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Research Article

Assessment of the Polluting Status of Sludge from a Physicochemical Water Purification Unit and Their Impacts on the Soil: Case of the Yato Station (Littoral-Cameroon)

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Abstract

The Yato physicochemical water purification station is located in Dibombari District Council 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, through the quantification of the concentrations of Trace Metal Elements (TMEs), the polluting status of the sludge from this drinking water production station and their impacts on the soil. To achieve this objective, mixed samples of sludge from sludge treatment ponds (taken according to the technique described in GIDS-A003 point 6 as explained in the Solid and pasty waste sampling strategy of Code of Good Practice No. 2) and samples of sludge from primary settling basins (taken in transparent bottles in polyethylene terephthalate of 1.5L) were analysed. Likewise, three soil wells were carried out and soil samples were taken on two levels of alteration then sent to the laboratory where physicochemical and TME analyses were carried out. The characteristics of the samples that were analysed are: particle size, texture (sand, silt, clay), physiochemistry (pH, electrical conductivity, temperature, phosphorus, nitrogen) and TME (chromium, copper, zinc, manganese). The results obtained show that the polluting status of the sludge from the Yato station is proven because their pollution index by heavy metals is greater than 1. The pollution index greater than 1 in the sludge from the treatment basins is due to the strong concentrations of TME originating from the accumulation of waste of all kinds in this location. Overall, TME concentrations in soils decrease for the most part from the surface towards depth. All the TMEs studied (Zn, Mn, Cu, Cr) are present in all horizons. There is multiple contamination of sludge by TMEs because their pollution index is greater than 1 (IP>1). Although the sludge pollution indices are greater than 1, those of the different horizons are much lower than 1. Thus, since the TMEs decrease with depth, the subsurface horizons would be less affected by the pollutants contained in the station sludge. marking a real pollution of the surface layers.

Keywords

Yato, Sludge, Elements Metal Traces, Pollutant, 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 [27]. 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. This sludge contains many pollutants which will end up in the environment. Thus, the development of urban, industrial and agricultural activities in recent decades has led to numerous pollution problems, particularly trace metal elements (TMEs) and organic pollutants [25]. Metals are ubiquitous in soil as well as surface water. However, their concentrations are generally very low, which explains their name “trace metals” or “metallic trace elements” (TME). Industrial activity, like agricultural activity, is ranked among the most important anthropogenic sources relating to the contribution and spatial redistribution of metallic trace elements in nature [11]. The uncontrolled and regular contributions of waste containing trace metal elements (TME) would therefore lead to an accumulation of these TME in the soil [17, 13]. Indeed, in oxisols subjected to compost, the vertical distribution of TMEs Cd and Pb decreases with depth [26] Contamination of soil and surface water by ETM presents a risk of toxicity for living beings and the man to through the food chain (Mubemba, 2014). It hinders the growth and variability of crops depending on the degree of contamination. Studies by Pauwels [19] indicate that several vegetables grown in market gardens absorb TMEs. Due to the growing resource needs of human societies, negative impacts on the environment are increasingly significant, and human activities are increasingly singled out [8]. Among the drinking water treatment plants in Cameroon, Yato is the most important. The waste produced there is not without consequences on the surrounding soils because we find there Trace Metal Elements (TMEs). If the fate of TMEs in soils is one of the subjects of controversy over the use of sludge in agriculture, we also know that many intrinsic parameters such as pH, soil texture or extrinsic parameters such as climate or the method of soil management, disrupt the TME-constituent balances of the soil. Indeed, the contamination of different trophic levels by heavy metals has become crucial in recent years, because of their potential accumulation in different biosystems through air effluent, soils and sediments [11]. Thus, for this work it will be a question of evaluating the polluting status of sludge in ETM and determining their concentrations in the soil over the entire study area to verify the real impact of this sludge on the quality of the soil and the direction of migration of these pollutants which are specifically Zinc, Manganese, Chromium, Copper and Magnesium.

2. Materials and Methods

2.1. Study Area

Yato in the Dibombari District Council, 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: 24meters (PCD Dibombari, 2012) [22].

The Yato station is a drinking water production station located approximately 20 km from Douala. 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.

