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Evaluation of the Fertilizing Power of Sludge from Physicochemical Water Purification Stations: Case of the Yato Station, Littoral-Cameroon

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Abstract

The Yato physicochemical water purification station is located in the commune of Dibombari in the Littoral-Cameroon region. It is one of the largest drinking water production stations in the Central African sub-region. This work aims to evaluate the agronomic power of the sludge from this drinking water production station. To achieve this objective, mixed samples of sludge from sludge treatment basins (taken according to the technique described in GIDS-A003 point 6 as explained in the Solid and pasty waste sampling strategy of the Code of Good Practice No. 2). and primary settling basins (collected in transparent 1.5L polyethylene terephthalate bottles) were analyzed. Likewise, three soil samples (marsh, Point 1 and Point 2) were taken and then sent to the laboratory where physicochemical analyzes were carried out. The characteristics of the samples that were analyzed are: particle size, texture (sand, silt, clay) and physicochemistry (organic matter, CEC, sum of exchangeable bases, calcium, nitrogen, potassium and magnesium). The results obtained show that the soils exposed to contamination from the sludge of the station have better agronomic properties both on a physical level with a stable structure favorable to plant growth and good aeration unlike the soils far from the station which presented a high risk. degradation; that on the chemical level with an optimal cationic balance, a high reserve of exchangeable bases, a strong CEC but average limitations in assimilable phosphorus and pH unlike the soil far from the station which presented an insufficiency of potassium which did not facilitate a balance cationic, a low CEC but a pH above 5.5 which is the value recommended in agronomy. Biochemically, organic matter is above 2% in all soils, a mineralization rate less than 20 favoring the rapid mineralization of carbon and a release of nitrogen available to the plant. These results obtained allow us to conclude that the sludge from the Yato station can be used in agronomy as an organic fertilizer in order to correct the soil structure, the CEC, the cationic balances and also provide the soil with a good base reserve. However, treating this sludge with lime could regulate the pH of the soil and reduce the mobility of heavy metals in the soil.

Keywords

Yato, Sludge, Fertilizing Power, Polluting, Drinking Water

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1. Introduction

Access to drinking water throughout the world has become a major issue for development and human health. There are an estimated 1.1 billion people without adequate access to drinking water and 2.6 billion people without basic sanitation in the world [47]. Guaranteeing equitable access for all to drinking water and sanitation and ensuring good management of water resources (Sustainable Development Goal No. 6 – SDG6) is becoming fundamental to ensuring global development. Furthermore, the strong demographic growth experienced by developing countries and their difficult economic conditions lead to accelerated urbanization which increases the demand for water. It's from the perspective of improving the situation that the Cameroonian Government had undertaken, between 2005 and 2008, a profound restructuring of the sector and the preparation of a medium-term intervention plan in particular with the Drinking Water Supply and Sanitation (DWS) project in semi-urban areas in 19 municipalities. Likewise, the Drinking Water Supply Project for Yaounde and its Surroundings (DWSPYS) from the Sanaga River is part of the same movement. The increase in the number of drinking water production infrastructures does not come without its share of problems, in this case the production of waste such as waste sludge. On the one hand, sewage sludge is harmful to the environment, but on the other hand, it can be used as fertilizer in organic agriculture [3, 45]. Generally, this sludge has physicochemical properties which give it a certain fertility, making it suitable for use as an agricultural amendment. The growth in agricultural production has accelerated in recent years thanks to numerous innovations focused on organic farming. This agriculture promotes the use of fertilizers of natural origin such as sludge from water treatment processes. They are rich in calcium, phosphorus, nitrogen and organic matter. [35]. The use of treated sludge in agriculture can significantly reduce the cost of disposal, protect the environment, reduce prices compared to commercial fertilizers, offer essential nutrients to plants and increase soil fertility [14]. Organic additions are necessary to improve soil fertility and productivity in drylands due to the low concentration of organic matter [43]. Urban sludge can improve the organic matter levels of agricultural soils, thereby promoting plant growth and reducing the volume of sewage sludge produced. At the same time, the presence of metallic trace elements in this sludge poses a phytotoxicity problem for widely consumed plants. According to [35], the increase in Trace Metal Elements (TMEs) levels available in soils is accompanied by an increase in total TME levels in plants. However, treated and carefully controlled, sludge replaces synthetic fertilizers for farmers, thus becoming a renewable and local resource. [38]. Therefore, the aim of this work is to show the fertilizing power of the station's treatment sludge for use in agronomy as a biological fertilizer.

