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Agricultural Soil Fertilizing Potential of Dry Faecal Sludge from Treatment Plants in Burkina Faso

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Abstract

The dry faecal sludge (DFS) are potential sources of organic fertilizers because of their high content in nutrients and organic matter, critical for plants growth and soil health maintaining. In Burkina Faso, the DFS are processed in faecal treatment plants. However, after drying, the DFS are most often dumped in the nature without any control or directly used as fertilizer without any idea of their potential risks for human health and the environment. This investigation aimed at physico-chemical and toxicological characterization of the DFS from faecal treatment plants according to the duration of their storage. For this purpose, DFS samples were collected in three (3) faecal treatment plants in Ouagadougou and one in Bobo Dioulasso, in Burkina Faso. The measurements were carried out on pH (H_2O), organic matter content, major nutrients (N, P, K), trace elements (Na, Ca and Mg) and metallic trace elements. Indifferently to the faecal treatment plants and the duration of the storage, the DFS showed strong acidity (4.85 ± 0.13 et 6.53 ± 0.10) and low content in total elements (Na < 200 mg/kg; Ca < 4000 mg/kg et Mg < 2000 mg/kg). the contents in major nutrient were between 1.08% ± 0.37% and 2.22% ± 0.56% for N and for P it were 8595.24 ± 281.33 mg/kg and 18687.55 ± 1570.68 mg/kg; and 519.40 ± 31.16 mg/kg et 1469.46 ± 1110.16 mg/kg for K. The C/N ratio (9.37 ± 0.33 - 12.17 ± 0.60) showed a good mineralization status of the DFS and its high content of organic matter (22.12% ± 6.83% à 40.97% ± 9.99%). Values recorded of the trace metallic elements showed there were no risk of contamination when used as fertilizers: (103.9 ± 2.00 mg/kg < Cu < 137 ± 25.69 mg/kg); (710.13 ± 18.97 mg/kg < Zn < 922.30 ± 7.04 mg/kg); (33.03 ± 1.65 mg/kg < Pb < 152.40 ± 19.40 mg/kg); (1.34 ± 0.17 mg/kg < Cd < 1.76 ± 0.04 mg/kg); (34.34 ± 0.27 mg/kg < Ni < 52.32 ± 3.60

mg/kg) et (771.15 ± 18.36 mg/kg < Cr < 1697.83 ± 55.11 mg/kg). The results indicated a high fertilizer potential of the DFS after addressing the issue of their acidity.

Keywords

Toxicity, Agronomic Potential, Dry Faecal Sludge, Burkina Faso

1. Introduction

The increasing population in Burkina Faso has led to sanitation pressure; the access to sanitation facilities is 63.4% in urban areas and 0.8% in the rural ones [1]. Thus, autonomous sanitation infrastructures have been built at household for sanitation needs and collection of faecal sludge. In most cases, these infrastructures are not connected to a sewer network. With the increase in the urban population, they produce large quantities of fecal sludge [2] [3]. Indeed, the national production of faecal sludge was estimated at 85,000 m^3 in 2020 according to the National Wastewater and Excreta Program (PN-AEUE). Most of the sludge produced in the big cities such as Ouagadougou and Bobo Dioulasso are processed in the faecal treatment plants and stored in the surrounding environment of the faecal treatment plants without any farther valorization [4] [5] [6]. This approach of the sludge management is a real risk for human health and environmentally unsustainable [7] [8]. Indeed, consistent information on the physicochemical characteristics of dry faecal sludge and its dynamics after application of a primary treatment such as dewatering is not available [9]. In Burkina Faso, one the common utilization of the dry faecal sludge (DFS) remains its used as organic amendment by resources poor farmers to address soil fertility decline, and economic and/or physical inaccessibility to fertilizers and organic amendments [10] [11]. According to [11], the use of row DFS (without any treatment) as fertilizers in small scale farming systems is sustained by the certitude that farmers have on their benefic actions on plants productivity. This empirical approach for using the DFS is done without any consistent information on their nutrients content for plants nutrition and maintaining soil health on the one hand, and on the other hand the risk of pollution that the DFS can present for human and the environment [12] [13].

The investigation reported here aimed to evaluate nutrients content and risks of toxicity of dry faecal sludge (DFS) from faecal treatment plants for their farther use as fertilizer amendments in farming systems in Burkina Faso.

