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LOCAL RESOURCE EXPLOITATION

Hygienization of faecal sludge with a view to recovery in agriculture

Hygiénisation des boues de vidange en vue d'une valorisation en agriculture

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ABSTRACT:

In the town of Sokodé, fresh faecal sludge and untreated dried faecal sludge are used by farmers and market gardeners as organic fertilizers. However, untreated sludge contains microorganisms that can contaminate market garden and agricultural products and infect people who consume them raw or improperly washed. Drying alone does not eliminate all pathogens and therefore the use of untreated faecal sludge for market gardening and agriculture is a danger for consumers. The objective of this work is then to stabilize the organic matter of the dried faecal sludge for its hygienic use for agricultural amendment. To do so, this faecal sludge was co-composted with the fermentable fractions of solid waste. The evaluation of the stability and maturity parameters shows that the co-composted sludge gives mature compost and can improve soil fertility without biological risk. The levels of metallic trace elements are lower than standard NFU 44-051. So, the use of these composts will not cause any problem for the environment.

Keywords: Hygienization, Faecal Sludge, Fermentable Fractions, Co-composting, Agriculture.

RÉSUMÉ :

Dans la ville de Sokodé, les boues de vidanges fraiches et les boues séchées non traitées sont utilisées par les agriculteurs et maraîchers comme fertilisants organiques. Or, les boues non traitées, contiennent des microorganismes pouvant contaminer les produits maraîchers et agricoles et infecter des personnes qui les consomment crues ou mal lavées. Le séchage seul n'élimine pas tous les agents pathogènes et donc l'utilisation des boues non traitées pour le maraîchage et l'agriculture est un danger pour les consommateurs. L'objectif de ce travail est alors de stabiliser la matière organique des boues de vidange séchées en vue de leur utilisation hygiénique pour l'amendement agricole. Pour se faire, ces boues de vidange ont été co-compostées avec les fractions fermentescibles des déchets solides. L'évaluation des paramètres de stabilité et de maturité montre que les boues co-compostées donnent un compost mûr et pourront améliorer la fertilité des sols sans risque biologique. Les teneurs en éléments trace métalliques sont inférieures à la norme NFU 44-051. Ainsi, l'utilisation de ces composts ne causera pas de problème pour l'environnement.

Mots clés : Hygiénisation, Boues de vidanges, Fractions fermentescibles, Co-compostage, Agriculture.

1. INTRODUCTION

The growing of population, each decade, generates an increase in food demand. In togo, population growth raises questions about meeting the needs for food, education, health, drinking water, energy, employment and protection of natural resources (FAO, 2013). Indeed, food demand can only be satisfied by an intensification of agricultural activity. The low yield of agricultural production and the insufficiency of foodstuffs are linked to the poverty of arable soil. In most developing countries, one of the major challenges in recent decades has been to meet the high demand for food as a result of accelerated population growth. To meet this demand, agricultural intensification appears to be an essential option. However, agricultural intensification puts pressure on the ecosystem and leads to reduced soil fertility. To make up for this loss, farmers apply nutrients in the form of chemical fertilizers to provide nitrogen and phosphorus that crops need to grow. However, the excessive use of chemical fertilizers has a negative impact on the environment because nitrogen and phosphorus not fully utilized can be lost in agricultural fields producing soil salinity, the accumulation of heavy metals, water eutrophication and nitrate buildup (Savci, 2012).

Faced with the high costs of chemical fertilizers and the risks of pollution due to the excessive use of chemical fertilizers, organic matter from solid waste and faecal sludge is also a source of significant nutrients for farmers in the urban and peri-urban environment. The use of urban waste without prior treatment in agriculture involves significant risks for human health. Greater caution is required in the case of using untreated organic waste on vegetable crops whose leaves are consumed, given that some metals, such as cadmium, preferentially accumulate in the leaf parts (Sotamenou, 2005). Also, viruses, bacteria, protozoa and pathogenic helminths can be transmitted orally when eating contaminated vegetables. In the town of Sokodé in Togo, an agreement is made between some farmers and the emptying trucks and faecal sludge is dumped in their fields without any treatment. In addition, a survey of market gardeners in the city revealed that due to the poor soil, around 40% of them directly use untreated dried faecal sludge to improve their production areas (PEAT2, 2018). However, untreated sludge contains microorganisms that can contaminate market garden and agricultural products and infect people who consume them raw or improperly washed. Fecal sludge dried for three months, still contains an average of 615 helminth eggs, 25 eggs / g and 932 protozoan cysts, 37 cysts / g of dried sludge (Ouedraogo, 2016). Thus, drying alone does not eliminate all pathogens and therefore the use of untreated faecal sludge for market gardening and agriculture is a danger for consumers. On crops, the toxic effect of raw waste and faecal sludge is similar to that of immature compost. In fact, immature compost emits ammonia (NH_3) (Tang et al., 2006) which, even in small quantities in the soil, is toxic for seed germination as well as for the normal development of roots, plants (Jiemenez et Garcia, 1989). Studies have shown that corn, tomatoes and vegetable carrots grown on soil polluted by faecal sludge are contaminated with Escherichia coli of 204 CFU / g (Tchanaté, 2018).

