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Research Article

Evaluating Water Quality and Distribution of Phosphates and Nitrates in Soils, Water and Sediments from Agrochemicals Usage in Santa, Cameroon

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Abstract: Worldwide pollution of soils, rivers, streams and lakes from anthropogenic activities has been one of the most crucial environmental problems since the beginning of the 20th century. In Santa, the increasing use of agrochemicals is disturbing, as most farmers have little or no idea about application techniques or the effects of these chemicals on the environment. The objective of this work was to determine the knowledge on pesticides and fertilizer use by tracing their availability in surface and subsurface soils, in water and sediments using nitrates and phosphates, and by evaluating the quality of some water sources in Santa. Questionnaires were used to survey the knowledge of fertilizers and pesticide utilization by farmers, while water, soil and sediment samples were collected from selected field sites to determine the distribution of phosphates and nitrates. The pollution of water from some water sources in Santa was evaluated using the National Sanitation Foundation Water Quality Index (*NSFWQI*). The results show that most farmers cultivate vegetables (86%), with high applications of pesticides for pest control, and 100% cultivate without fallowing using much fertilizer. 90% of the farmers used nitrogen, phosphorus and potassium (NPK) fertilizers along with urea fertilizers. Phosphates were present in soils and sediments but absent in water, while, nitrates were present in soils, water and sediments. While phosphates were significantly higher than nitrates in soils and sediments, the reverse was observed in water, where nitrate concentrations were significantly higher than those of phosphates. Phosphates showed more mobility in the soil than nitrates, as phosphate concentration values were higher in subsurface soils than surface soils. *NSFWQI* values for three water bodies studied indicated moderate pollution, making them not suitable for drinking. The absence of fallowing and lack of proper knowledge on soil nutrient content have led to excessive use of agrochemicals by farmers in Santa, which has resulted in soil, water, and sediment contamination.

Keywords**:** nitrates, phosphates, fertilizer, pollution, pesticides, water quality, Santa

1. Introduction

The Food and Agricultural Organization (FAO) report shows that agriculture accounts for the major use of land by humans [1]. For example, in 1999, 37% of the Earth's land area was used for pasture and crop cultivation. The same FAO report shows that over two-thirds of human water use is for agriculture, with this fraction being higher than four-fifths in Asia. The economy of Cameroon, like that of many developing countries, relies principally on agriculture, with

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about 75% of the active population involved in agricultural production, which accounts for approximately 50% of total exports and accounts for an estimated 45% of Cameroon's gross domestic product (GDP) [2-4]. Due to the vital role of agriculture in Cameroon's economy, measures were taken to increase agricultural production, which unfortunately resulted in the excessive use of chemical fertilizers and pesticides to improve yield. In 1972, the Cameroonian government encouraged the use of chemical inputs, subsidizing up to 65% and 100% of the cost of fertilizer and pesticides, respectively [2]. Due to these subsidies and special credits for farmers, many farmers shifted toward export crop production, and agriculture became heavily dependent on external inputs like fertilizers and pesticides. Due to this increase in agricultural pollution, mainly chemical fertilizer and pesticide pollution, there will be a greater quantity of nitrogen, phosphorus, pesticides and other organic or inorganic pollutants entering the surface water, groundwater, and soil environments through surface runoff, with serious negative consequences on the environment and the health of the local population. Fertilizers and pesticides threaten the flora and fauna of all habitats as they do not differentiate between targeted and non-targeted species due to their toxic nature [5]. These highly stable compounds can last for years or decades before breaking down in the environment. These chemicals can be globally transported far away from the sources through a repeated process of evaporation and deposit on soils and water bodies [6]. Experimental evidence has established the fact that prolonged use of chemical fertilizers affects the structural and functional properties of microbial communities in soil [7] and at the same time creates a nutrient imbalance in agricultural soils. Heavy nutrient loads (nitrate and phosphate) in bodies of water favor the growth of aquatic plants and create negative effects on water quality by accelerating the growth of algal clumps, causing bad odors, and causing discoloration. Such conditions create problems for its use for recreational and aesthetic purposes [8].

In the Santa production area, the farmers carry out market gardening, leading to increased land cultivation without fallowing. The absence of fallowing will require enormous amounts of fertilizer to maintain soil fertility. Secondly, it has been observed that most farmers are ignorant of fertilizer and pesticide guidelines (safety measures, application techniques, and dosages) [9]. Other authors [10] have equally reported the indiscriminate use of chemical fertilizers in the study area due to a lack of training and sensitization on pollution issues as well as non-compliance with the legal texts governing the safe use of chemical fertilizers and chemicals. The enormous, consistent and incorrect use of these fertilizers and pesticides by farmers in Santa has led to an increase in concern about the level of contamination of soil and water with phosphates and nitrates, which are the active components of these agrochemicals. Unfortunately, published data on the quality of soils, water and sediments in Santa is scarce. This work is therefore aimed at determining knowledge on pesticides and fertilizer use, tracing their availability in surface and subsurface soils, in water and sediments using nitrates and phosphates as tracers, and evaluating the quality of some water sources (possible targets of fertilizer and pesticides) in Santa, Cameroon.

2. Materials and methods

2.1 *Study area and the research design*

This study was carried out in the Santa sub-division which falls within one of the 32 sub-divisions of the North West Region of Cameroon and covers a surface area of about 532.67 km^2. It is located in the Western Highlands of Cameroon between latitudes 5° 42' and 5° 53' N of the equator and longitudes 9° 58' and 10° 18' E of the Greenwich Meridian. Farming is the main activity. A descriptive research design using questionnaires was employed to evaluate the use of fertilizers by farmers in Santa. Accordingly, questionnaires (see Appendix) were administered randomly to 50 people carrying out activities around where water and soil samples were collected. Soil, water and sediment samples were collected from selected locations in the study site and analyzed in the laboratory to quantify the phosphates and nitrates. The map of the study area is presented in Figure 1, while different stages of the study are summarized in Figure 2.

