Risk Assessment of Chemical Pollution of Industrial Effluents From A Soap Production Plant Located In Bafoussam (Western Region of Cameroon)

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Research

Keywords: Water and environmental pollution, Mewou River, Physico-chemical parameters, Heavy metals,

Posted Date: September 17th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-877488/v1

Abstract

The MEWOU river, which runs through the town of Bafoussam, is one of the main sources of drinking water and irrigation for the people who live there. It is subject to intense agricultural and industrial activity all along its banks. Soap and refined oil factories generate pollution in the form of liquid effluent which is released without any form of treatment. A total of seven samples were analyzed during the months of March, April and May of the year 2021. The results we obtained were analyzed according to the regulatory requirements recommended by the Guidelines for the quality of drinking water and the Algerian standard relating to the limit values of physicochemical parameters. The results we obtained showed signs of significant pollution in particular: chemical oxygen demand (COD: 125.32-959 mg L-1), 5 days-biochemical oxygen demand (BOD5: 23-99 mg L-1), turbidity (2-520 NTU), TDS (130-13430 mg L-1), Nitrite (4.96-21327.44 mg L-1) and many other parameters greatly exceed those required by the international standard, we have also noted a strong pollution to heavy metals: chromium (35.76- 1381.08 mg L-1), lead (0.21 - 2.49 mg L-1), iron (0.28- 17.82 mg L-1), and cadmium (0 , 03-0.19 mg L-1) which are above the values prescribed by the WHO. These heavily polluted effluents released into the natural environment are harmful to the environment, biodiversity and human health. This state of affairs requires urgent intervention to preserve the ecological balance. Otherwise, it can constitute a risk for public health in the short term by deteriorating the quality of the underground reservoir known as the main source of water supply for the local populations.

1. Introduction

Water pollution results from the introduction of foreign matter capable of deteriorating the quality of the water in a body of water, thus posing negative effects on human life and health. Industrial effluents represent a point source of water pollution [1]. While strict waste management and control policies have existed for years in developed countries, the implementation of the same model Regulation is struggling to take effect in developing countries like Cameroon, thus making it difficult to assess the current situation or compare and contrast its performance with other places / nations.

According to the 2005 review of global urbanization prospects [2], [3] half or more of Africa's population is expected to live in cities by 2030. In Cameroon, 50% of the population lives in cities; The urban population increased from 28.5% of the total population to 52.8% between 1976 and 2003. By 2030, it is expected to reach over 70% of the population. During the same 1976–2003 period, the population density in Cameroon increased from 16.4 to 35.7 inhabitants per km2 [2]. The population density is highest in the large urban centers of Bafoussam, the northeastern plains, Douala, Yaoundé and Garoua. This increase in the demographic pressure of cities like Bafoussam combined with the increase in population and the intensification of industrial activities makes the issue of controlling industrial effluents even more important.

In the town of Bafoussam Rivers are one of the main sources of fresh water supply, however they are also vulnerable to both point and diffuse types of pollution. Wastewater discharges from industries around the town of Bafoussam deteriorate the quality of surface and underground water and soils [4]. The effects of water pollution are often different depending on the mode of contamination. For humans, this is done by ingestion, contact or consumption of contaminated fish from polluted waters. For example, fish contaminated with biogenic elements such as copper and cadmium are highly toxic to humans. The presence of chromium and cadmium makes water unsuitable for domestic and agricultural use due to their toxicity [5].

The presence of toxic chemicals in industrial effluents can pose a threat to human and animal health as well as contaminate water quality[6].The objective of this study is to assess the impacts of effluent discharges from soap production on the quality of nearby water by analyzing certain physicochemical parameters of the discharge water leaving this soap factory.

2. Materials And Methods

The physico-chemical parameters analyzed in this study were the following: pH, Temperature, Turbidity (NTU), Electrical conductivity (µS / cm), TDS, Calcium, Magnesium, Potassium, Sodium, Bicarbonates, Carbonate, Nitric nitrogen, Nitrate, Nitrogen ammoniacal, Ammonium, Nitrite, Chlorine, Sulphate, Sulfur, Soluble phosphorus, Aluminum, Cadmium, Copper, Chromium, Iron, Lead, Zinc, Dissolved oxygen (mg L-1), chemical oxygen demand (COD) and 5 days of biochemical demand in oxygen, recommended by national regulations, to identify the sources of pollution with a global vision of the chemical quality of the wastewater discharged.

The analysis of the physico-chemical parameters was carried out at the Soil Analysis and Environmental Chemistry Research Unit, FASA, University of Dschang (Cameroon)

2.1 Presentation of the soap production plant (Cameroonian company of Soap factory)

This is a large soap production plant located in Bafoussam, Kamkop (in the western region of Cameroon). The city of Bafoussam is the capital of the Western region of Cameroon. It is located in the mountainous region of West Cameroon, in the Mifi Sud watershed, between 9 ° 30 'and 10 ° 35' East longitude and between 5 ° and 6 ° North latitude. It is at an average altitude of 1450 meters and extends over the highlands of the western mountain range. The expansion of the SCS plant in 2013 also boosted its production to 500 tonnes of refined oils every day. The SCS soap production plant releases a volume of raw polluted effluents of between 80 and 100 m3 / day into the environment.

