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Evaluation and Mitigation of Industrial Wastewater Pollutants from Soap Factories and Breweries in the Bafoussam City Vicinity (Western Highlands of Cameroon)

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Abstract: The discharge of wastewaters of industries in the Bafoussam city vicinity deteriorate the quality of surface and underground water and soils. The purpose of this study is to determine the level of ecotoxicity in the different industries and ways to mitigate this pollution. The following physico-chemical parameters were determined: COD, BOD_5, OM, TP, Cu, Cd, Zn, Cr, Fe, Al, EC, Turbidity, NH_4^+ and NO_3^- from wastewaters from two soap factories (SWC and SCS) and one Brewery (ASCB) in Bafoussam. Statistical analysis, were made to determine the correlation coefficient R and covariance. R varies from 0.715 to 0.897. These coefficients indicate a positive correlation different from 1; hence, we cannot predict the parameters of an industry based on the parameters of the other. Total heavy metals contents range from 118.66 mg/L for SCS to 39.58 mg/L for the SWC and to 2.45 mg/L for the ASCB. COD ranges from 122 to 959 mg/L; the highest value was obtained in the SCS. These results indicate that the SCS is the most polluting industry. To reduce the pollution we recommended that each industry recycle its wastewater and put in place specific treatment plants because pollutants to eliminate vary depending on the industry. The Municipal community is also advised to institute sensitization meetings with the promoters of these industries on proper wastewater handling and treatment. Penalties for pollution should be proportional to the degree of pollution.

Keywords: Correlation coefficient, ecotoxicity, heavy metals, physico-chemical parameters, sensitization meeting, treatment plants

INTRODUCTION

Cameroon, like most developing countries is undergoing a steady industrial development. The discharges of wastewaters of industries into the environment deteriorate the quality of surface and underground water and soils. Most industries eliminate their effluents directly into rivers, streams, ponds, ditches and farmland without treatment. The problem of water supplying cooperations today is the fight against water pollution (Butu and Iguisi, 2012). Metals are chemical elements that are known to be carcinogenic and deadly, because of their bio-accumulation (Dajoz, 1996). Metals produced by industries end up in the rivers when they are not treated and are a threat to the survival of aquatic organisms and humans that use the water for domestic purposes (Hankouraou, 1998). Wastewater from industries contains enormous quantities of pollutants such as nitrates, nitrites, cations, anions and toxic metals such as Fe (iron), Cr (chromium), Cd (cadmium), Cu (copper), Zn (zinc), etc., (Sial *et al*., 2006; Ullah *et al*., 2009). In addition, sewage also causes an increase in parameters such as Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), which deteriorates the water quality. On the other hand, organic nitrogen contained in organic matter is converted into ammonia (NH_3) or ammonium salts (NH_4^+), according to a bacterial process called ammonification. Nitrification of ammonium is performed under aerobic conditions; the demand for oxygen it carries is added to the final BOD (Champoux and Toutant, 1988). The lack of oxygen causes the opposite phenomenon, called denitrification, NO_3^- are then transformed into nitrite (NO_2^-) which is toxic or to molecular nitrogen (N_2) (Gingras, 1997). This oxygen consumption leads first to a decrease in