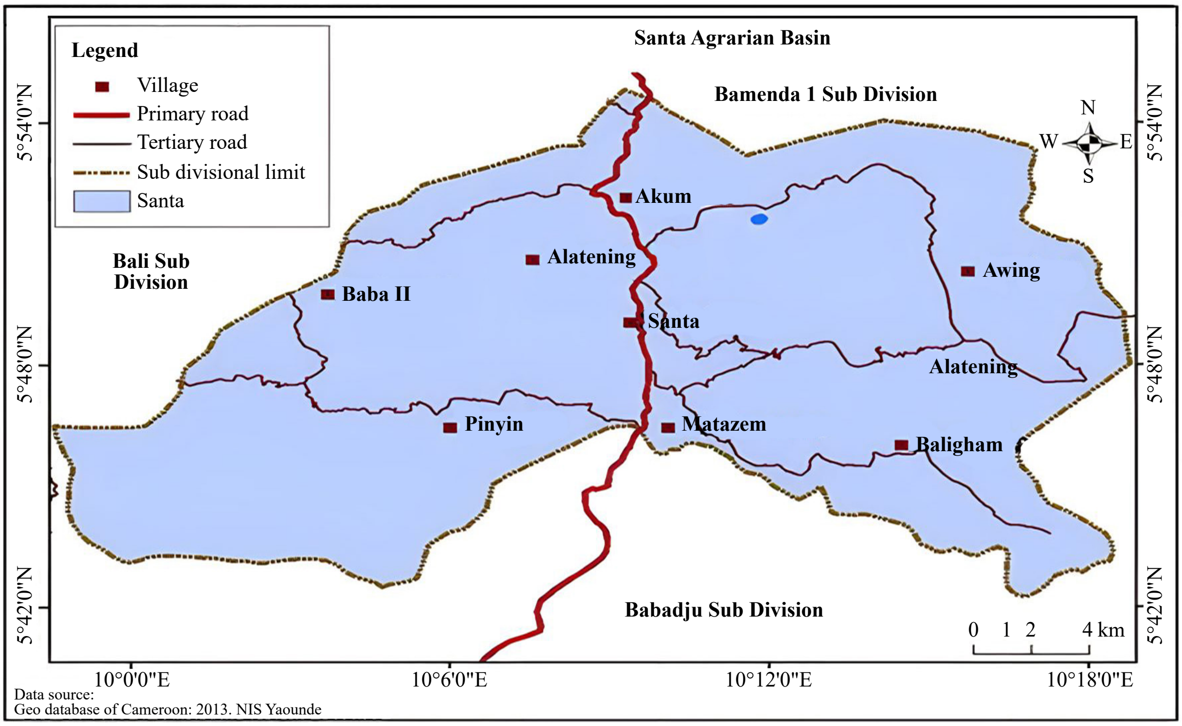


Figure 1. Location of Santa in Santa sub division [11]

