DOI: 10.21776/ub.jpacr.2018.007.03.366 *J. Pure App. Chem. Res.*, **2018**, 7(3), 230-238
1 September 2018

Study on Physico-Chemical Parameters of Wastewater Effluents from Cotton Development Plant of Maroua-Cameroon

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Received 4 September 2017; Revised 9 March 2018; Accepted 28 May 2018

ABSTRACT

The present research work aimed to study some of the important physicochemical parameters of wastewater effluents obtained from Maroua cotton processing plant namely "SODECOTON". The effluents were studied from June 2016 to August 2017. A preliminary investigation was carried out on the source of water used by the plant and management of its wastewater effluent. All were analyzed according to the standard methods. Water quality parameters such as temperature, pH, Electrical Conductivity, Total Dissolved Solid, Total Suspended Solids, Biological Oxygen Demand, Chemical Oxygen Demand, Total Nitrogen determined by the Kjeldahl method, Nitrate, and Phosphate were analyzed. Results of this study showed that nearly all values of these parameters were above the permissible limit. These values were significantly higher during the rainy season (from May–December) than during the dry season (January-April). Water used by the plant is from borehole. This water is treated by less adapted technology prior to use and thus probably contribute to the pollution load of the plant's wastewater effluent. Wastewater from the plant is discharged without being treated and without any quality analysis. It is due to inadequate enforcement of environmental regulations.

Keywords: Analysis, Cotton processing, Wastewater, Pollutant, Environment

INTRODUCTION

Until the mid-18th century, water pollution was essentially limited to small, localized areas. Then came the industrial revolution with the rapid development of various industries that use huge amounts of fresh water as raw material, principally for production (process water), and for cooling purposes. But, different kinds of raw material, intermediate products and wastes are brought into the water when water passes through the different industrial process. Consequently, wastewater can be considered as an "essential by-product" of the modern industry and it plays a major role as a pollution source in the pollution of water [1]. According to WHO [2], effluents from industries are associated with the pollution of water, air, and soil, thus causing several health burdens. Pollutants in these effluents such as heavy metals either in free form or adsorbed in suspended are toxic to humans and aquatic ecosystem. The guidelines for these textile wastewater pollutants vary from one country to another [2-4]. These pollutants are generally transferred to humans through food contamination [5]. One example of chemicals in industrial effluents that is toxic to fish and other aquatic species is ammonia in the free form within the concentration range of 10–50

The journal homepage www.jpacr.ub.ac.id
p-ISSN : 2302 – 4690 | e-ISSN : 2541 – 0733

μg/L and generally at high pH [6]. Also, the occurrence of sulfide in industrial effluents can contribute and hence posing a serious threat to the ecosystem [6]. (WHO, [7] has reported several health-related problems associated with the increase in pH of industrial effluents. The textile industries use high volumes of water for their different operations and consequently generate high amounts of wastewater as well [8]. The major water consuming operations in the textile industries are process water (90–94 %), cooling water (6–10 %) and polluters [9-10]. Cotton (the main raw material for textile industry) processing usually involves many operations as shown in Figure 1, with each of these operations significantly generating wastewater pollutants. The different characteristics associated with the effluents from the respective operations are given in Table 1 [11].