Faced with these potential risks, it is necessary to stabilize the sludge by appropriate treatments before its use in agriculture. Several low-cost treatment options like planted drying beds, unplanted drying beds, or faecal sludge co-composting can achieve high helminth egg inactivation efficiency when treating faecal sludge. For the specific case of co-composting, some authors, after successful trials, present it as the most efficient way to sanitize faecal sludge due to the high temperatures produced during anaerobic composting (Ouedraogo, 2016). Indeed, in dehydrated faecal sludge co-composted with fermentable fractions of solid waste, a reduction of more than one logarithmic unit of helminth eggs was obtained after two months (Gallizzi, 2003). According to the same study, during the first month, the temperature in the center of the compost heap is above 60°C, and near the edge it initially rises to over 45 °C. These temperatures can increase the permeability of the shell of Ascaris eggs, allowing the transport of harmful compounds and increasing the rate of desiccation of the eggs (Capizzi-Banas, 2004). Thus, the co-composting of faecal sludge with the fermentable fractions of municipal solid waste from the city of Sokodé appears to be the most interesting option. The objective of this work is then to stabilize the organic matter of the dried faecal sludge for its hygienic use for agricultural amendment. This pretreatment of sludge by co-composting, combined with the fermentable fractions of solid waste from the city of Sokodé, could be of added value for market gardeners and farmers in the city of Sokodé. The recovery of faecal sludge by co-composting, in combination with household waste, has many advantages, including effective biological stabilization and the production of an odorless organic amendment with significant agronomic characteristics.

2. MATERIALS AND METHODS

2.1. Materials

The fermentable fractions of solid waste and faecal sludge used for co-composting come from the city of Sokodé, capital of the Central Region in Togo. This city is located between 8 ° 57 'and 9 ° 03' North Latitude and 1 ° 05 'and 1 ° 11' East Longitude, 346 km north of Lomé with an estimated population of 111,258 inhabitants. A campaign to sort solid waste from households, hotels, markets and restaurants in the town of Sokodé was carried out and made it possible to obtain the fermentable fraction of solid waste. The dried faecal sludge comes from the faecal sludge treatment plant in the city of Sokodé. The co-composting was carried out (**pho. 1**) in the proportions of 1/3 for the dried faecal sludge (with a dryness of more than 80 %) and of 2/3 for the fermentable fractions of solid waste (ADEME, 2015 et Albrecht, 2007).

Pho.1. Co-composting

The windrows were turned two (02) times during the fermentation phase and two (02) times during the maturation phase to allow their homogenization (Kolédzi, 2011). The co-composting period was set at three months and the maturation was done in the shed. The resulting compost was screened and then stored.

2.2. Methods

2.2.1. Compost quality

The contents in % MO, % Ntotal, % P_2O_5, % K_2O and % MgO then the C / N ratio were determined to evaluate the quality of the compost produced. The organic matter content was determined by the loss on ignition method. The total organic carbon content and the total phosphorus (P_2O_5) content were respectively determined after the oxidation and spectrometric analysis (Tchanaté, 2018). Magnesium concentration and potassium content in the samples were determined by titration with Ethylene Diamine Tetra Acetic (Ouedraogo, 2016) after extraction and by atomic absorption spectrometry, respectively. Kjeldahl total nitrogen is determined by the Kjeldahl method (Barrena et al., 2010). The pH was determined on a compost solution using a pH meter. The application of self-heating tests (TAE) and the determination of Cationic Exchange Capacity (CEC), were used to assess the maturity and stability of the composts produced. The levels of trace metal elements in the composts were evaluated in order to estimate the environmental impact of the use of these composts as an agricultural amendment.