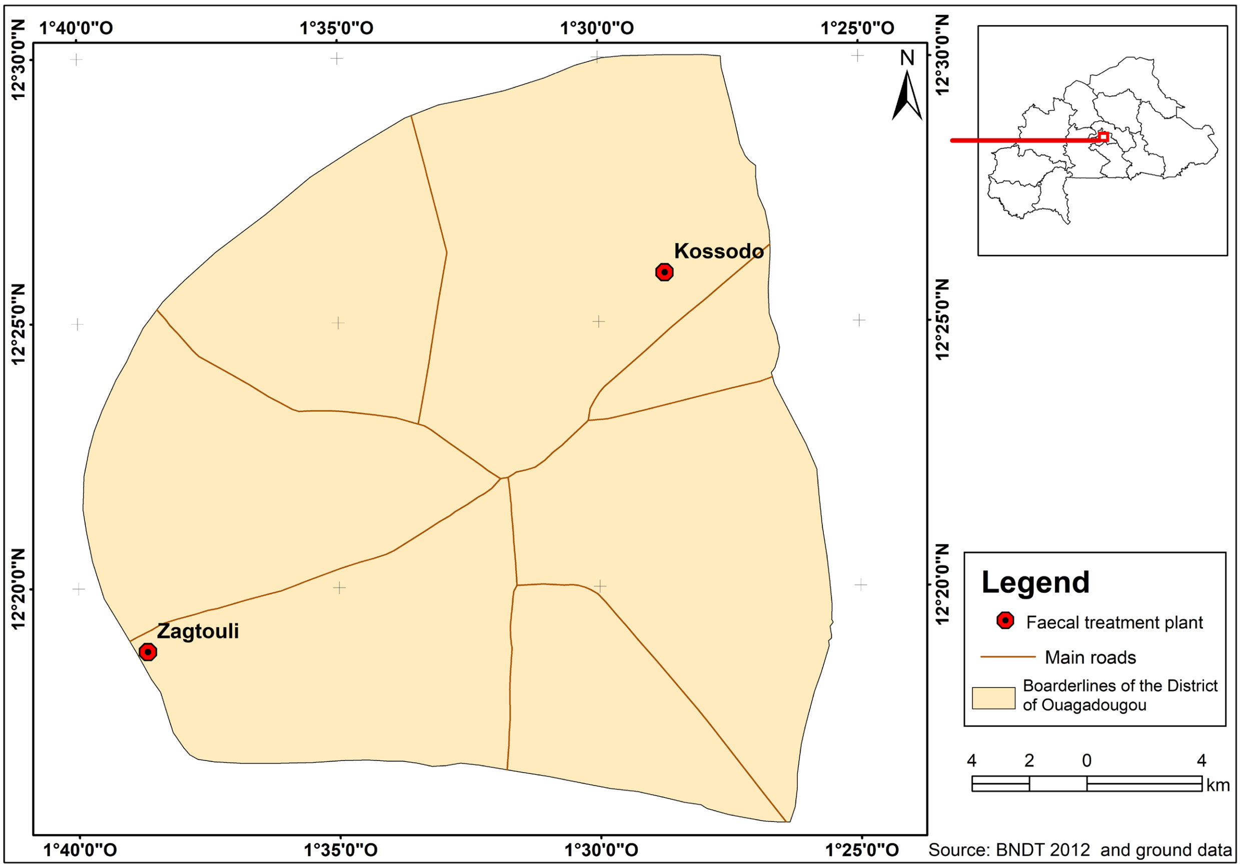
2. Material and Methods

2.1. Sites Description of the Faecal Treatment Plants

Samples of dry faecal sludge (DFS) were collected in four (4) faecal treatment plants in Burkina Faso. These faecal treatment plants were located in two administrative Regions: the Région du Centre and the Région des Hauts Bassins. For Région du Centre, samples were collected in Kossodo (12˚20'60"N et 1˚31'0.00"W) and Zagtouli (12˚19'46"N et 1˚37'31"W) (**Figure 1**) in Ouagadougou and in Sourgoubila (12˚25'3"N et 1˚48'25"W) (**Figure 2**). For Région des Hauts Bassins, sample collection concerned the faecal treatment plant of Dogona (11˚12'17.1"N et 4˚16'49.3"W), in Bobo Dioulasso (**Figure 3**). The faecal treatment plant of Zagtouli (**Figure 1**) was established since October 2014. Its main use is the treatment of faecal sludge and wastewater from the domestic and autonomous sanitation infrastructures. The faecal treatment plant includes 48 drying beds measuring 16 m × 8 m and with a useful volume of 64 m^3 each [11]. In the drying beds, the drying process of the DFS takes two to three weeks. Concerning the faecal treatment plants of Kossodo, it is located near the industrial zone of Ouagadougou. It includes eight (8) lagunage bassins with an estimated capacity of 180,000 m^3 [11]. Functional since 2016, the station of Sourgoubila has 40 drying beds with and estimated daily capacity 130 m^3. At Dogona, the faecal treatment plants include 60 drying beds with an estimated capacity of 250 m^3/day [6].

2.2. Description of the Dry Faecal Sludge

The dry faecal sludge (DFS) were collected from above described four (4) faecal



Source: BNDT 2012 and ground data

Figure 1. Faecal treatment plants of Kossodo and Zagtouli in the district of Ouagadougou.