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oxygen levels in the water. When the rate of oxygen saturation falls below 6 mg/L fish life is threatened. Below 5 mg/L most species die (Champoux and Toutant, 1988). The second consequence is that to compensate for a variation in the dissolved oxygen rate, the fish can increase the speed of water flow over the gills, which has the effect of increasing the volume of water in contact with blood; this increases the intoxication by heavy metals due to bioaccumulation. The Total Phosphorus (TP) is a limiting factor for the growth and development of organisms in the aquatic environments. They play a determinant role in triggering eutrophisation phenomena, when they are in high concentrations (>0.2 mg/L) (Dajoz, 1996). The effects of water pollution are often different depending on the mode of contamination. For man this is through ingestion, contact or through consumption of contaminated fish from polluted water. For example, fish contaminated with biogenic elements such as copper and cadmium are highly toxic to humans. The presence of chromium and cadmium make water unsuitable for domestic use and agriculture because of their toxicity (Kankou, 2004). These substances are sometimes toxic at very low doses (<1 mg/L for the most part) (Feujio, 2002). Wastewater can also contain dangerous chemical substances for the health of man. According to WHO (1998), McDonald and Kay (1988) and Super and Heese (1981), excess intake of nitrates in the short term may cause methemoglobinemia in infants and long-term carcinogenicity in adults. Nitrates and nitrites when absorbed produce nitrosamines, which are carcinogens (Castany, 1982; Beaux, 1997; Deoux, 1993). Aluminum has an affinity for bones, where it's accumulation (>5 mg/L) causes osteoporosis, characterized by decreased bone formation; even worse its presence in breast milk leads to its deposition in the infant brain causing symptoms of Elsheimer (Deoux, 1993). Zn in aquatic life has a certain toxicity (>3 mg/L) depending on the mineralization of the water and the species considered (Ghaouti *et al*., 2005). In the natural environment, any substance that contaminates the environment can be taken up by man. It thus enters the food webs of ecosystems, to join the cycle of matter in biological communities and have a negative effect on countless plant and animals species (Dajoz, 1995). The ecological consequence of pollution of water resources is the degradation of aquatic ecosystems. Like any natural environment, an aquatic ecosystem has a self capacitance to eliminate the pollutants it receives. However, when the intake of toxic substances is too large, the aquatic environment loses this capacity of self-purification, thus, a massive accidental intake of toxic substances can cause dramatic ecological disaster of the aquatic fauna. Water as a solvent for most inorganic or organic substances can carry any pollutant far downstream from the contamination source (Bernard, 1994). Gases are not very soluble in water and aquatic environments and consequently those environment are poor in dissolved oxygen, which is an essential element for the breathing of aquatic fauna. The relative poverty in natural aquatic dissolved oxygen, causes the animals to absorb large quantities of water to meet their needs for oxygen, thus the risk of intake of large quantities of toxic substances, though only very low concentrations of these elements exist in the environment.

Acids cause the destruction of the soil structure. Dajoz (1996), according to Hamburg and Cogbill (1988), report that acids cause leaching of soil nutrients such as Ca, K, Na and Mg and release Al and various heavy metals that are toxic to vegetation, resulting in the death of plants and soil exposure to different forms of degradation. Developed countries have established standards for the sanitary quality of water. In contrast, in the Third World countries, waterborne diseases (cholera, typhoid, dysentery, etc.) still kill millions of people a year (Fonkou, 1996; Agentia *et al*., 2000). According to WHO (2008), 80% of diseases encountered in the world are waterborne. Given its industrial pollution potential different researchers have proposed some solutions, involving detailed examination of the problem, installing wastewater treatment plants and review of working conditions (Thomazeau, 1985). According to Aubertot *et al*. (2005), the polluter pays principle should be applied.

In the city of Bafoussam no study has yet been carried out on industrial pollution. If nothing is done this city risks experiencing water shortages due to pollution, especially as none of the three companies has a wastewater treatment plant. Our study focuses on the evaluation of wastewater samples of the Anonymous Society of Cameroon Brewery (ASCB), Soap factory of Western Cameroon (SWC) and Soap Cameroon Society (SCS) for their ecotoxic effects through various physico-chemical parameters, in order to determine the industry with the most polluting degree and propose specific strategies for each industry to fight against these sources of pollution.

MATERIALS AND METHODS

The study area: Bafoussam, the capital of the West region of Cameroon is located 300 km from Yaounde. It is located in the highland area of the West, in the Mifi catchment area between longitude 9° 30' and 10° 35' east and between latitude 5° and 6° north. It has an average altitude of 1450 m. It lies in the highlands of the mountain range in the west.

This region is drained by four major rivers: the Mape, north tributary of Mbam; Nkam to the south-west, coastal river under the name Wouri, flows into the sea in Douala and drains the southwest edge of Bamileke and the region of Dschang; the Nde southeast tributary of Noun and the Noun, which drains much of the mountainous region of western Cameroon after taking its rise in M_t Oku (3070 m). The area of the Watershed is 1640 km^2. Bafoussam is located in the agricultural region of Western Cameroon. The latest

