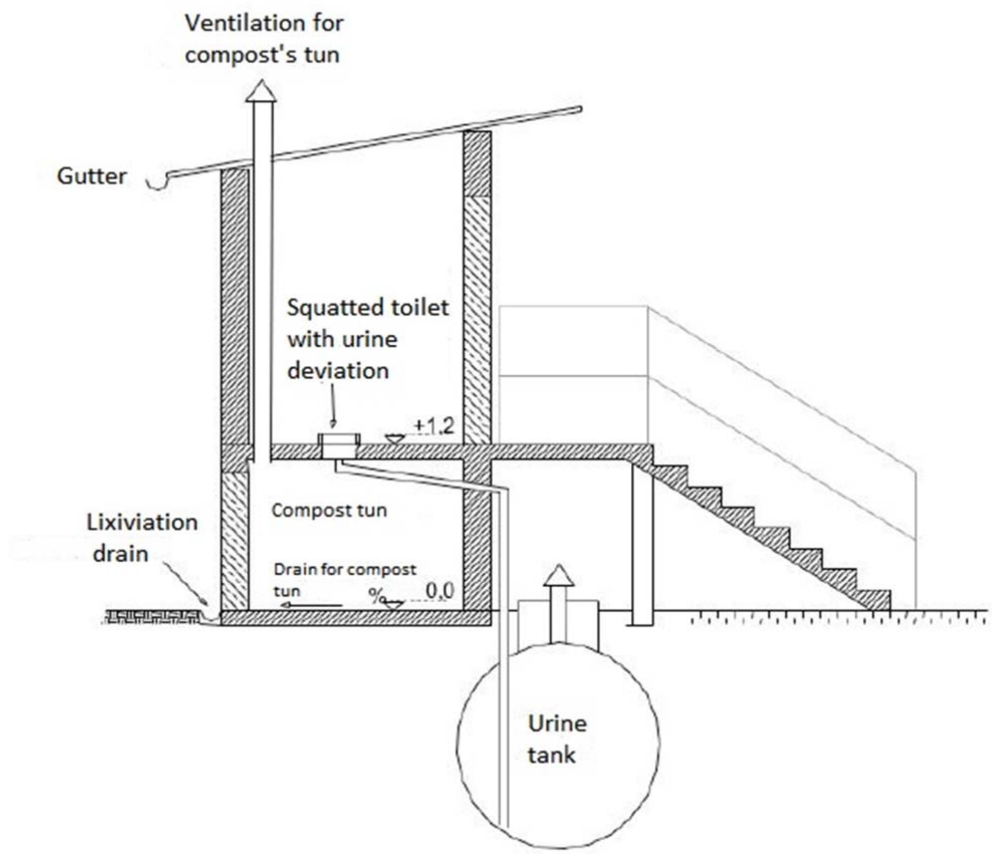


Figure 6-Transversal projection of an ECOSAN toilet model (Toilette du monde 2007)

II.1-2 Model of the projected composting toilet

Ameli-EAUR project tries to import and adapt the technology of the bio-toilet in Burkina Faso. Bio-toilet is the name of a dry toilet or composting toilet that uses sawdust as a bulky matrix for bioconversion of human excreta into compost which can be used either as organic fertilizer rich in N, P, and K, or as a soil conditioner (Kitsui and Terazawa, 1999; Del Porto and Steinfeld, 2000). It is an important subsystem of the Onsite Wastewater Differentiable Treatment System (OWDTS) becoming available and presently used in Japan. It possesses a composting reactor made of stainless steel, a microprocessor to control mixing frequency and temperature, a motor… It is a very ingenious system, but after all, too expensive for the African context.

Thus, Améli-EAUR, has designed a similar device but cheaper, by suppressing the mechanical engineering components (motor, microprocessor…) and changing the assembly materials like using wood for the composting reactor. The design has been made for family use, meaning an average of 4 or 7 persons. The air supply is done by human motor function (lever). It is also a separating system and the composting reactor emptying periodicity is about 1 year.

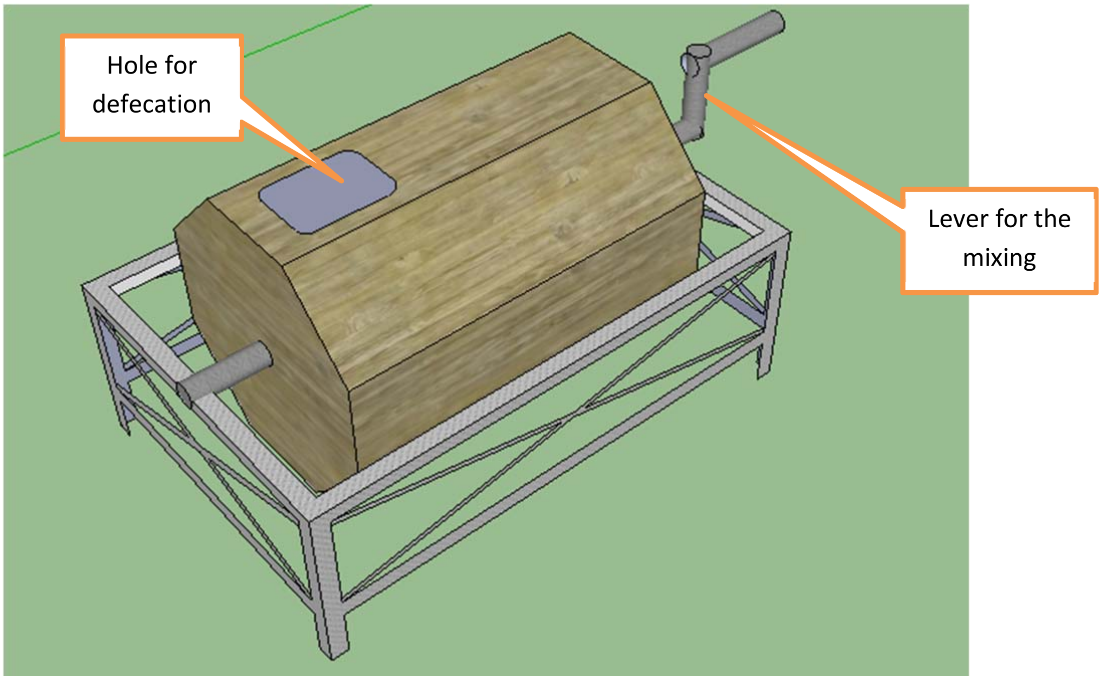


Figure 7-Ameli-EAUR's composting toilet

II.2 -ABOUT USUAL COMPOST

***Definition**

Composting process is a biological, aerobic conversion and valorization process of organic matter under controlled conditions into a stabilized, hygienic product rich in fertilizing elements for the soils.

***Process**

Two phenomenon succeed during composting process. The first is an intense aerobic degradation leading to the decomposition of fresh organic matter under high temperature (50-70 °C) and bacteria impulse. The second is the maturation. It is a light degradation under low temperature (35-45°C), turning fresh compost into a mature compost rich in humus.

***Composting methods**

There are two methods of composting: Free air composting and closed area composting or digester. Free air composting improves aeration in the compost and closed area composting permits to properly observe the physical and chemical interplays. Both of them gather different variants like shown below:

✓ *Free air composting*

- **Into pit**: This method has been used during a long time but it leads immediately to some anaerobic conditions. The pit is dug in a safe place and organic trashes are laid in there about 20 cm of thickness. Then they are covered with straw and soil. (Jean Pain, 1972)
- **In lot**: It is the most famous method. Trashes are gathered into swath of which height depend on both compost's porosity to the air and aeration mixing frequency. Generally it is appropriated to work with low height (20-30cm) in order limit overheating and to favor aerobic condition. (Jean Pain, 1972)
- **In corridor:** It is a similar method to the previous one (In lot), but in this case, trashes with swaths are collected between two lateral low walls. It is costly than the other(Jean Pain, 1972)

✓ *Closed area composting or digester*

- **Vertical silo:** Trashes are collected at the top of a "vertical tower" and transported at the bottom by an endless screw. Some pipes ensure aeration by taking air from the silo surface. The mature compost is taken at the tower's bottom. (Jean Pain, 1972)
- **Bio stabilizer:** The digester is laid horizontally and it is a rotary cylinder. The continuous rotation of the cylinder allows at the same time, the mixing, the aeration and the forwarding of trashes towards the device bottom. (Jean Pain, 1972)

NB: *Regarding the composting volume, the method could be qualified as domestic (family scale), intermediate (large family), industrial (commercial goals).* (Jean Pain, 1972)

***Parameters in composting process**

- **Aeration:** It is a very important parameter because composting is an aerobic process. If there is not enough oxygen an anaerobic condition may occur and smells may result. (Jean Pain, 1972)
- **Moisture:** This parameter is much closed to aeration. A moisture excess decreases available oxygen in the compost. So, it is necessary to find the balance value of moisture. For most materials, the recommended average value is about 40 to 60%. Below 40% the process starts slowing until totally stop about 15%. Beyond 60% there is an anaerobic condition. (Jean Pain, 1972)
- **Temperature:** By their respiration, microorganisms present in compost release high heat. This high temperature can be lethal for cells. So, transformations in compost must be gradually done from mesophilic organisms' step (20-45°C) to thermophilic organisms' step degradation (50-70°C). (Jean Pain, 1972)
- **pH:** The average value appropriated for bacteria growth in the composting process is about 6 to 7. Out of this range, meaning acidic (<6) or alkaline (>7) the process is corrupted. (Jean Pain, 1972)
- **C/N ratio:** During composting process, microorganisms consume organic carbon leading to CO_2 release and a gradual decrease of carbon rate. This carbon diminishing drops C/N ratio. A too low C/N ratio (<15) leads to nitrogen leak and the opposite (>30) slows the degradation. (Jean Pain, 1972)
- **C/P ratio:** Phosphorus is essential for microorganisms' energetics reactions. The average value is about 75 to 150, thus leading to fast organic matter degradation and a good humus production. (Jean Pain, 1972)
- **Particles dimensions:** It influences the air circulation in the compost. Big particles will accelerate air supply in the compost and small ones will slow the process and may lead to an anaerobic condition. (Jean Pain, 1972)

PART III: MATERIALS AND METHODS

This part of the work presents the methodological approach adopted and also the used materials for implementation of both pilot and laboratories activities.