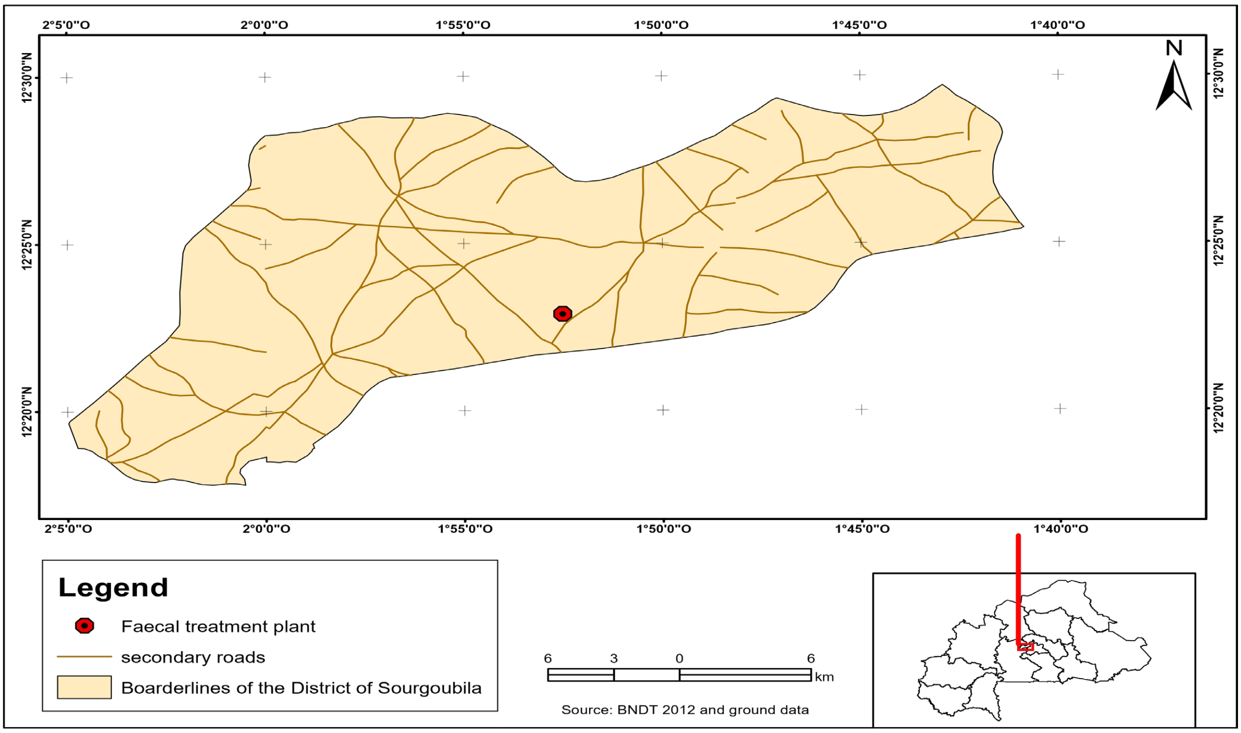


Figure 2. Faecal treatment plant of Sourgoubila in the district of Sourgoubila.

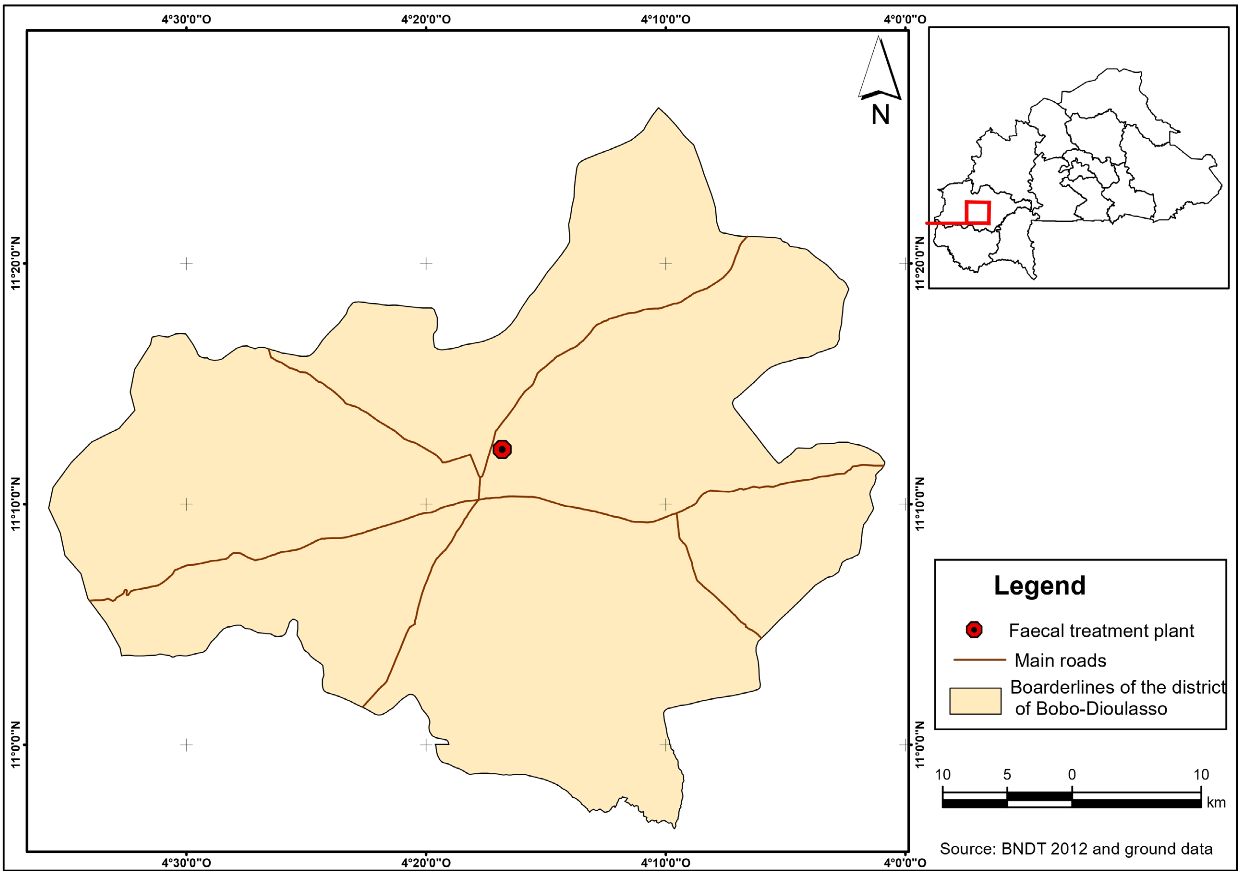


Figure 3. Faecal treatment plant of Dogona in the district of Bobo Dioulasso.

treatment plants. The faecal sludges were processed in non-planted drying beds for 21 - 30 days, period for which the moisture content of the substrate was 20% - 30%. After the drying process, the dry faecal sludge were removed and stored without any farther treatments.

2.3. Sampling Process of Dry Faecal Sludge

The dry faecal sludge (DFS) were classified in three (3) groups in each faecal treatment plants. The samples collected in each site were ranked as follow: "Old" DFS with storage period longer (3 years) at least; "Intermediate" DFS storage period to three (3) years; and the "Recent" DFS with storage period lower than two (2) years. In each class of DFS, samples were collected at three (3) locations at the center and the two (2) extremities of the heaps of faecal sludge. For each sampling point the faecal sludge were collected at different depth from the surface to the bottom of the heaps and thoroughly mixed up in composite sample. A mesure of 200 g of theses composite-samples were brought to laboratory for the different analyses. In total, 36 DFS samples were collected from 4 faecal treatment plants.