2. Location of the Study Area

Yato in the commune of Dibombari, Littoral region, is located in the Moungo plain on national road No. 3, 19 km from the municipal capital. The study area extends between the northern parallels 4°15'32" to 4°9'12" of northern latitude and the eastern meridians 9°33'31" to 9°55'87" of East longitude with an average altitude: 24 meters [40].
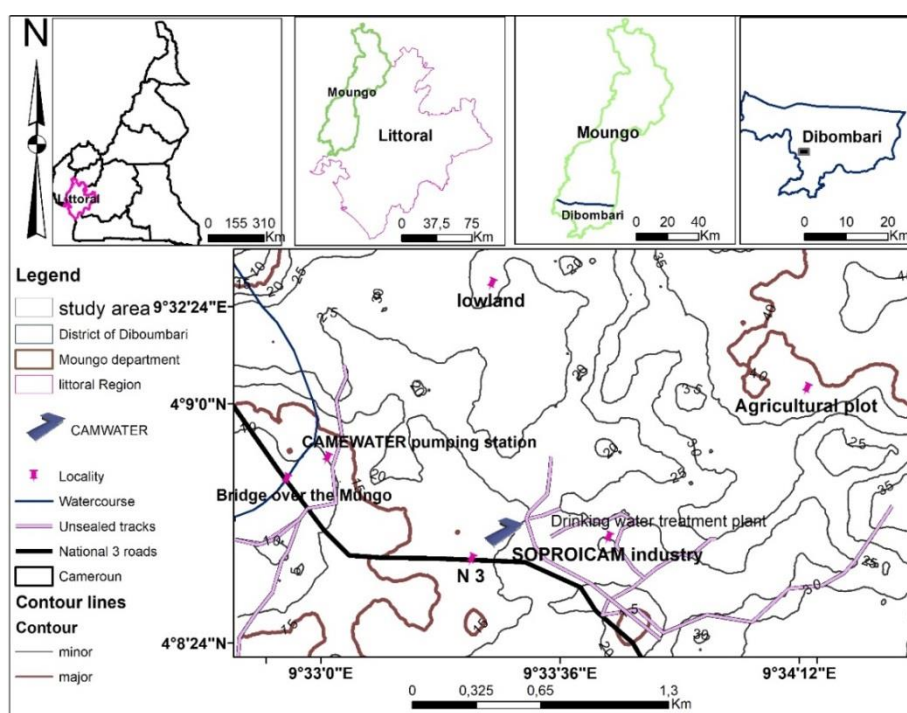

Figure 1. Study area location map.

The Yato station is a drinking water production station located approximately 20 km from Douala (figure 1). The company CAMWATER (Cameroon Water Utilities) has been capturing water from the Moungo which it treats to distribute to the surrounding populations as well as those of Douala and its surroundings for almost 15 years. The company's activities generate sludge which it deposits in treatment basins for a period. This sludge will be found at the level of the marshy lowlands thanks to the draining of water from washing structures, or from the cleaning of the treatment basins where it will interact with the environment, especially the soils.

Physical Setting

The climate of Moungo is humid coastal equatorial type, influenced by the proximity of the sea. There are two main seasons: a long rainy season of around 9 months (March to November) and a relatively short dry season of around 3 months (December to February) [12]. In Yato locality, average total precipitation ranges from 32.6 to 352.7 mm. The average total temperatures range from 24.4 to 27.7 ℃ (TIKO weather station 23 km from Yato). The geology and morphology of Moungo are quite complex and the combination between the two makes it possible to define fairly well characterized natural regions [29]. According to Delvaux (1988) cited by Bon (2011), the Moungo area has been subject to several significant fault movements. Pedology presents a diversity marked by the dominance of ferralitic soils, hydromorphic soils and poorly evolved soils [20]. Among the ferralitic soils, we note the dominance of yellow ferralitic soils derived from sandy and sandy-clay sedimentary rocks. The base content of these soils is very low and their pH is acidic (on average 5.5) [23]. From a topographic point of view, the altitudes in our study area vary from 0 to 100m and more precisely between 0 and 25m on our site with some points reaching 30m. The hydrography of the study area is particularly abundant. The station's water is collected from the Moungo River. The Moungo River and its tributaries drain large agricultural areas as well as semi-urban and urban areas where the population density reaches up to 150 inhabitants/km2 [1]. Lowland and highland agriculture with, among other things, industrial rubber and oil palm plantations such as those of the company called Société Camerounaise des Palmeraies (SOCAPALM) constitutes the predominant activity in the sector. Food crops such as corn, cassava, and vegetables are present in the lowlands.

3. Materials and Methods

In the field

The field campaign initially consisted of taking mixed samples of sludge from the sludge treatment basins (ST basins) according to the technique described in GIDS-A003 point 6. This sampling technique as explained in the Sampling Strategy for solid and pasty waste in the Code of Good Practice No. 2 (CDBP2) is mainly manual and aims to take a handleable quantity of waste into a larger whole, whose properties correspond as closely as possible to the average properties of the whole. The method consisted of taking 1kg of sludge at four different points in each basin, mixing them and taking 500g of these mixed samples in polyethylene plastics then stored in a cooler containing ice packs to be transported to the laboratory. Similarly, 1.5L transparent PET (polyethylene terephthalate) bottles were used to sample bottom sludge deposits at the drain outlets of each primary settling basin (PS basin). Secondly, the field campaign consisted of carrying out the topo sequence (succession of soils resulting from the relief) of the soil profiles around the station, taking into account the morphology. In total, three (03) soil profiles maximum depth 150 cm were carried out. One of the wells was located inside the station (P1), the second 2Km from the station (P2) and the third in the swamp adjoining the station (swamp). These wells were described (thickness, color, texture, structure of the horizons using the Munsell code) using the FAO soil description manual (2006).
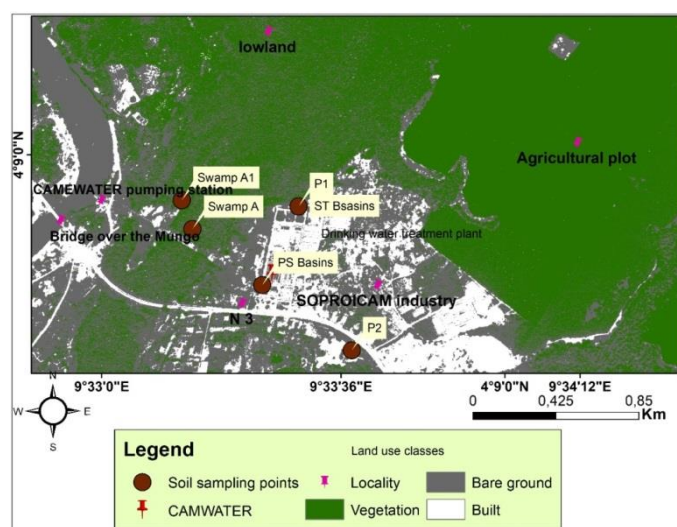

***Figure 2.** Sampling map of the study site.*

The soil samples were taken at the level of surface alteration (layer A) and were subjected to physicochemical analyzes with a view to evaluating the fertile nature of these soils. For each soil, samples were taken at the following depths of: 0-35cm (in the first well); 0-15cm (in the second well); 0-26cm (in the swamp well). The geographic coordinates of each sampling point were taken using a GPS. These samples were packaged in polyethylene plastic bags and sent to the laboratory. in a cooler containing "blocks" of ice (temperature less than 1°C) where physicochemical analyzes were carried out. Figure 2 shows the different points where the soil samples were taken (P1, P2 and Swamp A). This figure also shows the primary settling basins (PS basins) and the sludge treatment basins (ST basins) where the sludge samples were taken.