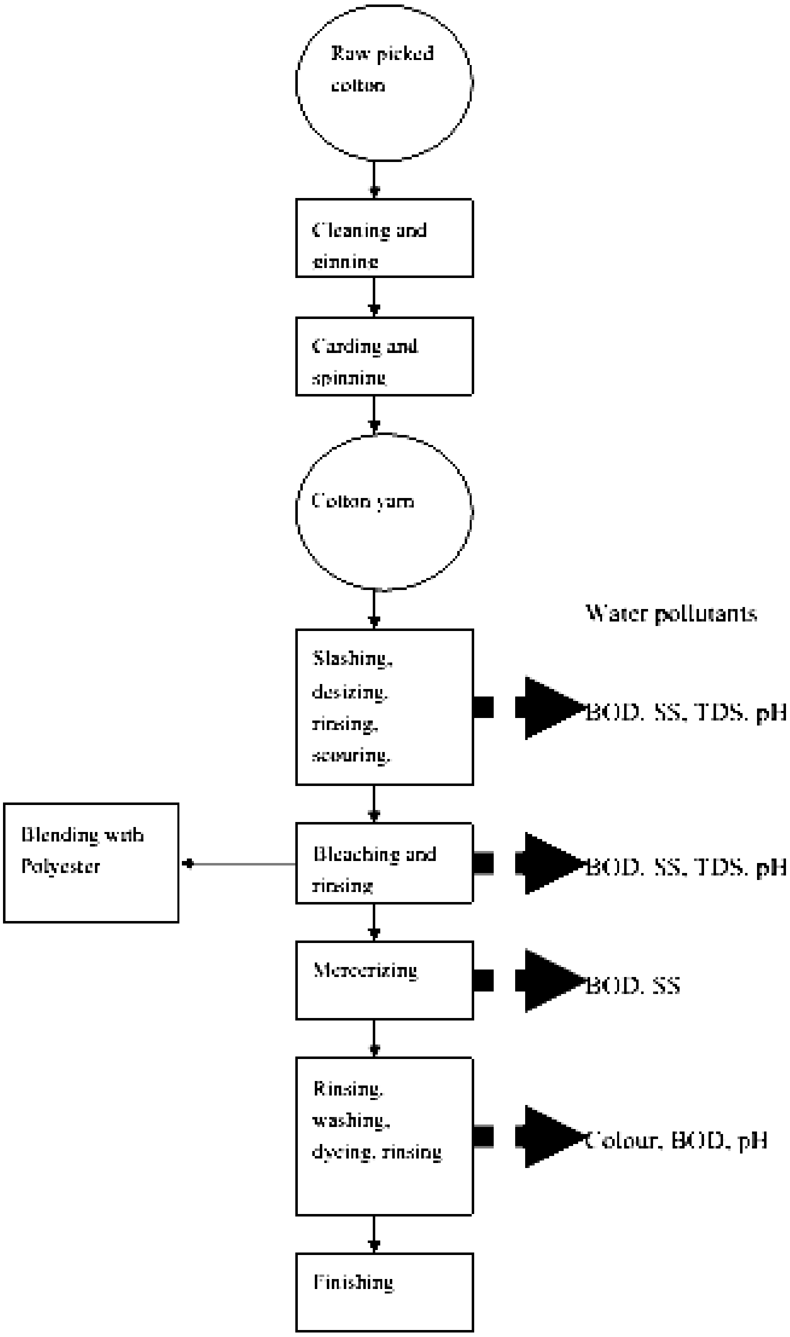

Figure 1. Cotton processing and Associated Water Pollutants.

Table 1. The different characteristics of effluent collected from Textile Industry.

Process	Effluent composition	Nature
Sizing	Starch, waxes, carboxymethyl cellulose (CMC), polyvinyl alcohol (PVA), wetting agents.	High in BOD, COD
Desizing	Starch, CMC, PVA, fats, waxes, pectins	High in BOD, COD, SS, dissolved solids (DS)
Bleaching	Sodium hypochlorite, Cl_2, NaOH, H_2O_2, acids, surfactants, $NaSiO_3$, sodium phosphate, short cotton fiber.	High alkalinity, high SS
Mercerizing	Sodium hydroxide, cotton wax	High pH, low BOD, high DS
Dyeing	Dyeing	Strongly colored, high BOD, DS, low SS, heavy metals
Printing	Pastes, urea, starches, gums, oils, binders, acids, thickeners, cross-linkers, reducing agents, alkali	Highly colored, high BOD, oils appearance, SS slightly alkaline, low BOD

