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Characterization of Faecal Sludge with a view to Modeling Agro-Economic and Environmental Valorization

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Abstract
Based on a compilation of data from several studies, it was found that only 15% of faecal sludge was treated and that the residues are poorly managed or even not recovered in Madagascar. In particular, in 2011 the city of Mahajanga with its 240,000 inhabitants fell victim to the latter case and it could deserve to benefit from a clear assessment allowing a sanitation strategy to be drawn up for the entire city. Taking into account the different eventualities, the Training in Waste Treatment Sciences and Techniques (STTD) of the Faculty of Sciences, Technologies and the Environment (FSTE) of the University of Mahajanga worked together with IRCOD of Mahajanga in order to find an example of the good management and treatment of faecal sludge. This study sheds light on the value of faecal sludge in terms of its ecological and environmental interests and also the efficiency of its treatment in correlation with the number of inhabitants of the city. The methods used are to conduct a survey of the population using toilet latrines to be emptied, to take samples at the level of the target neighborhoods. The samples of the drained sludge were analyzed in the Laboratory for Analysis and Research in Environment and Waste (LARED). According to the statistical analysis of the data by the Least Square method and by the confidence interval, the result showed that it is possible to carry out the management of faecal sludge with an awareness of the population that the proportion of their organic matter is similar to that of other biological waste which is favorable to the different agricultural valuations after solar drying. The practice of this management of faecal sludge provides a new avenue for ecological and environmental development without neglecting their recovery in biogas production.

Keywords: Faecal Sludge, Recovery, Analysis, Organic Matter, Biogas, Environment

1. Introduction
Currently the world is changing, the population is increasing and at the same time the environmental problem threatens the whole world. There are several causes that have caused it: ecological degradation, the massive production of urban waste, especially faecal sludge. The latter will emit a lot of gases into the atmosphere in the event of mismanagement, later causing global warming. The trend will certainly continue on the production of faecal sludge, which characterizes developing countries because no structuring investment has been made to accept waste in treatment channels or on suitable landfill sites (USA National Academy, 2006) [3].
In Madagascar, it has been observed that only 15 % of faecal sludge has been treated and that the residues are poorly managed or even not recycled, while waste recovery has remained in its infancy and is not governed by incentive laws or regulations. As for the ecological, sociological and economic parameters, it appears that the strategic key to sustainable waste management lies in the treatment of the considerable organic part which constitutes more than half of it.
Particularly, in 2011 the city of Mahajanga with its 240,000 inhabitants is a victim of this last case. The objective is to come up with a sanitation strategy for the entire city because it could deserve to benefit from a clear assessment allowing it to get out of these impasses. Taking into account the different eventualities, the Training in Waste Treatment Sciences and Techniques

(STTD) of the Faculty of Sciences, Technologies and the Environment (FSTE) of the University of Mahajanga worked together with the IRCOD of Mahajanga in order to find an example of the good management and treatment of faecal sludge. This study makes understand the value of faecal sludge vis-à-vis their ecological and environmental interests and also the effectiveness of their treatment in correlation with the number of inhabitants of the city (Alix, 2011) [1].

2. General

2.1 Carbon balance and cycle

The production of waste is one of the human activities that modify the carbon cycle. On a global scale, the quantity of carbon emitted by human activity in the atmosphere is estimated at 6.4 Gt/year for the 1990s and 7.2 Gt/year for the period 2000-2005. In 2006, 10 Gt/year of carbon were emitted, i.e., 37 % more than in 1990. About half of this carbon was reabsorbed by the biosphere and oceans respectively by photosynthesis and dissolution (USA National Academy, 2006) [3].

The exchanges carried out by the lithosphere are slow exchanges; it is fossilization while the biosphere-atmosphere exchange constitutes the carbon reservoirs with rapid renewal. This last case works in both directions:

- Respiration: living beings absorb O_2 and release CO_2 into the atmosphere.
- Photosynthesis: chlorophyllous plants fix CO_2 and release O_2 into the atmosphere in the presence of sunlight.

These two mechanisms are part of both the carbon cycle and the oxygen cycle (Rasoanandrasana, 2010) [7].