In the laboratory

Physical parameters such as the Beat Index (BI) and the Structural Stability Index (SSI); chemical parameters such as the N-pHwater binary diagram, the Ca-Mg-K ternary diagram, the Ca/Mg, Mg/K and Ca/K balances, the CEC, the sum of exchangeable bases, the cationic balance (Ca +Mg)/K) and biochemical parameters such as OM contents and the C/N ratio made it possible to evaluate the fertility of the sludge from the Yato drinking water treatment plant. The particle size was determined by the pipette method of Robinson-Köhn (1970) on soil samples dried and sieved to 2mm. The organic matter is first destroyed by attack with hydrogen peroxide. The sol is subsequently dispersed by rotary stirring in the flasks after addition of sodium hexa-metaphosphorus ($Na-PO_3)_6$. The different fractions are obtained by pipetting for the clay and silt fractions then by sieving for the sand. A solution of ammonium acetate at pH 7 made it possible to obtain the CEC. It consists of three phases: (1) Saturation of the absorbing complex with NH4+ ions and extraction of exchangeable bases; (2) Washing the soil with alcohol to remove excess NH_4^+ ions; (3) Determination of NH_4^+ by distillation after desorption of a KCL solution [22]. The pH was determined using a soil-water solution in a ratio 1/2.5 using a pH meter fitted with a glass electrode. The pH meter was previously calibrated using standard solutions [45]. The method of Walkley and Black [48], which is an oxidation with potassium bicarbonate ($K_2Cr_2O_7$) in an acidic medium (H_2SO_4) using a calorimetric dosage made it possible to determine the organic carbon. To obtain the organic matter content, the Sprengel factor (1826), which is 1.724 for cultivated soils and 2 for uncultivated soils, is multiplied by the organic carbon content previously obtained.

The structural stabilization index (SSI), which makes it possible to evaluate the sensitivity of soil aggregates to destruction when they are subjected to the action of fluids [26], is a physical parameter making it possible to determine the degree of degradability and erodibility of a soil [16]. It is defined by Pieri (1992) according to the ratio: SSI = (% OM×100)/ (L + A); 0≤ ISS ≤∞ With: OM = organic matter content of the soil, A = clay content contained in the soil. L = silt content contained in the soil. The sloughing index (IB) for its part designates the degradation of the structure of the surface soil under the influence of precipitation with water clogging. It is calculated using the beat risk estimation formula of Rémy et al., (1974):

$$BI = \frac{(1,5\ X\ LF)+ (0,75\ X\ LG)}{(A-10MO)} - C$$

With C = 0.2 * (pH -7) LF = Fine silt. LG = Coarse silt A = clay, MO = Organic matter.

Statistical analyzes

Statistical analyzes of the data were carried out using Microsoft Excel and SPSS IBM statistics 20. Arc-Gis and Arcview mapping software were used for producing maps and locating sampling points.

4. Results and Discussion

The parameters which made it possible to evaluate the fertility of the sludge from the Yato drinking water treatment plant are the sludge index (SI), the structural stability index (SSI); the N-pHwater binary diagram, the Ca-Mg-K ternary diagram, the Ca/Mg, Mg/K and Ca/K balances, the CEC, the sum of exchangeable bases, the cationic balance (Ca+Mg)/K), the OM contents and the C/N ratio (Table 1).

Table 1. Presentation of some fertility parameters of the Yato station.

Codes	Pond Mud	Swamp	P1 A	Primary Sludge	P2 A
S (meq/100g)	10.75	10.86	7.67	10.54	4.88
CEC (meq/100g)	15.75	16.15	15.4	15.08	9.08
Ca-Mg-K	75/8/17	43/52/5	76/18/6	77/8/15	55/37/8
Ca/Mg	9.80	0.83	4.12	9.85	1.49
SSI	19.24	8.46	8.76	17.02	5.43
SI	-0.57	-3.21	-3.21	-0.74	9.76

Codes	Pond Mud	Swamp	P1 A	Primary Sludge	P2 A
Mg/K	0.46	11.91	2.89	0.53	4.32
(Ca+Mg)/K	4.94	14.79	8.81	5.75	10.74
Ca/K	4.48	9.87	11.91	5.22	6.43
C/N	21.80	20.89	20.88	24.36	15.74
%OM	10.39	6.68	4.86	9.87	2.23
S/CEC	68.25	67.24	49.81	69.89	49.94

4.1. Physicochemical Parameters of Sludge and Their ETM Concentrations

4.1.1. Structural Stability Index (SSI)

The results (table 1) show that the structural stability index (SSI) at the P2 Control point is 5.43%, or between 5%<ISS<7%. Which means that these soils present a high risk of structural degradation. This is due to the lower level of organic matter in these soils (2.23%). Soils with a high risk of structural degradability have a high probability of erodibility in terms of fertility. They reduce the rate of water infiltration, which determines water availability for plants [7]. At the swamp and at point P1 in the station, the structural stability index is between 7%<SSI<9% (SSI: 8.46 and 8.76 respectively) reflecting soils with a low risk of degradation. While pond and primary sludge have a structural stability index greater than 9 (SSI> 9%). This reflects a good capacity for internal cohesion of the aggregates in this soil [25]. These aggregates are not easily carried away by runoff or wind, they are therefore less sensitive to any form of erosion [26].