2.4. Determination of Physical Parameters of the Dry Faecal Sludge

The dry faecal sludge (DFS) collected was subjected to manual storing in order to remove all non-organic impurities (plastic bags, iron, stones and any other non-biodegradable solid elements). The sludge was then oven dried in at 120˚C for one (1) hour before performing the different analyses.

2.5. Determination of the Chemical Parameters

Chemical analyses were conducted according to Walinga [14]. The pH_{H2O} was measured according to ISO 10390 standards in a solution of sludge/water in the ratio 1/5 [15]. The solution (sludge/water) was stirred for 10 minutes and left for 30 minutes before measuring the pH using a glass electrode pH meter. The same solution was used for the determination of the electrical conductivity using a GLP 21 Grison conductivity meter equipped with a glass electrode according to the method described by [16] [17]. The organic matter content of the sludge was determined by the calcination method [18]. Coming to the process, the sludge samples were heated to 550˚C in an oven for five hours; and their organic matter content determined by the formula (1):

$$\text{OM} = \left(M_0 - M_1\right)/M_0 \tag{1}$$

with M_0 and M_1 the respective masses of the dried faecal sludge before and after calcination. The organic carbon content was deduced according to the formula (2):

$$\text{CO} = M_0/2 \quad [19]. \tag{2}$$

For the determination of nutrients content major elements: (Nitrogen, phosphorus and potassium) and total elements (calcium and magnesium) were measured, for the process, the sludge samples were mineralized by a mixture of H_2SO_4-Se-H_2O_2 for four hours. Then the N and P contents were determined by the colorimetric measurement method for P [18] and by near infrared spectrometry for C (ISO 10694) [20]. Finally, the K, Ca and Mg contents were determined using a flame atomic absorption spectrophotometer [21]. The C/N ratio was calculated from the results of carbon and nitrogen.

2.6. Determination of Dry Faecal Sludge Content in Metallic Trace Elements

The metallic trace elements (TME) measured in the dry faecal sludge (DFS) were: copper (Cu), zinc (Zn), lead (Pb), chromium (Cr), nickel (Ni) and cadmium (Cd). Concentrations of different TME were determined using Atomic absorption spectrometer ECL-AAS-4141 [22]. For each class of dry faecal sludge, one (1) g of a forehand dry sample at 105˚C for 24 hours was grounded before putting it in an Erlenmeyer flask of 250 ml. Once in the flask, the sample was digested using nitric acid and perchloric acid according to the ratio (3:1). The mixture was kept in a water bath, this operation was followed by adding 3 to 4 drops of hydrogen peroxide H_2O_2 (30%) in order to neutralize and dissolve the fat. After cooling, each sample was dissolved by adjusting its volume to 10 mL using denatured water and, the mixture was transferred to a disinfected glass vial and stored at room temperature for one hour before measuring heavy metal contains. The spectrophotometer was initially calibrated for each metal. The different concentrations of the targeted heavy metals were analyzed by atomic absorption spectrophotometry in the furnace and in the graphite flame.

3. Results

3.1. Origin of Dried Faecal Sludge from Plants

The dry faecal sludge (DFS) used for the investigation reported herein were from various origins; indeed, the stations of Dogona, Kossodo, Sourgoubila and Zagtouli receive in their drying beds sludge from the faecal collection pits and cesspools of households in Ouagadougou and Bobo Dioulasso, the faecal collection pits and cesspools were mechanically emptied by tank trucks with 3.5 m^3 to 16 m^3 of capacity. This diversified origin of the sludge imposes at each station the need to process the leachate after lagooning downstream of the beds.

3.2. Chemical Characteristics of Dry Faecal Sludges

The results of the determination of the chemical parameters of the DFS showed that the origins (faecal treatment plants) and the storage time led to variabilities. Indeed, indifferently to the faecal treatment plants, the pH (H_2O) of the DFS varied from 4.85 ± 0.13 to 6.53 ± 0.10. Regarding the class of "*Recent*" sludge for all the four faecal treatment plants, the highest acidity (pH (H_2O) = 5.16 ± 0.05) was recorded at the Kossodo station (**Table 1**) and the lowest acidity (pH (H_2O) = 6.53 ± 0.10) at the Dogona station (**Table 2**).

Concerning the "old" DFS, their acidity was relatively low (pH (H_2O) = 5.96 ± 0.45) for the Dogona station compared to the Sourgoubila site (pH (H_2O) = 4.85 ± 0.13) (Table 3). The overall trend from the four faecal treatment plants shows acidification of the DFS when storage time increased. For the "intermediate" DFS, the lowest acidity was recorded at Dogona (pH (H_2O) = 5.59 ± 0.38) and the strongest ones at the faecal treatment plants of Zagtouli (pH (H_2O) = 4.96 ± 0.13) (Table 4).

Table 1. Physico-chemical composition of dry faecal sludge (DFS) of the faecal treatment plant of Kossodo.

Storage time	**ST > 3 years**	**2 ≤ ST < 3 years**	**ST < 2 years**
parameters	"old" DFS	"intermediate" DFS	"recent" DFS
pH (H_2O)	4.95 ± 0.31	5.01 ± 0.28	5.16 ± 0.05
CE (mS/cm)	2.30 ± 0.51	3.51 ± 0.24	2.64 ± 0.52
CO (%)	13.64 ± 3.75	12.83 ± 3.96	17.79 ± 0.91
MO (%)	23.52 ± 6.46	22.12 ± 6.83	30.66 ± 1.58
N-t (%)	1.21 ± 0.36	1.08 ± 0.37	1.46 ± 0.11
C/N	11.34 ± 0.49	12.06 ± 1.11	12.17 ± 0.60
P-t (mg/kg)	12,603.90 ± 1847.90	12,922.95 ± 1155.06	13,476.13 ± 2882.28
K-t (mg/Kg)	556.22 ± 71.68	576.13 ± 189.23	704.72 ± 113.15
Na (mg/Kg)	152.31 ± 44.99	169.69 ± 61.43	148.90 ± 27.76
Ca (mg/Kg)	3680.58 ± 665.33	3931.76 ± 741.89	4702.55 ± 502.39
Mg (mg/kg)	2012.57 ± 597.70	1425.57 ± 87.61	1503.04 ± 400.78

Table 2. Physico-chemical composition of dry faecal sludge (DFS) of the faecal treatment plant of Dogona.