2.2 Sampling and physico-chemical analyzes

2.2.1 Sampling conditions

For the results to be valid, special care must be taken when taking a water sample. First of all, the sample must be homogeneous, representative and obtained without modifying its physicochemical or microbiological characteristics [7].

The water samples used for the physico-chemical analysis were taken according to the method described by [7] in sterile disposable plastic bottles and stored at + 4 ° C, then to be analyzed within 24 h following sampling, with the exception of two parameters, pH and temperature, which were measured on site.

Samples were taken in the morning, and the used vials were held directly and extended to a depth of 30 to 50 cm from the surface of the polluted effluent of the SCS, a total of 7 samples were collected and analyzed (Table 1) .

2.2.2 Physico-chemical analyzes

All the physico-chemical parameters analyzed were based on the standard methods given by the American Public Health Association [8] as follows:

• The temperature and the hydrogen potential (pH) were measured respectively by a thermometer and a pH-meter (Thermo-scientific ORION STAR 225)

• The electrical conductivity was measured using the (Thermo-scientific ORION STAR 225). The result was expressed in microsiemens per centimeter (µS / cm);

Table 1: Description of study sites.

Sampling Point	Districts	Characteristics	Geographical locations	
			Longitude	Latitude
P1	Kamkop	Effluent discharge point	10°23'11"	5°29'43"
P2	Kamkop	Furnished, proximity dwellings	10°23'15"	5°29'41"
P3	Kamkop	Points of contact between a river and effluents	10°23'14"	5°29'39"
P4	Kamkop	Unfinished, nearby dwellings used as laundry point	10°23'17"	5°29'39"
P5	Kamkop	Under a scupper	10°23'20"	5°29'25"
P6	Kamkop	Points of contact with another river	10°23'21"	5°29'19"
P7	Kamkop	Meeting with the MEWOU river	10°22'48"	5°29'10"

2.2.3 Assessment of organic pollution of SCS effluents

For a better evaluation of the organic pollution of the discharged effluents, the parameters relating to biodegradability such as the coefficient K = COD / BOD5, the BOD5 / COD ratio, are of capital importance. The use of these characterization parameters is an excellent way to estimate the level of pollution of the raw effluents discharged and also to optimize the physicochemical parameters of these industrial effluents in order to propose a suitable wastewater treatment method.

2.2.4 Interpretation of physicochemical results

Thanks to the analysis of physico-chemical and bacteriological parameters, it is possible to determine the sources and the pollutant load of wastewater. Before being released into the natural environment, they must meet the standards established to protect the receiving environment against pollution. The limit thresholds are published in the Official Journal of the Algerian Republic and those of [6], [9].

2.2.5 Statistical analyzes

The experiment was repeated three times where the results obtained were presented as the mean ± SD, calculated using the MATLAB software from which the graphical representations were obtained in the form of curves.

3. Results And Discussion

3.1. Results

3.1.1. Physico-chemical analyzes

Table 2
Limits of the physicochemical parameters of industrial liquid effluent discharges from the SCS

Parameters	**Limit**	**Physicochemical analysis results**		
		Minimum value	**Maximum value**	**Mean ± SD**
pH	8,5–6,5 [9]	7.4	13.2	10.53 ± 2.67
Temperature ° C	30 [9]	22.9	24.8	23.61 ± 0.86
Turbidity (NTU)		2	520	201.86 ± 201.83
Electrical cond (µS / cm)		320	19980	9490.00 ± 9054.89
TDS (mg L-1)	0.2 [6]	130	13430	5362.86 ± 4597.07
COD (mg L-1)	120 [9]	125.32	**959**	414.85 ± 259.216
BOD5 (mg L-1)	35 [9]	23	99	48.43 ± 26.19
COD / BOD5	-	3.79	19.67	9.42 ± 5.22
BOD5 / COD	-	0.0508	0.26	0.14 ± 0.07
Calcium (mg L-1)	-	2.4	26.4	7.09 ± 7.98
Magnesium (mg L-1)	-	3.4	10.21	4.93 ± 2.23
Potassium (mg L-1)	-	13.31	26.53	22.02 ± 4.75
Sodium (mg L-1)	-	3.8	452.06	167.46 ± 180.94
Bicarbonates (mg L-1)	-	2135	75640	24948.13 ± 31917.52

Parameters	Limit	Physicochemical analysis results		
		Minimum value	Maximum value	Mean ± SD
Carbonate (mg L-1)	-	6	13134	2250.00 ± 4511.40
Nitric nitrogen (mg L-1)	-	1.12	4814.32	1137.04 ± 1849.77
Nitrate (mg L-1)	50 [6]	4.96	21327.44	5037.09 ± 8194.50
Ammoniacal nitrogen (mg L-1)	-	1.12	4.48	2.56 ± 1.15
Ammonium (mg L-1)	-	3.7	14.78	8.45 ± 3.81
Nitrite (mg L-1)	3 [6]	3,67	15782,3	3727.44 ± 6063.93
Chlorine (mg L-1)	5 [6]	39.05	223.65	112.08 ± 62.79
Sulphate mg L-1 (mg L-1)	1000 ～1200 [6]	1049.6	9725.2	5046.51 ± 3368.62
Sulfur (mg L-1)	-	346.37	3209.32	1665.35 ± 1111.65
Soluble Phosphorus (mg L-1)	10 [9]	5.64	1700.05	1113.11 ± 692.77
Aluminum (mg L-1)	3 [9]	0	0.03	0.01 ± 0.01
Cadmium (mg L-1)	0.003[6]	0.03	0.19	0.10 ± 0.05
Copper (mg L-1)	0,5 [9]	0	0.04	0.01 ± 0.01
Chromium (mg L-1)	0.7 [6]	35.76	1381.08	717.47 ± 412.30
Iron (mg L-1)	3 [9]	0.28	17.82	7.13 ± 5.86