4.1.2. Beat Index (BI)

The swing index allows floors to be grouped into two categories: non-beating floors (BI < 1) and very swinging floors (BI > 1.8). The control point P2 presents a beat index greater than 1.8 (BI: 9.76). This refers to very heavy soils which therefore have a crust of soil on their surface, thus increasing the cohesion of the soil and its resistance to detachment, thus preventing the harmonious penetration of roots and soil micro-organisms, which are difficult to work, due to compactness when dry or high plasticity when wet. They can also present temporary waterlogging phenomena during heavy rains [33]. The sludge from the primary basin and the sludge treatment basin, point P1 in the station and the swamp have negative values of the sludge index (SI<1). This means that the soil groups in the area are non-beating and therefore offer no resistance to root growth and stem expansion. They are ventilated and facilitate the exchange of CO_2 and O_2 with the atmosphere. They increase the rate of water infiltration and consequently that of the water reserve

[25]. The non-threshing of this group of soils would be due to the high sand content compared to the silt content. From an agronomic point of view, the soils in contact with this sludge have good aptitude in terms of physical fertility. The high sand contents come from the waters of the Moungo River which are taken and subjected to the action of treatments and therefore the residues are contained in the basins in the form of mud. This sludge, rich in organic matter and sand, contaminates the station's soils as well as the marshy lowlands near the station, thus improving their physical fertility.

4.2. Index Chemical Parameters

4.2.1. The CEC

On the chemical level, all the sludge and all the soils of Yato with the exception of the control point P2, have a high CEC content (10< CEC <25) [3], this is due to their levels high in organic matter (greater than 2% overall). Consequently, they have a good capacity to retain and exchange cations because the cations are retained on negatively charged sites found on the surface of particles of organic matter (IPNI, 2006). According to the table of Quemada and Cabrera, 1995 modified by NGuemezi et al., 2020 [36], these soils have little limitation in CEC. The CEC is a relative indicator of the fertility power of a soil [29]. Soils with a high CEC can retain more cations and have a greater capacity to exchange them than soils with a low CEC. According to the work of [2, 24], the CEC is closely linked to the organic matter content and the clay content of the soil. The presence of organic matter in the soil significantly increases the CEC in this soil (for example 1% of organic matter provides 2meq/100g of matter in terms of CEC to the soil) [35]. The highest CEC contents are recorded in the sludges from the PS and ST basins. The P1 points in the station and the swamp have high CECs due to their proximity to the station. A supply of sludge from the PS and ST basins could also improve the CEC contents at the control point P2. The clay content cannot be modified [48].

4.2.2. The Sum of Exchangeable Bases

The sum of exchangeable bases (S) is very high in the

sludge from the different basins; and in the swamp (S > 10 meq/100g) then moderately high at point P1 in the station (S: 7.67 meq/100g), suggesting that these soils have a good nutrient reserve which consequently leads to good chemical fertility [5]. The P2 control point (S: 4.88 meq/100g) records a low content of exchangeable bases (2 < S (meq/100g) < 5) [3]. On a chemical level, treatment pond sludge and primary sludge as well as soils subject to contamination by sludge (P1 in the station and the swamp) have good chemical fertility. The control point P2 shows a deficit in nutrients and a poor CEC which reflects not very good chemical fertility. Adding this sludge to the soils of the control point P2 could correct these exchangeable base and CEC deficits.

4.3. Balances Between Certain Fertility Parameters

4.3.1. Ca-Mg-K Balance

The calculation of the balance of the Ca/Mg/K cationic

balance of the different sites shows that the pond sludge and the point P1 in the station are in optimal balance. This demonstrates a balance in the absorption of cations from these soils and good assimilation by plant roots [5, 23]. The swamp and the control point P2 present potassium deficits. Fertilizers rich in K-Mg would be necessary for the soils of these sites (figure 3).