2.2 Impact on the environment

The gases not reabsorbed by green plants always remain in the atmosphere and cause carbonic acids by combining with rainwater before falling on the biosphere, this is acid rain. Alongside the strictly ecological discourse, the pressing threats to the environment are now at the heart of a cultural, economic and political debate on the issues. Many institutions and personalities are committed to finding alternative solutions to continue the evolution of civilizations towards a higher quality of life: technical progress and modernity and while preserving a viable environment. (LEA, 2014) [8]

2.3 Biogas and history

Biogas is solar energy stored by the plant. It is a combustible gas in the same way as a fossil gas, and which, when oxidized, produces heat. Apart from biogas, the residue is a product similar to compost from aerobic oxidation-reduction, but richer in nitrogen compounds. The digester is a device in which fermentation takes place. It is an installation creating the precise physico-chemical conditions making it possible to maintain an environment favorable to the development of biological material (enzymes, microorganisms). The cost of building a 10m3 unit is 3,000,000 Ar on average that was in 2009. This leads to an annual economic amortization of 300,000 Ar in the case of a 10-year amortization (Ramampiherika, 2010) [6].

2.4 Study zone

The collection of information on faecal sludge, in particular volatile matter, was practically carried out from June to July 2011; that is, at the beginning of the dry season. This data collection has two components, namely:

- Collection of faecal sludge near the district;
- Physico-chemical analysis in the laboratory

The study focuses on 21 neighborhoods of the city of Mahajanga which are the neighborhoods identified as representing our problem with regard to the city's fecal sludge. Within the same district, different geographical and hydrographic areas were sought for the sampling to be reliable.

The physico-chemical characterization of faecal sludge requires precise laboratory analysis. With the team of the Waste Treatment Sciences and Techniques (STTD) team led by Doctor RASOLONJATOVO Martial Zozime, the analysis took place at the Laboratory for Analysis and Research on the Environment and Waste (LARED).

3. Materials and methods

3.1 Matérials

For the necessary documentation, we also used the following materials to have information related to our theme of study such as scientific works, scientific journals, and books of dissertations and thesis, document of organizations, archives of the office of competent authorities, document on the Internet and course materials. For the experimental realization in the laboratory, we mainly used faecal sludge.

3.2 Méthods

3.2.1 Investigation

It is a method of acquiring information or knowledge that affects our research topic. During the investigation period, we proceeded to three types of approach such as geographical approach, anthropological approach and scientific approach. In the study areas, we carried out this survey in two phases:

- preparatory phase and
- actual investigation

During the fieldwork, the most practicable technical procedures were:

- interview or interview,
- opinion poll and
- participant observation.

3.2.2 Physico-chemical characterization of sludge

In order to better understand faecal sludge, characterization is carried out in two stages:

- A sludge sampling campaign in the neighborhoods,
- Laboratory analysis of the pre-washed samples.

4. Results

4.1 Physico-chemical characteristics of faecal sludge

4.1.1 Sludge concentration

A total of 50 faecal sludge samples were sampled in 9 days, 96% were taken from traditional latrines and 4% from septic tanks.

4.1.1.1 Sludge quality

From the point of view of consistency, the sludge sampled has liquid to pasty consistencies and colors ranging from yellowish to blackish. 68% of the sludge was said to be “pasty” after observing the sample with the naked eye; 30% were said to be “liquid”; 2% were said to be "solid" but penetrable.

The average sludge density is 1.02.

4.1.1.2 Dry materials
The observation of the MS values shows a great variability of the concentrations, as illustrated in Fig 1 below.

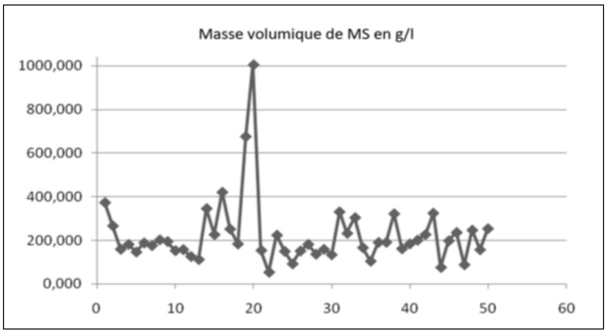

Fig 1: Distribution of DM concentrations

Of the 50 samples, 3 samples show an excessively high DM concentration: 463 g/l, 701 g/l and 1074 g/l. These very high values are attributed to the presence of sand in the samples. In fact, sample no. 22 with MS=1074 g/l taken from a septic tank is practically only made up of sand.
The mean, standard deviations and median values of the dry matter as well as the percentage of dry matter are collated in Table 1 below.