III.1- METHODOLOGICAL APPROACH

In order to plan and conduct some good studies, the whole work had been set in three steps like following:

-Field stage: (i) assembling of the experimental separating toilet (ii) supply of the composting reactor (iii) sampling for laboratory analysis.

-Laboratory stage: consists to measure and assess chemical and physical interplays in both compost and feces.

-Office stage: It consists to finalize the report including the bibliographical research on the subject and laboratory's data analysis.

III.2- THE EXPERIMENTAL DEVICES

III.2-1 Description and purpose of the toilet

Like stated above, compost is a mix between organic and carbonated matter. Thus, the composting toilet aims to use feces and/or urine mixed with a matrix rich in vegetable carbon. Regarding the composting way, it is possible to use separating or mixing systems (**Figure 7**). For our topic requirements we worked only on feces, so we used the compact model of the separating system with separation at the source (**Figure 8**).

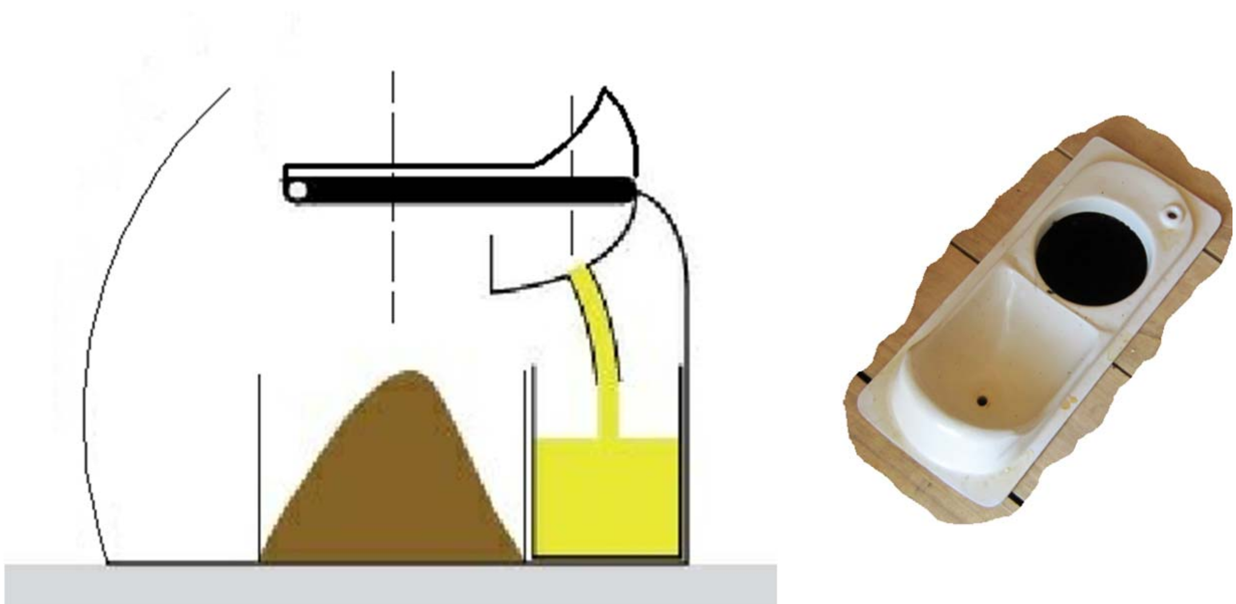


Figure 8-Model with separation at the source

We built this model (**Figure 8**) in order to supply the composting reactor with feces. We needed to collect feces amount every day for the bio reactor during a month (30days) with a view to balance C/N ratio and monitor stabilization of biological, microbiological, physical and chemical phenomenon occurring in the compost.

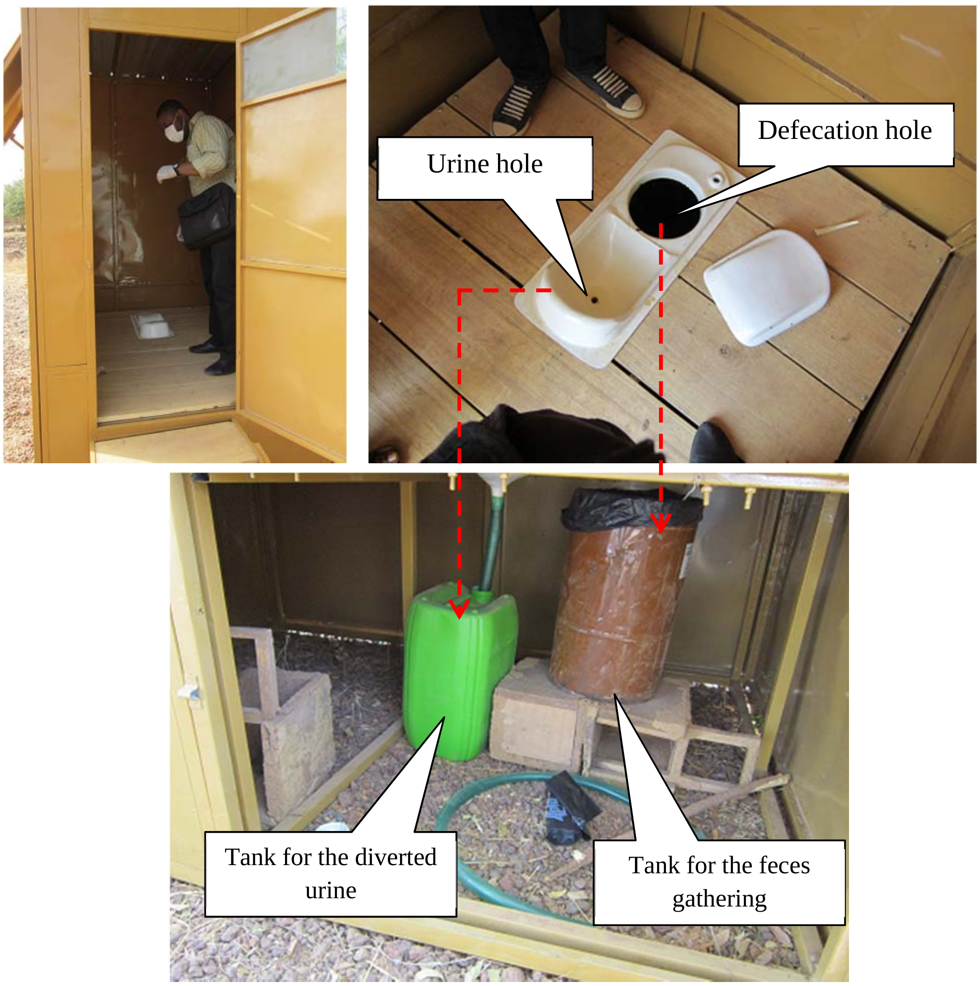


Figure 9-The diverting toilet

III.2-2- The composting reactor

The mixture between feces and a carbonated matter in order to produce compost is done on a composting reactor. This device is made to supply air for aerobic condition, ensure a correct mixture to homogenize temperature distribution and take all the interplays between biological, microbiological, physical and chemical elements. The carbonated added matter is a matrix from vegetable. It has a physical-chemistry role. It absorbs bad smell from feces and balance C/N ratio by supplying carbon matter

For our experiments we used Shea husks as the matrix which one has a C/N ratio around 100. Moreover, it is cheap and very easy to find in the country (Burkina Faso). The total amount put in the composting matrix is about **12, 61 Kg**.

Figure 10-The composting reactor

- ✓ ***Supply of the composting reactor:*** Initially, we planned to feed the composting reactor with an exact amount of 1Kg of feces every day during one month (30 days). Unfortunately, the amounts we've got were below the wished ones. Somehow, this misfortune helped us to simulate the unpredictable household situation. We often had been in situation where there were no feces in the gatherer tank (**N.D**=**N**o **D**ata).

Table 1-Daily weight of feces put into the reactor

Collection days	Volume (g)	Collection days	Volume (g)
Day 1	640	Day 12	930
Day 2	610	Day 13	940
Day 3	110	Day 14	340
Day 4	420	Day 15	N.D
Day 5	430	Day 16	1380
Day 6	480	Day 17	1138
Day 7	1050	Day 18	800
Day 8	1650	Day 19	N.D
Day 9	350	Day 20	240
Day 10	N.D	Day 21	N.D
Day 11	1150	Day 22	N.D
Total volume of feces (Kg)			***12,658***

In this table, one can notice that there are 22 days instead of 30, like planned before. Such result is relative to the fact that we didn't collect feces during the weeks-end (Saturday and Sunday). However the amounts of feces relating to weeks-end had been collected at the beginnings of the following weeks.

III.3- <u>LAB-SCALE STUDIES</u>: Physical and chemical analysis

The physical and chemical assessment must be done on stabilized compost. So, regarding this situation, after stabilization process, we took 25 g of compost every (03) day during a month. The physical and chemical parameters we needed to assess in the compost were Temperature, pH and electric conductivity (EC), moisture content (MC), total phosphorus (T-P), total nitrogen (T-N), chemical oxygen demand (COD), C/N ratio and Oxygen Utilization Rate (OUR).