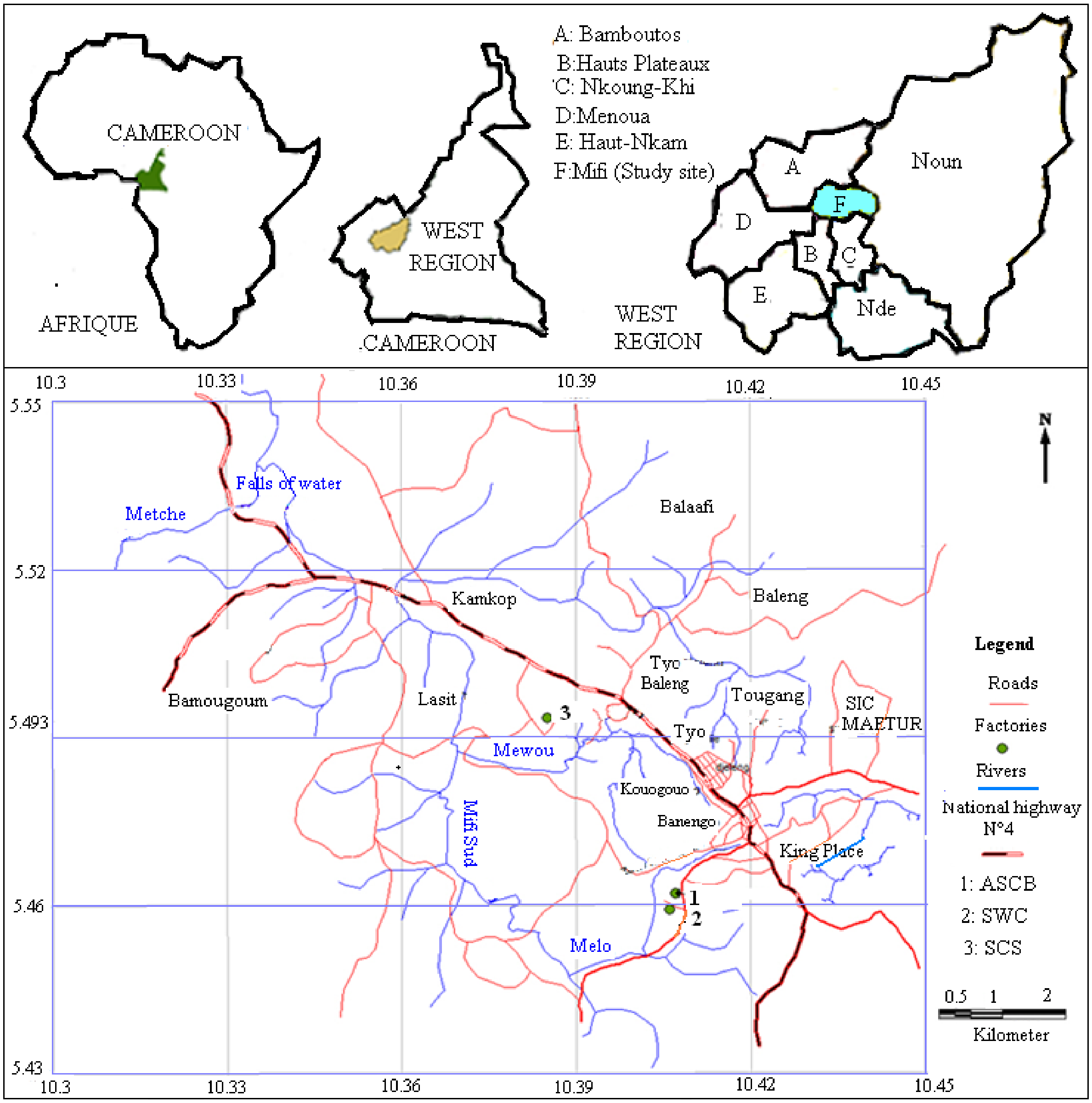

Fig. 1: Partial hydrographic network of southern Mifi showing site locations of ASCB (Anonymous Society of Cameroon Brewery); SWC (Soap factory of Western Cameroon); SCS (Soap factory of Cameroon Society)

statistics released by D.S.N.A. and R.P.G.H.C. (2000) show that this region has a population of 1,339,791 inhabitants. This population is growing at an annual rate of 2, 37%. In 2013 a population of 1,816,695 inhabitants. Liquid discharges from industrial sources are discharged directly into the Mewou and Melo rivers which cross the city. The latter is transformed into an open sewer running through the city and surrounding Villages and seeping into the ground over a distance of about 40 km before flowing into the River Noun. Along its path, resident farmers use it for irrigation of cereals and forage crops.