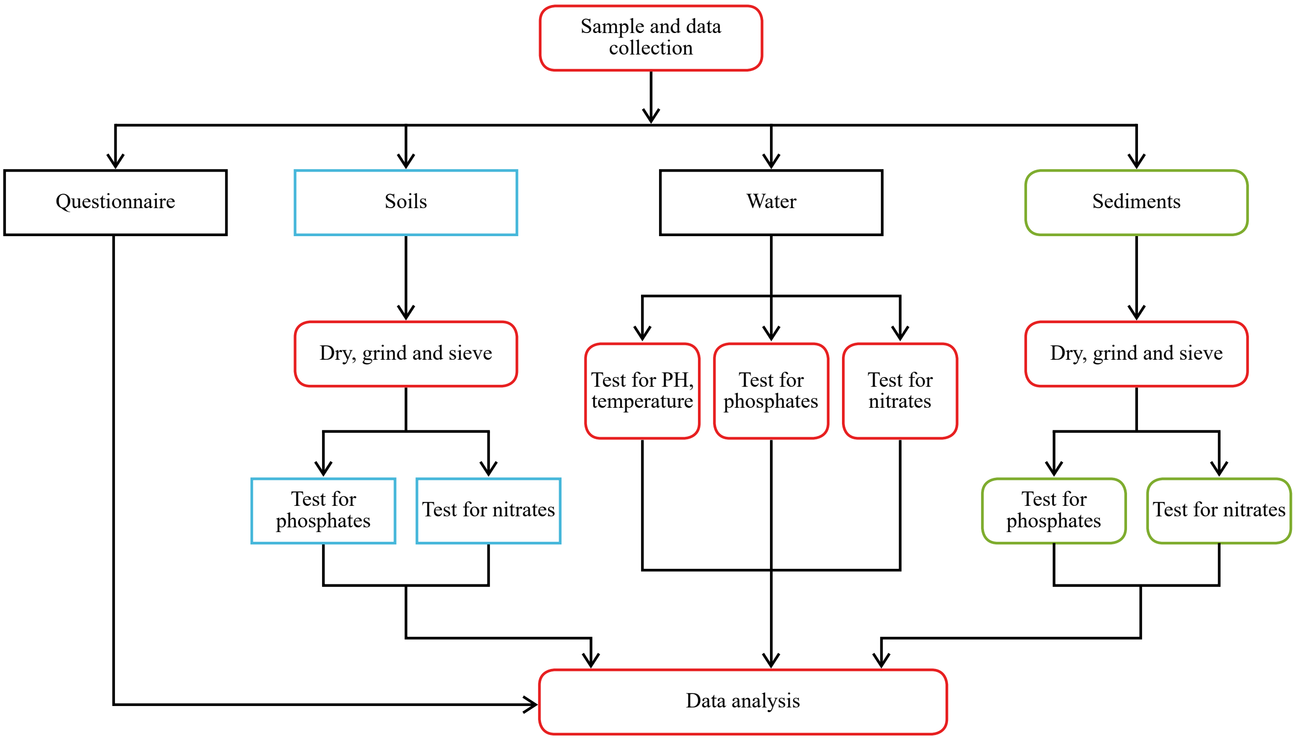


Figure 2. General flow-chat of research design

2.2 *Sample collection and preparation*

Surface and subsurface soils were obtained from 12 different locations in Santa, and their geographic coordinates were determined using a global positioning system (GPS) such as the Garmin eTrex® 10 GPS, as presented in Table 1. A composite sampling approach was used. Five samples (surface and subsurface samples separately) were collected from each site, and a representative sample of both surface and subsurface soil was obtained by mixing the five samples. While surface soils were collected at 0 cm depth, subsurface soils were collected at 1 cm to 65 cm depth. The subsurface soils were collected by digging with a shovel. Each sample was appropriately labeled (GPS location and name of the area) and stored on plastic paper. Collected soil samples were then dried under the sun for 15 days (the average environmental temperature is 27 °C), crushed, sieved, and their nitrate and phosphate contents determined.

Samples of water and their sediments were taken from 10 different places (Table 2). Eight of the places were streams and two were drinking water sources. The eight locations were areas with intense farming activities and were located downward from the farms, while the two tap glasses of water served as the control. Water sampling was done using polyethene bottles washed with distilled water, followed by 10% HNO_3 and distilled water again 24 hours before sampling to allow it to dry properly [12]. Four water and sediment samples each were collected at the shores (on both sides), with the farms covering a distance of 50 m (to cover most of the farm dimension downstream) and two at the center of the stream for water and sediment each. The five water samples as well as the five sediment samples were each mixed to obtain a representative sample used for analysis. This study was done in the dry season with a low volume of water in the stream that was flowing very slowly. While water samples were collected by letting the water enter the polyethene bottles directly, the sediment samples were collected by using a short shovel and then transferred into the polyethene bottles. Before the final collection, the polyethene bottles were washed with the water samples to be collected, and parameters such as pH, temperature, and electrical conductivity were measured on-site. The polyethene bottles containing water samples were placed in an ice bath and transported to the laboratory for the determination of other properties.

Table 1. GPS coordinates for soil (surface and subsurface soil) samples

Zone	Activity	Latitude	Longitude
Zone 1 (Farmland)	Abandoned farmland	5° 46’ 35.7” N	10° 09’ 45.7” E
Zone 2 (Ntary)	Uncultivated farmland	5° 47’ 28.3” N	10° 09’ 54.3” E
Zone 3 (Baptist Center)	Cultivated farmland	5° 47’ 31.9” N	10° 09’ 30.9” E
Zone 4 (Pinyin Boundary)	Uncultivated farmland	5° 47’ 43.9” N	10° 09’ 06.8” E
Zone 5 (Lower Konkibat)	Cultivated farmland	5° 47’ 41.5” N	10° 08’ 40.5” E
Zone 6 (Government residential area, Santa)	Uncultivated farmland	5° 48’ 17.0” N	10° 09’ 33.6” E
Zone 7 (Ngasaah)	Cultivated farmland	5° 48’ 24.5” N	10° 08’ 49.4” E
Zone 8 (Wumbon)	Uncultivated farmland	5° 48’ 39.5” N	10° 09’ 02.2” E
Zone 9 (Rock Farm)	Uncultivated farmland	5° 49’ 17.5” N	10° 07’ 38.4” E
Zone 10 (Nstam)	Uncultivated farmland	5° 49’ 23.4” N	10° 08’ 43.3” E
Zone 11 (Ntaw)	Cultivated farmland	5° 49’ 19.2” N	10° 08’ 59.8” E
Zone 12 (Mideno)	Uncultivated farmland	5° 48’ 58.8” N	10° 09’ 26.6” E

Table 2. GPS coordinates for water and sediment samples

	Latitude	Longitude
Sample 1	5° 49’ 45.6” N	10° 08’ 40.6” E
Sample 2 (Wubon)	5° 48’ 52.9” N	10° 09’ 11.2” E
Sample 3 (Santa-Akum)	5° 47’ 31.9” N	10° 09' 46.1” E
Sample 4 (Tiam)	5° 49' 10.4” N	10° 09’ 02.2” E
Sample 5 (Rock Farm)	5° 49' 06.5” N	10° 08’ 03.9” E
Sample 6 (Mubaku)	5° 49’ 06.9” N	10° 08’ 03.9” E
Sample 7 (Mbei-Pinyin Boundary)	5° 47’ 42.0” N	10° 09’ 08.4” E
Sample 8 (Government residential area)	5° 48’ 17.5” N	10° 09’ 34.1” E
Sample 9 (Tap water, Ntaw)	5° 49’ 33.6” N	10° 08’ 26.5” E
Sample 10 (Tap water)	5° 48’ 53.4” N	10° 09’ 24.0” E

2.3 *Determination of phosphates and nitrates in soil and water*

Phosphate was extracted from the soil and sediment samples using the Olsen method [13], in which 1 g of soil was mixed with 50 mL of a 0.5M $NaHCO_3$ solution and stirred using an electric mixer for 30 minutes at a rate of 20 rounds per minute (rpm). The mixture was then filtered using a Whatman filter paper No. 1 and 20 mL of the solution was used for phosphate determination using the molybdenum blue method at a wavelength of 620 nm (pre-determined) with an Ultra Violet-Visible (UV-VIS) Spectrophotometer (Model 752(D)). Nitrate was extracted from soils and sediments using the deionized water method [14] and quantified using the salicylic acid method [14] at 410 nm using the same UV-VIS Spectrophotometer.