- ✓ ***Temperature****:* By using a probe thermometer (*Digital Thermometer 343*), temperature was determined on compost samples taken from the first day of the beginning of the stabilization and then every 3 days during 30 days.

- ✓ ***pH and Electric Conductivity (EC):*** pH was determined on the taken sample by the following the next procedure:
  - 5g of compost in 10 ml of distilled water
  - Agitate the mixture in a beaker which contains a magnetized bar using the mechanical agitator during 30 minutes
  - Let the mixture rest for 30 other minutes and then carry out the reading. For the reading, a multi parameter probe (*WTW 330 i*) is used and calibrated with water distilled at the beginning.
  - Read the pH of the solution on the screen of the pH-meter

The device used to determine the pH of the solution is the same for the assessment of the conductivity. The electric conductivity of the solution is given in µs/cm.

- ✓ ***Moisture content:*** It has been determined by heating 10g of each collected sample in an oven at 105°C and weighing the dry ones resulting. The assessment process is referred to the Standard methods (1995) detailed in appendix 1.

- ✓ ***Chemical Oxygen Demand (COD):*** The method is based on the oxidation of the organic matter in acid surroundings by adding potassium dichromate (K_2CRO_7) and sulfuric acid. The oxidation is done into a DRB 200 reactor at 150 °C. Then, the sample is cooled to room temperature. HACH's DR 890 spectrophotometer allows to directly read COD concentration in mg/L at 600nm of wave length by using stored program N° 17.

- ✓ ***Total Nitrogen:*** The method used is the total persulfate digestion. In order to convert all forms of Nitrogen to nitrate, an alkaline persulfate digestion is done. Sodium metabisulfite is added after the digestion to eliminate halogen oxide interferences. Nitrate reacts with chromotropic acid under strongly acidic conditions to form a yellow complex. The concentration of the diluted samples has been determined by HACH's DR 890 spectrophotometer using stored program N° 69.

- ✓ ***Total Phosphorus:*** It has been determined by Phospher® 3 method with Acid Persulfate Digestion. Program N° 76 of HACH's DR 890 spectrophotometer permitted to determine concentration of the diluted samples.

NB: *The concentration given by the spectrophotometer had been converted on a dry basis to get the real concentration of the parameters in compost in "mg/g of dry compost (dry weight)".*

- ***Oxygen Utilization Rate (OUR):*** **Figure 11** shows the device used to determine OUR. It is based on the input and the output oxygen. A bio-reactor (4) made with glass and steel and having a steel porous plate at its bottom in order to ensure good distribution of air supply is placed into a water bath (6). Sensors for oxygen (2) and temperature are set before and after the bio-reactor, which one having an additional temperature sensor inside. All sensors are connected to a computer (Omron RX-45 data multi logger) for monitoring every five seconds. Air is supplied into the bioreactor by pumping continuously. Air flow rate and pressure are controlled and kept constant by using a flow meter (1). Before entering the bio-reactor, the supplied air is humidified by a bottle containing water (3). Air is dried before measuring oxygen concentration by using silica gel (5). The bio-reactor is submerged into water whose temperature is kept constant by using a temperature controller (combined with 6).

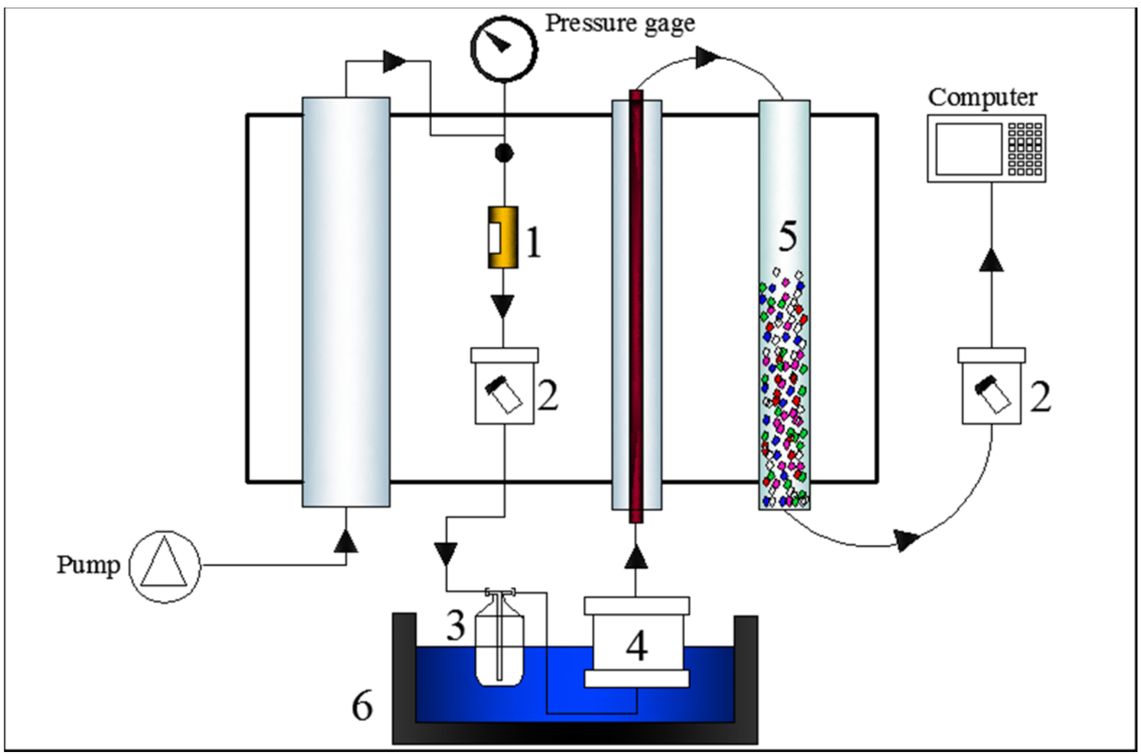


Figure 11-OUR measurement device

Feces were properly mixed with Shea husks to ensure proper distribution. Batch tests have been done during one month on parameters able to influence OUR. We tried at first to find the effect of temperature by moving between three levels of temperature (40, 50, 60 °C). ***Table 2*** summarizes the experimental conditions set up.

Table 2-Experimental conditions set up for evaluating temperature effect on OUR

Temp (°C)	Total solids (g)		Moisture Content (%)		Moisture content mix (%)	Additional water (mL)	Air flow rate (ml/min)	N° Experiment
	Shea husks	Feces	Shea husks	Feces				
40	200	4	13	90	30	0	100	**T1**
40	200	4	13	40	40	0	100	**T2**
40	200	8	13	40	40	90	100	**T2**
40	200	15	13	40	50	90	100	**T3**
50	200	10	13	80	25	0	100	**T4**
50	200	10	13	80	25	0	100	**T5**
60	200	20	13	50	20	150	100	**T6**
60	200	20	13	50	20	150	100	**T7**

Simultaneously, by adding distilled water, we changed the moisture content of the mixing "Shea-Feces" to find out the interplay between this one (MC) and the Oxygen utilization Rate. ***Table 3*** shows the experimental conditions.

Table 3-Experimental conditions set up for evaluating moisture effect on OUR

Moisture Content mix (%)	Total solids		Temperature(°C)	Moisture content (%)		Additional water(mL)	Air flow rate (ml/min)	N° Experiment
	Shea husks	Feces		Shea husks	Feces			
15	174	5	40	13	40	0	100	**M1**
20	174	20	60	13	50	0	100	**M2**
25	174	10	50	13	80	0	100	**M3**
30	174	4	40	13	90	0	100	**M4**
40	174	5	40	13	40	90	100	**M5**
50	174	5	40	13	40	150	100	**M6**

Finally, by setting temperature to 40 °C, we changed *F/S ratio* in order to determine which rate of mixing between feces and Shea is the best.

Table 4-Experimental conditions set up for evaluating F/S effect on OUR

F/S (%)	**Temp (°C)**	**Total solids (g)**		**Moisture Content of the mix (%)**	**Additional water (mL)**	**Air flow rate (ml/min)**	**N° Experiment**
		Shea husks	**Feces**				
2	40	174	5	40	90	100	**F1**
2	40	174	5	50	150	100	**F2**
5	40	174	10	40	90	100	**F3**
5	40	174	10	50	150	100	**F4**
10	40	174	20	40	90	100	**F5**
10	40	174	20	50	150	100	**F6**

- ✓ ***C/N ratio:*** This parameter has been estimated by using the ratios of wastewater treatment performed by Wendy C. Quayle et *al*. The formula underneath was used to compute it.

$$C/_N = \frac{TOC}{TN} = \frac{0{,}8COD}{TN}$$

According to Wendy C. Quale, 80% of Chemical Oxygen Demand consumption is function of Total Organic Carbon concentration.

PART IV: RESULTS AND DISCUSSION

This section of the work presents the results of the different measurements done in the laboratory on the compost's samples.

IV- PRESENTATION OF THE RESULTS

The assessed elements of the compost are only the physical and chemical parameters.