Storage duration	**ST > 3 years**	**2 ≤ ST< 3 years**	**ST < 2 years**
Parameters	"old" DFS	"intermediate" DFS	"recent" DFS
pH (H_2O)	5.96 ± 0.45	5.59 ± 0.38	6.53 ± 0.10
EC (mS/cm)	6.23 ± 1.38	5.76 ± 0.79	4.17 ± 0.49
CO (%)	23.76 ± 5.80	14.70 ± 0.05	17.71 ± 2.29
MO (%)	40.97 ± 9.99	25.34 ± 0.09	30.52 ± 3.95
N-t (%)	2.22 ± 0.56	1.47 ± 0.07	1.70 ± 0.16
C/N	10.74 ± 0.11	10.02 ± 0.47	10.41 ± 0.69
P-t (mg/kg)	14,234.32 ± 3442.41	11,761.33 ± 1533.33	8595.24 ± 281.33
K-t (mg/Kg)	781.34 ± 33.07	519.40 ± 31.16	902.37 ± 38.98
Na (mg/Kg)	103.34 ± 15.78	119.56 ± 16.12	652.88 ± 119.32
Ca (mg/Kg)	8978.98 ± 2798.18	4118.16 ± 409.50	5350.92 ± 70.13
Mg (mg/kg)	2432.56 ± 35.55	2579.55 ± 1661.59	2467.39 ± 78.02

Table 3. Physico-chemical composition of dried faecal sludge from Sourgoubila.

Storage duration	SD > 3 years	2 ≤ SD < 3 years	SD < 2 years
Parameters	"old" DFS	"intermediate" DFS	"recent" DFS
pH (H_2O)	4.85 ± 0.13	5.24 ± 0.60	5.83 ± 0.16
EC (mS/cm)	6.55 ± 0.06	2.50 ± 0.42	3.92 ± 1.12
CO (%)	19.07 ± 5.18	21.86 ± 0.92	24.17 ± 2.52
MO (%)	32.88 ± 8.93	37.68 ± 1.59	41.68 ± 4.34
N-t (%)	1.62 ± 0.51	1.83 ± 0.15	2.11 ± 0.31
C/N	11.89 ± 0.64	11.98 ± 0.44	11.53 ± 0.61
P-t (mg/kg)	14,516.26 ± 2408.43	17,693.63 ± 1178.07	18,687.55 ± 1570.68
K-t (mg/Kg)	660.58 ± 114.56	891.51 ± 122.25	1469.46 ± 1110.16
Na (mg/Kg)	58.34 ± 39.02	159.16 ± 69.24	389.94 ± 288.77
Ca (mg/Kg)	4659.90 ± 856.61	6415.95 ± 1127.03	6839.61 ± 1521.90
Mg (mg/kg)	1706.97 ± 264.97	1933.64 ± 608.00	2894.92 ± 329.88

Table 4. Physico-chemical composition of dried sewage sludge from Zagtouli.

Storage duration	SD > 3 years	2 ≤ SD< 3 years	SD < 2 years
Parameters	"old" DFS	"intermediate" DFS	"recent" DFS
pH (H_2O)	4.93 ± 0.21	4.96 ± 0.13	5.77 ± 0.06
EC (mS/cm)	2.66 ± 0.25	3.67 ± 0.32	5.01 ± 1.03
CO (%)	14.38 ± 3.22	17.35 ± 0.51	18.13 ± 3.17
MO (%)	24.79 ± 5.55	29.91 ± 0.88	31.25 ± 5.47
N-t (%)	1.46 ± 0.07	1.85 ± 0.06	1.80 ± 0.33
C/N	9.79 ± 1.81	9.37 ± 0.33	10.07 ± 0.74
P-t (mg/kg)	18,027.34 ± 1436.19	18,119.28 ± 1011.93	15,343.85 ± 1188.32
K-t (mg/Kg)	616.77 ± 104.35	739.83 ± 14.68	1462.68 ± 1139.34
Na (mg/Kg)	69.31 ± 15.22	80.31 ± 43.32	438.86 ± 179.31
Ca (mg/Kg)	4641.98 ± 552.68	5428.60 ± 73.59	5846.85 ± 774.26
Mg (mg/kg)	1841.89 ± 70.34	2176.42 ± 286.64	2649.79 ± 682.55

3.3. Variation in the Organic Matter Content of DFS with Storage Duration

Organic matter (OM) contained in the DFS varied according to the faecal treatment plants and on the same faecal treatment plants according to the storage time. Of all the stations, for recent sludge, the highest OM content (41.68% ± 4.34%) was recorded at Sourgoubila and the lowest (30.52% ± 3.95%) at Dogona (Figure 3). Regarding "intermediate" DFS, the highest OM content (37.68% ± 1.59%) was recorded at the Sourgoubila station and the lowest (22.12% ± 6.83%) at Kossodo. For the "old" DFS, the station of Dogona recorded the highest OM content (40.97% ± 9.99%), and the lowest ones observed at the station of Kossodo (23.52% ± 6.46%). Within each station, with the exception of Dogona, a drop in OM content was observed when moving from the class of recent sludge to that of old sludge. In fact, from the class of recent sludge to that of intermediate sludge, the OM contents fell by (−7.14%); (−8.8%) and (−6.46%), respectively for the stations of Kossodo, Sourgoubila and Zagtouli (**Figure 3**). On the other hand, an increase in the OM content of 10.45% was observed at the Dogona station for the same classes of sludge (**Figure 3**). Except the faecal treatment plants of Dogona, a global decrease in organic matter content of the DFS was recorded from the "recent" DFS to the "old" ones. In fact, from the "recent" DFS to the "intermediate" ones, the OM contents droped by (−7.14%); (−8.8%) and (−6.46%), respectively for Kossodo, Sourgoubila and Zagtouli faecal treatment plants (**Figure 4**). However, an increase in the OM content of 10.45% was observed at the Dogona station for the same DFS classes (**Figure 4**).