On the chemical level, the cationic balance (Ca+Mg)/K is high in the swamp and the control point P2 is (Ca+Mg)/K greater than 10. This reflects a deficiency in K compared to Ca and Mg [5]. This is due to the exchangeable calcium levels being much higher than the others (Omogo, 1996). Too high a Ca level can cause Ca/Mg imbalances that are detrimental to the soil [24]. The primary sludge, treatment sludge and point P1 of the station have a cationic balance of between 5< (Ca + Mg)/K <10. Thus, the balance is optimal between Ca, Mg and K, this reflects a perfect balance between Ca, Mg and K [13] and therefore does not present any risks of magnesium deficiency compared to calcium and potassium.
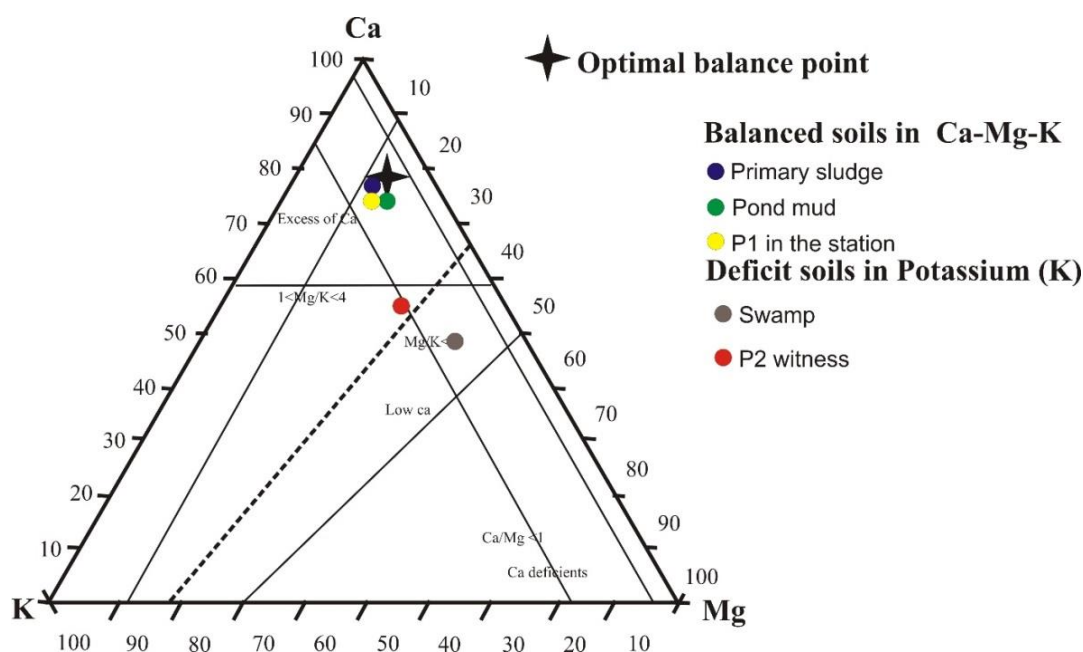

Figure 3. Global Ca-Mg-K balance (Dabin, 1961).

4.3.2. N-pH Balance

Soil pH affects how efficiently a crop grows in a soil; it affects the availability of nutrients, and the activity of microorganisms [32]. It plays an important role in the biological activity of the soil and the supply of mineral nitrogen to plants [34]. The results show that the point P1 below, the sludge from the primary and treatment basins are grouped into the medium fertility class according to the binary fertility diagram or N-pH diagram of Dabin (1961) [9], (figure 4). The limita-

tion of these medium fertility soils is due to the acidity levels between 5.1 and 5.5. They are characterized by their slightly acidic pH. However, the control points P2 and P1 in the station are found below the total nitrogen deficit threshold while the other sites are found above the deficit threshold. This reflects a need for nitrogen fertilizer for points P1 and P2. The P2 control point and the swamp are grouped in the good fertility class. This particularity is due to their pH above 5.5. They are characterized by medium to high exchangeable base reserves.
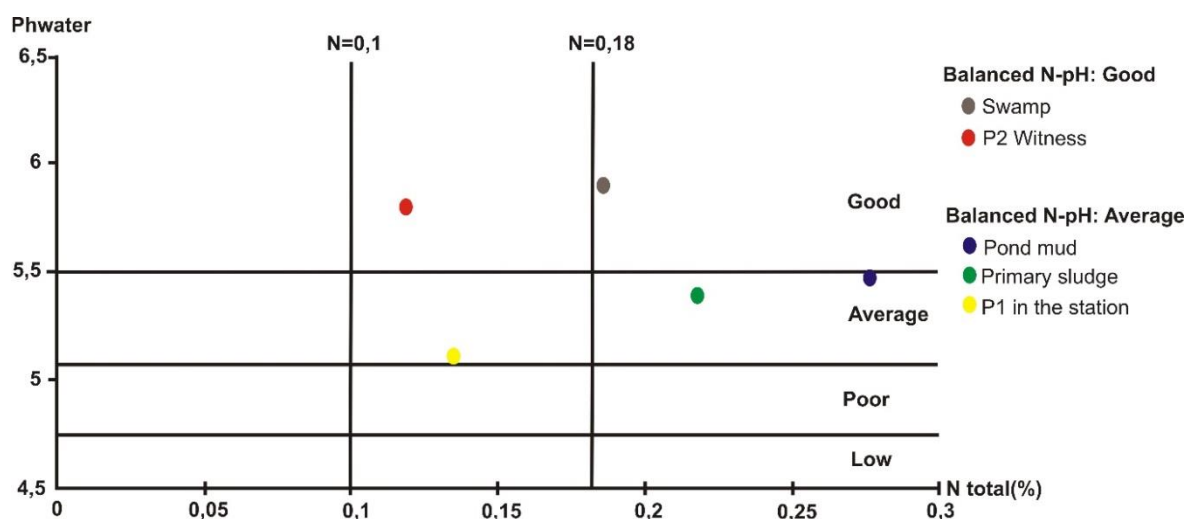
Figure 4. N-pH balance (Dabin, 1961).