The assessment of the quality of the water samples was done using standard procedures [15]. In addition to pH, temperature, and electrical conductivity, properties such as nitrate (NO_3^-), phosphate (PO_4^{3-}), chloride (Cl^-), chemical oxygen demand (COD), 5-day biochemical oxygen demand (BOD_5), total hardness, carbonate ion (CO_3^{2-}), nitrogen (N_2), nitrite (NO_2^-), aluminum (Al), bicarbonate (HCO_3^-), sulfate (SO_4^{2-}), iron (Fe), and turbidity were equally determined. These properties were used to evaluate the water pollution in Santa using the National Sanitation Foundation Water Quality Index (*NSFWQI*) method Equation 1 [16]. This index has a value ranging from 0 to 100 (Table 3). The index decreases with increasing pollution and has values ranging from 0 to 100.

$$NSFWQI = \Sigma_{i=1}^{n} Q_i W_i \quad (1)$$

where Q_i is the sub-index for *i*th water quality parameter, W_i is the weight associated with *i*th water quality parameter, and *n* is the number of water quality parameter.

2.4 *Data analysis*

Microsoft Excel (Version 2010) was used to record and compute the data from the study. SigmaPlot (Version 12.0) was used to perform the Analysis of Variance (ANOVA) at a 95% confidence level, while OriginLab (Version 8.0) was used for graphical analysis.

Table 3. The guide of the *NSFWQI* [17]

The index limit	Water quality	Classification of the type of water resource usage
90 to 100	Excellent	Having a natural state, it has no need to be treated if it is used to provide drinking water; it is appropriate for training the fishery and water-resistant species.
70 to 90	Good	If it is used to provide the required drinking water, it requires conventional treatment. Appropriate for fish farming and water-sensitive kinds; appropriate for recreational purposes like swimming.
50 to 70	Moderate	If it is used to provide drinking water, it requires advanced treatment, is appropriate for fisheries and water-resistant types, and is appropriate for domestic animals as the drinking water.
25 to 50	Bad	Appropriate for irrigating the agricultural lands.
0 to 25	Very bad	It is not appropriate for any of the mentioned usages, and it has only the ability to support a limited number of aquatic animals.

3. Results and discussion

3.1 *Evaluating knowledge on the use of fertilizers and pesticides*

3.1.1 *Identification of the respondents*

The findings regarding the demographic characteristics of the respondents are presented in Table 4. It can be observed that the majority of the interviewees were male (64%). A large number of the respondents (54%) fell within the age group of 31 to 40 years, while 36% of them had ages between 21 and 30 years. The majority of them had their levels of education as First School Leaving Certificate (FSLC) holders (58%), with the highest level of education being the advanced level certificate. Finally, a large number of the interviewees were farmers (92%) and just a few were traders (8%).

Table 4. Demographic characteristics of respondents

Parameter	Characteristic	Number	Percentage (%)
Group concerned	Male	32	64
	Female	18	36
	Total	50	100
Ages (years)	Less than 20	1	2
	21 to 30	18	36
	31 to 40	27	54
	41 to 50	3	6
	More than 50	1	2
	Total	50	100
Educational level	FSLC	29	58
	Ordinary level	18	36
	Advanced level	3	6
	Total	50	100
Occupation	Farmer	46	92
	Trader	4	8
	Total	50	100

3.1.2 *Cultivation practices*

Results of farm cultivation practices show that land cultivation is done continuously without fallowing. They thus resort to the continuous use of fertilizers for the maintenance of soil fertility.

Table 5. Land cultivation practices

Practice	Frequency	Percentage (%)
Fallowing (Skipping)	0	0
No fallowing (Without skipping)	50	100
Total	50	100

3.1.3 *Crops cultivated by respondents*

From the information gotten, the majority of the interviewees cultivated vegetables (86%), followed by cereals (10%), and about 4% of them cultivated legumes (Table 6).

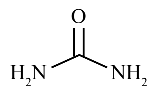
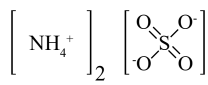
Table 6. Types of crops cultivated in the center of Santa

Crops	Frequency	Percentage (%)
Vegetables	43	86
Cereals	5	10
Legumes	2	4
Total	50	100

3.1.4 *Fertilizers used by respondents*

Most of the interviewees used nitrogen, phosphorus and potassium (NPK) fertilizers (48%), followed by urea (21%), and ammonium sulfate (10%) (Table 7).

Table 7. Types of fertilizers used by respondents

Fertilizer (Commercial name)	Frequency	Percentage (%)	Chemical formulas or active molecules
NPK	24	48	N, P_2O_5, K_2O
Urea	21	42	
Ammonium sulfate	5	10	
Total	50	100	

3.1.5 *Frequency of fertilizer application*

The frequency of fertilizer application varied with different individuals (Table 8). Some of the respondents applied fertilizers once per season (14%), twice per season (20%), and thrice per season (30%). A large number of respondents applied fertilizer more than three times per season (36%).

Table 8. Frequency of fertilizer application on crops

	Frequency	Percentage (%)
Once per season	7	14
Twice per season	10	20
Thrice per season	15	30
More than three times per season	17	36
Total	50	100

3.1.6 *Pesticides used*

Table 9 presents the different types of pesticides being used by respondents. A great number (80%) of them used fungicides, with the most common types being mancozeb and chlorothalonil; 18% used insecticides, with the most common type being cypermethrin; and about 2% of them used insecticides.

