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RESEARCH ARTICLE

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# FAECAL SLUDGE STABILIZATION BY TWO CHEMICAL PROCESSES

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**ABSTRACT**

The search for an alternative solution to biological faecal sludge stabilization methods that requires significant funds and a lot of time, led us to undertake work on chemical stabilization processes for FS that are less expensive and fast. Thus, the faecal sludge collected is stabilized by quicklime (CaO) on the one hand and sodium nitrite $NaNO_2$) on the other. The results of the analyses showed that these stabilized faecal sludge are hygienic due to the total absence of pathogenic germs (Thermotolerant coliforms, Entamoeba Coli, Faecal streptococci, Anaerobic sulfito-reducers, Salmonella sp) and the very sensitive abatement of parasites (Entamoeba Coli cysts) and metal pollutants (Zn, Cu, Ni, Pb, Cd and Cr). The white bean germination test also appreciated the germinative and fertilising power of the treated faecal sludge. Then, the sludge volume index calculation yielded 25 ± 0.08 mL/g and 32 ± 0.12 mL/g respectively for CaO-stabilized sludge and $NaNO_2$-stabilized faecal sludge. These values are less than 100 mL/g, indicating that these stabilized faecal sludge sediment easily and will optimize their drying time.



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# INTRODUCTION

The implementation of a variety of self-contained sanitation systems, including septic tanks, traditional latrines and public toilets, has helped to limit the spread of oro-fecal diseases (Akpaki et al, 2016 ; Kone and Strauss, 2005).This mode of sanitation requires repetitive emptying and the sludge thus obtained is unfortunately discharged without prior treatment near the houses, in the watercourses, the gutters, the growing areas or on inappropriate land.As a result, these feacal sludge discharges are responsible for an increase in infectious diseases in riparian populations, as well as for environmental degradation (Akpaki et al, 2016 ; Kone, 2010).These faecal sludge drains contained germs, some of which are pathogenic (compliant bacteria, salmonella, helminth eggs, ....). In addition, they are very fermentable and are at the origin of the production of gases (amines, hydrogen sulphide, mercaptans) that cause olfactory nuisances (Recalde et al, 2018).In order to limit the rapid biodegradation process of these faecal sludge discharges, it is possible to develop a pre-treatment step by stabilization on the treatment lines to obtain sludge which no longer evolves or, at the very least, evolves slowly, both biologically and physico-chemically (Strandea et al, 2018). Indeed, lime and sodium nitrite stabilization processes are one of the most technically, economically and ecologically efficient chemical sludge conditioning techniques.They require simple equipment, low energy consumption and low maintenance (Gaïd, 2008). Thus, this study is based on these two chemical processes to stabilize the faecal sludge (FS). By setting itself as an objective, the reduction of the fermentable power of the FS by oxidising the organic matter so as to make it more easily bio-assimilable, eliminating the reducing germs responsible for fermentation and by reducing the concentration of metal pollutants. Afterwards, the treated sludge is hygienized, deodorized and does not interfere with the agricultural devolution which remains the preferred destination.

# MATERIALS AND METHODS

**Lime stabilization:** A 500 mL of faecal sludge (FS) contained in a 1000 mL beaker is added gradually and under agitation using a glass rod of solid calcium monoxide (CaO) to bring the pH to 12 (Photo 1). To this mixture is added 2 g of iron chloride III ($FeCl_3$ at 98%) to improve the dehydration of stabilized sludge (Jean-Paul and Willem, 2008)· The reaction medium thus prepared is left to rest for 24 hours to allow for more advanced removal of germs and dewatering of the sludge.

**Photo 1. Liming of sludge at pH = 12**

**Sodium Nitrite Stabilization:** In a 1litre beaker containing 500 mL of a sludge sample from the storage pits, a solution of sodium nitrite is gradually added at 800 mg $N.NO_2$/L. The pH of this mixture is brought to 2 by adding the concentrated sulphuric acid ($H_2SO_4$ at 95%), (Photo 2). The reaction medium is left at rest for 24 hours to promote pathogenic germ removal and sludge stabilization reactions (Bonnin and Coriton, 1999)**.** After this reaction time, the sludge is dehydrated by adding iron chloride III as in the case of liming.