Parameters	Limit	Physicochemical analysis results		
		Minimum value	Maximum value	Mean ± SD
Lead (mg L-1)	0.01[6]	0.21	2.49	+ 0.68_0.75
Zinc (mg L-1)	3 [9]	0.51	1.98	+ 1.72_1.97
Dissolved oxygen (mg L-1)	-	0.32	1.92	+ 1.10_0.48

3.1.2. Temperature

Water temperature is an important factor as it governs the types of aquatic organisms that inhabit it. Its role being, among other things, to dissolve the gases in water, and to separate the dissolved salts, its measurement is necessary. The temperature of the industrial SCS effluents analyzed indicates a variation from one sample to another (Fig. 3). The highest value was recorded for sample P1 (24.8 ° C) and the minimum value for sample P4 (22.8 ° C), with an average value for all samples analyzed equal to 23.61 ° vs. These values are lower than the limit set by the Algerian standard (Table 2).

3.1.3. Hydrogen potential (pH)

The hydrogen potential of water represents its acidity or alkalinity [10]. The pH of the industrial effluents studied reveals a high value for sample P3 (13.2); and a minimum value for the sample P7 (7.4); with an average value for all the samples analyzed equal to 10.53; that exceeds the range required by national and international regulations.

3.1.4. Electrical conductivity (CE)

The electrical conductivity of water is a direct indicator of its salinity. This is an essential factor to follow when considering the reuse of wastewater for irrigation (agricultural field) [11]. A maximum value of the electrical conductivity of the effluents was recorded for the sample P4 (19980 µS / cm), and a minimum value of 320 µS / cm for the samples P7 (Fig. 6), with an average value for all the samples. samples analyzed equal to 9490 µS / cm (Table 2).

3.1.5. Total Dissolved Solids Content (TDS)

Total Dissolved Solids (TDS) is the term used to describe inorganic salts and small amounts of organic matter present in solution in water. The main constituents are generally cations, calcium, magnesium, sodium, potassium, carbonate, hydrogen carbonate, chloride, sulfate and nitrate anions. [6].

The TDS parameter of the effluents analyzed showed a significant Variation from one sample to another (Fig. 7), where the highest value indicated a TDS content of 13430 mg L-1for sample P2, and a content in the lowest TDS equal to 130 mg L-1 for sample P7. The mean TDS value of all samples analyzed was 5362.86 mg L-1.

3.1.6. Nitrate content (NO_3^-)

Nitrate concentrations in surface water can change rapidly due to surface runoff, uptake by phytoplankton and denitrification by bacteria, but groundwater concentrations generally show relatively slow changes [6]. The nitrate content of the SCS effluents varies from 4.96 to 21327.44 mg L-1with an average content of 5037.09 mg L-1 (Fig. 7).

3.1.7. Nitrite content (NO_2^-)

Nitrite is considered to be an intermediate ion between nitrate and ammoniacal nitrogen, which explains its low concentration in aquatic environments [12].The nitrite contents were between 4.96 and 21327.44 mg L-1, with an average content of 3727.44 mg L-1 (Table 3; Fig. 9).

3.1.8. Sulphate content (SO_4^{-2})

Sulphates occur naturally in many minerals and are used commercially, primarily in the chemical industry. They are released to water in industrial wastes and by atmospheric deposition [6].The sulphate content of the industrial effluents analyzed varied from one sample to another (Fig. 10). The highest content is revealed for sample P3 (9725.2 mg L-1) and a minimum value for sample P7 (79.38 mg L-1), with an average value of all the samples analyzed equal to 1049, 6 mg L-1 (Table 2).

3.1.9. Chemical oxygen demand (COD)

The chemical oxygen demand (COD) is an important parameter for determining the organic load in water. In particular, for the operation of wastewater treatment plants, as well as for the characterization of water quality, this parameter is used worldwide and is one of the many directives relating to water quality. [13].

The COD values of the liquid effluents analyzed showed high concentrations ranging from 125.32 to 959 mg L-1 (Fig. 11), with an average value of 414. mg L-1. These results exceed the recommendations of [9].

3.1.10. Biochemical oxygen demand (BOD5)

The importance of the water oxygenation parameter is very clear since the presence of oxygen modulates the aerobic decomposition reaction of organic matter and more generally affects the biological balance of aquatic environments. The organic pollution values expressed in BOD5 show significant variations from one sample to another (Fig. 12). The recorded BOD5 values vary from 33 mg L-1 (minimum value) to 99 mg L-1 (maximum value) with an average value of 48.43 mg L-1 (Table 2).

3.1.11 Organic pollution assessment

Table 3
variation of organic pollution indicators in the MEWOU river.

samples	Organic indicators		
	DO (mg L-1)	COD (mg L-1)	BOD5 (mg L-1)
P1	1.92	959	71
P2	1.28	555.3	99
P3	1.28	217.5	34
P4	1.28	333.5	55
P5	0.96	260.85	24
P6	0.64	452.52	23
P7	0.32	125.32	33

Biodegradability provides information on the ability of an effluent to be decomposed or oxidized by microorganisms involved in the biological process of water purification. It is expressed by the coefficient K.