4.3.3. K-Mg Balance

This ratio makes it possible to establish the balance between Mg and K cations in the soil. Dabin's diagram (1961) highlights this antagonism or synergy between two cations in the soil (figure 5). This diagram shows that all the soils of the Yato sites are above the potassium and magnesium deficit thresholds. Point P1 in the station has a good K-Mg balance ($1 < Mg/K < 4$). This reflects a nutritional balance between Mg and K. While the primary sludge and treatment basins are found above the Mg/K=1 ratio, it therefore reflects a nutritional imbalance between K and Mg. This reflects an excess of assimilation of Mg in the soil compared to K. This imbalance is also observed in the control point P2 and the swamp, where there is an excess of assimilation of K compared to Mg.
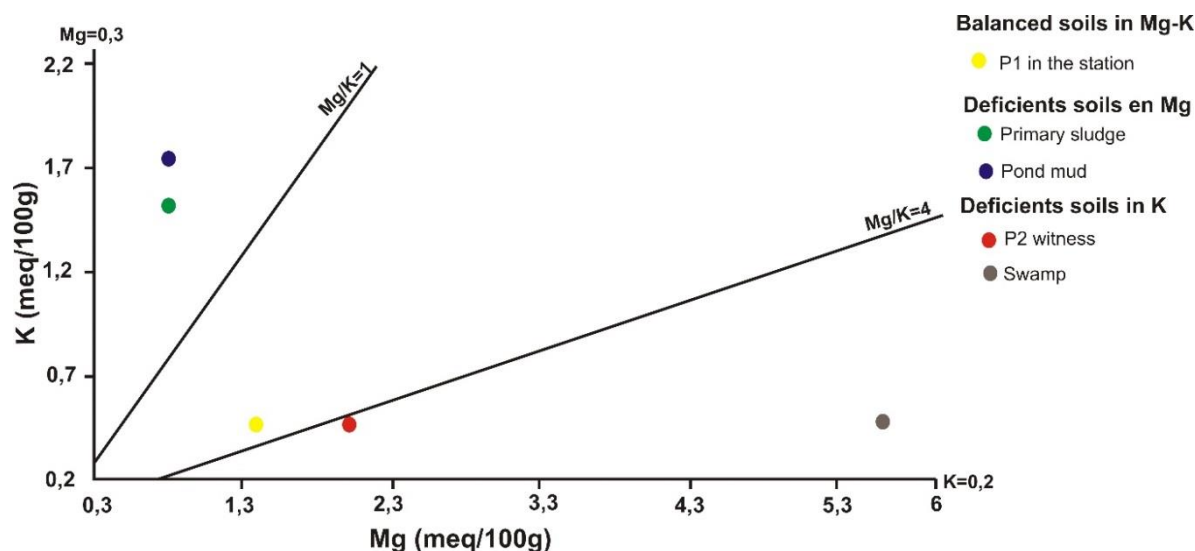

Figure 5. K-Mg balance according to Dabin (1961).

4.3.4. Ca-Mg Balance

The Ca-Mg diagram relating to the binary fertility diagram of [29] establishes the balance between calcium and Magnesium in soils. There is a clear antagonism in the soil between Ca and Mg (figure 6). The presence of one regulates the absorption of the other by the roots and vice versa. These two cations play a plastic and physiological role in soils [10]. According to this diagram, all the soils of the Yato sites are found above the deficit and deficiency thresholds for magnesium (Mg=0.3meq/100g) and calcium (Ca=1meq/100g). Points P1 in the station and P2 control present a perfect Ca-Mg balance ($1 < Ca/Mg < 5$) also indicates good absorption of magnesium in the presence of calcium and their good stability [45]. While the swamp presents a deficit in Mg com-

pared to Ca (Ca/Mg > 5) and consequently a nutritional imbalance which indicates an excess of Ca in the soil compared to Mg. Primary sludge and treatment sludge present a deficit

of Ca compared to Mg. Which means that these soils are satisfactory and reflect a nutritional balance between Ca and Mg [13].
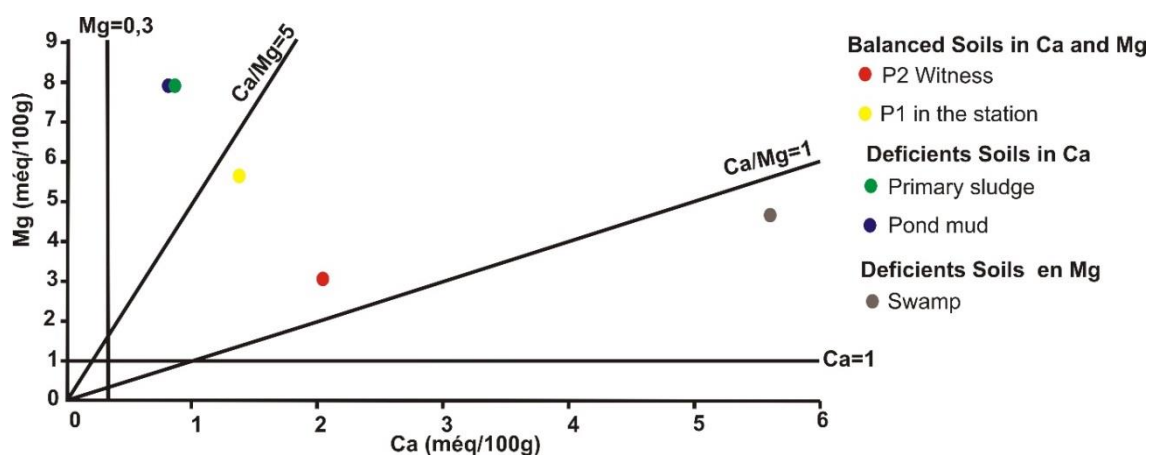

Figure 6. Ca-Mg balance according to Martin (1979).

4.3.5. S/CEC-pHeau Balance

The pH reflects the base saturation state of the absorbent complex. The S/CEC tends towards 100% when the soil pH is high. A very precise indicator of the chemical evolution of soils consists of measuring their saturation rate with Ca, Mg, Na and K cations in relation to the CEC (figure 7). The base saturation rate (S/CEC) as well as the pH provide precise information on the level of soil acidification [41]. Thus, the soil pH is closely linked to the sum of bases present in the soil