The stations selected for the study are as follows (Fig. 1):

- Point 1 (ASCB), is the wastewater of Anonymous Society of Cameroon Brewery that produces: soft drinks (syrup manufacture) and alcoholic beverages (Beer).
- Point 2 (SWC) shows the liquid discharges from the Soap Factory of Western Cameroon that produces: laundry soap, toilet soap, soap powder, liquid soap, cooking oil, vinegar, deodorant, glycerin, waxing and plastics.
- Point 3 (SCS) represents the liquid discharges from Soap Factory of Cameroon Society that produces: laundry soap, toilet soap, soap powder, liquid soap, cooking oil, vinegar, deodorant, Glycerin, Waxing and Plastics.

Sampling and analysis: All samples were collected in plastic containers of 500 mL and sent to the laboratory six hours before the determination of the following Physicochemical parameters: COD, BOD_5, OM, TP, Cu, Cd, Zn, Cr, Fe, Al, EC, Turbidity, NH_4^+ and NO_3^-.

The determination of COD was made by digestion of potassium dichromate in a DRB2000 HACH digester at 150°C for 2 h and results were obtained on a DR2000 spectrophotometer at a wavelength of 620 nm (Hach, 1997). BOD_5 was determined by the respirometric BOD Trak^{TM} 2000. A 160 mL aliquot of each sample was introduced into a BOD bottle on the BOD Trak and incubated at 20°C for 5 days. Readings were made on the screen of the BOD Trak (Hach, 1997). The OM was determined by the following equation OM = $(COD+2BOD_5)/3$ (Rodier *et al*., 2009). TP was determined spectrophotometrically according to Pauwels *et al*. (1992).

The determination of Cu, Cd, Zn, Cr, Fe and Al were done using an atomic absorption spectrophotometer (Benedetto, 1997). EC was determined according to Pauwels *et al*. (1992), using a conductivity meter. Turbidity was determined according to Pauwels *et al*. (1992), using a spectrometer at a wavelength of 720 nm. NH_4^+ (ammonium) and NO_3^- (nitrate) were determined according to Pauwels *et al*. (1992) ,using a specific sensor electrode of ammonia (NH_3) the medium being sufficiently basic to transform the ammonium ions (NH_4^+) into ammonia (NH_3) gas.

The study of the pollution was based on the analysis of physico-chemical parameters.

These parameters were obtained from analyses in the Laboratory of Soil and Environmental Sciences, Faculty of Agricultural Sciences (FASA) of the University of Dschang, Laboratories of Applied Botany and the Analysis Laboratory of Soil, Plants, Fertilizer and Water (LASPEE) of IRAD (Institute of Agricultural Research and Development) of the Ministry of Scientific and Technical Research of Yaounde Cameroon.

Statistical analysis of data: In the present study we determined the covariance and Pearson correlation coefficient R using Microsoft Office Excel (Microsoft, 2010).

RESULTS AND DISCUSSION

The concentrations of the physico-chemical parameters vary from point 1 to point 3 (Table 1 and Fig. 2 to 6).

BOD_5, COD and OM: COD is Chemical Oxygen Demand, which gives an indication of oxidizable organic matter present in the sample. BOD and COD indicate the pollution of water by oxygen depletion (Sridhar and AdeOluwa, 2009; Awotoye *et al*., 2011; Okwute and Isu, 2007; Ahmad *et al*., 2003; Khalid and Wan Mustafa, 1992; Hartley, 1988). OM quantifies the oxidizable organic matter. In our study the ASCB has a BOD_5 of 71 mg/L; COD of 156 mg/L and OM 93 mg/L (Fig. 2). These values are greater than those values specified in the regulations (Table 1). The SWC has a BOD_5 of 99 mg/L; COD of 122 mg/L and OM of 106 mg/L (Fig. 2). These values are higher than those prescribed by the standard (Table 1).

SCS has a BOD_5 of 34 mg/L; a COD of 959 mg/L and OM 342 mg/L (Fig. 2). The values of COD and OM are higher than those prescribed by the regulation (Table 1). SCS has a BOD5 below the value of

Table 1: Comparison of physico-chemical parameters of the wastewater of ASCB, SWC and SCS industries of the town of Bafoussam