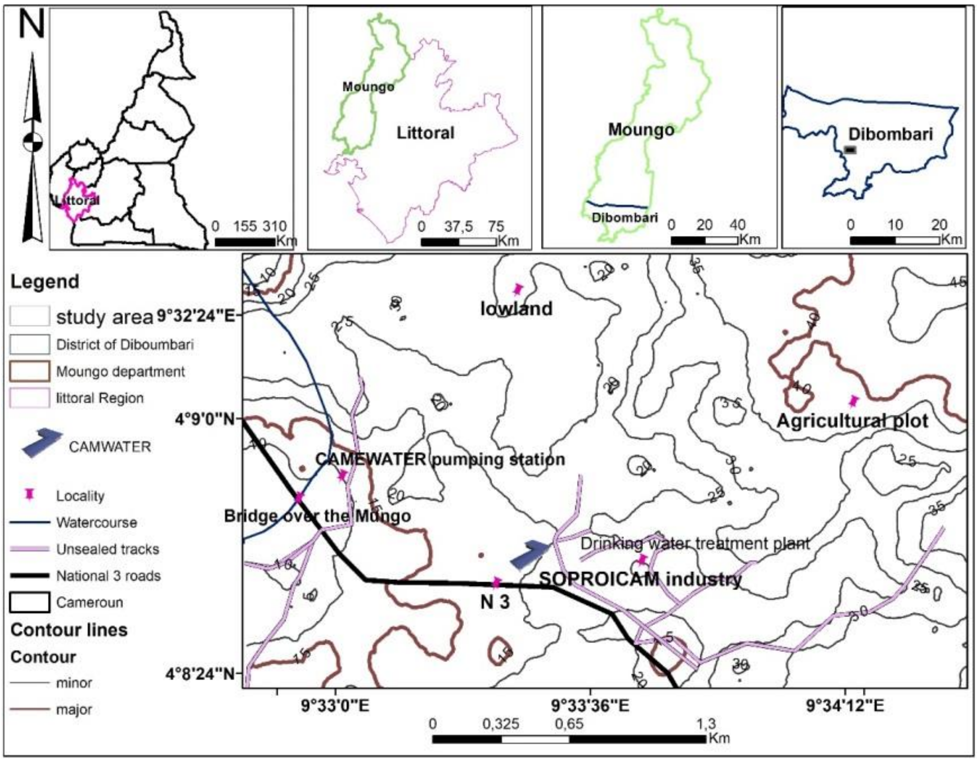

Figure 1. *Study area location map.*

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) [9]. 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. According to Delvaux [6], 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 [12]. 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) [15]. 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/km^2 [1]. Lowland and highland agriculture with, among other things, industrial rubber and oil palm plantations such as those of the Cameroonian company of palm oil production (SOCAPALM) constitutes the predominant activity in the sector. Food crops such as corn, cassava, and vegetables are present in the lowlands.

2.2. Analytical Methods

In the field

The field campaign initially consisted of taking mixed samples of sludge from the sludge treatment ponds 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 (CGP2) is mainly manual and aims to take a maliable quantity 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. Secondly, the field campaign consisted of carrying out the topographic sequencing (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, colour, texture, structure of the horizons using the Munsell code) using the FAO soil description manual (2006).