Germination tests (Phytotoxicity) make it possible to establish a relationship between the dose of compost and the germination rate. The tests are carried out on maize (Zea mays) for two doses of compost: a high dose (2/3 of co-compost and 1/3 of sand) and a low dose (1/3 of co-compost and 2 / 3 sand).

Self-heating tests (TAE) were carried out; the maturity index is a function of the highest temperature reached during the test. The contents of trace metallic elements (Zn, Cu, Ni, Cd, Pb) were determined by flame atomic absorption spectrophotometry (Mathieu, 2003). The Cationic Exchange Capacity (CEC) of samples is calculated using equation 1.

$$CEC\left(\frac{Cmol}{kg}\right) = \frac{[Ca]}{200} + \frac{[Mg]}{120} + \frac{[K]}{390} + \frac{[Na]}{230} \quad (1)$$

[Ca], [Mg], [K] et [Na] in mg/kg.

2.2.2. Microbiological analyzes

Pathogens were looked for in composts and dried sludge in order to assess the impact of co-composting on the reduction of these germs in dried sludge (**Table 1**).

Table 1. Germs sought and methods used

Germs sought	Methods	Culture media	Culture conditions
Fecal coliforms	NF V08-016 December 1992	VRBL (Red rose)	44 °C, 24 h
Faecal streptococci	(NF. T90-416, October1985)	Slanetz et Bartley	37 °C, 24 h to 48 h
Salmonella	NF V08-052, October 1996	EPT, RV, MH, (Black)	37 °C, 24 h to 48 h
Molds	NF V08-075, August 1985	Sbouraud + Choramphénicol	30 °C, 48 h to 72 h

3. RESULTS AND DISCUSSION

3.1. Compost quality

Table 2 shows the results of the nutrients of the compost obtained. The organic matter content (45 %) obtained in the compost remains high. It complies with standards NFU 44-051 and NFU 44-095 and indicates that the compost obtained is mature and stabilized for use as a soil amendment (Rafolisy et al., 2015). The nitrogen content at the end of the process is 1.1 %. This content complies with the quality standards for compost. Co-compost is rich in nitrogen; thus, its contribution to improving agricultural yield will be higher. The quality of the compost at the end of the process was also assessed by its C / N ratio. The results obtained show that the C / N ratio is 12.72 and is therefore close to the value recommended by standard NFU 44 - 051 which is 13 for mature compost. Co-composting has improved the C / N ratio. Ammoniacal nitrogen and easily mineralizable organic nitrogen from sludge and fermentable solid waste fractions in compost are thus readily available to plants (Ouedraogo, 2016).

With regard to total phosphorus, the results show that the content is 2.2 %. The potassium content is 1.54 %. These levels also comply with standards NFU 44-051 and NFU 44-095. These levels could help promote flowering and fruit development (Ouedraogo, 2016). The pH obtained is 8. This basic pH would be linked to the production of ammonia gas associated with the degradation of proteins and the decomposition of organic acids or the contamination of solid waste by wood ash and charcoal (Koledzi, 2018).

Table 2. Nutrient content

Parameters	Co-compost
%OM	45
%N	1.1
%C	14
C/N	12.72
$\%P_2O_5$	2.2
$\%K_2O$	1.54
%MgO	0.56
pH	8

Table 3 shows a practically constant consumption for the fourth day (for a degree of maturation of IV (temperature of 40 ° C)) for the two types of composts. The results show that the two composts produced are already very stabilized (Kolédzi, 2011).

Table 3. Measurement of AT4, Phytotoxicity and CEC

Scenarios	Scenario 1 : 1/3 of sand + 2/3 of compost	Scenario 2 : 2/3 of sand + 1/3 of compost
Phytotoxicity (%)	67.5 %	75 %
Self-heating capacity (AT4)	Degree IV (temperature < 40 °C)	
Cationic Exchange Capacity (meq / 100 g)	68	

Cationic Exchange Capacity values greater than 60 meq / 100g in the compost indicate that the compost is ripe (Mustin, 1987).