- Si ($K < 1.5$): This means that the oxidizable materials are largely made up of highly biodegradable materials.
- Si ($1.5 < K < 2.5$): This means that oxidizable materials are moderately biodegradable.
- Si ($2.5 < K < 3$): This means that oxidizable materials are not very biodegradable.
- If $K > 3$: This indicates that oxidizable materials are not biodegradable. A very high K coefficient implies the presence of elements in the water that prevent bacterial growth, such as, detergents, metal salts, hydrocarbons, phenols, etc. [14].

The industrial effluents studied have a K coefficient which varies from 3.79 to 19.67, which corresponds to that of industrial wastewater having a COD / BOD5 ratio greater than [10]. In addition, the average BOD5 / COD ratio of 0.14 reflects the low biodegradability of the substances contained in these effluents.

3.1.11 Metal concentrations

The values of the metals in the sample stream varied as follows: chromium (35.76-1381.08 mg L-1), zinc (0.51–1.98 mg L-1), lead (0.21–2.49 mg L-1), potassium (13.31–26.53 mg L-1), iron (0.28–17.82 mg L-1), copper (0- 0.04 mg L-1), and cadmium (0.03–0.19 mg L-1); the presence of lead is noted here with values greater than the WHO prescription, ie 0.01 mg L-1 in drinking water. The health risks of an elevated lead concentration include, kidney damage, anemia and brain edema [6]. Only the values of copper and Zinc were within the admissible standards; other heavy metals was clearly and unequivocally above allowable standards; which allowed us to establish a definite link between the contamination of the Mewou River with heavy metals and the discharge of industrial effluents from the SCS.

3.2 Discussion

Throughout this study, the pollution assessment of industrial effluents from SCS was carried out by analyzing certain physicochemical parameters which characterize these effluents. To this end, the industrial effluents analyzed were characterized by a hydrogen potential (pH) ranging from 7.4 to 13.2 very alkaline, and located beyond the recommended standard [6], [9]. These variations in pH are strongly influenced by the use of palm oil, chemicals such as nitric acid and caustic soda (NaOH) in the operations of soap production, cleaning and disinfection of equipment and facilities. industrial piping circuits, which can influence the pH of the receiving environment [10].

Even more, the effluent temperature varied from 22.9 to 24.8 ° C. This factor plays a very important role in the solubility of salts and gases (in particular O2) in water as well as the determination of the pH and the speed of chemical reactions. Relatively high temperatures act as additional pollution, thus influencing biological cycles [15] by decreasing dissolved oxygen activities, which can cause serious sewage disposal problems [16].These values depend on the use of hot water where the waste water generated by the pre-rinsing and detergent cleaning operations carried out at temperatures up to 55 and 70 ° C, respectively, is too hot, and the regenerative heat exchange in dairy processing [17].

Regarding the sulphate content of the discharged industrial effluents which was between 1049.6 and 9725.2 mg L-1, these values are not tolerable because the WHO suggests that the sulphate content limit should not be higher than 1000 1200 mg L-1[6].

The BOD5 values obtained by the analysis of industrial effluents indicated an average value of 48.43 mg L-1. This result is close to that found by [4] which ranged from 34 to 71 mg L-1, whose high BOD5 values could be explained by the abundance of organic matter. Chemical oxygen demand (COD) is the amount of oxygen consumed by materials present in water that can oxidize under defined operating conditions. Indeed, the measurement corresponds to an estimate of the oxidizable matter present in the water either from its origin (organic or mineral) [18].

The COD values ranged from 125.32 to 959 mg L-1, these values were much too high compared to the limits prescribed by the regulations [9]. These high concentrations were due to the high pollutant loads of organic matter released by the water, since the production of soap involves the use of large quantities of palm oil [19].These results are similar to those reported by [4] 122–958 mg L-1. An industrial effluent with such a high COD can pose serious problems with reducing the oxygen concentration in waterways.

Nitrate concentrations in surface water can change rapidly due to surface runoff, uptake by phytoplankton, and denitrification by bacteria, but groundwater concentrations generally show relatively slow changes. Some groundwater can also be contaminated with nitrates due to the leaching of natural vegetation[6]. The nitrate content ranged from 4.96 to 21327.44 mg L-1; this is probably due to the use of nitric acid as a chemical disinfectant for closed pipeline circuits [20], by the nitrification reaction of the organic nitrogen present in industrial effluents at the basin level . In fact, nitrification is a two-step process in which ammoniacal nitrogen is oxidized to nitrites (NO2-) then to nitrates (NO3-) [21].

Conductivity is a measure of the ability of water to conduct an electric current, therefore an indirect measure of the ionic content of water. Indeed, contrasting measurements on an environment make it possible to highlight the existence of pollution, mixing or infiltration zones [22]. The electrical conductivity of the industrial effluents studied was between 320 and 19,980 µs / cm, which can be explained by the mineral composition of the soap and also by the use of NaOH. These values were higher than those cited by [4], for industrial effluents from the SCS, with turbidity values ranging from 355 to 1859 µs / cm.