Table 9. Distribution according to the pesticides used

Pesticide type	Example	Frequency	Percentage (%)
Fungicides	Mancozebe compounds, e.g., Pencozeb, Mancostar, Terazeb, Cozeb, and Agrezeb Chlorothalonils, e.g., Banko, Banko Plus, and Balear	40	80
Insecticides	Cypermethrine, e.g., Caiment, Supercot, Paraster, Pyreforce, Sigon, and PACHA	9	18
Herbicide	Round up, Plantop, Glycot	1	2
	Total	50	100

3.1.7 *Waste disposal means*

A majority of respondents dumped their waste on land (92%), some in water (6%), and just one individual used other means of disposal (2%) (Table 10). Biodegradable wastes from households were thrown on farmlands as manure or buried in the ground, while a few respondents acknowledged having thrown waste in streams. Only a few disposed of waste using other means, such as burning.

Table 10. Waste disposal means

	Frequency	Percentage (%)
Land	46	92
Water	3	6
Others	1	2
Total	50	100

3.2 *Determining the presence of phosphates and nitrates in soils, water and sediment*

3.2.1 *Levels of phosphates and nitrates in surface and subsurface soils*

The results for the analysis of phosphates in soils are presented in Figure 3(a) while the results for nitrate in the soils are shown in Figure 3(b). The concentration of phosphate varied from 78.41 µg/L to 168.57 µg/L in surface soils and from 61.53 µg/L to 190.01 µg/L in subsurface soils (Figure 3(a)). The mean phosphate concentrations in surface and subsurface soils were 132.115 µg/L and 135.772 µg/L, respectively. There is not a statistically significant difference (P = 0.769) in phosphate concentration levels in surface and subsurface soils. The nitrate concentrations varied from 0 µg/L to 8.47 µg/L in the surface soils and from 0 µg/L to 6.99 µg/L in the subsurface soils.

Six zones had no nitrates in either the surface or subsurface soils, while zones 3 and 10 had small concentrations of nitrates in the subsurface soils only. It is also seen that nitrate is mostly present in the subsurface rather than in the surface soils (sites 2 and 10). The mean nitrate concentrations in surface and subsurface soils were respectively 1.855 µg/L and 3.020 µg/L. There is no statistically significant difference (P = 0.738) in nitrate concentration in surface and subsurface soils.

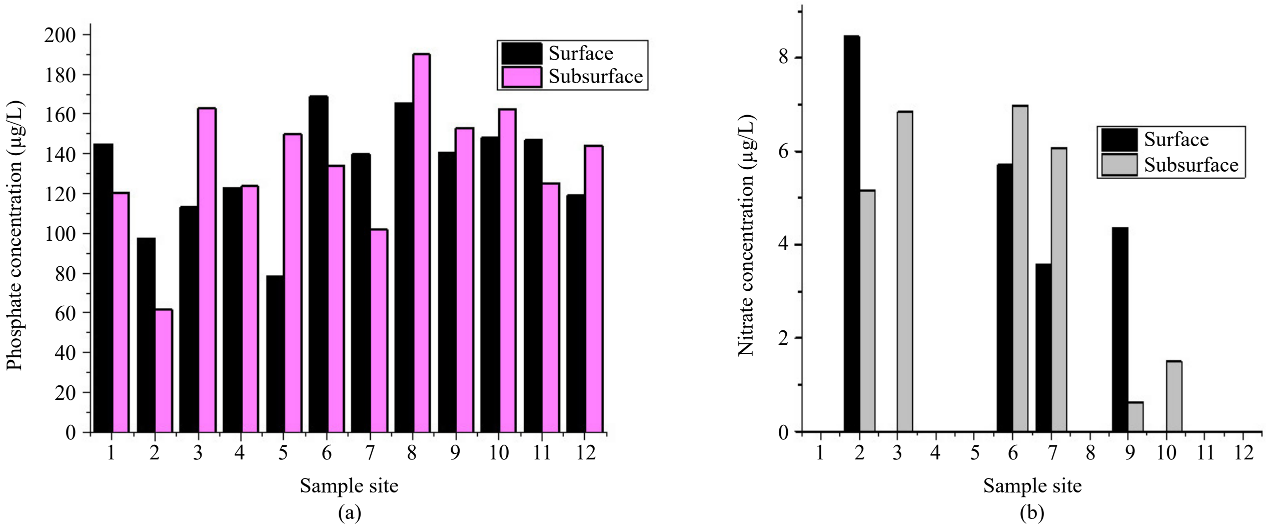


Figure 3. (a) Phosphate and (b) nitrate concentrations in surface and subsurface soils

3.2.2 *Levels of phosphates and nitrates in water and sediment samples*

The results for the analysis of phosphates in water and sediments are presented in Figure 4(a), while values for nitrate are presented in Figure 4(b). It can be seen that the phosphate concentrations of all the water samples are equal to zero, implying that no phosphate was present in the ten water samples as per the time analyzed, indicating a mean value of zero. In the sediments, the phosphate concentration varies from 11.58 µg/L to 160.56 µg/L giving a mean value of 110.232 µg/L.

There is therefore a statistically significant difference (P = < 0.001) in the distribution of phosphates in water and sediments. Meanwhile, the concentrations of nitrates in the water varied from 3.49 µg/L to 17.20 µg/L, with Sample 10 having the lowest value and Sample 3 having the highest value. For sediments, the concentrations varied from 1.05 µg/L to 10.36 µg/L, with Sample 7 having the lowest and Sample 5 having the highest concentrations of nitrates. It can be seen that the concentrations of nitrates were much higher in water than in sediments, with an average value of 10.334 µg/L compared to 3.364 µg/L in sediments. There is a statistically significant difference (P = 0.016) in nitrate distribution between water and sediments.