Table 1: Concentration of dry matter and average dryness of sludge

Caractéristiques	MS (g/l)	MS (%)
Moyenne	228	21
Ecart-type	156	10
Médiane	191	20

The average dryness of the sludge is 21%. The sludge is very concentrated. The high dryness of the samples taken can be linked on the one hand to the low proportion of households pouring water into their pit and on the other hand to the high permeability of the soil causing the infiltration of the liquid part of the sludge.

4.1.2 Volatile Matter
Apart from the three sandy samples, the correlation between MS and MV shows good overall consistency as shown in Fig 2 below.

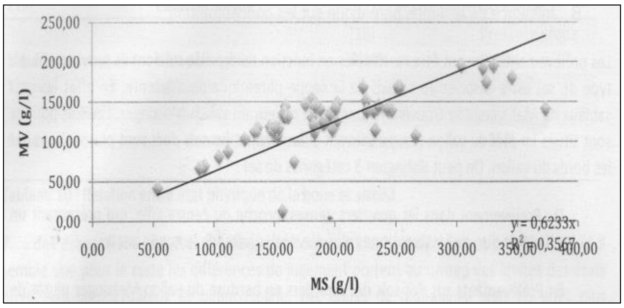

Fig 2: Correlation between MS, MV of the sludge analyzed (Source: Alix, 2011) [1]

Avec un taux de matière volatile de 66%, les boues peuvent être considérées plutôt digérées. Parmi les 50 échantillons, 30% des sont très bien digérés avec MV<60%, alors que 21% des échantillons sont néanmoins plus frais avec MV>80% qui sont donc sujets à des phénomènes de dégradation à venir et à une moins bonne déshydratabilité.

La concentration en matière volatile des boues prélevées, bien que très variable est de 130 g/l environ. L'observation des valeurs en matière volatile montre une grande variabilité des concentrations comme le montre le Table 2.
With a volatile matter rate of 66%, the sludge can be considered rather digested. Among the 50 samples, 30% of the are very well digested with MV<60%, while 21% of the samples are nevertheless fresher with MV>80% which are therefore subject to future degradation phenomena and less good dehydratability.
The concentration of volatile matter in the sludge sampled, although very variable, is around 130 g/l. The observation of the volatile matter values shows a great variability of the concentrations as shown in Table 2.

Table 2: Average volatile matter concentration

Valeurs observées	MV (g/l)
Moyenne	127
Ecart-type	35
Médiane	130

4.2 Type of sludge
4.2.1 Categorization of sludge
Among the n numbers in the sample; Faecal sludge could be statistically grouped into 3 categories according to their degree of stabilization shown in Table 3.

Table 3: Characteristics of sludge according to their category

Catégories	n	MS (g/l)		MV (g/l)	
		Moyenne	Ecart-type	Moyenne	Ecart-type
A	6	471	258	41	23
B	16	219	30	60	8
C	28	156	41	77	8

Among the category C sludges described, 5 examples carried out on the top of latrines, with the aim of characterizing them. These 5 samples have a volatile matter (VM) concentration slightly higher than the average with MS=182; MV=76%. This confirms the "fresh" aspect of category C sludge.

4.2.2 Physical state of sludge and dryness
The physical state of a sludge corresponds to a given dryness range. The observations of the analyzes of the city of Mahajanga nevertheless lead to a classification slightly different from that reported in the temperate climate. Table 4 presents a comparison between the indications and the observations of the present study.

Table 4: Relationship between physical state of sludge and dryness

Etat des boues	Caractéristique	Siccité correspondante
Liquide	Non pelletable	0-18%
Pâteux	Pelletable ou gerbable	18-30%
Solide	Sec, avec ou sans retrait	>35%

Among the faecal sludge analyzed, 72% of the samples observed in the districts of Mahajanga correspond to the proposed classification and it seems that for the rest the differences in judgment concern the level of the limits of the liquid/pasty and pasty/solid physical states. Samples with a dryness greater than 30% were taken using a syringe, which clearly shows that at this dryness the sludge still has a consistency that is more pasty than solid. The presence of sand as well as the temperature could explain these differences with the observations made in a temperate environment.