Turbidity, which is caused by suspended chemical and biological particles, can have implications for both water safety and aesthetics for the drinking water supply. Turbidity in itself does not always represent a direct risk to public health; however, it can indicate the presence of pathogenic microorganisms and be an effective indicator of hazardous events throughout the water supply system, from abstraction to point of use. For example, high turbidity of water sources can harbor microbial pathogens, which can attach to particles and interfere with disinfection; high turbidity in filtered water may indicate poor elimination of pathogens; And an increase in turbidity in distribution systems may indicate flaking of biofilms and oxide scales or the penetration of contaminants through faults such as power outages [23].

The effluents studied have turbidity values ranging from 2 to 520 NTU, due to the presence of colloidal materials from palm oil used for soap production. These results are close to those found by (Gouafo and Yerima, 2013) which were from 37.4 to 105.5 NTU.

The origin of the accumulation of nitrite may be linked to the inhibition of nitration, or to the incomplete denitrification or even decoupling of the activities of the various reducing enzymes in the denitrification[24]. The values obtained which ranged from 3.67 to 15782.3 mg L-1 were 5,000 times higher than the prescribed standards ([6].

The COD / BOD5 ratio according to [25], [26] makes it possible to deduce whether the wastewater directly discharged into the receiving environment has the characteristics of domestic wastewater. this COD / BOD5 ratio is greater than 3 in our case, which means that the oxidizable materials thus released are not biodegradable. It can be deduced that the low biodegradability of these industrial wastewater from SCS may be associated with the presence of certain inhibitor products, such as palm oil heavily used for soap production, or with a high load of organic matter.

4. Conclusion And Recommendation

In view of the results that we obtained, it is clear that the industrial effluents of the SCS analyzed were highly polluted, in particular in heavy metals (lead, chromium and cadmium), and in organic matter, underlined in particular by high values of turbidity. , COD, and BOD5. All these indicators, witnesses of undeniable pollution, indicate that these effluents constitute a source of contamination of the receiving environment and present a threat to the ecosystem and to public health.

This situation is caused by the lack of an industrial effluent treatment procedure at the production site. Finally, the following practices are recommended to limit the volume as well as the polluting load of liquid effluents:

• Beyond its position as a major economic actor (employers and producer of goods) that the soap production company SCS plays in the city of Bafoussam, these managers must become aware of the social responsibility incumbent on them and set up an effluent treatment unit.

• Develop practices that will make it possible to minimize discharged effluents as much as possible, in an approach of "Cleaner production techniques", focused on the use of good practices to minimize water consumption;

• Set up anaerobic basins much more adapted to hot climates With relatively short retention times of only a few days, which can reduce the organic load by 40 to 70% [11].

Declarations

Acknowledgements

Not applicable.

Authors' contributions

ZGM conducted the field studies, laboratory analyzes, interpretations and wrote the draft manuscript. TPK organized the data and revised the manuscript. All authors have read and approved the final manuscript.

Funding

Not applicable.

Availability of data and materials

All of the data generated or evaluated during this study has been reviewed by our group and certified several time

Declarations

Competing interests

The authors declare they have no competing interests.