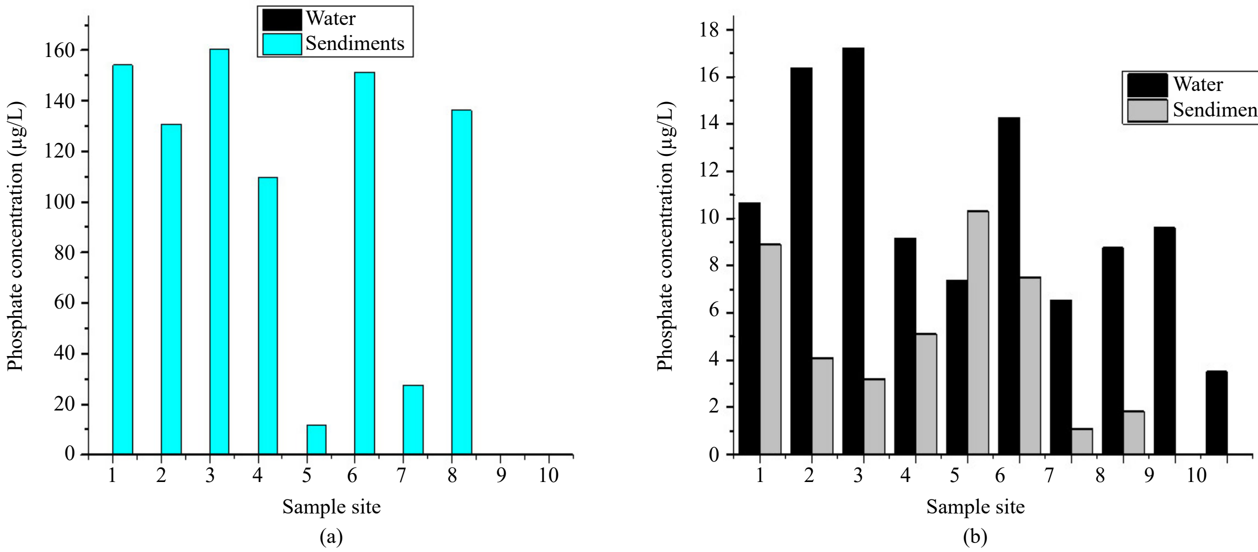


Figure 4. (a) Phosphate and (b) nitrate concentrations in water and sediment samples

3.2.3 *Comparison of the concentrations of phosphates and nitrates in surface and subsurface soils*

Figure 5(a) shows the results of a comparison of the concentrations of phosphates and nitrates in surface soils, and Figure 5(b) shows the same comparison for subsurface soils. Phosphate was more present in surface soils than nitrates, and unlike phosphates, nitrate concentrations in surface soils were very small (with the greatest concentration being 8.47 μg/L), as shown in Figure 5(a). Just like with the surface soils, the phosphate concentrations in subsurface soils were greater than nitrates (Figure 5(b)). Just about six zones had nitrates in the subsurface soils, unlike phosphates, which were present in all the zones. The mean concentration of phosphate in the surface soils is 132.115 μg/L compared to 2.962 μg/L in the subsurface soils. The corresponding mean values are 127.783 μg/L for phosphate and 29.008 μg/L for nitrate in subsurface soils. This shows that there is, therefore, a statistically significant difference ($P = < 0.001$) between phosphate and nitrate concentration levels in surface soil and subsurface soils.

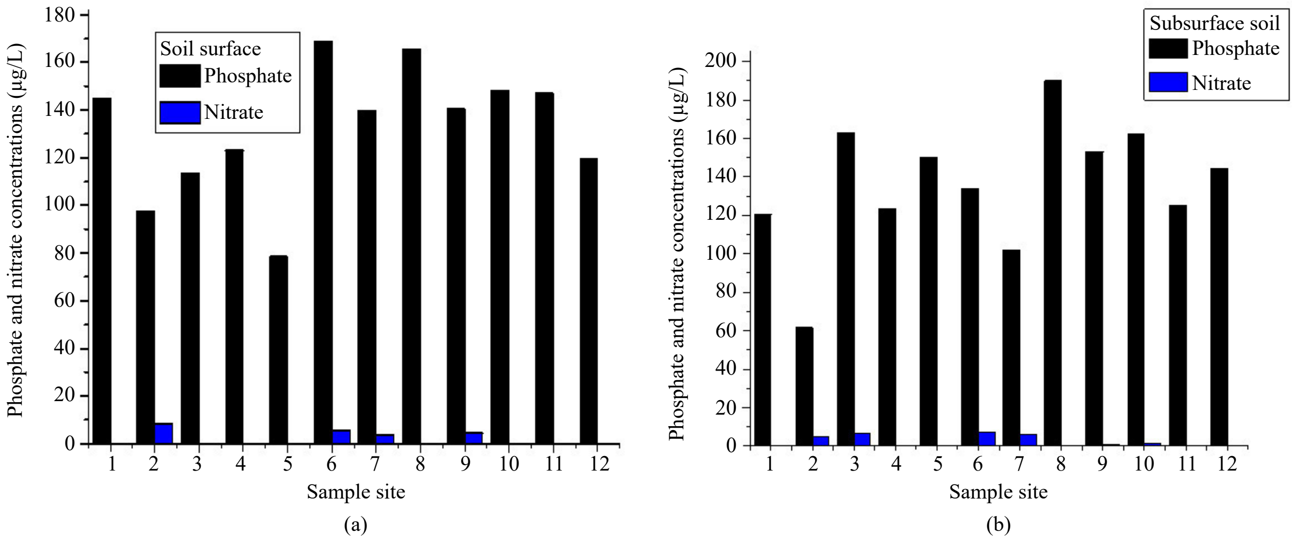


Figure 5. Comparing phosphate and nitrate concentrations in (a) surface soil and (b) subsurface soil samples