5. Discussion

The city of Mahajanga is essential in the field of the economy, not insignificant when it comes to the population. The production of waste is linked to the number of inhabitants. So, when there is strong population growth at the same time there is a huge production of waste. The natural population growth rate is 3% globally (FAO, 2010) [2].

The quantity of waste in 2025 is estimated at 2100.6 tons against 1533 tons in 2010. However, the waste management policy is not very coherent because of the non-motivating investment problem. The collection is not sufficient while the discharge is not controlled. According to the National Policy and Strategy for Sanitation of August 18, 2003, the city of Mahajanga will occupy an important place in the evacuation of human excreta in the former six provinces of Madagascar. But there is the organic recovery initiative for agricultural recovery as well as preservation.

Furthermore, we know that an incinerator cannot market co-products other than energy. On the other hand, the composts produced by anaerobic digestion can replace chemical fertilizers with a positive economic and environmental balance sheet as well as on an environmental level. The energy that is drawn from this biological treatment perfectly faces the competition of a wind or solar power plant. This is why it can be argued that the share of energy recovery provided by anaerobic digestion is more important than incineration (Nadjyat, 2009).

The methanization process has ecological advantages because it not only cleans up the environment, it is one of the best controls for polluting substances. Consequently, the COD removal rate is in the order of 23.6 kg per cubic meter of methane released (WWF, 2010) [9].

Finally, anaerobic digestion is one of the perfectly viable processes when the input is suitable. This again raises the question of selective collection and the participation of those responsible.

6. Conclusion

To conclude, economically and demographically speaking, the rise of waste production shows the rise of the economy. Mismanagement of waste involves the disruption of public health due to the scattering of waste in the city, i.e., the more the waste is mismanaged the more human health is hampered. The insufficiency of waste recovery or even the non-existence of their treatment causes the emission of gases into the atmosphere, mainly methane, carbon dioxide and nitrogen monoxide. The more abundant the emission of gases, the greater the greenhouse effect.

Ecological prudence and environmental awareness are therefore key objectives in the development of sustainable waste management because they are the basis for the mobilization of waste producers, without which no strategy can hold. Indeed, neither the necessity nor the cost of processing the waste resulting from this change in consumption patterns has been taken into account, which will destroy in the short-term part of the natural resources on which populations could rely. This trend is already visible as a brake on the development of ecotourism due to the deterioration of landscapes.

Sustainable waste management, by protecting the environment, therefore contributes strongly to the fight against poverty and that faecal sludge plays an important role, because it provides a large part of urban sanitation through the production of biogas. Like the results obtained, it is possible to carry out the management of faecal sludge with an awareness of the population that the proportion of their organic matter is similar to that of other biological waste and which is favorable to the various agricultural valuations after drying solar. The practice of this management of faecal sludge provides a new path for ecological and environmental development without neglecting their recovery in the production of biogas.

7. References

1. Alix L. Assainissement et Santé de la ville de Mahajanga. IRCOD de Mahajanga, 2011, 80p.
2. FAO. Le taux de croissance démographique à l'échelle mondiale, 2010, 21p.
3. Académie Nationale des USA. Phénomène de l'effet de serre: Le développement durable; Législation environnementale, 2006, 12p.
4. Rafamantanantsoa JG. Matrice de conception des nouveaux produits: Valorisation par compostage aérobie. Cours théorique en Master 1, Parcours STTD de la FSTE de l'Université de Mahajanga, 2010.
5. Politique et stratégie nationales pour l'assainissement du18 Août. Evacuation des excrétas dans les 6 provinces de Madagascar, 2003, 15p.
6. Ramampiherika KD. Biogaz, mise en route d'un digesteur et développement durable. Université de Toliara, 2010, 120p.
7. Rasoanandrasana E. Cycle de carbone. Cours théorique en Master 1, Parcours STTD de la FSTE de l'Université de Mahajanga, 2010.
8. Lea S. Épuration fine des biogaz en vue d'une valorisation énergétique. Ecole doctorale de chimie, Université de Lyon, France. Thèse de Doctorat, 2014, 232p.
9. WWF. Protection de l'environnement et écosystème équilibré, 2010, 28p.