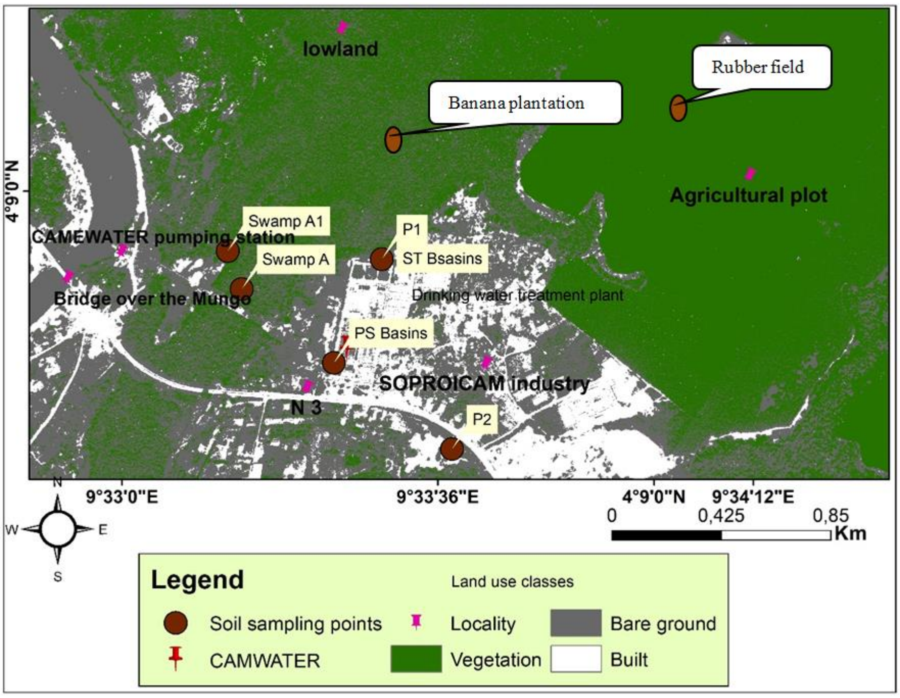

Figure 2. *Sampling map of the study site.*

The soil samples were taken by level of alteration along the soil profile taking into account an equidistance of sampling with depth more than 20cm. For each well, three samples were taken at respective depths of: 0-35cm and 35-120cm (in the first well); 0-15cm and 15-150cm (in the second well); 0-26cm and 26-50cm (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 ℃) where physicochemical and TME analyses were carried out. Figure 2 shows the different profile points (P1, P2 and Swamp A) where the topographic sequencing was carried out and the soil samples taken. This figure also shows the primary settling basins (BP) and the sludge treatment basins (Mud basin) where the sludge samples were taken.

In the laboratory

The determination of the concentrations of heavy metals began with drying the various samples in ambient air, crushing and sieving using a 2 mm sieve. They were broken up by mineralization. The levels of trace metal elements present in the soil samples were measured by atomic absorption spectrophotometry (AAS). The process consisted of attacking the metals with a strong acid (HNO_3 and HCl). Five (05) grams of soil sample were digested in 50 ml of aqua regia (concentrated nitric acid and concentrated hydrochloric acid ratio 3:1) on a hot plate for thirty minutes. After cooling, the samples were filtered and supplemented with an HNO_3^- solution in a 100ml volumetric flask. Each element in the solution was read based on the series of nanometre wavelengths marked on each cathode lamp.

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-metaphosphoric $(NaPO_3)_6$. 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 NH_4^+ 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 [14]. 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 [23]. The method of Walkley and Black [28] 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 pollution index (PI) by soil ETMs is calculated in order to determine the toxicity of the soils in the different sites in the area and facilitate the delimitation of the zone of high pollution. The pollution index makes it possible to assess the overall toxicity of contaminated soil [29]. However, it makes it possible to highlight multi-element type contamination in the samples [5, 24]. It is calculated from the average of the ratios of metal concentrations in soil samples based on guideline limit values [5]. The limit values corresponding to the tolerable levels of metal concentrations (ETM) in the soil are given according to the AFNOR U44-41 standard [2]. The IP is determined by the following formula: IP = [(Cd/2 + Hg/1 + Cu/100 + Ni/50 + Pb/100+Zn/300)/6]; IP > 1 corresponds to soil polluted by several metals.

2.3. Statistical Analyses

Statistical analyses of the data were carried out with Microsoft Excel software (for calculations of means, sums) and IBM SPSS STATISTICS (for calculations of means, standard deviations, sums, frequencies, indices and correlation). In fact, the tests of Pearson correlation between the different physicochemical parameters and the TMEs concentrations of the soils were carried out using the SPSS IBM statistics 20 statistical software. The Arc-Gis and Arcview mapping software were used for the production of the maps and the identification of sampling points.

3. Results and Discussion

3.1. Physicochemical Parameters of Sludge and Their TME Concentrations

The results of analyses of the physicochemical properties of hydroxide sludge, taken from the Primary Settling Basins (PSB) and Sludge Treatment Basins (STB) of the station, carried out on a few parameters (percentage of clay, pH, organic matter) which influence the mobility of metallic trace elements in the soil are presented in Table 1 below.