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Figures

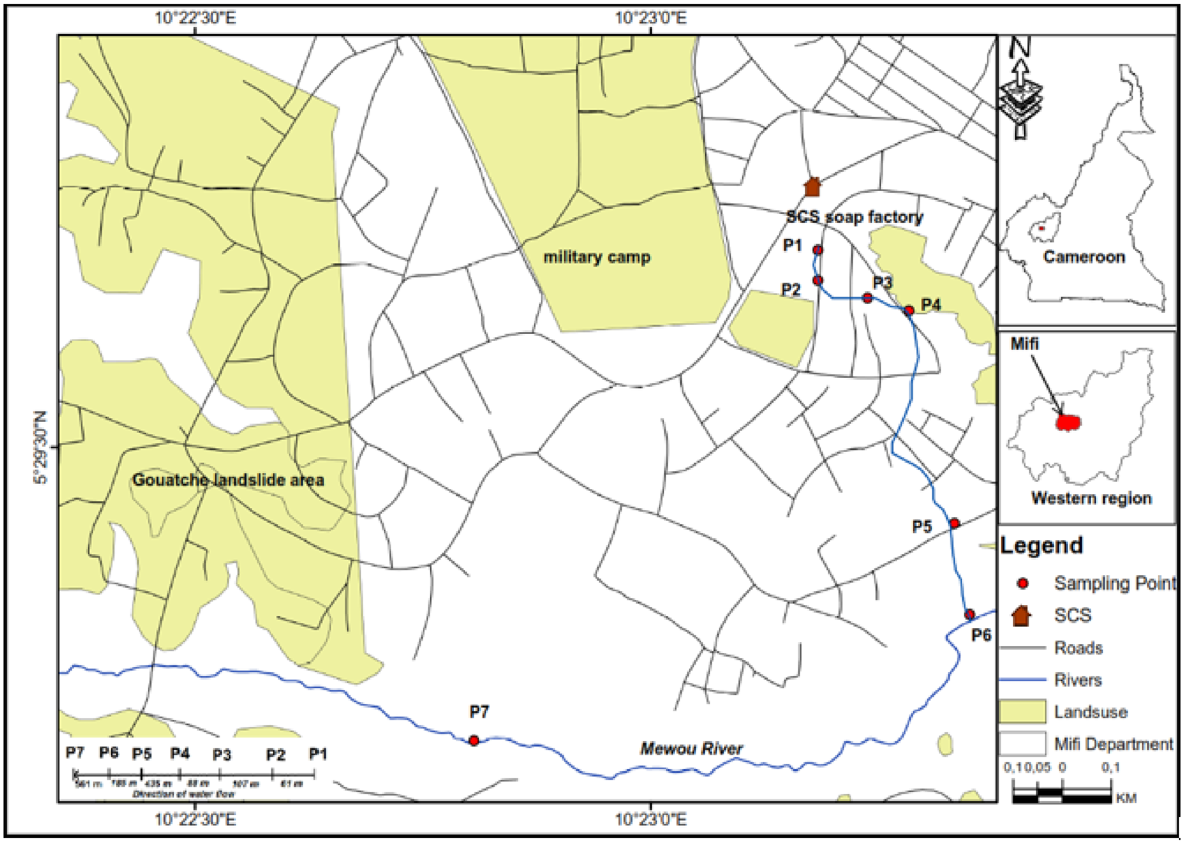

Figure 1

Partial hydrographic network of the southern Mifi showing the location of the sites of the SCS (Cameroonian company of Soap factory)

a) b)

Figure 2

(a) effluents released by the Cameroonian company of Soap factory in bafoussam, kamkop. (b) one of the meeting areas between the effluents and a watercourse in the town of bafoussam.