IV.1.1 - Evolution of the temperature

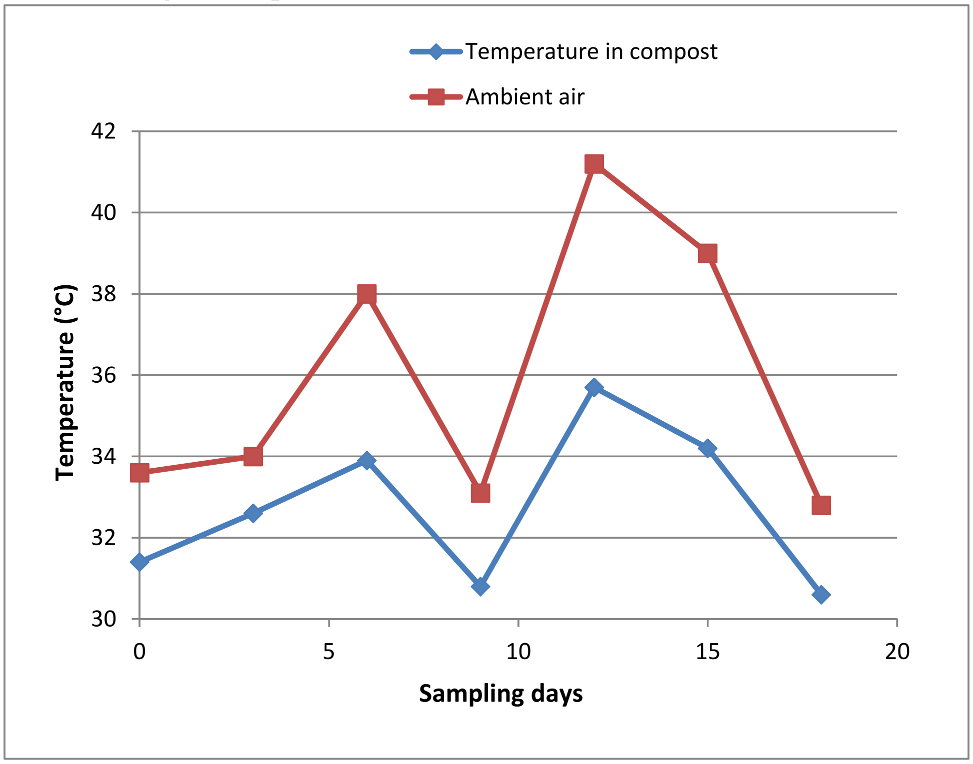


Figure 12-Evolution of temperature during the composting process

This figure shows that the temperature's behavior doesn't have a continuous tendency. From the lowest value (30,6 °C) to the highest one (35,7°C) the temperature is moving up and down in the time. This range of temperature proves that the composting process is mesophilic (20-45°C) and such situation is explainable by the nature of the matrix which is not rich in carbon.

IV.1.2 - pH

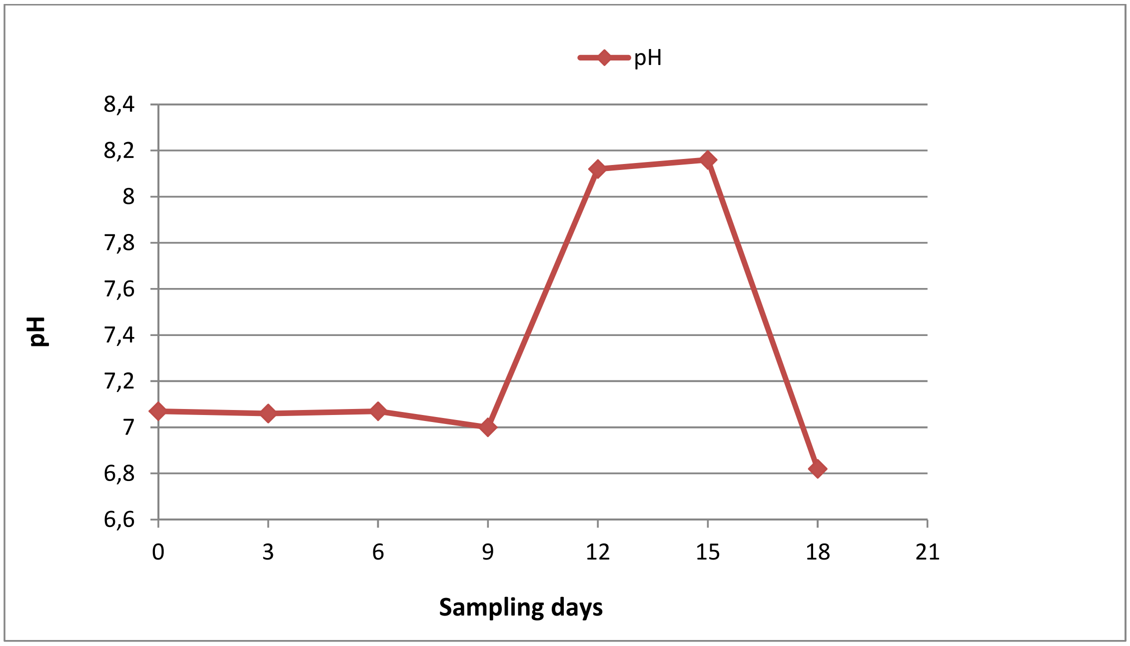


Figure 13-Evolution of pH during the composting process

Figure 13 shows that pH's value is around 7 from the first day to the eighth. From the 11th day to the 14th, the value suddenly increases, moving from 7 to more than 8 and decreases after. The evolution of pH is in an alkaline range, thus favoring the mesophilic flora and an intensive production of carbonic acid gas (Mustin, 1987).

IV.1.3 - Electric conductivity

The peak is observed on the 14th day at 993µS/cm and the lowest value on the first day.

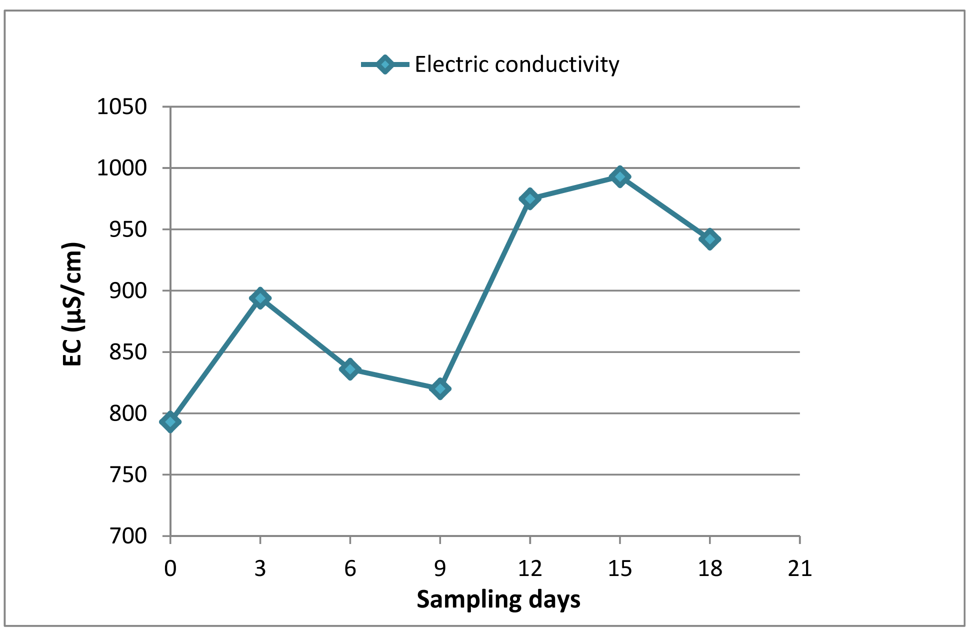


Figure 14-Evolution of EC during the composting process

IV.1.4 – Moisture content

Figure 15-Evolution of Moisture content during the composting process

During the whole composting process, the moisture content has a descendant tendency as **Figure 15** shows it.

IV.1.5 – Chemical Oxygen Demand

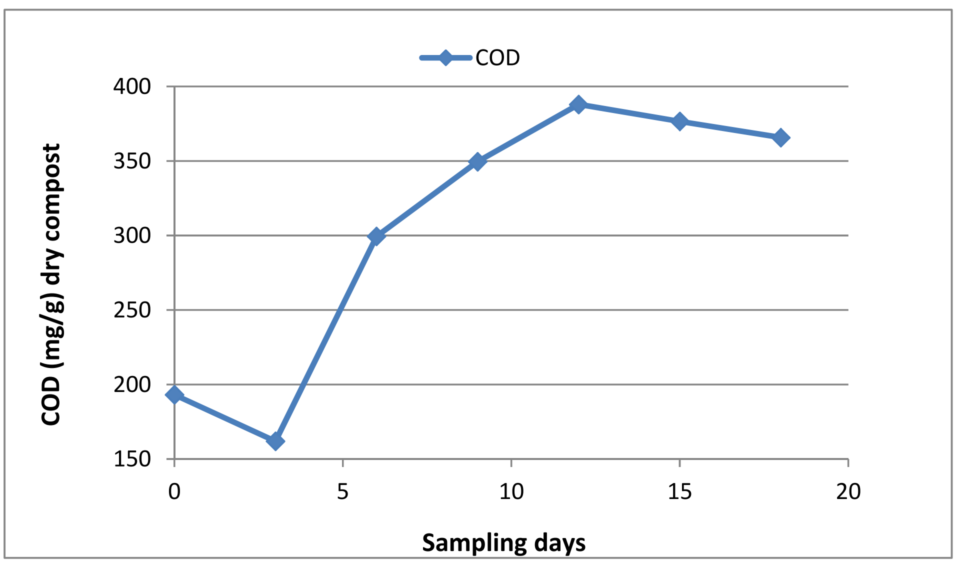


Figure 16-Evolution of COD during the composting process

During the composting process, the Chemical Oxygen is always ascending.