Table 1. *Physicochemical properties in sludge.*

Codes	%HAS	%L	%S	%MO	P (mg/kg)	EC (ms/cm)	Da (g/cm3)	water pH	SBE (meq/100g)	CEC (meq/100g)
Treatment sludge	22.5	31.5	46	10.39	7.3	2.81	0.49	5.5	10.75	15.75
Primary Sludge	21.5	36.5	42	9.87	7.2	2.61	0.51	5.4	10.54	15.08

These results show that in terms of particle size, the sand fraction is dominant in all the samples with an overall rate greater than 40%. The apparent density is very low overall with values below 0.6 g/cm3. It varies depending on the clay and silt content in the soil. Indeed, the apparent density varies proportionally depending on the silt contents while it is inversely proportional to the clay contents [3]. The organic matter content is higher in treatment pond sludge and that of primary settling ponds with rates greater than 9%. This can be justified by the fact that numerous biosynthesis phenomena take place in sludge treatment basins which have characteristics close to the natural environment while inside primary settling basins, there are artificial conditions characterized by the presence of newly added chemical inputs (alumina sulfate, quicklime) in full interaction with other compounds in the raw water. The pH is moderately acidic overall (pH: 5.4; 5.5). According to [27], low pH values can be responsible for the dissolution of heavy metals; which would increase their mobility. The sum of exchangeable bases is high in the sludge of both types of basin, (S (meq/100g) > 10), which gives these substrates good fertilizing power [16]. The electrical conductivity is higher in the sludge from the treatment basins than in that from the primary settling basin (EC: 2.81 and 2.61 (ms/cm)). It changes depending on the concentration of metals in the environment. The CEC is average in all the sludge from the station (10 < CEC (meq/100g) < 25).

The chemical composition of this sludge shows the presence of numerous metallic trace elements which are of certain toxicity for the environment. Table 2 below presents the variation in ETM contents according to the different sludge samples taken from the study site.

Table 2. *Concentration of some ETM in the sludge of the Yato station.*

Codes	Zn (mg/kg)	Cu (mg/kg)	Cr (mg/kg)	Mn (mg/kg)
Pond Mud	463.47	141.3625	14.9	491
Primary Sludge	383.25	149.28	17	494

According to Table 2, Mn concentrations are higher in all bassins. They vary from491mg/kg in the sludge from the treatment basin494mg/kg in primary settling basins. Then come the concentrations of Zn and Cu; with the highest values respectively 463.47 mg/kg and 149.28 mg/kg. Cr concentrations are lowest in the sludge from the study site. They vary from 14.9 mg/kg in the sludge from the treatment basin to 17 mg/kg in the sludge from the primary settling basin. Overall, TME concentrations in plant sludge are high. Indeed, the banks of the Moungo River have been the subject of intense agricultural and sand extraction activities for several decades. Agricultural inputs such as fertilizers and pesticides are used in market gardening fields which are grown all year round. Upstream of the catchment where sand extraction is intense, we regularly notice oils and greases coming from trucks littering the ground near the water. Metals such as…Cu, Mg, Mn, Fe, Zn have high aqueous solubility which gives them high mobility [21],

3.2. Physicochemical Properties of Soils and Their TME Concentrations

The results of the physicochemical analyzes in the soil samples from the study site are recorded in the following table 3:

Table 3. *Physicochemical properties in Yato soils.*

Codes	%HAS	%L	%S	%MO	P (mg/kg)	EC (ms/cm)	Da (g/cm3)	water pH	S (meq/100g)	CEC (meq/100g)
Swamp A	43.5	35.5	21	6.68	14.95	1.39	0.59	5.9	10.86	16.15
Swamp A1	42.5	21.5	36	5.61	10.66	0.82	0.64	6.2	13.03	17.35
P1 A	37	18.5	44.5	4.86	8.99	1.53	0.55	5.1	7.67	15.4
P1 B	33	14.5	52.5	2.64	9.08	0.83	0.68	5.9	8.46	15.15
P2 A	37.5	22	40.5	3.23	11.98	0.98	0.69	5.8	5.88	12.08
P2 B	38	18	44	1.89	12.06	0.83	0.58	6.1	3.79	10.9