3.4. Major Nutrients Contained in the Sludge as Affected by the Storage Duration

The general trend of the major elements (N, P and K) contained in the sludge as well as their biodegradability (C/N) varied according to the stations in one hand and the storage time in the same station in the other hand. As for nitrogen, on all four sites and in the class of "recent" sludge, the highest total nitrogen content was recorded in Sourgoubila (2.11% ± 0.31%) and the lowest in Kossodo (1.46% ± 0.11%) (**Table 3**). In the "intermediate" sludge class, the highest content in total nitrogen (1.85% ± 0.06%) was recorded in the faecal treatment plant of Zagtouli and the one of Kossodo had lowest content of total nitrogen (1.08% ± 0.37%). In the "old" sludge class, the station of Dogona had the highest total nitrogen content (2.22% ± 0.56%) and the lowest one at Kossodo (1.21% ± 0.36%).

Concerning the total phosphorus content of the dry faecal sludge, the highest value was recorded in the faecal treatment plant of Sourgoubila (18687.55 ± 1570.68 mg/kg), followed by the station of Dogona (11761.33 ± 1533.33 mg/kg) and Zagtouli (18027.34 ± 1436 .19 mg/kg) respectively for "recent", "intermediate" and "old" dry faecal sludge. As for the lowest phosphorus contents, they were recorded at Dogona (8595.24 ± 281.33 mg/kg and 11761.33 ± 1533.33 mg/kg) and Kossodo (12603.90 ± 1847.90 mg/kg) respectively for "recent", "intermediate" and "old" sludges. The global trend of total phosphorus contained in the dry faecal sludge showed an accumulation of total phosphorus with the storage time.

For the total potassium contained in the "recent" dry faecal sludge, the highest content (1469.46 ± 110.16 mg/kg) was measured in the station of Sourgoubila and the lowest one (704.72 ± 113.15 mg/kg) at Kossodo. Concerning the "intermediate" sludge, the highest potassium content was observed in the station Sourgoubila and the lowest content in the station of Dogona with respective values of (891.51 ± 122.25 mg/kg) and (519.40 ± 101.16 mg/kg). For the "old" sludge, Sourgoubila had the highest phosphorus content (660.58 ± 114.56 mg/kg) and the lowest in Kossodo (556.22 ± 71.68 mg/kg). The overall trend shows that the total potassium content of the sludge decreases with storage duration.

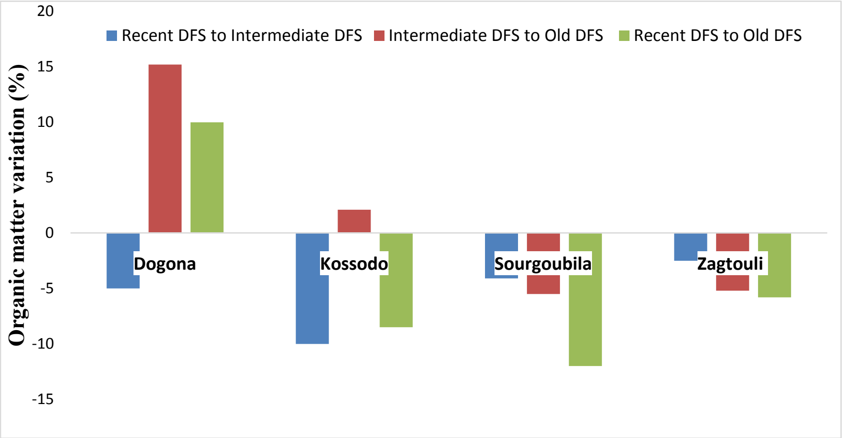


Figure 4. Variation of organic matter content between the classes of dry faecal sludge (DFS) in the different faecal treatment plants.

3.5. Variation of Calcium and Magnesium Contained in the Sludge as Affected by the Storage Duration

The overall trend showed a decrease in calcium and magnesium contained in dried faecal sludge (DFS) with the duration of storage. Thus, the recently stored dried faecal sludge/"recent" DFS had higher contents of these elements compared to the formerly sore ones/"old" DFS. Indeed, drops (−21.74%); (−31.87%) and (−20.60%) in the calcium contained in the sludges were recorded respectively on the faecal treatment plants of Kossodo, Sourgoubila and Zagtouli. However, in the station Dogona an increase of (+67.80%) was observed. The magnesium content of the sludge, was between 1503.04 ± 400.78 mg/kg and 2894.92 ± 329.88 mg/kg, dropped for all the stations except Kossodo where an increase of (+33.90%) has been recorded. Despite these drops observed during their storage, the calcium and magnesium contents of the sludge remain higher than the standard norms for agricultural use.