Thus, wastewater from cotton industries may have a high proportion of suspended solids, dissolved organic and inorganic solids, BOD, alkalinity or acidity, phosphate, temperature, toxic chemicals, oils and grease, sulphides, and coliform bacteria and their different constituents may not be in same proportion as they exist in a typical domestic sewage [11]. Unfortunately, there is a widespread reluctance on the part of industries to treat their wastewater before discharge especially in developing countries like Cameroon, where environmental regulations are generally relaxed. In the present study, the wastewater from a local (Maroua) cotton processing plant (SODECOTON) was examined. Maroua has been the center of many water-borne diseases like the repeated cholera outbreaks between 1996 and 2010 that caused 600 deaths from over 9000 detected cases [12]. The poor quality of water used in Maroua being responsible for these epidemics. Results of this study will thus help the government through its local representation to compel this cotton plant to treat its wastewater with appropriate technology before discharge. They can also be compelled to provide a daily statistics of the composition of wastewater discharged. This can contribute to improving the overall hygiene and sanitation of the town, thus contributing to improving the water quality situation of Maroua.

EXPERIMENT

This study was carried out from June 2016 to August 2017. The source of the water used in the plant and its pretreatment methods, the main operations requiring the use of water, the nature and points of different effluents and sewage disposal systems of the plants were identified. This was aimed at identifying the locations of sampling (geographical coordinates: 10°35.144'N and 014°18.864' E, altitude 404 m, determined by GARMIN etrex 10 GPS). Water samples were collected at the isolated wastewater discharge points by the plant using polyethylene bottles (washed by detergent, then with deionized water, 2M nitric acid, then deionized water, and finally the wastewater collected). These samples were placed in an ice bath and brought to the laboratory immediately for analyses. The physicochemical properties determined such as temperature, pH, chemical oxygen demand (COD), biological oxygen demand (BOD_5), electrical conductivity (EC), total suspended solids (TSS), total dissolved solids (TDS), total nitrogen content by Kjeldahl procedure (NTK), total phosphorus, and nitrates. Samples brought to the laboratory were filtered on Whatmann filter paper N^o 1 prior to use for different analyses. The temperature, pH, conductivity and total dissolved solids were analyzed immediately on arrival in the laboratory as it took just five minutes by car from sampling point to the laboratory. While filtered samples for total **s**uspended Solids, COD, BOD_5, total nitrogen determined by Kjeldahl method, total phosphorus and nitrates analyses were stored in a refrigerator (no preservatives were added to the samples) prior to studies as these analyses require more time-consuming procedures.

While the temperature, pH, conductivity, and total dissolved solids were analyzed using a portable HANNA Multimeter (HI 9811-5PH/C/EC/TDS), total suspended solids (TSS), COD, BOD_5, total nitrogen by Kjeldahl method (NTK), total phosphorus and nitrates were determined according to the standard methods [13-15].

RESULT AND DISCUSSION

Preliminary investigations

The main source of water used by this plant is from borehole installed by the cotton plant. The water requirement of this cotton development plant is estimated at 10 m^3 to completely processed one ton of cotton. This is obtained exclusively by drilling (100%) their borehole water. The drilled water undergoes a series of treatment before utilization. The major treatment operations are clarification for the elimination of mineral and organic micropollutants followed by disinfection with hypochlorite, sand, and activated carbon filtration.

Unfortunately, wastewater generated from these treatment operations as well as other operations requiring the use of water in this plant such cleaning of tanks and pipes storage, packaging, cooling machines, pressing and cooking, extraction and refining and water from the different sewage disposal systems (rainwater drainage network, sewage system from production and general waste sewage system) are discharged without any treatment to the environment. However, the wastewater from all the different operations are internally canalized and discharged through a single exit, the point where the sampling of wastewater for this work was done.

Physico-chemical characteristics of SODECOTON wastewater

The evolution of temperature, pH, total phosphorous and nitrogen during the period (August 2016 to June 2017) is shown in Table 2 and while that of COD, BOD_5, TSS, NTK, EC, and TDS is presented in Table 3

Table 2. Results of temperature, pH, nitrate and phosphorus analyses of SODECOTON wastewater within the period August 2016 to June 2017.