	Standard values			Sampled points		
Parameters	Limits values	Authors	Date of samples	Point 1 (ASCB)	Point 2 (SWC)	Point 3 (SCS)
COD (mg/L)	90	ISO and MINEP (2005)	22/02/2013	156	122	959
BOD_5 (mg/L)	30	ISO and MINEP (2005)	22/02/2013	71	99	34
OM (mg/L)	50	ISO and MINEP (2005)	22/02/2013	93	106	342
Non-biodegradable material (mg/L)				63	16	617
TP (mg/L)	0.20	Dajoz (1996)	15/03/2013	17.270	0.0000	0.690
Cu (mg/L)	2 0 .50 1	Rodier *et al*. (2009) ISO and MINEP (2005) Rodier *et al*. (2009)	15/03/2013	0.057	0.0673	0.160
Cd (mg/L)	0.01	Benedetto (1997) and Rodier *et al*. (2009)	15/03/2013	0.005	0.0050	0.320
Zn (mg/L)	3	Ghaouti *et al*. (2005)	2/03/2012	1.190	37.9000	115.370
Cr (mg/L)	0.10	Benedetto (1997) and Rodier *et al*. (2009)	15/03/2013	0.210	0.1100	1.012
Fe (mg/L)	0.30	Ghaouti *et al*. (2005)	15/03/2013	0.490	0.8800	0.990
Al (mg/L)	5 0.10	Hicham *et al*. (2008) and Rodier (1996)	2/03/2012	0.490	0.6100	0.810
EC (µS/cm)	2880	Rodier *et al*. (2009)	2/03/2012	355	1859	992
Turbidity			2/03/2012	103.500	37. 4000	105.600
NH_4^+ (mg/L)	Sum<10	ISO and MINEP (2005)	2/03/2012	4.760	3.3600	4.480
NO_3^- (mg/L)			2/03/2012	5.040	5.6000	5.880

Laboratory work

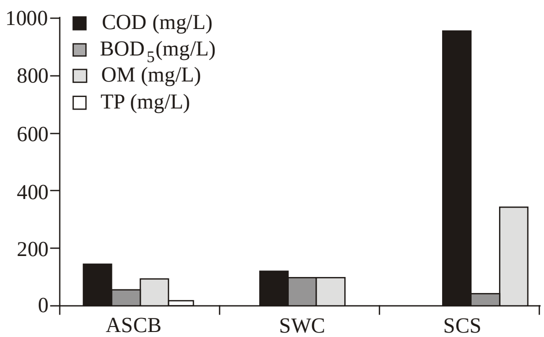

Fig. 2: Level of COD, BOD_5, OM and TP in the wastewater from ASCB; SWC and SCS industries

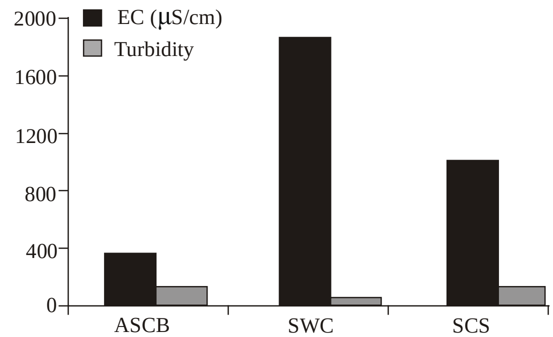

Fig. 5: Level of EC and turbidity in the wastewater from ASCB; SWC and SCS factories

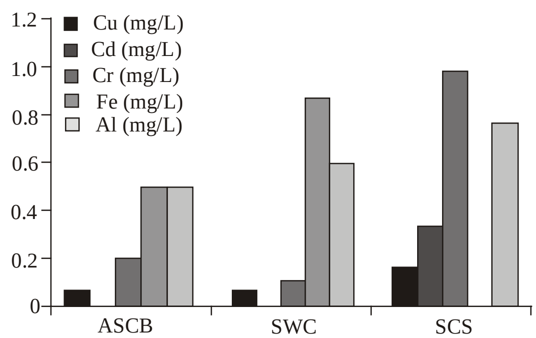

Fig. 3: Level of Cu, Cd, Cr, Fe and Al in the wastewater from ASCB; SWC and SCS factories

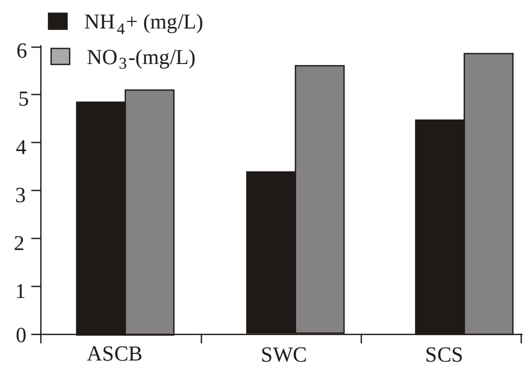

Fig. 6: Level of NH_4^+ and NO_3^- in the wastewater from ASCB; SWC and SCS factories