**Photo 2. Stabilization of sodium nitrite sludge at pH = 2**

**TOC Content:** A 1 g of dried sludge, at 80°C in the oven for 24 hours, is inserted into a 500 mL flask with an addition of 10 mL of potassium bicarbonate 1 N followed by a progressive addition of 20 mL of concentrated sulphuric acid. Thus, the mixture is covered and shaken vigorously for 1 minute and let stand for 30 minutes. It is followed by an addition of 300 mL of distilled water, 10 mL of concentrated phosphoric acid and 15 drops of ferroin solution. Finally, the excess potassium bichromate in the mixture is titrated with the ferrous sulphate solution 0,5 N (CEAEQ, 2014). The percentage of carbon in the sample expressed in % C is determined by equation 1.

$$C = \frac{(A-B)\times 1\ \ \times 0,0\ \ \ \times 1}{P\times A}$$ Equation 1

C: concentration of organic carbon (% C);
A: volume of ferrous sulphate used for the control (mL);
B: volume of ferrous sulphate used for the sample (mL);
10: volume of bichromate initially added;
0.004: number of g of C per mL of bichromate;
P: weight of the titrated sample expressed on a dry basis (g);
100: factor to obtain a percentage.

**Photo 3. Test of settling of stabilized sludge with test-tube**

**Sludge volume index:** The sludge volume index (SVI) test is used to assess the suitability of stabilized sludge for settling. A 25 mL of stabilized drain slurry taken from a 100 mL test piece is added 75 mL clarified water to cause dilution at ¼. After some shaking by a movement from bottom to top of the hermetically sealed test piece, the mixture is left to rest at laboratory ambient temperature and on a horizontal bench isolated from all vibrations. After 30 minutes of settling, the level of faecal sludge cover in the test-tube is read and noted $VS_{30}$ (Photo 3). The sludge volume index (SVI) represents the volume occupied by one gram of sludge after thirty minutes of static settling in a one-litre graduated transparent-walled test tube (Canler, 2005). The sludge index is denoted SVI, expressed in $mL.g^{-1}$ of suspended solids (SS), and is defined by equation 2.

$$S \ = \frac{V\ \ 3}{S}$$ Equation 2

**$VS_{30}$ =** volume of faecal sludge settled after 30 minutes ($mL.L^{-1}$).
**SS =** concentration of suspended solids in the test piece ($g.L^{-1}$).

The determination of suspended solids shall be made by filtration on glass fibre filters taking into account the domestic origin of the effluents. The measurement of suspended matter by filtration is based on the principle of double weighing: a volume of faecal sludge is filtered on a membrane (previously weighed empty) of 1.5 microns and the residues on it are weighed (Bhola and Vinay, 2017).

**Metal trace element content:** The samples are mineralized by acid digestion with regal water. For each sample, 3 tests of 1 g each were performed. Each sample is placed in a glass Erlenmeyer flask where it receives 3 mL of demineralized water, 7.5 mL of hydrochloric acid (38%, normapur) and 2.5 mL of nitric acid 65%, normapur). The mixture is sealed and left at room temperature for 12 hours. The mineral is then concentrated by boiling for 2 hours. After cooling, the volume is adjusted to 20 mL with demineralized water. Mineral whites (without mud) are prepared simultaneously (Rarty, 2007).The determination of metallic trace elements in mineralogies is made by flame-mode atomic absorption spectrometry (Aanalyst 800/PERKIN ELMER).

**Microbiological analysis:** Determination of Thermotolerant Coliforms, E. coli, Fecal Streptococci, Sulfito-reducing anaerobes, Salmonella sp and Parasites (Entamoeba coli cysts) in raw and stabilized faecal sludge is based on the search and enumeration of bacterial colonies by membrane filtration and seeding into appropriate culture media followed by incubation at the appropriate temperature for 18-24 h. The analyses were carried out according to the routine analysis methods of the Association Française de Normalisation (AFNOR): Decree of 21 December 1979.