The sandy fraction is dominant in all of the soils, except in the soils of the swamp horizons where it is the clay fraction which is dominant (43.5 and 42.5 in the A and A1 horizons of the swamp). The apparent density is low in all soils with values less than 1.5 g/cm3. It is higher in subsurface horizons compared to surface horizons. It varies depending on the clay and silt content in the soil. Organic matter is average in the horizons of profiles P1, P2. Low levels of organic matter are recorded in the subsurface horizons, with values between 1 < MO (%) < 2. Phosphorus is low in all the soils of the study site (P (mg/kg) <16). The pH is moderately acidic in all of the Yato soils (5.3 < pH < 6), except in the subsurface horizon soils of the P2 profiles and swamps where it is slightly acidic (respectively: pH: 6.1; 6.2). Soil acidification is also due to organic acids resulting from the biological activity of the soil, which releases hydrogen ions, [15]. The lowering of pH promotes the mobility of trace metal elements (TME) in particular by putting metal salts into solution or destroying the retention phase [10]. The sum of exchangeable bases is high in the swamp (10 < S (meq/100g) < 15). It is average in profiles P1 and P2 (5 < S (meq/100g) < 10); then weak in horizon B of profile P2 (S =3.79meq/100g). Electrical conductivity is higher in surface horizons. It changes depending on the concentration of metals in the soil. The lowest values of electrical conductivity are recorded in the B horizons of profiles P1, P2 (EC: 0.83; 0.36 ms/cm). The CEC is average in all the soils of the study site (10 < CEC (meq/100g) < 25).

Table 4 below presents the variation in TME contents according to the different soil profile samples taken from the study site.

Table 41. *Concentration of some TME in Yato soils.*

Codes	Zn (mg/kg)	Cu (mg/kg)	Cr (mg/kg)	Mn (mg/kg)
Swamp A	65.94	17.13625	12.5	180
Swamp A1	43.47	14,455	13.65	121
P1 A	189	12.5	12.35	102

Codes	Zn (mg/kg)	Cu (mg/kg)	Cr (mg/kg)	Mn (mg/kg)
P1 B	84	23,805	9.32	68
P2 A	71.4	27.95	9	28.9
P2 B	67.2	11.67	10	14.85

According to Table 4, Zn concentrations are highest throughout the surface and subsurface horizons. Then come the concentrations of Mn and Cu which are high both in the surface and subsurface horizons. Cr concentrations are lowest in the soils of the study site.

The concentration of each TME varies from one horizon to another along the profile.

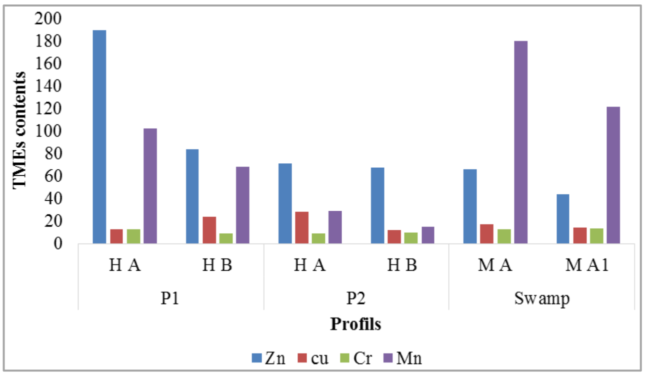

Figure 3. *Variation of TMEs in profile horizons.*

According to Figure 3, the concentration of Zn varies in the A horizons from 189mg/kg at 65.94 mg/kg. It is very high in the A horizon of profile P1 (Zn: 189mg/kg). In the depth horizons, the highest value is 84 mg/kg recorded in profile P1 while the lowest value is 43.47 mg/kg recorded in the swamp. The concentration of Zn in all profiles decreases with depth. This reduction is very noticeable in the P1 profile.