IV.1.6 – Total Nitrogen

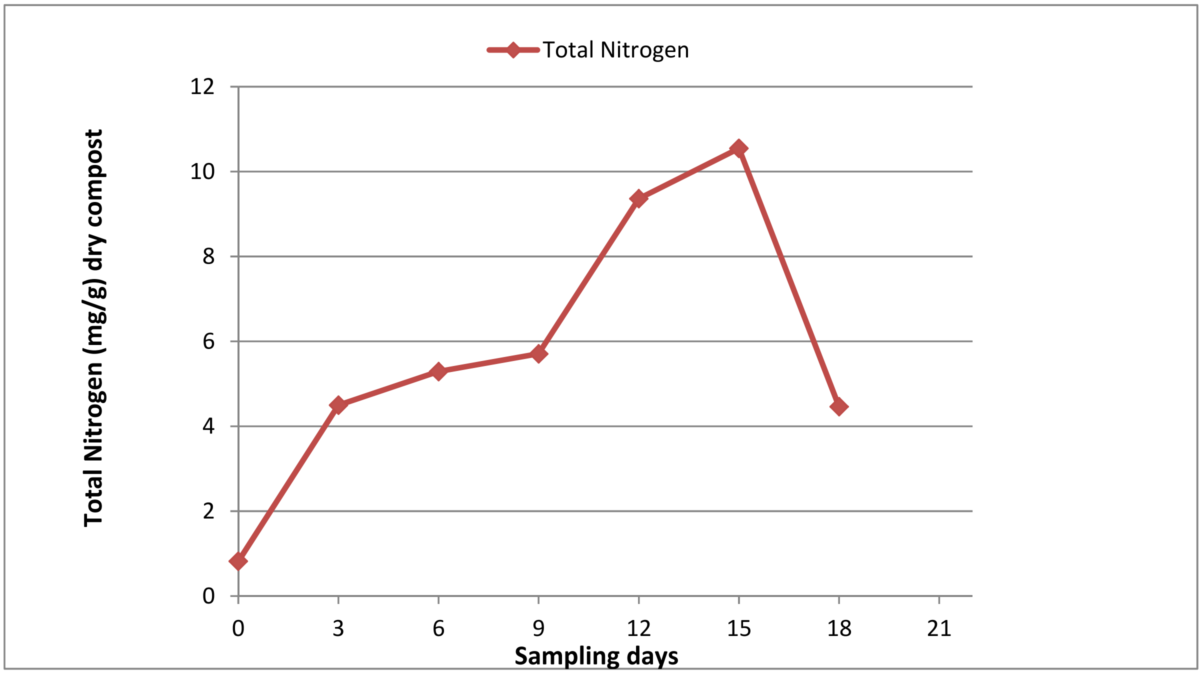


Figure 17-Evolution of T-N during the composting process

Total nitrogen is ascending from the beginning to the 15th day and then decreases after.

IV.1.7– Total Phosphorus

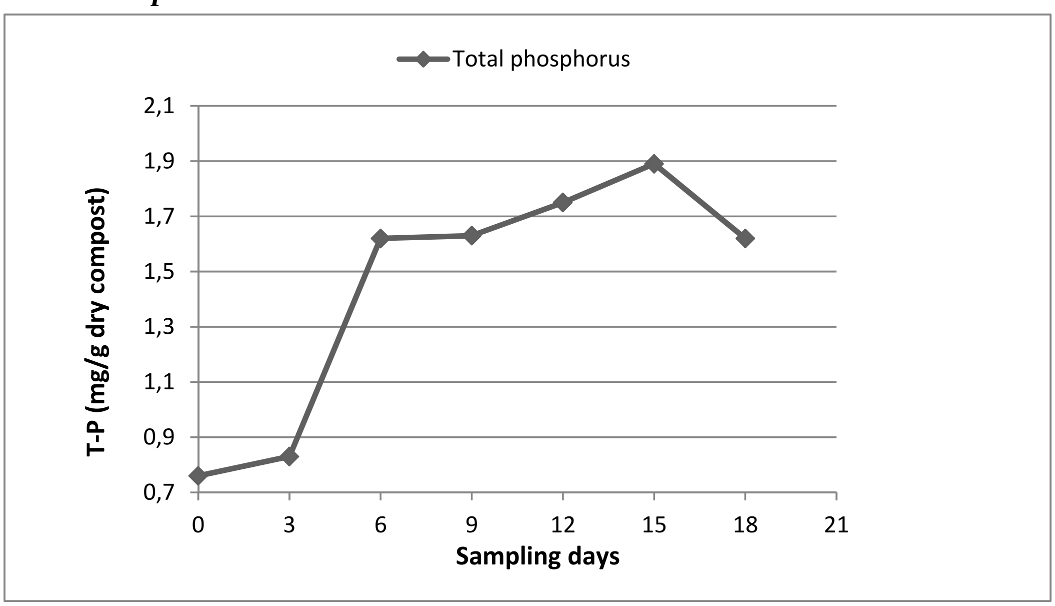


Figure 18-Evolution of T-P during the composting process

Total Phosphorus is ascending from the beginning to the 15th day and decreases after.

IV.1.8– Oxygen Utilization Rate (OUR)

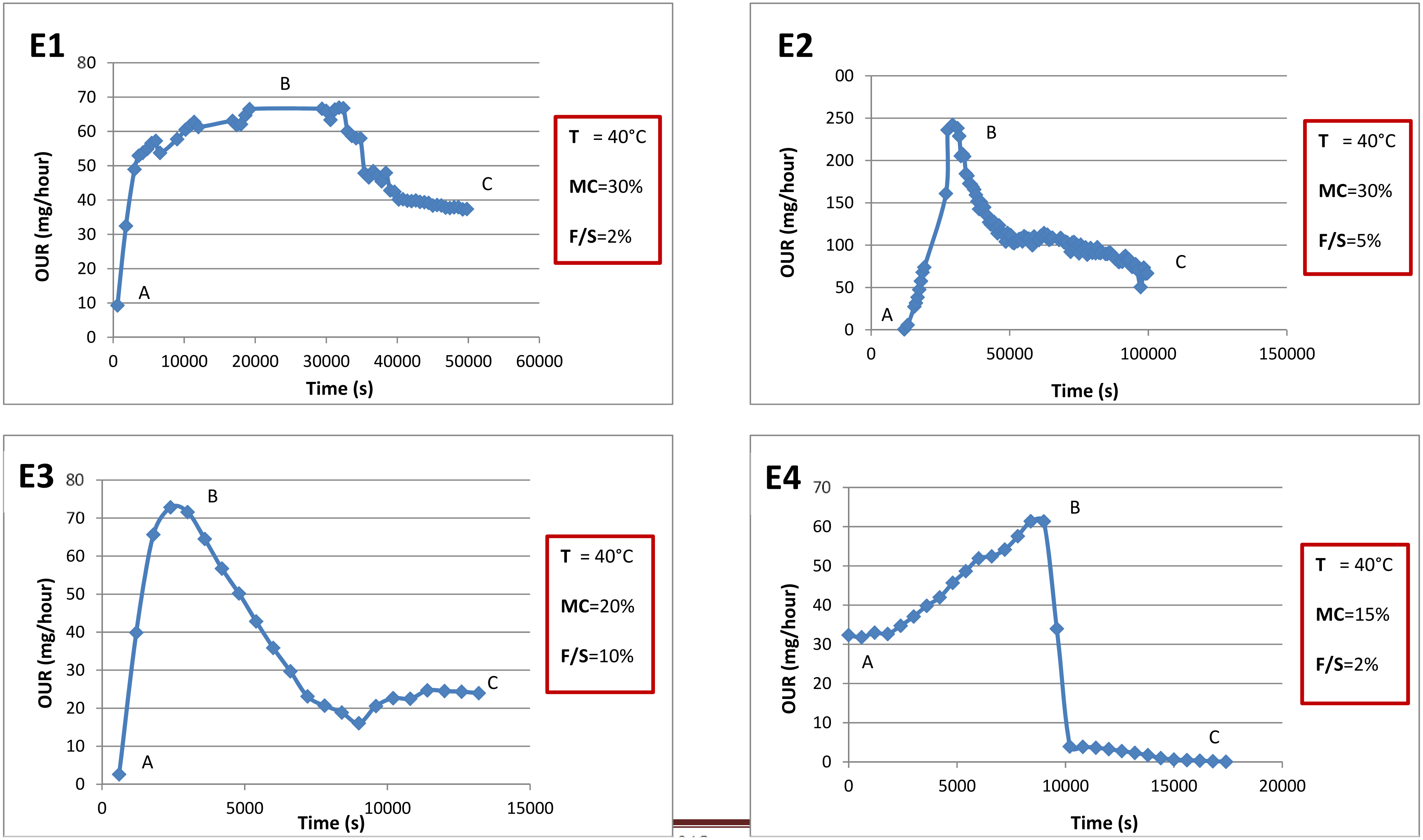
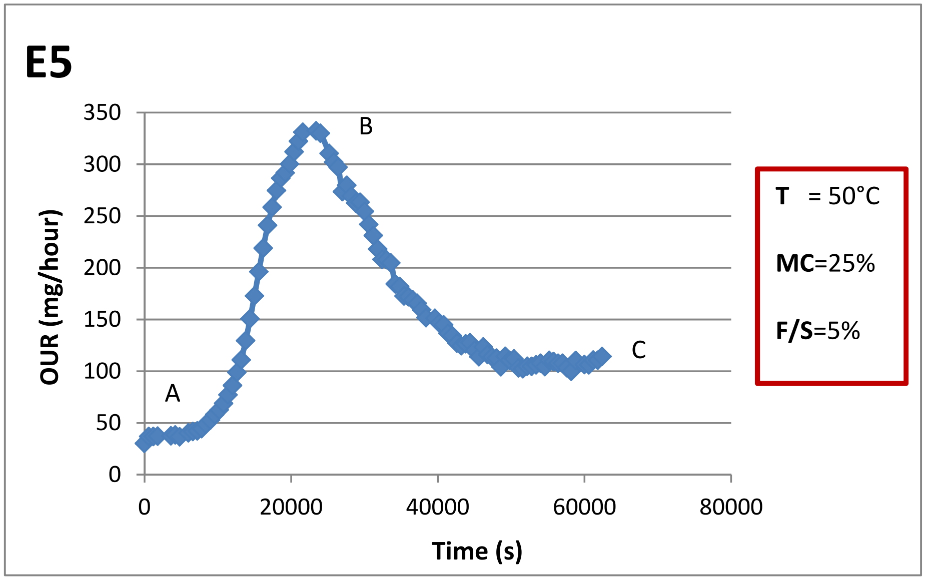
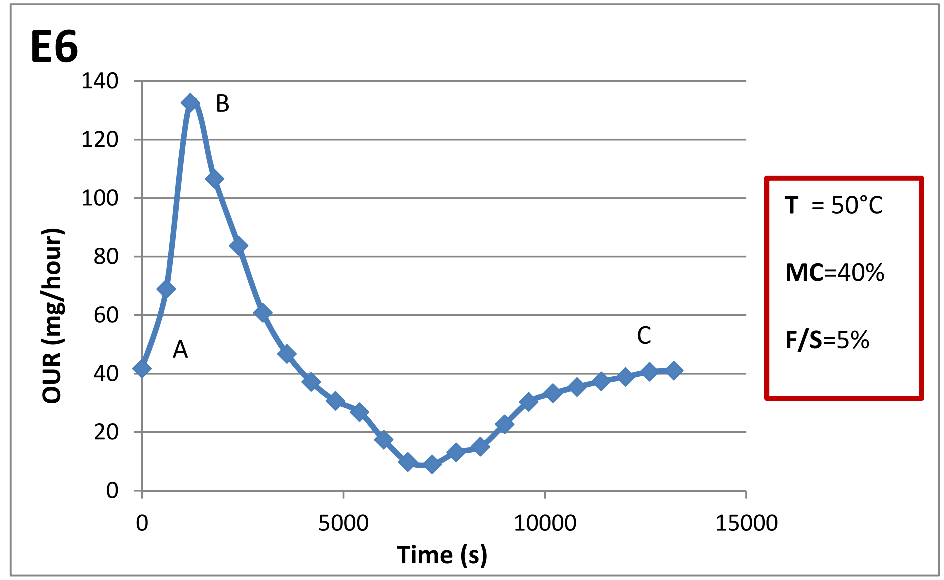