[34]. The balance between the saturation rate and the pH makes it possible to highlight the influence of pH on the evolution of exchangeable bases in the soil. In the Yato station, sites with a good saturation rate (S/CEC>50%) include pond sludge, treatment sludge and marshland. This reflects a good reserve of exchangeable base in these soils. The sites with an average saturation rate include points P1 in the station and P2 control. This means that these soils have average contents of exchangeable cations [19].
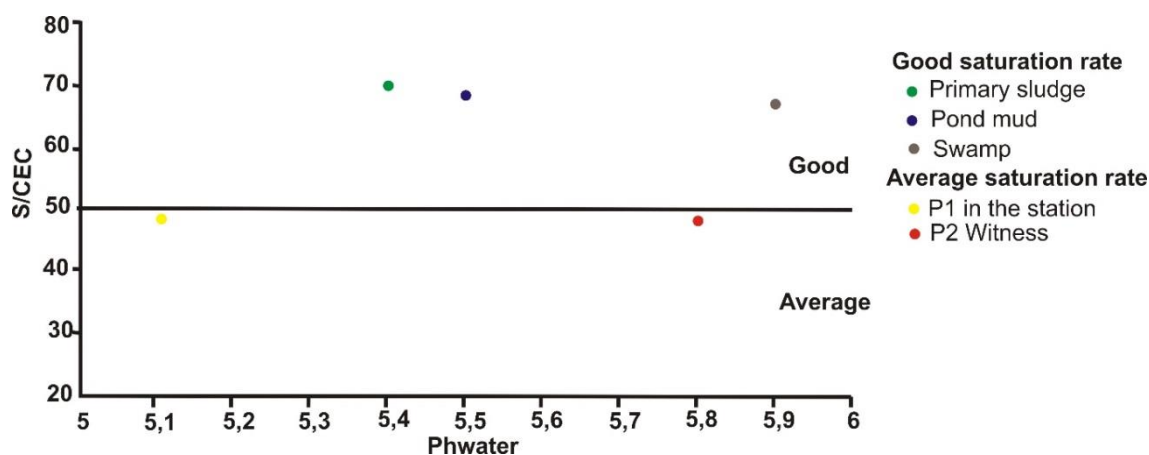

Figure 7. S/CEC-pH balance.

4.4. Biochemical Parameters

4.4.1. Organic Matter (OM)

The transformations of organic matter are essentially car-

ried out by the processes of recombination (humification) and degradation (mineralization) [6]. The mineralization of organic matter gradually releases nutrients into the soil such as: N, P, S [17]. The results show that all sites have MO values above 2%. This reflects high levels of organic matter [41]. According to Kemper et al., 1966 a content of 2% in OM

could be considered as a threshold value below which the aggregates become unstable, thus increasing the risks of degradation. It also testifies to the richness of this soil in nutrient elements [18]. Organic matter and biological activity greatly influence the physical and chemical properties of soils [42]. The aggregation and structural stability of a soil increase with its organic matter content.

4.4.2. C/N

The nitrogen rate is high in pond and treatment sludge (respectively N: 0.2765% and 0.2172%) [3] but their C/N mineralization rate is low (lower C/N to 25) while in points P1, P2 and the swamp, the nitrogen contents are average. This reflects rapid mineralization of carbon in the soil; which suggests that biological activity is abundant and mineralization encounters no difficulty. Indeed, mineralization is rapid and returns a significant quantity of mineral nitrogen to the soil [19]. Thus, anaerobic and acidity conditions are excessive (LCA, 2008).

4.4.3. Assimilable Phosphorus

The high assimilable phosphorus in the P2 control and swamp site (10< Pass (ppm) <20) [41] while the pond sludge, treatment sludge and the P1 point in the station have average contents (5 <Pass (ppm) <10). These soils are therefore weak in ensuring appropriate phosphate nutrition for most plants [11] and precipitating exchangeable aluminum thus reducing its toxicity [15, 17]. The deficiencies in assimilable phosphorus in point P1 in the station would be strongly influenced by the high fixing power due to the presence of heavy metals or iron oxides and hydroxides present in the sludge (in contact with the soils of station P1, the metals heavy binds the phosphorus present) [13].

5. Fertility States of Soils and Sludge

Fertility classically encompasses three types of interdependent components [32].

Physical fertility is linked to the depth of the soil, its texture and its influence structure which conditions the penetration capacity of the roots and the movements of water and air within the soil (drainage, infiltration, capillarity). All this conditions the germination, development and growth of plants.

Chemical fertility corresponds to the abundance in sufficient proportion of essential nutrients. It therefore evokes a notion of presence and quantity. The bioavailability of these nutrients is influenced by: CEC, clay and organic matter contents, pH, balance of certain nutrients.

Biochemical fertility corresponds to the capacity of organisms living in the soil (plants, bacteria, animals, etc.) to contribute to plant nutrition. It is linked to climate-dependent biological activity.

The table below presents the qualities and limits of each site according to the different fertility parameters of the soils and sludges studied. It shows that the sludge from the primary settling and sludge treatment basins has very good physico-chemical and biochemical characteristics with the exception of their assimilable phosphorus content and their acidic pH. The swamp and point P1 in the station have good fertility properties, however limitations in potassium and cationic balance are observed in the swamp; then the assimilable P and the pH are observed in point P1 in the station. The P2 control point presents an average fertility due to severe limitations in nitrogen, potassium, exchangeable bases, ISS and IB.

Table 2. Assessment of soil fertility parameters in Yato.