**Germination test:** The germination test makes it possible to know the germinative power (or germination rate) of white bean seeds in the presence of the sludge recovered after the treatment of the sludge. Ten (10) seeds are sown on "sand + stabilized faecal sludge" supports in different proportions. The different proportions of stabilized faecal sludge and sand defined in this study are:

- Sand + 5% in dry mass of stabilizedfaecal sludge;
- Sand + 10% in dry mass of stabilized faecal sludge;
- Sand + 15% dry mass of stabilized faecal sludge.

Germination rate is assessed relative to the control (100% sand) ((Chennaoui et al, 2016).

# RESULTS

**Effects of germ abatement:** The results of the microbiology analyses showed the destruction of all the germs sought by the two chemical procedures with the exception of Entamoeba Coli Cysts, which were significantly reduced (Table 1).

**Abatement effects to metallic trace elements (MTE):** The results obtained on the abatement of (MTE) in treated sludge are summarized in Table 2.The analysis in Table 2 showed that, for stabilized faecal sludge (II and III), its concentrations in Zn, Cu, Pb and Cd dropped considerably compared to the control sample (I), the raw sludge.

**Recovery of stabilized sludge: germination test:** The germination test results for stabilized faecal sludge, whether pure or mixed with soil, are shown in Table 3. These results show that the incorporation of 5% of the faecal sludge into the soil allows a germination rate of 90% and 100% of the beans for CaO and $NaNO_2$ stabilised faecal sludge. In terms of plant development, sodium nitrite stabilized sludge yields better (Photo 4).


**Photo 4. Germination test**

**Total organic carbon content:** The carbon percentage results for stabilized sludge were 10.64 ± 1.58 and 14.59 ± 0.97, respectively, for lime-stabilized (II) and sodium nitrite-stabilized (III) sludge (Figure 4). At the same time as %C in the noise sludge (I) of 16.43 ± 2.51, the %C in sample II was found to be relatively low.

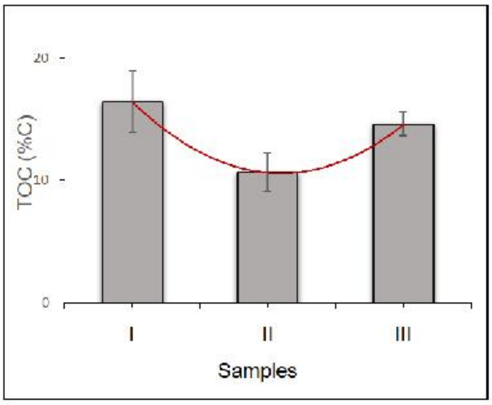


**Figure 4. Percentage of total organic carbon**

**Settling test:** The Sludge volume Index (SVI) is an essential tool for the operator of a faecal sludge drying station to characterize sludge for dewatering. For this study, the SVI calculations for stabilized sludge give 25 ± 0.08 mL/g and 32 ± 0.12 mL/g respectively for CaO-stabilized faecal sludge (II) and $NaNO_2$ stabilized faecal sludge (III).

# DISCUSSION

Lime (CaO) is a strong base. In sufficient quantity, it allowed to achieve and maintain a pH equal to 12 at least for 3 months conferring a stabilizing action by destruction or mitigation of the germs (Bonnin and Coriton, 1999).Apart from its destructive effect on germs, lime has also been used to treat smelly compounds: organic and inorganic sulphides, nitrogen compounds and fatty acids by a purely chemical reaction with many sulphur molecules (Reactions 1-3).

*a. At pH >12, ionic species ($HS^-/S^{2-}$) coexist*
*$pKa(H_2S/HS^-)=7 << pKa(HS^-/S^{2-})=13 < pKa(H_2O/OH^-)=14$*

*pH* **> 6:** $H_2S + OH^- \quad HS^- + H_2O$ Reaction 1
*pH* **> 9:** $HS^- + OH^- \quad S^{2-} + H_2O$ Reaction 2

*b. At pH >12, the ionic species ($RS^-$) are formed*
*$pKa\ (C_2H_5SH/C_2H_5S^-) = 13 < pKa\ (H_2O/OH^-) = 14$*
*pH*> **8 :** $C_2H_5SH + OH^- \quad C_2H_5S^- + H_2O$ Reaction 3

**In its CaO form, it also enabled two additional actions to be taken by reacting with the sludge water**

– a dehydrating action induced on the one hand by the transformation of part of the free water of the sludge into water combined with lime, and on the other by the evaporative effect according to stoichiometry of reaction 4, exothermic:

$CaO + H_2O \rightarrow Ca(OH)_2$ + heat **Reaction 4**

– an additional germicidal action by increasing the temperature of the mass, reaction 4, exothermic, giving off 160 kJ/kg CaO.