3.2.4 *Comparison of phosphates and nitrates in water and sediment samples*

Figures 6(a) and 6(b) show the results of a comparison of the concentrations of phosphates and nitrates in water and sediments. As seen in Figure 6(a), nitrate was more concentrated in water than phosphates. The water samples had no phosphates present. 4.39 µg/L is the mean value of nitrate in the water, compared to zero for phosphate, indicating there is a statistically significant difference ($P = < 0.001$) in phosphate and nitrate distribution in the studied water samples. Unlike with the water samples, there was a greater concentration of phosphates in the sediments than nitrates (Figure 6(b)). The phosphate average concentration in the sediment is 110.232 µg/L, against 3.364 µg/L for nitrate, indicating a statistically significant difference ($P = < 0.001$) in the distribution of these two species in the studied water sediments.

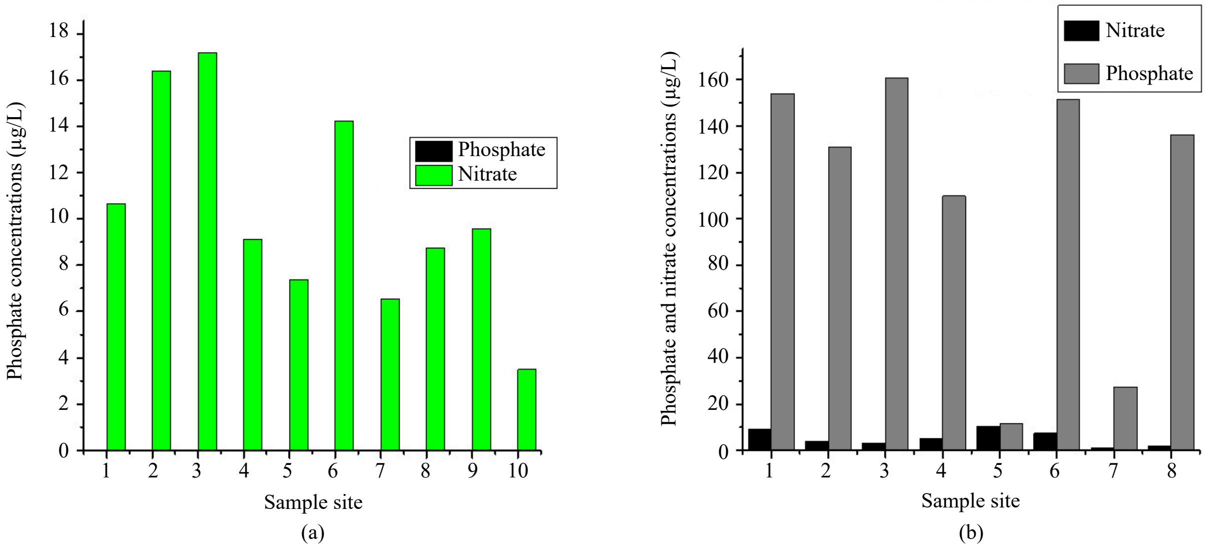


Figure 6. Comparison of phosphate and nitrate concentrations in (a) water and (b) sediment samples

3.3 *Data analysis*

Table 11 presents the physicochemical parameters of three different water bodies in Santa. These streams were chosen since they flow through farms, thus enabling the pathway of nutrients from fertilizers applied on farmlands to be easily established. These results were fitted into Equation 1 to assess the level at which these water sources were polluted. As evident from Table 12, all *NSFWQI* calculated varied from 53 to 59 for the three water samples, thus indicating moderate pollution.

Table 11. Results for the physicochemical parameters of water for three streams in Santa

	Results		
Parameter	Sample 1	Sample 2	Sample 3
pH	5.99	5.74	5.49
Temperature (°C)	28.91	29.10	28.7
Turbidity (NTU)	3.48	4.80	3.72
Conductivity (µs/cm/mg/L)	91.20	78.48	125.4
Ferum (mg/L)	0.03	0.09	0.08
Sulfate (mg/L)	13	19	36

Nitrite (mg/L)	0.25	0.58	1.1
Hardness	19.20	21.28	0
Alkalinity (CO_3^{2-}; mg/L)	3.0	2.48	2.88
Bicarbonate ions (mg/L)	4.9	4.67	3.9
Nitrate (mg/L)	0.09	2.2	2.4
Phosphate (mg/L)	8	4.5	1.5
Nitrogen (mg/L)	88	40.6	56
COD (mg/L)	65	15	25
BOD_5 (mg/L)	23.6	5.32	7.09
Aluminum (mg/L)	0.15	0.19	0.17
Chloride (mg/L)	37	29	18

Table 12. The results of water quality evaluation of three different streams in Santa using the *NSFWQI*

Zones or streams	Latitude	Longitude	Attitude	Values	Water quality status
Sample 1	5° 49’ 45.6” N	10° 08’ 40.6” E	1871	53	Moderate
Sample 3 (Santa-Akum)	5° 47’ 31.9” N	10° 09’ 46.1” E	1724	59	Moderate
Sample 6 (Mubaku)	5° 49’ 06.9” N	10° 08’ 03.9” E	1961	59	Moderate

4. Discussion

4.1 *Evaluating the use of fertilizers and pesticides*

From the survey conducted, the majority of the interviewees were males with low levels of education (FSLC). The lack of training in handling most of these agrochemicals is reflected in the low levels of education of most respondents, thus confirming the studies carried out by Sonchieu et al. [9]. Land cultivation in this area is done continuously without any fallow on farmlands since most of the respondents carried out market gardening as this helps provide income for the maintenance of their livelihoods. Also, the low levels of training received by these farmers account for the indiscriminate use of these chemicals, confirming the studies carried out by Tucker [18], which found that farmers in some developing countries apply fertilizers to their cropland excessively and indiscriminately because of the lack of training in continuous innovations.