The C/N ratio indicating the biodegradability of DFS varied from one station to another and according to the storage duration of the sludge on the same station. However, this ratio remained strictly below 15. Indeed, in the station of Kossodo had the highest C/N ratio (12.17 ± 0.60) and the one of Zagtouli the lowest (10.07 ± 0.74), as regards the class of "recent" DFS. In relation to the duration of the storage, in the "intermediate" DFS, the highest C/N ratio is observed at the Kossodo station (12.06 ± 1.11) and the lowest at Zagtouli (9.37 ± 0.33). The highest C/N ratio is recorded in the station of Sourgoubila (11.89 ± 0.64) and the lowest at Zagtouli (9.79 ± 1.81), for "old" sludge. The lowest C/N ratios are recorded in the station of Zagtouli station regardless of the DFS storage time. The electrical conductivity varied between 2.64 ± 0.52 mS/cm and 5.01 ± 1.03 mS/cm on all four stations while remaining above 1 mS which is the sludge discharge standard from raw drain [11].

3.6. Trace Metallic Elements Contained in the Dry Faecal Sludge

The copper, zinc, lead, cadmium, nickel and chromium contained in the DFS showed that there were no risk of pollution when used for amendment of agricultural soils. In fact, the levels of the six heavy metals in the DFS comply with the standards recommended for their agricultural use (**Table 5**). Nevertheless, variations in the content of these elements were observed at all four stations. Thus, the lowest content in copper, zinc, nickel and chromium were recorded in DFS of the station of Dogona and the highest ones in the station of Kossodo. The lead content was higher in the station of Sourgoubila (152.40 ± 19.40) mg/kg and the lowest content at Dogona (33.03 ± 1.65) mg/kg.

For cadmium, Sourgoubila station recorded the lowest level (1.34 ± 0.17) mg/kg and Kossodo station the highest level (1.76 ± 0.04) mg/kg. With the exception of cadmium, the lowest levels of heavy metals in the sludge were observed at Dogona plant, while remaining below the standards for agricultural use of dry faecal sludge (DFS).

4. Discussion

4.1. Physicochemical Parameters of the Dry Faecal Sludges as Affected by Storage Duration

The physico-chemical analyses revealed a strong acidity of the dry feacal sludge (DFS) of the four (4) investigated sites regardless of their storage time. The strong acidity of the DFS observed and the increase of their acidity in the different stations when storage takes longer time could be explained by the heaping up of the sludge without any aeration system. Indeed, in anaerobic conditions, the partial oxidation of organic matter induces acidification due to the production of organic acids deriving from the degradation of simple sugars and the production of CO_2 [24] [25]. In the storage and processing conditions of the DFS on the investigated sites, the different classes of the DFS were piled up; resulting in to creation of limited aeration, favorable conditions to induce acidification. The low cation (Ca^{2+} and Mg^{2+}) contained in the DFS can be due to an intrinsic poor content of faecal sludge these elements. Also, since the DFS are stored without protection any against rain water, the cations (Ca^{2+} and Mg^{2+}) that they contained are subject to leaching. That is why the content of the DFS in Ca^{2+} and Mg^{2+} decreased with storage when the time lasted, resulting in progressive acidification of the DFS. Another reason why acidification took place in the DFS with storage time is that a decrease of their content in Ca^{2+} and Mg^{2+} leads to a decrease in the saturation rate of the DFS and an increase in the exchangeable aluminum content, leading to acidification [26] [27]. This analysis was confirmed by the decreasing trend of the Ca^{2+} and Mg^{2+} and the drop of pH_{H2O} from the "recent" to the "old" DFS. These results showed that the issue of acidity of the DFS has to be solved before any use of it for sustainable soil fertility management in agriculture. Indeed, due to their acidity, the application of raw dry faecal sludges could lead soil acidification while compromising long-term agricultural productivity by inhibiting the microbial activity of the soil on the one hand, and on the other hand by the accumulation of aluminum above the tolerate content

Table 5. Trace metallique elements contained in Dry feacal sludge in the different feacal treatment plants.

TME	Feacal treatment plant of				
	Dogona	Kossodo	Sourgoubila	Zagtouli	Standards of agricultural use [23]
Cu (mg/kg)	103.9 ± 2.00	137 ± 25.69	106.5 ± 1.20	121.7 ± 5.70	1750
Zn (mg/kg)	714.83 ± 15.2	922.30 ± 7.04	710.13 ± 18.97	870 ± 18.60	4000
Pb (mg/kg)	33.03 ± 1.65	39.32 ± 3.80	152.40 ± 19.40	34.79 ± 0.66	1200
Cd (mg/kg)	1.46 ± 0.11	1.76 ± 0.04	1.34 ± 0.17	1.60 ± 0.11	40
Ni (mg/kg)	34.34 ± 0.27	52.32 ± 3.60	35.83 ± 3.03	38.016 ± 2.28	400
Cr (mg/kg)	771.15 ± 18.36	1697.83 ± 55.11	840.67 ± 12.91	1253 ± 22.67	1750

for plants growth [28]. These results are in line with those of [10] and [29] which showed that, regardless of their storage time, faecal sludge is too acidic to be applied directly as an organic amendment in agricultural production.

The electrical conductivity (CE), indicator of the salinity of the DFS, showed increasing trends when the storage time of the DFS lasted regardless of the site. With the EC values between 2.64 ± 0.52 mS/cm and 6.23 ± 1.38 mS/cm on the four (4) stations, the salinity of the DFS are above the recommended standards (1mS/cm) for agricultural use c. The high salinity observed would be related to the release and/or accumulation of dissolved salts (K^+ and Na^+) during the mineralization process of the organic matter of the piled-up sludges. Tadjouwa [8], on planted and non-planted drying beds for a period of six months, showed an increase in the salinity of the dried faecal sludge with EC values lower than those recorded in the present study. Confirming that the storage time is an inducing factor DFS salinity. The results reported herein are also online with those of [10] which revealed a strong salinity of the faecal sludge discharged from the feacal treatment plant of Zagtouli. As shown by the results on the EC, the high salinity of the DFS is a serious limitation for their direct use as substrate for soil amendment in agriculture. Indeed, if directly used without any forehand processing the DFS can induce soil clogging and disruption of the bacterial ecosystem and dysfunction of ion pumps [30].