Figure 19-Evolution of OUR at 40°C and various MC and F/S





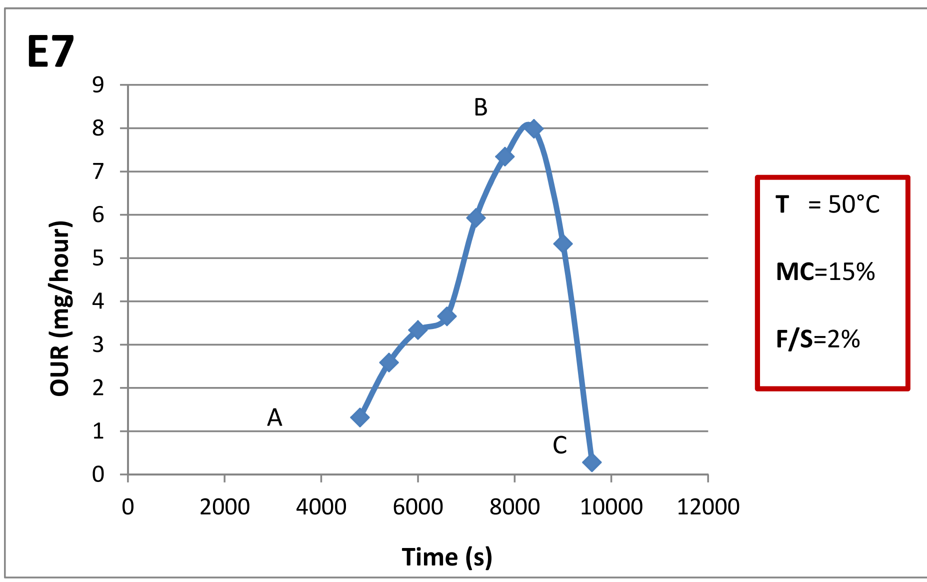


Figure 20-Evolution of OUR at 50 °C and various MC and F/S ratio

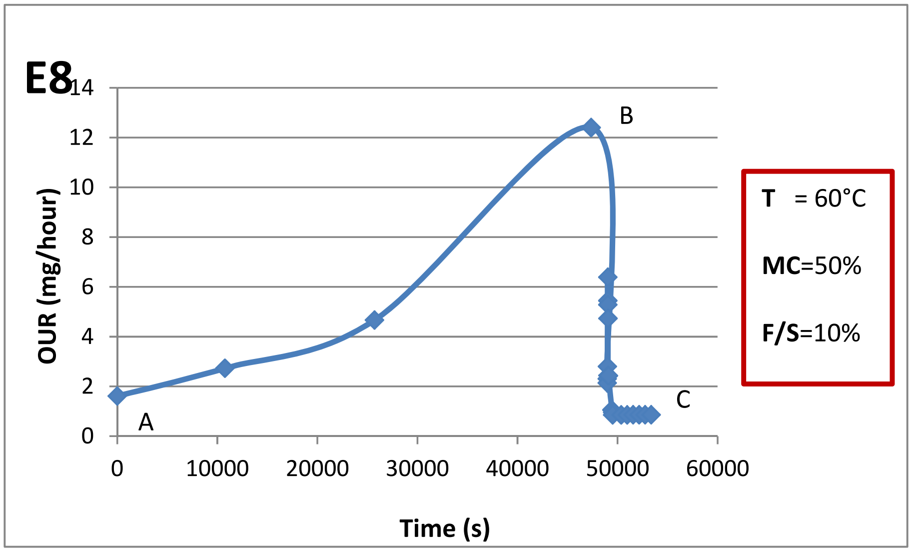


Figure 21-Evolution of OUR at 60 °C MC 50% and F/S ratio 10 %

Figures (19), (20), and (21) show evolution of OUR relatively to 3 parameters **(T; MC; F/S)**. The highest consumption of oxygen is observed for the experimental condition (T=50°C; MC=25%; F/S=5%) and the lowest consumption is relative to the experimental condition (T=50°C; MC=15%; F/S=2%).

IV.1.9 – C/N ratio

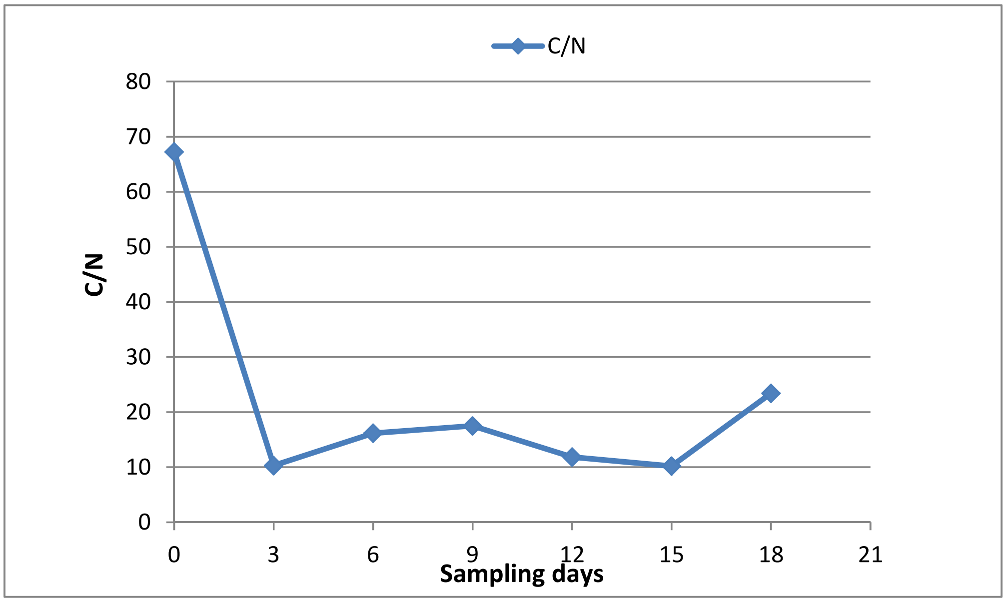


Figure 22-Evolution of C/N ratio during composting process

During the first 3 days, we notice a rapid decrease of C/N and after a stabilization of the parameter around 10 and 20.