**Table 1. Results of microbiological analyses**

| Germes | UFC/mL | | |
|---|---|---|---|
| | I | II | III |
| Thermotolerant coliforms (44°C) | 8 000 | 0 | 0 |
| Escherichia coli | 4 400 | 0 | 0 |
| Faecal streptococci (37°C) | 23 000 | 0 | 0 |
| Sulfito-reducer anaerobes (44°C) | 100 000 | 0 | 0 |
| Salmonella sp | Absence25/mL | Absence25/mL | Absence25/mL |
| Parasites | Cysts of Entamoeba *coli* +++ | Cysts of Entamoeba *coli* + | Cysts of Entamoeba *coli* + |

*I :FS ; II : FS+CaO+$FeCl_3$; III : FS+$H_2SO_4$+$NaNO_2$*

**Table 2. Metal trace elements contents**

| Sample | Parameter in mg/kg | | | | | |
|---|---|---|---|---|---|---|
| | Zn | Cu | Ni | Pb | Cd | Cr |
| I (FS) | 6,46±0,04 | 1,27±0,02 | 0,19±0,02 | 0,34±0,03 | 0,0024±0,001 | < 0,002 |
| II (FS+CaO + $FeCl_3$) | 2,61±0,20 | 0,38±0,41 | 0,12±0,11 | 0,04±0,03 | < 0,0005 | < 0,002 |
| III (FS+$NaNO_2$+$H_2SO_4$) | 3,70±0,1 | 1,18±0,02 | 0,06±0,02 | 0,09±0,01 | < 0,002 | < 0,002 |

**Table 3. Bean germination test on stabilized faecal sludge mixed with sand**

| | *Sand* | *Sand + 5 % stabilized sludge* | | *Sand + 10 % stabilized sludge* | | *Sand + 15 % stabilized sludge* | |
|---|---|---|---|---|---|---|---|
| | | *CaO* | *$NaNO_2$* | *CaO* | *$NaNO_2$* | *CaO* | *$NaNO_2$* |
| *White bean* | *45* | *90* | *100* | *60* | *55* | *10* | *2* |

Alkaline hydrolysis also led to the destruction of cellular constituents and nucleic acids. The addition of ferric chloride ($FeCl_3$) to the lime allowed the increased dehydration of the sludge draining stabilized by the effects of coagulation and flocculation (Jing et al, 2017). The calcium element ($Ca^{2+}$) neutralized the surface loads of the suspended materials (cationic packaging) and the increase in pH to 12 led to the formation of amorphous gels with metallic salts (Fe and Cl) behaving as inorganic polymers (Bonnin and Coriton, 1999; Meyel and Berbers, 2008)**.** The $NaNO_2$ process is a chemical faecal sludge stabilization process that allows for easy storage or storage to reduce odours (Bonnin and Coriton, 1999).It is envisaged as a hygienic process and as a dehydration improvement technique. For this purpose the faecal sludge was subjected for about 1 hour to the action of nitrite ions, a powerful reagent potentiated in acidic medium.