Despite the constraints linked to the direct use of this sewage sludge to amend soils (high acidity and electrical conductivity), its present a good trophic balance ratio (C/N). Indeed, the C/N ratio of dry fecal sludge ranged from 9.79 ± 1.81 to 12.17 ± 0.60 at all plants. The low values of the C/N ratio would be attributable to the high mineral nitrogen content of the sludge due to the mineralization of the organic matter and the origin of the sludge. Indeed, the strong mineralization of the organic matter would have favored the important production of mineral nitrogen and a consumption of carbon, explaining the low ratios C/N. In addition, the sludge used came from sewage systems such as septic tanks and public toilets that regularly receive urine that is very rich in nitrogen. According to [31] and [32], sanitation by-products are rich in nutrients (N, P, K), which are necessary for plants. Seen from the perspective of mineralization potential, these results show that dry sewage sludge are in the favorable range (15 and 10) for agricultural valorization [24] [28] [33].

A high variability in the trace metallic elements (TME) contained in the sludge was recorded between the four stations. Despite this variability, the DFS content in the TME: copper, zinc, lead, cadmium, nickel and chromium were favorable for their use as amendments in crops production. The low TME contained in the sludge compared to the standards authorized for agricultural use, can be explained by the origin and nature of the components of the sludge on the one hand and on the other hand, by the characteristics of the faecal treatment plants (depth of the basins, presence or absence of screens), the processing techniques and storage conditions for sludge after removing it from the drying beds. Indeed, the very diversified diet of the populations related to their geographical location and living standard, influence the physico-chemical quality of the faecal sludge and for sure its contents in TME.

In addition, reasons outlined above, the faecal treatment plants did not have the same procedures for the pre-treatment and treatment of faecal sludge. At the station of Zagtouli and Dogona screens were used to prevent the entry of coarse and bulky waste (solid waste) into the drying basins. The other stations did not have this disposal. Also, the dimensions (length, width and useful volume) of the basins and the storage time of the sludge in the drying beds differ from one site to another. The storage time of the sludge in the drying beds before removing the dry sludge was two to three weeks depending on the site; as for the depth of the settling basins, it varied between 1 and 1.5 m. All these above outlined differences could explain why high variability was observed in TME contained in DFS.

According to [33] and [34], the dry faecal sludge TME contained in organic substrats such as dry feacal sludges depend strongly to their origin; and that most often their content in TME meet the standards for their valorization as fertilizer amendments. However, [35] outlined that the sludge can have quite high levels of TME which will decrease over time, depending on the processing and the storage conditions of the dry feacal sludge. They have shown a large decrease in the lead and zinc content during storage or co-composting with domestic. They have related the decrease on these TME to the mineralization of soluble non-humic substances (polysaccharides, peptides and amino acids, etc).

4.2. Biological Parameters of the Dry Faecal Sludges as Affected by Storage Duration

From a faecal treatment plant to another, a high variability in organic matter contained in the dry faecal sludge (DFS) has been recorded. Also, the storage duration led to the decrease of OM contained in the dry faecal sludge on most of the investigated sites. Indeed, from the “recent” DFS to that of “intermediate” DFS, a drop in OM content of (−5.18%); (−8.54%); (−4%) and (−1.34%) was recorded respectively for the stations of Dogona, Kossodo, Sourgoubila and Zagtouli. From the "intermediate" DFS to the "old" DFS, the drops were more significant (−23.28%); (−21.11%) and (−20.67%), respectively for the stations of Kossodo, Sourgoubila and Zagtouli. Unlike the other stations an increase of +25.50% was recorded at Dogona. The decrease in the organic matter content of the DFS is due the mineralization of organic substrates which a normal process. However, the process is speedup by the climatic factors such as temperature, rain water, which plays a catalytic role. Indeed, in the stations where drops in OM contained in the DFS were recorded are located in the central part of the country where temperatures are generally the highest. The temperatures of the area would have led to a rapid mineralization of OM by stimulation of microbial activity, and subsequently caused a drop in the OM content of the sludge According to [6] [10], temperature is an important factor in reducing the organic charges faecal sludge because it stimulates mineralization process. The microbial activity responsible for the evolution of organic matter depends on external factors such as water pH, humidity and the level of aeration [27]. However, our results showed that organic matter in the DFS did not decrease during storage at the Dogona station despite its favorable pH_{H2O} for good mineralization of organic matter, compared to the other three stations. This trend of the mineralization of OM in the DFS is probably due to their origin. Indeed, the very diverse origin of the DFS from the Dogona station would have slowdown effects on the mineralization of the organic matter of in the DFS. According to [6], the DFS treated at the Dogona plant is very heterogeneous in terms of origin and original substrates. Indeed, DFS is mixed with liquid discharges from industrial units (breweries, oil mills, etc.) and slaughterhouses. The addition of these liquid discharges could explain the increase in the OM content of the DFS regardless of the storage duration.

5. Conclusions

For sanity and environmental reasons, dry faecal sludge recycling through compost in Bukina Faso has to be addressed in a sustainable manner. It is why the investigation carried out herein has been conducted. The results on the physicochemical characteristics of the dry feacal sludges showed a good potential for their use as fertilizer amendments for agricultural use view to their high nutrients content; their content in heavy metal was also in line for their use for agricultural purposes. However, the results showed strong acidity of the dry faecal sludge indifferently to their storage time and their origin (dry faecal sludge treatment plants), showing that these limitations have to be addressed for their sustainable use as fertilizer amendment in the context of Burkina Faso. Therefore, further investigation is needed in order to address these issues.

In addition, these results must be supplemented by a microbiological characterization in order to determine the risks of contamination with pathogenic agents in dried faecal sludge before any large scale treatments and use of dry faecal sludge fertilizer amendment.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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