Collection sites	Fertility parameters														
	P	NOT	K	ISS	IB	N-pH	Ca/Mg	Mg/K	Ca/K	Ca/Mg/K	C/N	S	pH	Quality	Limitation
Primary sludge	+	++	++			+	++	++	++	++	+	++	-	Very high	P, pHwater
Treatment Sludge	+	++	++			+	++	++	++	++	+	++	-	Very high	P, pHwater
Swamp	++	++	+	++	++	++	+	+	+	+	+	++	++	pupil	K, Ca/Mg/K
P1 in the station	+	++	++	++	++	+	++	++	++	++	+	++	-	pupil	P, pHwater
P2 Witness	++	-	-	-	-	++	++	+	+	-	+	-	++	Average	N, K, ISS, IB, S

++: No limitations +: Average limitations -: Severe limitations

6. Agronomic Value of Sludge

In general, from an agronomic point of view, the sludges from the PS and ST basins have good physical, chemical and biochemical fertility. The limitations observed could be the subject of treatments in order to improve their pH and their level of assimilable phosphorus. These sludge limitations would be caused by their high contents of certain heavy metals (iron oxide and hydroxide) which fix phosphorus in the environment [14]. The acidity of this sludge also reflects the presence of Al^{3+} ions which can bond with oxygen to form aluminum oxides (Al_2O_3) [28]. However, this sludge can also have a positive effect on soil fertility by improving their physical, chemical and biochemical properties. This is observed at point P1 in the station and at the swamp, places with high contamination by sludge. According to the work of Girard et al., 2005, sludge spreading provides the soil with quantities of fertilizing elements equivalent to mineral fertilization. The comparison between the point P1 in the station exposed to the sludge of the station and the control point P2 2Km from the station despite the soils located at the same altitude and on the same geological formation, shows a significant difference in the contents of the physico-properties. chemical and biochemical. According to Table 1, at point P1 in the station, physical properties such as SSI and SI are good, favorable for plant growth, water retention and aeration while at point P2 control soils present physical characteristics unfavorable to plant growth.

7. Value of Sludge Amendments

According to the work of Adémé, 2010; a contribution of 50% organic matter would help maintain stable organic matter in the soil. According to Dudkowsi (2000) [15], sludge acts as green manure. Only compost can fulfill the humic function. Liming treatment makes it possible to stabilize and hygienize water purification sludge such as that of the Yato station. This reduces the mobility of MTEs in the soil after spreading. Sludge limed with 20% to 30% CaO is used as a limestone amendment to raise the pH of acidic soils [19, 8].

On a physical level: Several authors have shown that repeated additions of sludge promote the aggregation and stability of the structure of loamy soils [6, 4]. By increasing the OM contents in the surface horizons, the water contents and retention properties increase at all potentials. According to Culot 2005, the organic matter in sludge provides better water retention by limiting capillary rise and also improves the structure and density of the soil. In the Yato station, point P1 has a good structural stability index and beat index unlike point P2.

On a Chemical level: the availability of nutrient elements is expressed as a proportion of the fertilizing element added per crop year after the addition of sludge [19]. Studies have shown that around 30% of nitrogen from sludge is available in the soil during the year of spreading [21]. In the Yato station, the soils at point P1 have higher nitrogen contents compared to point P2. However, the variable availability of nitrogen in sludge can lead to risks of nitrate leaching if the sludge is added during the dry season and in the absence of a nitrate trap crop. The availability of sludge phosphorus in the soil is important. Morel 2009, shows that the contribution of 55Kg of total P_2O_5 from sludge has the same effect as 55Kg of P_2O_5 from mineral fertilizer, although the proportion of phosphorus assimilable by the plant is slightly low due to the presence of oxides and iron and aluminum hydroxides in certain solid sludges which fix a large quantity of phosphorus available to the plant in the soil. This is the case in the Yato station where the assimilable phosphorus contents are lower in point P1 than in point P2. The reserve of exchangeable bases as well as potassium is well high at point 1 in the station and the balance between them is perfect unlike the soils of point P2 not subject to the action of sludge. The high CEC values in the soils of point P1 compared to point P2 would also be due to its exposure to sludge contamination. Soils with a high CEC can retain more cations and have a greater capacity to exchange them than soils with a low CEC. According to the work of Alexandre and al. (2012), Koull and Halilat (2016), the CEC is closely linked to the organic matter content. The presence of organic matter in the soil significantly increases the CEC in this soil (for example 1% of organic matter provides 2meq/100g of matter in terms of CEC to the soil) [35]. Soils with CEC can be corrected by regular additions of mud.

On a biological level: organic fertility stimulates the biological activity of the soil. Soil organisms have central functions in plant nutrition [27]. Microbial communities in agricultural soils play a key role in the cycling of organic matter and mineral elements. Soil fertility is therefore largely dependent on it. Microorganisms act both in the mobility of metals and in the adsorption and degradation of organic molecules.

8. Conclusion

This work aimed to show the agronomic effect of hydroxide sludge resulting from the treatment of Yato water on the soil. The study was carried out on soils exposed to the station's sludge and soils far from the station's sludge. It appears that the soils exposed to contamination from sludge from the station have better agronomic properties both on a physical level with a stable structure favorable to plant growth and good aeration unlike soils far from the station which presented a high risk of degradation.; that on the chemical level with an optimal cationic balance, a high reserve of exchangeable bases, a strong CEC but average limitations in assimilable phosphorus and pH unlike the soil far from the station which presented an insufficiency of potassium which did not facilitate a balance cationic, a low CEC but a pH above 5.5 which is the value recommended in agronomy. Biochemically, organic matter was above 2% in

all soils, a mineralization rate less than 20 favoring the rapid mineralization of carbon and a release of nitrogen available to the plant. These results obtained allow us to conclude that the sludge from the Yato station can be used in agronomy as organic fertilizer in order to correct the soil structure, the CEC, the cationic balances and also provide the soil with a good reserve. In base. However, treating this sludge with lime could regulate the pH of the soil and reduce the mobility of heavy metals in the soil.

Abbreviations

CAMWATER: Cameroon Water Utilities

DWS: Drinking Water Supply and Sanitation

DWSPYS: Drinking Water Supply Project for Yaounde and Its Surroundings

TMEs: Trace Metal Elements

SDG: Sustainable Development Goal

SOCAPALM: Société Camerounaise des Palmeraies

Conflicts of Interest

The authors declare no conflicts of interest.

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