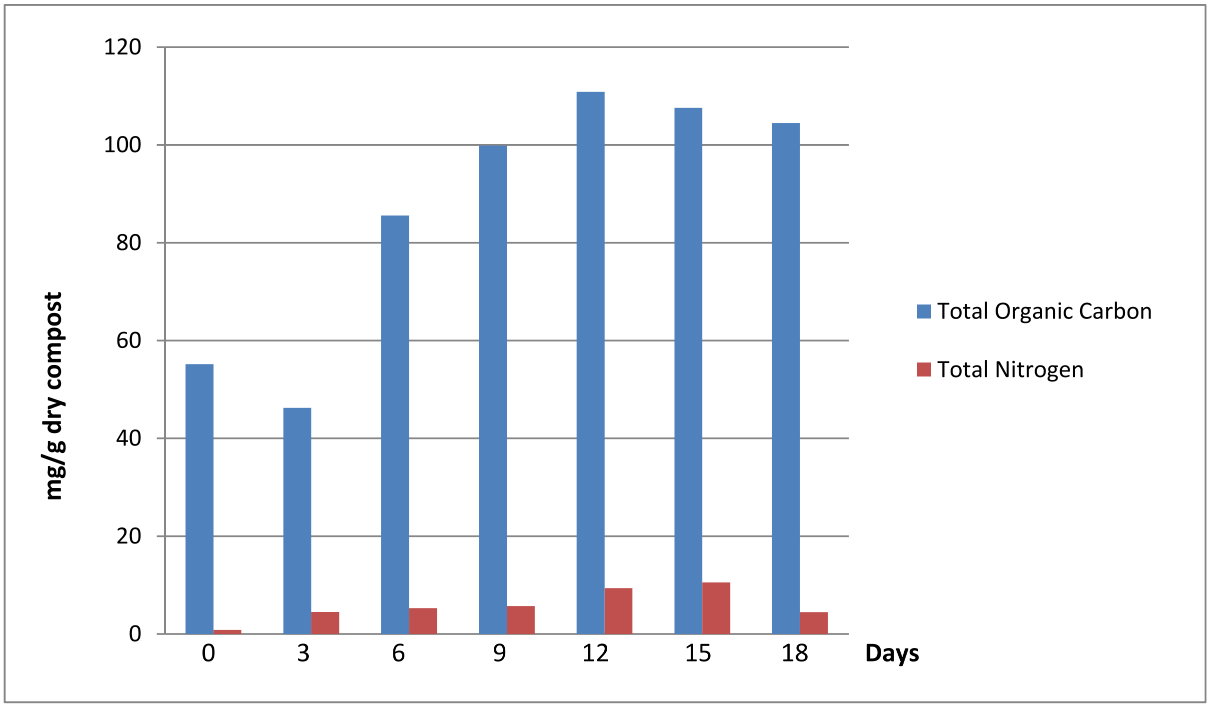


Figure 23-Couples of evolution of TOC and TN during composting process

Evolution of C/N ratio is inversely proportional to Nitrogen's trend. **Figure (23)**, shows the couple of evolution per day between Total Nitrogen and Total Organic Carbon. We notice that there is a large amount of Nitrogen in the samples.

IV.2 - DISCUSSION

The peak value of **temperature** measured in the composting reactor was 35,7°C. The trend is discontinuous and all the process is in mesophilic scale. Such situation could be explained by the nature of the matrix used. Finally, temperature in the compost was almost fitted to ambient air's, indicating a low microbial activity. The suitable temperature for good compost is between 45-55°C (Sari Huuhtanen et *al*, 2009).

The **pH** value is scaled within the range of 6-7,5 for almost the entire process. However, from the 9th day to the 15th, there is a sudden increase of the value, upper than 8. This increase is the result of urine intrusion in the bioreactor during these days. Indeed, urine is rich in urea, which one turns to ammonia and increase pH. Nevertheless, the standard condition for compatibility with most crops is around 6-8,5 (*Hogg et al*., 2002), a condition fitted by the samples we got.

Electric conductivity **(EC)** is within 790µS/cm and 1000 µS/cm. In reference to the Greek's standards, there are some bearable values for plants with medium sensitivity. Additionally, WHO's standards guideline (2009) for wastewater and excreta reuse for agricultural intent states that, soil's salinity problem occurs around 3000 µS/cm (Sangaré, 2011), meaning that regarding this, our could be used.

The moisture contents **(MC)** of the compost decreases all along the process with an average speed of 1 per cent every 3 days. The peak value is 12,5% and decreases in the time while optimal for a good compost is 60% (RAE, 2010).

Chemical Oxygen Demand **(COD)** grows up during the process until 388mg/g and starts a low decrease on the final days. Lopez Zavala et *al.* (2005) showed that there is a linear correlation between feces and COD, meaning that, both of them move in the same way. So, this decrease is due to the fact that microorganisms used their own bodies to feed themselves because of lack of feces.

Total Nitrogen **(T-N)** rises at the beginning of the process then goes down at the end. The rapid increase and decrease is in the same range of days than pH's, meaning that Total Nitrogen is influenced by ammonia too. Lopez Zavala et *al.*(2005) found a similar result. T-N reductions in the composting reactors are caused by (i) ammonification of the organic nitrogen contained in feces and, (ii) volatilization of ammonia from the composting reactors due to the high temperature (Lopez Zavala et al, 2005). In our case the temperature is the ambient air's temperature and scaled around 40°C. Furthermore, in general agriculture, to produce 1 kg of grains (cereals), it is necessary to put 22g of nitrogen (Sari Huuhtanen, 2009). Based on this fact, the calculus showed that to have 1 kg of grains, we need to put 2132g of our compost, meaning that Nitrogen concentration is low.So this compost needs more feces load.

Total phosphorus **(T-P)** accumulates during the composting process. But as Total Nitrogen, concentration in the compost is low. To produce 1kg of cereals, 2,8g of phosphorus is needed (Sari Huuhtanen, 2009). We must provide 1400kg of our compost to produce 1 kg of cereals.

Three stages were observed during all experimental **OUR** profile: (a) rapid increase stage from the origin up to reach the peak (from point A to B), (b) rapid decrease stage from the peak down to the beginning of stabilization of the profile (from point B to C), and (c) steady stage. The experimental conditions (40°C; MC=30%; F/S=2%) and (40°C; MC=30%; F/S=5%) shown in **Figure 19**, describes peak values of OUR having respectively 67mg/hr. and 242mg/hr. Regarding these facts, it possible to conclude that, at constant temperature and constant moisture content, OUR increases with F/S ratio. In general, higher OUR at the peak occurred at higher F/S organic loading (Lopez Zavala et *al.* 2005). Oxygen Utilization Rate is the result of microbial activities in the compost and these activities are responsible of the reduction of solid matter. This reduction is correlated to the Total Solid of feces used in each organic loading (Lopez Zavala et *al.* 2005). Furthermore, experimental conditions (50°C; MC=25%; F/S=5%) and (50°C; MC=40%; F/S=5%) showed that, moisture has an effect on oxygen consumption. A high moisture in the Shea husks (>50%) slows the consumption of oxygen and lead to anaerobic conditions (Lopez Zavala et *al.* 2005). Still, the experiments proved that, temperature, moisture content and F/S ratio should be consider together to balance OUR. The best result of combinations brought out from the experiment is the condition (50°C; MC=25%; F/S=5%) with a peak reaching 332mg/hr. With comparison with sawdust, at the same experimental conditions, Shea husks OUR curves got low areas, meaning oxygen consumption rate is less than sawdust's. To summarize for Shea husks compost:

-For same condition of temperature and MC, OUR moves in the same way than the organic load F/S (E1 and E2).

-For same temperature, OUR moves in the opposite way than moisture content and organic load *F/S* (E3 and E4).

-For same condition of temperature and organic load, OUR moves inversely to moisture content (E5 and E6).

-Increase of temperature reduces OUR (E4 and E7-E8) because there is no thermophilic bacteria to consume oxygen.

(**C/N** for the whole process is between 10 and 23, while good carbon-nitrogen ratio for composting is between **20** and **35** (Sari Huuhtanen et al, 2009). C/N ratio behavior is inversely proportional to Nitrogen's evolution. **Figure 23** shows that Total Carbon concentration in the sample is higher than Total Nitrogen's, but still not enough to fill the conditions for a good ratio. However, during the latest days of the process, C/N ratio increases and it is due to the evaporation of nitrogen.

CONCLUSION AND RECOMMENDATION

The main objective of this study was to assess the physical and chemical parameters (Temperature, pH, MC, EC, COD, C/N, T-N, T-P, OUR) occurring during the composting process. This composting process took 1 month and another month for laboratory analysis. At the end of this study, the results of the researches allow us to make the following conclusions:

- There is non-conformity with standards concerning Temperature, Moisture Content, Total Nitrogen, Phosphorus and C/N.
- Shea husk compost (at this stage) needs longer operation or addition of external element like chemical product to increase its N and P.
- The matrix is not able to contain moisture higher than 50%.
- It releases in the air essential element like Nitrogen.
- When the temperature increases (>50°C), the OUR slows.
- OUR moves in the opposite way than moisture content
- In comparison with other matrix (sawdust), at the same experimental conditions, Shea husk has low oxygen consumption rate.

In reference to these conclusions, there are many irregularities with the use of Shea husks as matrix. However, in one month the study is not exhaustive. We know that several parameters in the composting process are influenced by the amount of feces. For instance, concentration in Nitrogen and Phosphorus could be enhanced by addition of feces in the time. So, to complete this work, further researches are welcome. These further researches should focus, firstly on the effect of time on the composting process. Secondly, a characterization of feces should be done, to bring out the effect of the quality of the feces on the quality of the compost. Thirdly, to make a good simulation, the compost should be performed in the reactor designed by Améli-EAUR project. Finally, it is necessary to learn the evolution of the substrates occurring into the reactor by performing a mathematical model of the kinetics reactions.