The concentration of Cu varies in the A horizons of27.95 mg/kg to 12.5 mg/kg. It is very high in the A horizon of profile P2 (Cu: 27.95 mg/kg). In the subsurface horizons, the highest Cu concentration is 23.80 mg/kg recorded in profile P1 while the lowest concentration is recorded in profile P2 (Cu: 11.67 mg/kg). The Cu concentration decreases with depth in profile P2 while in profile P1 it increases with depth. When copper is found in the soil, it binds strongly to organic matter and minerals. Generally speaking, it is accepted that copper has low mobility in soils [20]. However, as in the case of the P1 profile, Baize [2] demonstrated that the transfer of copper could take place particularly in acidic soils such as in certain podzosols because of the pH which impacts its mobility through its speciation.

Cr varies in A horizons of profiles of 9 mg/kg to 12.5 mg/kg. In the subsurface horizons, it varies from 9.32 mg/kg in profile P1 to 13.65 mg/kg in the swamp. These values are much lower than those obtained in Niger by Ousseini et al. [18] in the soils of the Komabangou gold zone which are respectively from 18.699 to 257.79 mg/kg. The Cr concentration decreases with depth in the P1 profile and increases slightly with depth in the P2 and swamp profiles. In the soil, chromium binds strongly to soil particles and, therefore, does not move to groundwater. The chromium values encountered in the different horizons are lower than the limit value of 3000 mg.kg-1 established by the USEPA (1992) and 1000mg.kg-1 of AFNor 44 041 [4].

In the A horizons of the profiles the highest Mn concentration is recorded in the swamp profile (180mg/kg) and the lowest is recorded in profile P2 (28.9 mg/kg). In subsurface horizons, Mn is higher in the swamp (121mg/kg) and lower in the P2 profile (14.85mg/kg). The Mn concentration decreases considerably with depth in all profiles. Manganese from human sources can also enter surface water, groundwater, and sewage. So, when using manganese pesticides, manganese can penetrate the soil at proportions of up to 59.09% as demonstrated by Cherfouh [10] in a study conducted in Yébouékro (Djékanou) in the south-central from Ivory Coast.

3.3. Sludge and Soil Pollution Index by Heavy Metals

The calculation of the heavy metal pollution index of sludge and soil was used to determine the level of contamination of these environments by TMEs as well as the associated effect of these different metals on soil quality.

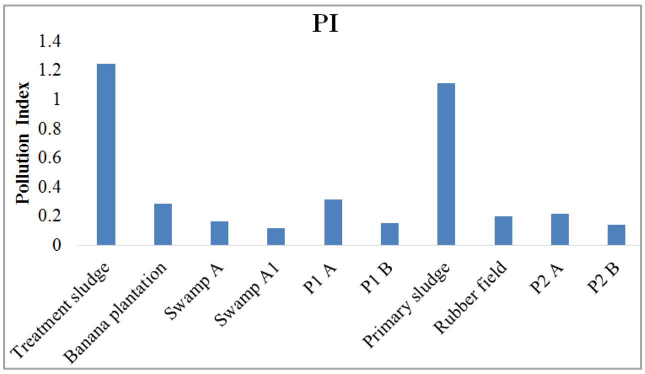

Figure 4. *Variation of the Soil Pollution Index.*

The analysis of Figure 4 reveals that the pollution indices decrease as we move away from the station and also decrease with depth.

Indeed, the results show that the sludge from the treatment basin and the primary sludge have a pollution index greater than 1 (IP>1). This value testifies to the fact that this sludge is very polluted according to the WPI classification of Hossan and Patra (2020), effectively attesting to the very polluting status of the sludge from the Yato station. This suggests that there is multiple contamination of this sludge by TMEs. The pollution index greater than 1 in the sludge of the basins would be due to the high concentrations of TMEs coming from the accumulation of waste of all kinds, the less clayey texture of the sludge (%A<30) and the content of organic matter [20] because its very low clay texture facilitates the mobility of TMEs towards the outlets which are surface water and the surrounding soil. As a result, the layers of clay minerals are not numerous enough to capture the metal ions in the environment [7].

The pollution index varies from sludge treatment basins (1.24) to primary settling basins (1.11). It varies from 0.20 in the swamp to 0.11 in profile P2. The ponds sludge treatment and primary settling show a pollution index greater than 1 (IP>1). This suggests that there is multiple contamination of this sludge by TMEs. While other soils as well as their lower levels show a soil pollution index less than 1 (IP<1). Which suggests that there was no contamination of multiple TMEs in these soils or in their depths [29]. We also note the presence of the four TMEs studied in all the samples, whether sludge or soil; which indicates the existence of a certain correlation between them.