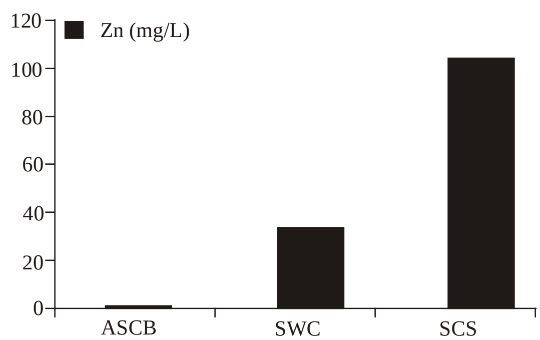

Fig. 4: Level of Zn in the wastewater from ASCB; SWC and SCS factories

ASCB and SWC (Table 1) this indicates the presence of a significant amount of non-biodegradable material, which will pollute the environment in comparison to the value of the COD that is 959 mg/L. The amount of non-biodegradable material is 63 mg/L for the ASCB, l6 mg/L for the SWC and 617 mg/L for SCS (Table 1). The amount of non-biodegradable material is greater in the effluents of the SCS (Fig. 2).

TP: Phosphorus concentration is 17.27 mg/L for the ASCB; 0, 000 mg/L for the SWC and 0.697 mg/L for the SCS Fig. 2). The SWC has a zero concentration which is within the norms, while ASCB and SCS had values above the norms (Table 1). The ASCB has the highest concentration (Fig. 2).

Cu: The values found in this study are: 0.057 mg/L for discharges of the ASCB, 0.067 mg/L for discharges of the SWC and 0.16 mg/L for discharges of SCS (Fig. 3). The values are lower than those prescribed by standards (Table 1). SCS has the highest value (Fig. 3).

Cd: Cadmium causes respiratory and kidney problems. Our results are 0.0048 mg/L for the ASCB, 0.0048 mg/L for the SWC and 0.3168 mg/L for SCS (Fig. 3). The ASCB and SWC have values below guideline levels, however SCS exceed the prescribed limit (Table 1). SCS has the highest value (Fig. 3).

Zn: Toxicity to fish occurs from a few milligrams per liter. For agricultural use, the deterioration of the plants can occur from 5 mg/L. For the wastewater studied the zinc content is 1.19 mg/L for the ASCB, 37.90 mg/L for the SWC and 115.37 mg/L for SCS (Fig. 4). Releases of the ASCB were below 3 mg/L, which meets the standards (Table 1). However the release from the SWC 37.90 mg/L and SCS 115.37 mg/L are higher than the norms (Table 1). Releases from the SCS are higher than the concentration prescribed by the norm (Table 1). Releases of the SWC and the ASCB flow into the Melo rivers, where fish killed had been reported by the authorities of the city of Bafoussam (Nkake, 2011). Based on our results releases of the SWC, could be at the origin of the death of the fish reported above.

Cr: Chromium causes cancer, dermatological disorders and anemia. We obtained the following concentrations: 0.21 mg/L for discharges of the ASCB; 0.11 mg/L for discharges of the SWC and 1.012 mg/L for discharges of SCS (Fig. 3). The value of the SWC is close to the norm, but those of the ASCB and SCS are higher than that of the norms (Table 1). The highest concentration is that of the SCS which is 1011.7% more than the norms, 475% higher than that of the ASCB and 950% higher than that of the SWC (Fig. 3).

Fe: In fact, if one wants to avoid all the disadvantages (taste, color, precipitate and tasks on the machine), the water supply should not have iron. For our analysis this concentration is 0.494 mg/L for discharges of the ASCB, 0.884 mg/L for those of SWC and 0.988 mg/L for SCS (Fig. 3). All these concentrations are higher than the norms (Table 1). The highest concentration is that of the SCS which is 200% higher than that of the ASCB and 111.72% higher than that of the SWC (Fig. 3).

Al: Our analysis gives us the following concentrations: 0.487 mg/L for discharges of the ASCB, 0.613 mg/L for discharges of the SWC and 0.813 mg/L for discharges of the SCS (Fig. 3). All its levels are below the norm (Table 1), but they are harmful to the storage tanks. This concentration is highest for the SCS (Fig. 3).