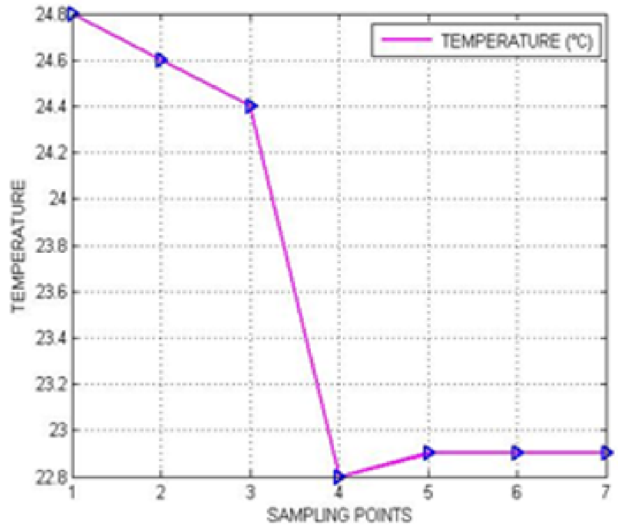

Figure 3

Average effluent temperature values

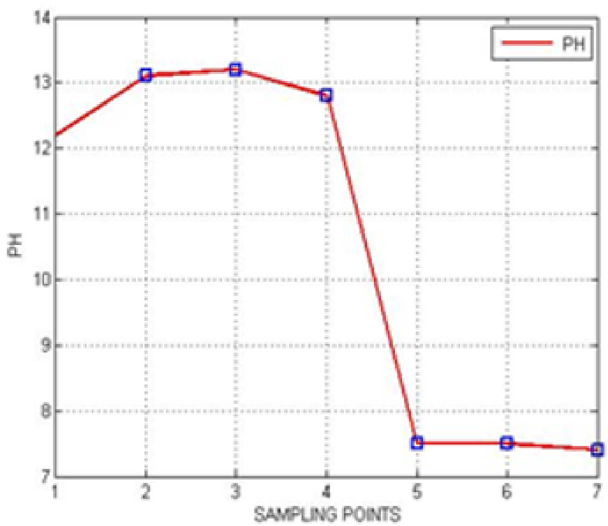

Figure 4

Average pH values of effluents

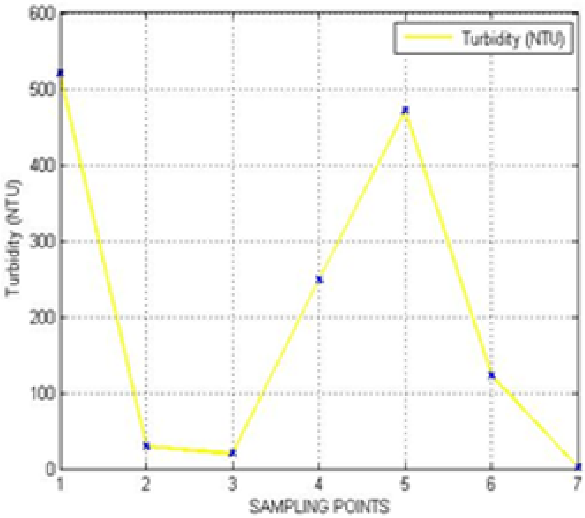

Figure 5

Average effluent turbidity values

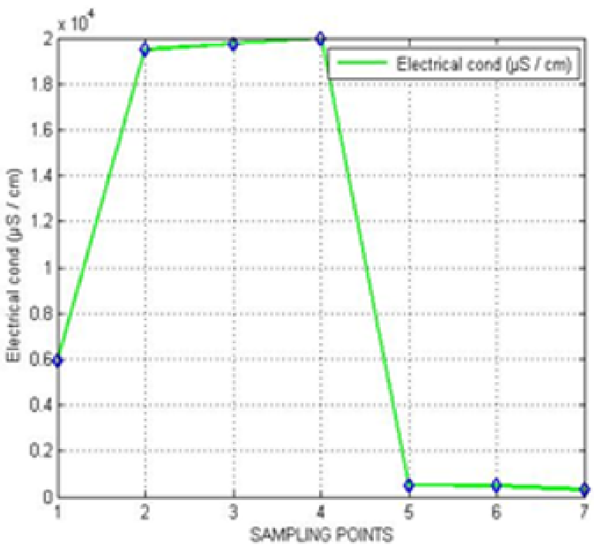

Figure 6

Average electrical conductivity values of effluents

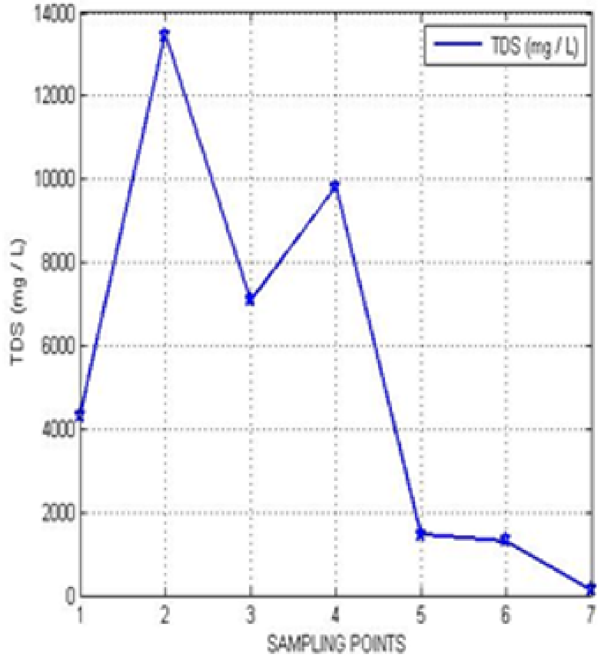

Figure 7

Average values of TDS of effluents

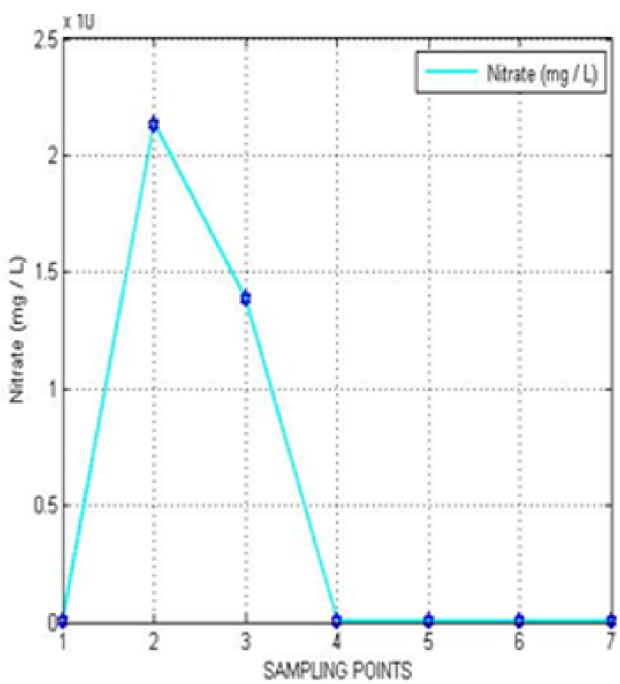

Figure 8

Average values of nitrate of effluents