3.4. Correlations Between the Different Heavy Metals Studied

The Pearson correlation analysis reveals a strong positive relationship between the different ETMs studied (Zn, Cu, Mn, Cr) indicating high probabilities of encountering them together at the different points sampled (Table 2). We also note that the presence of these is strongly linked to that of organic matter (>0.7). This shows that organic matter plays a determining role in the distribution of these ETMs in the soil.

Table 52. *Relationship between the different ETMs (Pearson correlation).*

	Zn (mg/kg)	Cu (mg/kg)	Cr (mg/kg)	Mn (mg/kg)	%HAS	%MO	water pH	EC (ms/cm)
Zn (mg/kg)	1	0.84	0.679	0.909	-0.851	0.827	-0.483	0.516
Cu (mg/kg)		1	0.399	0.885	-0.839	0.727	-0.302	0.507
Cr (mg/kg)			1	0.739	-0.339	0.732	-0.434	0.589
Mn (mg/kg)				1	-0.707	0.894	-0.374	0.741
%HAS					1	-0.671	0.402	-0.187
%MO						1	-0.412	0.675
water pH							1	-0.178
EC (ms/cm)								1

On average the sequence of ETM contents in the samples is Zn > Mn > Cu > Cr

3.5. Risks Linked to Pollution of Yato Soil by TMEs from the Station's Sludge

The analyses having demonstrated the effectiveness of the polluting status of the sludge from the station, we have the right to fear a possible transfer of this pollution to the surrounding soils. This sludge therefore constitutes a possible source of direct or indirect diffusion of TMEs in the environment, via water [29] and other migratory mechanisms where they become dangerous because they are potentially absorbed by living beings. Topographically, water flows in the direction from the station towards the marsh floors below. Thus, thanks to rains and other drainage, part of the sludge goes towards the swamp where its components are dissolved in the surface water and another part infiltrates into the soil, thus impacting the physicochemical properties of it. this. This explains the presence of TMEs encountered in the various basins of the station and in the surrounding soils.

The Pearson equation having demonstrated that the presence of TMEs is strongly linked to this organic matter (OM), it goes without saying that the concentration of each TMEs in each soil horizon will be a function of the rate of OM in said horizon (table 5).

4. Conclusion

The main objective of this work was to evaluate, through the quantification of TME concentrations, the polluting status of Yato sludge and their impacts on the surrounding soils.

The results revealed the polluting nature of the station's sludge with metal pollution indexes greater than 1 attesting to multiple contamination of this sludge by TME. The pollution index greater than 1 in pond sludge and primary sludge is due to the high concentrations of TME coming from the accumulation of waste of all kinds in this place. Likewise, in soils, all the TMEs studied (Zn, Mn, Cu, Cr) are present in all horizons. The orders of evolution of concentrations in the horizons are: Zn>Mn>Cu>Cr. In soils, TME concentrations decrease for the most part from the surface towards depth. The metal pollution indexes are lower than 1, attesting to the absence of multiple contamination of the sludge by TME. This is the result of the interactions between these compounds and the physicochemical parameters of the soils, in particular the high content of organic matter in the surface layers which contributes to sequestering TMEs coming from the muddy waters of the station. However, the presence of TMEs in the surface layers (0 - 120cm) which is the root zone, would constitute a permanent danger of contamination of plants and consequently of the entire trophic chain by these compounds.

Abbreviations

CAMWATER: Cameroon Water Utilities
CGP2: Code of Good Practice N°2
DWS: Drinking Water Supply and Sanitation
DWSPYS: Drinking Water Supply Project for Yaounde and its Surroundings
TMEs: Trace Metal Elements
PSB: Primary Settling Basins
SDG: Sustainable Development Goal
STB: Sludge Treatment Bassins
SOCAPALM: Société Camerounaise des Palmeraies
USEPA: United States Environmental Protection Agency

Conflicts of Interest

The authors declare no conflicts of interest.

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