This resulted in the inactivation or destruction of the germs responsible for the degradation of organic matter as shown by the results of microbiological analyses. The treatment also led to the removal of olfactory nuisances ($H_2S$, mercaptans..) and the inhibition of fermentative activity. The faecal sludge was stabilized to the extent that it could be stored without any strong or unpleasant odours. This was a pseudo-stabilization since the biodegradable fraction was not destroyed, but only blocked (Bonnin and Coriton, 1999). In this $NaNO_2$ process, the formation of $NO_x$ was observed: nitrogen monoxide (NO) and nitrogen dioxide ($NO_2$). However, the nitrogen injected was mainly in the form of NO nitrogen monoxide. As a basic solution, NOx from the gaseous sky is vented to the atmosphere with sufficient dilution (Gaïd, 2008)**.** Thus, in subsequent works, an air treatment on activated carbon will be installed in order to rid it of the $NO_x$ generated. The metal trace elements abattements are justified by the formation of metal salts. Their formation results from an oxidizing attack: the metal is oxidized into a positive ion (cation) and is then combined with a negative ion (anion) to give a salt such as sulphides, chlorides, sulphates, nitrates, phosphates, lead, mercury, zinc, tin, nickel (Bonnin and Coriton, 1999).

However, the parallelism of the metallic trace element concentrations of the stabilized faecal sludge (II and III) shows that the abatement rate is very sensitive in the case of (II) than in (III). This difference would be justified by the precipitating power of lime. Liming tends to move the elements from the most labile forms to more stable and therefore less extractable forms (Douss et al, 1999). This would be explained by the precipitation of the elements in the form of carbonates.This would be explained by the precipitation of the elements in the form of carbonates and hydroxides. The solubility of metallic trace elements is therefore limited by the formation of metallic carbonates and hydroxides. However, this is only done if the metal trace elements are in the ion state and not complex. The liming of the sludge reduces the amount of soluble and bioavailable metals for plants and terrestrial organisms, both by dilution effect and by the movement of metals to stable forms. Thus, thanks to liming, the metals brought by the sludge take more stable, less mobile and bioavailable forms, and therefore less contaminating to the environment.

The germination test is a means of assessing the toxicity of incorporating stabilized sludge into the sand in order to recognize the germinative capacity of stabilized faecal sludge. Thus, sodium nitrite stabilized faecal sludge showed better germination and good plant development. This difference was justified by the fact that, at the level of the faecal sludge stabilized by CaO, a contribution of dry matter was noted which would have reduced the fertilizer content. This is confirmed by their potassium (K) content which was 23.44; 22.81 and 13.58 mg/kg respectively for unstabilized faecal sludge, $NaNO_2$ stabilized faecal sludge and Cao stabilized faecal sludge. However, the germination test showed that this relative dilution of organic matter in CaO stabilised faecal sludge had little effect on the cationic capacity of the soils and the retention of nutrients and water available to the plants. For the sludge volume index < 100 mL/g, sludge was readily sedimentary and was most often well mineralized[11]**.**It could be said that these stabilized sludge (II and III) are suitable for settling treatment.

However, when comparing the sludge indices, it was found that the lime-stabilised sludge was more suitable for settling due to the addition of ferric chloride ($FeCl_3$). The addition of $FeCl_3$ to the FS + CaO mixture contributed to the increased dehydration of sludge stabilized by the formation of amorphous gels (Bonnin and Coriton, 1999; Meyel and Berbers, 2008)**.** Thus, the FS stabilized by the liming process more optimized the drying time in the drying beds. Hence, an economic interest

# CONCLUSION

This research led to the development of chemical processes for the treatment and management of faecal sludge (FS). Thus, the FS stabilized by the liming and sodium nitrite processes show a very satisfactory hygienicization with the complete destruction of all the germs sought and in addition, a significant reduction of the metal trace elements and Entamoeba Coli Cysts contained in this sludge.The settling test applied to these stabilized faecal sludge assessed their settling ability by their sludge index of less than 100 mL/g. This shows that these chemical stabilization processes also increase sludge drying and for impact direct, the reduction of the drying time of these stabilized faecal sludge once allowed in the drying beds. Apart from their hygienic characteristics, these stabilized sludge have a fertilising quality confirmed by the white bean germination test. Liming and stabilization with nitrite have the advantage of being purely physico-chemical operations perfectly controllable on the one hand and on the other hand the optimization of the duration of stabilization which is less than 24 hours. In addition, investment costs are modest. However, liming is less efficient than nitrite stabilization because liming increases dry matter. Thus, for agricultural application, nitrite stabilization may be proposed.