Electrical conductivity: The measurement of the electrical conductivity gives an indication of the quantity of dissolved salts in water. Our results are 355 μS/cm for the ASCB, 1859 μS/cm for SWC and 992 μS/cm for the SCS, which are within the norms (Table 1). Mineralization is 355×0.715920 = 254.15 mg/L for the ASCB, 1859×0.850432 = 1580.95 mg/L for the SWC and 992×0.758544 = 752.48 mg/L for the SCS. The highest mineralization is that of the SWC (Fig. 5).

Turbidity: It takes into account the greater or lesser presence of materials of inorganic or organic origin in water (Bechac *et al.*, 1983), the more the wastewater will have suspended solids, it will require much oxygen for biodegradation, resulting in a depletion of the aquatic environment where it empties dissolved oxygen. In our study the turbidity was 103.5 mg/L for the ASCB, 37.4 mg/L for the SWC and 105.6 mg/L for SCS. This turbidity is higher for the waste of the SCS (Fig. 5).

Total nitrogen: For our study the concentration of $NH_4^+ + NO_3^-$ is 9.80 mg/L for the ASCB; 8.96 mg/L for the SWC and 10.36 mg/L for SCS. The highest value was that of the SCS (Fig. 6). The values of the ASCB and the SWC are below guideline values. The value of the SCS is higher than the norm (Table 1).

Statistical analysis: Our results show that the correlation coefficient between points 1 and 2 is 0.897, between points 1 and 3 is 0.884 and between points 2 and 3 is 0.72. These results indicate that between these points there is a positive correlation, the variables are related to each other but we cannot predict a variable knowing each other because the correlation coefficients are different from 1. Covariance between points 1 and 2 is 40621.4, between points 1 and 3 is 29.85 and between points 2 and 3 is 120.12. These positive values indicate that the couple of variables differ from their average in the same direction.

CONCLUSION

This result shows a higher concentration of heavy metals (Cu, Cd, Zn, Cr, Fe, Al) released by the SCS (118.66 mg/L) then for the SWC (39.58 mg/L) and finally than the ASCB with a concentration of 2.45 mg/L. Regarding the COD, the SCS comes in first with a concentration of 959 mg/L, followed by ASCB with a concentration of 156 mg/L and lastly the SWC with 122 mg/L. The TP concentration of 17.27 mg/L in the discharges of the ASCB, is the cause of its COD concentration being higher than that of the SWC. We conclude that because of the phenomenon of bioaccumulation of heavy metals in the environment and their integration in the food chain, the most polluting industry based on our results is the SCS, followed the SWC; the ASCB occupies the last position. The authors recommendations are that:

Each industry must implement a wastewater treatment plant adapted to its specific Wastewater. The SCS should establish a plant capable of purifying: Cd, Zn, Cr, Fe, phosphorus and organic nitrogen. The SWC should be able to purify: Zn, Cr, Fe and organic nitrogen. Finally, the ASCB should establish a water treatment plant capable of purifying: Cr, Fe, phosphorus and organic nitrogen. In addition to the treatment plants, wastewater recycling in the manufacturing circuit before sending to the treatment plant would achieve zero pollution status regarding the following metals: Cu and Al for SCS; Cu, Cd and Al for SWC and Cu, Cd, Zn and Al for the ASCB. In fact the concentration is lower than the norm for these metals; the concentration would reach zero due to a long recycling purification circuit.

From the difference between the concentrations of pollutants in the SCS and the SWC, both soap producing, a quarterly meeting between the industries in the city to discuss on the methods of manufacturing may result in the reduction of pollution.

The municipality should bring sponsors of industries to raise awareness on the impact of pollution on the environment and human health.

Penalties for pollution should be proportional to the degree of pollution; this would encourage sponsors to fight against pollution.

RECOMMENDATIONS

- A research on the methods of manufacture of the SCS and the SWC with the aim of determining the causes of the differences in concentrations in pollutants between the two Soap factories
- The impact of the effluents from the SCS on the surrounding soils
- The impact of the discharges from the ASCB and the SWC on the surrounding soil
- The impact of the release of the pollutants of the ASCB and the SWC on the water quality of the Melo river
- Impact of these effluents of the ASCB, SWC and SCS on the quality of water of the river Mewou

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