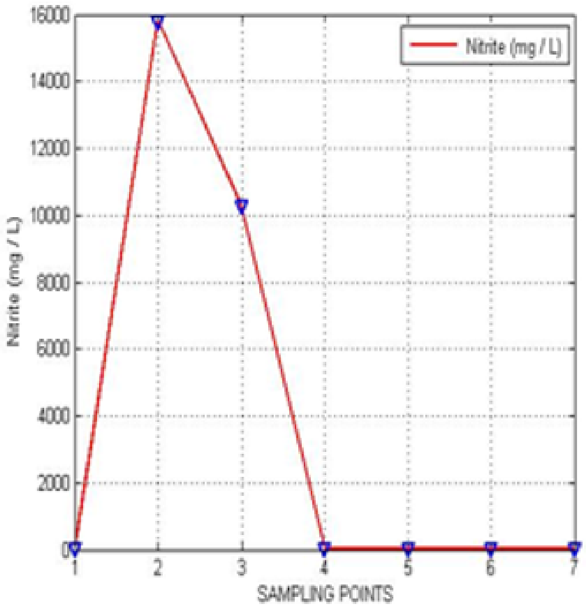

Figure 9

Average nitrite values in effluents

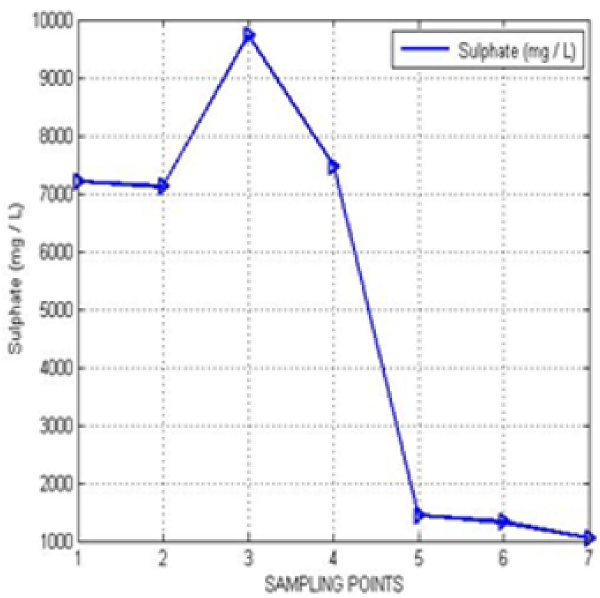

Figure 10

Average sulphate values in effluents

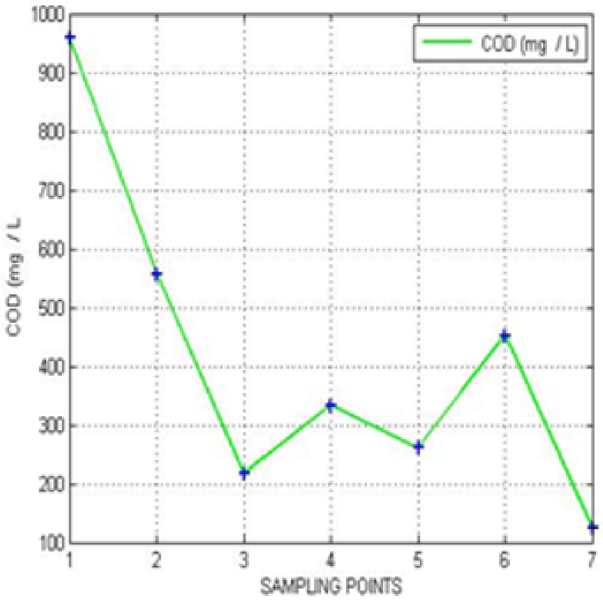

Figure 11

Average COD values of effluents

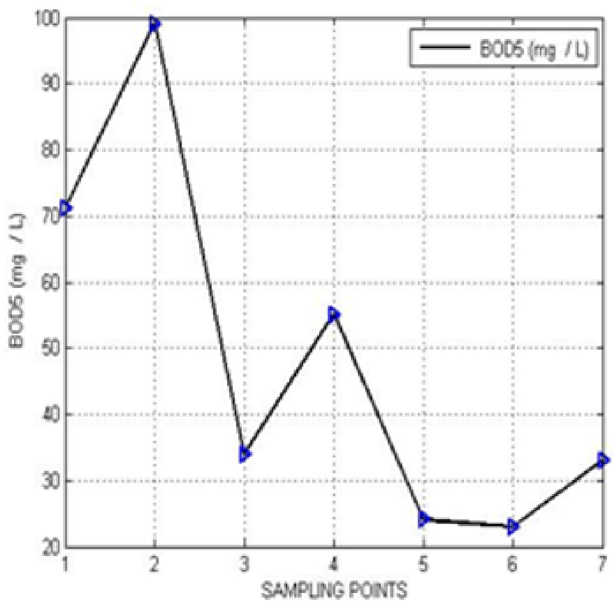

Figure 12

Average values of BOD5 of effluents

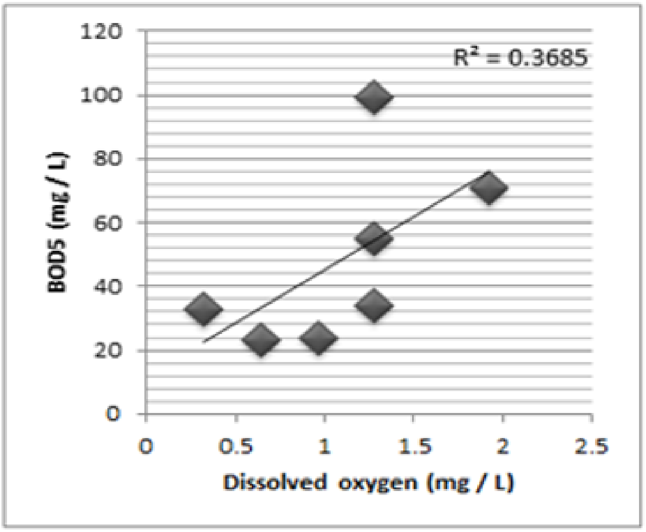

Figure 13

BOD against DO for River Mewou.

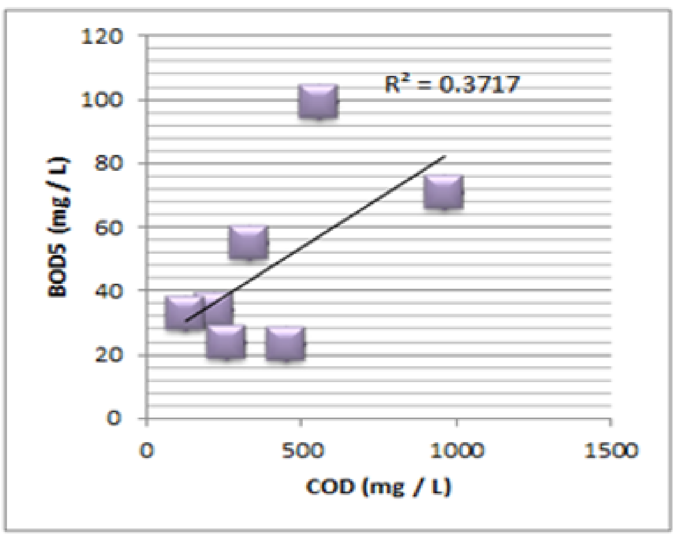

Figure 14

BOD5 against COD for River Mewou