The majority of the respondents cultivated vegetables. According to the ecological zone repartition in Cameroon, Santa belongs to the Western High Plateaus Zone, where the climate is very favorable for crop production, especially vegetable farming. Continuous cultivation without fallowing requires that farmers resort to the use of inorganic fertilizers, with some applying fertilizer more than four times per season. This goes to confirm the presence of phosphates and nitrates in soils and water, respectively. To protect crops from infections and improve yields, a great number of respondents resorted to the use of pesticides. A similar situation was observed by Matthews [19]. The frequency of pesticide usage depended on the season, the frequency of rainfall, financial capabilities, and the type of crops cultivated. This was in line with the findings of Sonchieu et al. [9]. Vegetable crops were more susceptible to infection than cereals and legumes, thus requiring more pesticide usage [20].

4.2 *Evaluating the presence of phosphates and nitrates in soils, water and sediments*

On average, the concentration of phosphates in subsurface soils was higher than in surface soils. The higher concentration of phosphates in subsurface soils than in surface soils could be attributed to two reasons. Firstly, phosphates that have accumulated over the years in the surface soils will gradually move down to the subsurface soils, and as a result of erosion, most of the phosphates in the surface soils become washed off into water bodies. Secondly, continuous cultivation and tillage increase soil macropore flow, thereby easing the mobility of nutrients (such as phosphorus) to the subsurface layers of the soil. This confirms the results carried out by Williams et al. [21], who studied phosphorus transport through macropores and concluded that macropore flow is the primary transport mechanism of total phosphorus through soil layers. Also, they concluded that high drainage phosphorus loads after fertilizer application can be attributed to macropore transport.

Based on the results we obtained in the laboratory, there were no phosphates present in the water bodies. Most of the phosphates were present in the sediments, firstly because phosphate binds with soil particles (sediments), and secondly because sediments are normally the final pathway for both natural and anthropogenic components produced in or derived from the environment. Higher phosphates in sediments than in water confirm the results carried out by Onwugbuta-Enyi et al. [22] on the presence of phosphate in sediments. Phosphorus in its soluble state (phosphate) quickly adsorbs at the surface of mud and slowly re-enters the water column.

Unlike phosphates, there were little or no nitrates present in our soil samples. The very low concentrations of nitrate in soils could be attributed firstly to the absence of nitrogen-fixing bacteria, which are responsible for the conversion of nitrogen to ammonia and then to soluble nitrate in the soils. Secondly, nitrate is the secondary form of nitrogen that is available for plant uptake and might have been taken up by the plants, especially on the surface soils and those not taken up by plants were washed off by runoffs into streams.

Nitrates being water soluble had greater concentrations in water than in sediments. The presence of nitrates in water goes to confirm the results carried out by Shinozuka et al. [23], who stipulated that runoff and organic matter decomposition in surface water also produced inorganic nutrients such as ammonia and nitrates, which remain in the water since they are not easily being taken up by plants. The low nitrate concentration in sediments is further contradicted by Kir et al. [24], who in their study stipulated that the most accumulated anion in sediment was nitrate. Generally, the overall concentrations of nitrates in the soil were low, stipulating that the quantity of nitrate supplied to the soil was just sufficient for the plant's uptake.

4.3 *Evaluation of water quality of three small streams*

In this study, the *NSFWQI* was used to evaluate water quality. According to the results, all three water bodies were located within the moderate range (53 to 59). From the survey conducted, most of the areas around streams had little or no habitation, thereby reducing the level of water pollution that is associated with densely populated areas. The presence of phosphates, nitrates, nitrogen, CO_3^{2-}, HCO_{3-}, Cl^-, Al^{3+}, and SO_4^{2-} in these streams resulted probably from the application of inorganic fertilizers. Water rated in the moderate range will require that the water be subjected to an advanced level of treatment if it is to be used for drinking.

5. Conclusion

In this study, the possibility of pollution of surface and subsurface soils, water and sediments, and some water sources from the increased use of pesticides and fertilizer by farmers in Santa, Cameroon, was investigated. The results show that 58% of the farmers have FSLC (58%), implying they can at least read and write. A greater number of them (100%) cultivate without fallowing, thus resulting in the greater use of fertilizer as 36% of farmers apply fertilizer four times per season. Vegetables are the most cultivated crop (86%), requiring the use of pesticides for pest control with 80% of the farmers using fungicides. Most of the wastes are dumped on land (92%) and can be a source of water pollution through runoff as well as soil pollution through leaching. Phosphate was more abundant in the subsurface than in surface soil as well as in water sediments. Except in water, all nitrate concentrations were lower than phosphates in the different samples studied. A maximum of about 180 μg/L of phosphate was obtained in either surface or subsurface soils, compared to 8 μg/L for the nitrate. Water sources studied showed moderate pollution as per the *NSFWQI*. Results obtained show there is a possibility of pollution of soil, water and sediments around the study area, with one of the likely causes being the indiscriminate use of agrochemicals; hence, there is a need for an awareness campaign to farmers by the government and local authorities with respect to the rules guiding the use of agrochemicals and the risks associated with their inappropriate usage.

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Conflict of interest

The authors declare no known competing financial interests or personal relationships that could have appeared to influence the work reported in this research.

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