Germination tests (Phytotoxicity) make it possible to establish a relationship between the dose of compost and the germination rate (Table 3). For the highest dose, the germination rate is 67.5 % for the highest dose and 75 % for the lowest dose. Whatever the dose of compost, the rates obtained are lower than those obtained by others studies which are between 75 % and 93.75 % for composts from household waste and between 62.5 % and 93.75 % for compost from catering waste (Toundou, 2016). However, these rates are in the meantime obtained by others authors (40 % - 60 %) (Aziablé et al., 2017). It emerges from these results that the germination rate increases with a lower dose of co-compost. A high dose of compost therefore has a negative influence on seed germination and plant growth (Toundou, 2016). Compost is considered non-toxic when the germination index exceeds 50 % (Zucconi et al., 1981). Thus, whatever the dose of compost applied, the prepared co-compost exhibits no toxicity towards corn.

3.2. Trace Metallic Element content

The concentrations of metallic trace elements are shown in Table 4. The levels obtained are below the threshold authorized for using compost in agriculture. They are comparable to those obtained in composts from Lomé by Koledzi et al. (2018) which are between 17 - 23 mg / kg for Pb, 11 - 13 mg / kg for Ni, 0.45 - 0.60 mg / kg for Cd (Koledzi et al., 2018). However, the Cu contents are lower than those obtained by this same study which are between 51.00 - 54.30 mg / kg. This difference would be linked to the nature of the substrates of each city. The use of this compost as an organic fertilizer does not present any danger for the environment.

Table 4. Comparison of TME contents with standard NFU 44-051

Analyzed elements (mg/kg)	Co-compost	NFU 44-051
Cu	17	300
Zn	222	600
Ni	9	60
Cd	2	3
Pb	20	180

3.3. Microbiological characteristics of composts

In order to identify the value of co-composting, a comparative study of faecal germs in dried sludge and composts is established. The germs sought are germs indicative of hygienic quality (*thermo-tolerant coliforms, E. coli*), sanitary quality (*salmonella and molds*) (Tchanaté, 2018) and commercial grade indicator organisms (*faecal coliforms and faecal streptococci*). **Table 5** shows the number of bacteria counted in the dried sludge and the composts in comparison with standard NFU44-095. If the value obtained is below the limit of acceptability, then the compost can be marketed. The values obtained per gram of compost are lower than those obtained in dried faecal sludge. These results clearly show that co-composting reduces a large amount of pathogenic germs in faecal sludge. The mixture therefore underwent an aerobic fermentation step with a rise in temperature allowing the compost to be hygienized.

Table 5. Comparative study of the microbiological characteristics of dried faecal sludge and composts

Germs	Dried sludge	Co-compost	Standards NFU44-095
E. Coli (UFC/gMS)	$0.12.10^4$	$0.23.10^2$	-
Fecal coliforms (UFC/gMS)	10^5	$2.1.10^2$	10^4/g MS
Faecal streptococci (UFC/gMS)	10^6	0	10^5/g MS
Molds	$4.6.10^4$	< 1	-
Salmonella	Present/g MS	Absent/g MS	-

The comparative analysis of these results with the requirements of standard NFU 44-095, reveals that the number of all the germs sought per gram meets the normative value. According to the principle of the NFU 44-095 standard, any compost whose quality conforms to the NFU 44-095 standard is no longer a waste but a product and, as such, can be distributed without other formality, in the same way than any organic fertilizer or growing medium. Based on this, we can conclude that the resulting compost can be used as an amendment without endangering the health of consumers.

4. CONCLUSION

In this study, the co-compost was made from a mixture of the fermentable fractions of solid waste and dried faecal sludge in a 2/3 and 1/3 ratio (respectively). The self-heating capacity (AT4) and the Cationic Exchange Capacity on the compost were carried out and made it possible to obtain the indicators that define the quality, maturity and stability of the composts produced. The AT4 test gives a practically constant consumption for the fourth day (for a degree of maturation of IV (temperature of 40 °C)). The values of these parameters show that the composts are ripe. The content of metallic trace elements is lower than NFU 44-051, indicating that the use of these composts will not cause problems for the environment. Co-composting has made it possible not only to obtain a high temperature which can destroy certain pathogenic germs in the faecal sludge but also to stabilize the organic matter of the fermentable fractions of the solid waste as well as that of the faecal sludge and to reduce at all few of the environmental risks that the application of these substrates in the raw state would cause.

5. CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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