**Significance statement**

The study stabilized the sludge in less than 24 hours with a very satisfactory performance without damaging the environment. These chemical sludge stabilization processes are an alternative to biological sludge stabilization, which was very costly and required several months. The results of the work will allow the market gardeners and farmers to have, permanently and at a lower cost, organic amendments for the fertilization of their soils. The other advantage of the results of this work is that for acidic soils, stabilized sludge at pH 12 will be used for their amendments and for alkaline soils, stabilized sludge will be applied at pH 2.

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# REFERENCES


Akpaki O, Baba G, Koledzi KE and Segbeaya KN 2016. Quantification et valorisation en biogaz des boues de vidange du site d'Attidjin à Lomé. *J. Soc. Ouest-Afr. Chim.* 042 : 30-35.

Barty K. 2007. Dosage des métaux lourds dans les sols, les boues et les sédiments. Intersol 2007, Paris.

Bhola RG and Vinay KT 2017. Sludge Management. CRC Press/Balkema, © 2017Taylor & Francis Group, London, UK.19-20.www.crcpress.com–www.Taylorandfrancis.com.

Blumier P. 2004. La collecte et le transport mécanisé des boues de vidange dans la ville de Ouahigouya Burkina Faso : Analyse du marché et propositions de réorganisation des flux financiers. EAWAG/SANDEC: 82 p.

Bonnin C and Coriton G. 1999. Procedé de stabilisation de boues. Fascicule de Brevet Europeen EP 0 817 760 B1. Office européen des brevets.

Canler J-P. 2005. Dysfonctionnements biologiques des stations d'épuration : origines et solutions. Document technique FNDAE n° 33. http://www.eau.fndae.fr.

CEAE Q. 2014. Détermination du carbone organique total dans les solides : dosage par titrage, MA. 405 – C 1.1, Rév. 1, Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques. 9 p.

Chennaoui M., Y. Salama, A. Makan, and M. Mountadar, 2016. Valorisation agricole d'un compost produit à partir du compostage en cuve des déchets municipaux. European Scientific Journal.1235: 247-265.

Douss S, Morel JL and Wiart J. 1999. Influence du chaulage sur la biodisponibilité des éléments métalliques en trace incorporés au sol lors de l'épandage de boues. Étude et Gestion des Sols, 6, 2: 105-114.

Gaïd A. 2008. Traitement des boues, Réf : C5221 v1. Editions T. I. https://www.techniques-ingenieur.fr/base-documentaire/archives-th12/archives-travaux-publiques-et-infrastructures-tiace/archive-1/traitement-des-boues-c5221/

Jean-Paul VM and Willem B. 2008. Une solution performante pour le traitement des boues d'épuration, le Procédé Codecal. CARMEUSE, Natural Chicals. www.codecal.com.

Jing W, Rongbing F and Zhen X. 2017. Stabilization of heavy metals in municipal sewage sludge by freeze-thaw treatment with a blend of diatomite, $FeSO_4$ and $CaOH_2$. Journal of the Air & Waste Management Association. 678: 847-8537. https://doi.org/10.1080/10962247.2017.1281175

Kone D. 2010. Making urban excreta and wastewater management contribute tocities' economic development: a paradigm shift. Water Policy.124: 602-610.

Kone D. and M. Strauss 2005. Les aspects de santé pathogènes liés à la gestion des boues de vidange in la gestion des boues de vidange. SANDEC/EAWAG. Université de Yaoundé I. 68-86.

Meyel J-P. and Berbers W. 2008. Le procede codecal® : Une solution performante pour la traitement des boues d'épuration. Conférence Pollutec Lyon Le 3 Décembre 2008. www.codecal.com

Recalde M, Woudstra Tand Aravind PV. 2018. Renewed sanitation technology: A highly efficient faecal-sludge gasification–solid oxide fuel cell power plant. Applied Energy. 222: 515–529.

Strandea L., Schoebitza L, Bischoffa F, Ddibab D and Okellob F 2018. Methods to reliably estimate faecal sludge quantities and qualities for the design of treatment technologies and management solutions. Journal of Environmental Management. 223: 898–907.


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