ANNEXE: NOTICE OF ENVIRONMENTAL IMPACT

Analysis of immediate and backwards, temporary and permanent impacts of the project upon the environment

Regarding human excreta management, this project tries to bring help, e.g. by doing thorough studies in order to turn feces into good compost for agriculture. Indeed this compost is cheap to produce; it contributes to the sustainable development by water savings, and it is an alternative to the chemical ones. Moreover the use of this product will decrease pesticides' demands and will improve grounds' capacities of water retention. Nevertheless, composting process begins by using dry toilet and for the good continuation of this project, we have to consider some parameters, in the circumstances:

- **The sanitary risk**: If people don't take precautions, the permanent and prolonged contact with feces is dangerous for the health. Indeed, the use of a same lever by several persons to mix feces could be a pathogens' transmission way. The unwashed hands after defecation (Fig A.1) is a hygiene less comportment and may lead to diseases like:

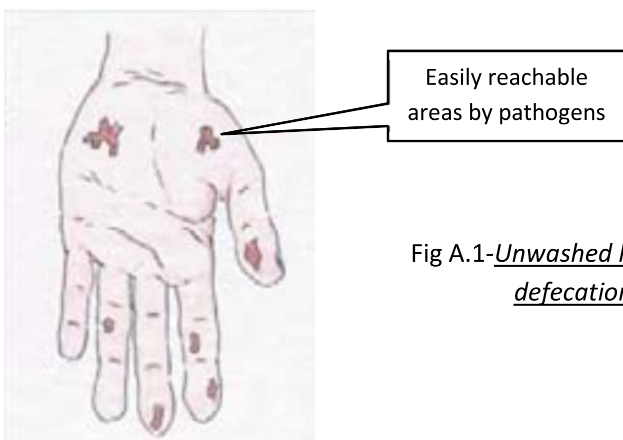


Fig A.1-*Unwashed hand after defecation*

- ✓ *Cholera*: Caused by Vibrio cholerae – bacteria, its epidemics spread more widely than diarrhea and more than 90 percent of all cases are symptom less but can still infect others. Every year in the world, more than 140.000 people are infected and 5000 die. (Sari Huuhtanen et al, 2009)

- ✓ *Typhoid fever*: Caused by Salmonella typhi or Salmonella paratyphi -bacteria. Symptoms include fever, dysphoria, headache and diarrhoea. (Sari Huuhtanen et al, 2009)

- ✓ *Hepatitis A*: Caused by RNA related picorna virus, it can generate fever, exhaustion, lack of appetite and jaundice. Symptoms may vary from mild to severe. Majority of the infected are children, who after a recovery from the disease gain immunity. (Sari Huuhtanen et al, 2009)

- ✓ *Leptospirosis:* Caused by Leptospira spp. microbe, it leads to high fever, intense headache, muscular pain, redness of eyes, stomach aches, jaundice, skin and mucous membrane bleeding, vomiting, diarrhea and rash. (Sari Huuhtanen et al, 2009)

- ✓ *Schistosomiasis:* It is the second largest infectious disease caused by helminthes. It is caused by Schistosomas haematobius, S. japonicum or S. mansoni flatworm. The larva of the flatworm swimming in the wild pierces through skin and causes infection. Symptoms are blood in urine and solid excrement, expansion of spleen and liver and on some occasions and disturbances in central nervous system. (Sari Huuhtanen et al, 2009)

- ✓ *Ascariasis:* is one of the most common parasitic diseases in the developing countries, but the helminthes is found all over the world. It is caused by Ascaris lumbricoides roundworm. Infection can cause stomach aches, coughing, breathing difficulties or fever. Infected individuals suffer from under nourishment, anemia and slowdown in growth. (Sari Huuhtanen et al, 2009)

- ✓ *Hookworms*: For example, Ancylostoma duodenale and Necator americanus are common intestinal parasites and cause especially to children e.g. anaemia, stomach aches, diarrhoea and weight loss. Hookworms are extremely dangerous to small children. (Sari Huuhtanen et al, 2009)

- ✓ *Giardia intestinalis:* Also known as Giardia lamblia, this protozoon creates very durable cyst forms, which can last in the excreta even several years. It can cause digestional problems such as diarrhoea, stomach aches and nausea. The symptoms can lead to weight loss or dehydration. Giardia can occur also as symptom less. (Sari Huuhtanen et al, 2009)

- **The Agronomic risk:** Firstly, regarding the case where the nutriments from compost can be in excess quantity in the soil, such situation could decrease yield by impoverishing the ground. Secondly, if the compost is not performed in the appropriated conditions, its use may affect raw vegetable eater's health and according to Devaux (2007), the farmers working on fields are the most exposed to helminth than anyone.

- **The religious considerations:** Religion affects remarkably to formation of sanitation culture since many religious habits and rituals have a connection to sanitation. Definitions of good and bad, polluted and clean can be found in many religions. The fourth population's census (December, 2006) in Burkina Faso stipulates that there are 60.5% of Muslims, 23.2% of Christians, 15.3% of Animists, 0,6% of other religions, 0.4% of people without religious belief. For example Islam determines specific rules on how to handle with excreta. Only left can be used for washing purposes after defecation (right hand is used for eating purposes) and water is used for washing. Therefore in Islamic countries it is very hard to justify use of dry latrines and in some cases dry latrines are forbidden by law.

  In some Islamic countries such as Yemen dry latrines are used and in this case washing can be carried out in washing places in contact with latrines. (Sari Huuhtanen et al, 2009)

- **The social and psychological factors:** Attitudes are formed from experiences and can change in time. Especially different occupational groups have different opinions of latrine waste handling depending on whether the person has interest or contact through work to sanitation and hygiene issues. Generally it is difficult for people to accept the fact that the food they eat had been grown in human dejections.

- **The cultural influence:** It is to be remembered that there are no right or wrong attitudes or methods but these are formed according to one's culture. People have their own attitudes regarding water, hygiene and sanitation. They don't change these attitudes based merely on health education. Nevertheless, although they have their traditional beliefs, it does not rule out their possibility to learn new habits.

- **The gender relatedness:** Regarding hygiene, women are more careful and more demanding (pregnancy, menstruation…) than men. This carefulness generally obliges them to use water for their needs.

- **The ecological risk:** Ground water and surface water could be polluted by infiltration of the not well performed compost.

Proposals to collapse detrimental situations

There are some elementary attitudes that people can adopt and which could improve the hygiene in their location. For example:

-Wash hands after using toilets

-Depending on the breed, don't directly apply compost on some vegetables.

- Don't apply compost one month before harvest

Furthermore, it is necessary to rule out religious, social, cultural and psychological consideration by organizing sensitizations campaigns to inform people about how to use the composting toilets and the advantages they could get.

BIBLIOGRAPHY

- **ASSAINISSEMENT ET EAU POUR TOUS**. *Un cadre d'action global*, 2012.

- **DEL PORTO AND STEINFELD**. *The composting toilet system book*. Concord Massachusetts, USA: Center for Ecological Pollution Prevention (CEPP); 2000.

-**GWENNAËL BOLOMEY, JACQUES MOREL.** *Les toilettes sèches a compostage, solution d'avenir pour l'agriculture et l'environnement, Tome 1 : l'exemple de la fossa alterna.* 2009

-**INSTITUT NATIONAL DE LA STATISTIQUE ET DE LA DEMOGRAPHIE (INSD).** *Rapport de recensement* 2009.

-**INTERNATIONAL WATER MANAGEMENT INSTITUTE (IWMI).** *Problèmes majeurs liés à la (Mauvaise) Gestion des Eaux Usées: Pollution des fleuves, des lacs et des Océans. Appauvrissement des sols (dramatiquement sous-estimée) Utilisation inefficiente de l'Eau La matière organique retourne au sol!* 2000

- **JEAN PAIN.** *Un Autre Jardin ou les Méthodes Jean Pain*, première édition 1972.

-**JOSEPH ORSAGH**. *La toilette sèche une question de cohérence*, 2000.

-**KITSUI AND TERAZAWA.** *M. Environmentally friendly toilets for the 21st century, Bio-toilet. Proceedings of the 10th ISWPC*. 1999.

-**LOPEZ ZAVALA et al. 2004.** *Biological activity in the composting reactor of the biotoilet systems.* 2004.

-**LOPEZ ZAVALA et al. 2004.** *Modeling of aerobic biodegradation of feces using sawdust as a matrix.2004*

-**LOPEZ ZAVALA et al. 2004. *2004.*** *Temperature effect on aerobic biodegradation of feces using sawdust as a matrix.* 2004.

-MICHAUD, Lili. 2007. *Tout sur le compost:Le connaître, le faire,l'acheter, l'utiliser. Québec : Multimondes.* 2007.

-**MORGAN**. *Toilet that Make Compost*: *Stockholm Environment Institute*. 2007

-MUSTIN, Michel. 1987. *Le compost:Gestion de le matière organique. Paris : François DUBUSC.*1987.

- MUELLEGGER. *Ecological Sanitation: a way to solve global sanitation problems.* 2004

-RESEAU ASSAINISSEMENT ECOLOGIQUE (RAE). *Guide de bonnes pratiques pour le compostage des sous-produits de toilette sèches,* 2010.

-SARI HUUHTANEN , ARI LAUKKANEN. *A guide to sanitation and hygiene in developing countries* (2009)

-**SCHÖNING ET *AL***. *Guidelines to the Safe Use of Urine and Faeces in Ecological Sanitation Systems.* 2004

-TOILETTE DU MONDE. *Des toilettes sèches… à la maison, comment les choisir, les installer, les utiliser.* 2009

-**WASTE advisers on urban environment and development**. *Smart Sanitation Solutions*.2006

- WENDY C. QUAYLE et *al.* *Evaluation of organic matter concentration in winery wastewater: A case study from Australia. 2009*

APPENDICES

Appendix 1: Standard method for measurement of Moisture content (MC)

For moisture content, take 10 g of compost in a tare and put it in the stove at 105°C for 24 hours. Come the other day and weight the dry compost. MC is determined by the formula:

$$\mathbf{MC\ (in\ \%)} = \frac{(\mathbf{P_H} - \mathbf{P_D})}{(\mathbf{P_H} - \mathbf{P_T})} \times \mathbf{100}$$

Where $\mathbf{P_T}$ the weight of the tare

$\mathbf{P_H}$ weight of the tare charged before drying and

$\mathbf{P_D}$ the weight of the tare charged after drying.

Appendix 2: Summarization of physical and chemical parameters

PARAMETERS	Range (Min-Max)		Average	Standard Deviation
Temperature (°C)	30,6	35,7	32,74	1,93
pH	6,82	8,16	7,32	0,56
Moisture content(%)	12,5	7,04	9,56	1,92
Electric Conductivity (µS/cm)	793	993	893,28	79,27
COD (mg/g dry compost)	161,9	388	304,93	91,93
Total Nitrogen (mg/g dry compost)	0,82	10,56	5,81	3,26
Total Phosphorus (mg/g dry compost)	1,73	***4,06***	3,16	0,95
C/N	10,2	***67,25***	***22,38***	***20,34***