Months	Temperature (^{0}C)	pH	Nitrate (mg/L)	Phosphorus (mg/L)
August	35.0	11.0	3.8	5.0
September	55.0	11.0	8.5	1.0
October	40.0	13.0	8.2	6.0
November	43.0	11.0	12.3	7.0
December	40.0	10.0	23.8	9.2
January	33.0	10.0	10.0	9.4
February	38.0	10.0	3.7.0	9.5
March	38.0	9.0	7.8	8.3
April	34.0	10.0	3.5	10.0

May	36.0	11.0	3.2	18.5
June	35.0	11.0	3.25	19.6

Table 3. Results of COD, BOD_5, TSS, NTK, EC and TDS analyses of SODECOTON wastewater within the period August 2016 to June 2017.

Months	COD ($mgO_2.L^{-1}$)	BOD_5 ($mgO_2.L^{-1}$)	BF (mg/L)	TSS ($mg.L^{-1}$)	NTK ($mg.L^{-1}$)	Conductivity (µs/cm)	TDS ($mg.L^{-1}$)
August	1200	600	2.00	200	10	12 200	6000
September	1350	800	1.69	380	8	9 200	4500
October	1000	420	2.38	180	9	8 000	3900
November	1380	590	2.34	210	15	7 400	3650
December	1050	400	2.63	280	8.5	6300	3100
January	380	200	1.90	100	25	5 200	2600
February	420	220	1.91	100	4.6	3 600	1700
March	610	310	1.97	30	5.15	2 700	1300
April	580	320	1.81	20	5.7	2 900	1650
May	570	330	1.73	25	4.7	8 500	2400
June	640	340	1.88	15	4.1	11 100	3200

BF = biodegradability factor (COD/BOD5)

Temperature

Most ecological features are regulated by temperature; particularly organisms' behavior as well as gases and salts solubility in water[16] Temperatures values obtained for this study varied from 33-55 °C (Table 2) and were all higher than 30 ^{0}C set by Cameroon government[17]. The microbial activity of water increases with increasing temperature and contribute in affecting the quality of surface water used by the aquatic organisms and humans. The major sources of thermal pollution are industrial cooling systems working in a manufacturing plant [16] as environmental temperatures in Maroua were around 30 ^{0}C on average within the period of study.

pH Analysis

The acidity or basicity of water is determined by its pH value and is of primary importance in water chemistry as it controls most chemical reactions in the aquatic medium. The toxicity of heavy metals also gets enhanced at particular pH. Thus, pH has primary importance in deciding the quality of wastewater effluent. The limit of pH value for wastewater specified in Cameroon is 5.5 to 9[17]. The pH values were all above the permissible limit (Table 2) except for March which is the still the dry season. The basic pH may be due to the presence of carbonates of calcium and magnesium [18-19] and excessive use of dyes [10]. They possibly came from groundwater or borehole water as they are tough to be removed even with most conventional water treatment methods.

Total Nitrogen determined by Kjeldahl method (NTK)

It is the sum of ammonia-nitrogen plus organically bound nitrogen but does not include nitrate-nitrogen or nitrite-nitrogen. The minimum concentration of Ammonical Nitrogen was found at range from 4.1 mg/L in June to maximum of 10 mg/L in August (Table 3). Presence of ammonia is due to slashing/sizing and dyeing operations which use a lot of organics and dyes which contain amine ($–NH_2$), and azo (–N=N–) functional groups. In aqueous environment ammonia is formed from these groups. In water, Ammonia exists in two forms of ammonium ion ($NH4^+$) and free ammonia (NH_3) depending on the pH of water. At higher pH, ammonia is toxic to aquatic organisms and also for terrestrial organisms [20].

Total Nitrate Analysis

The concentration of nitrate was recorded in the range of 3.8 mg/L to 23.8 mg/L maximum (Table 2). The concentration of different forms of nitrogen gives a useful indication of the level of micronutrients in the wastewater and hence their ability to support plant growth. These values were lower than the allowed value of 50 mg/L [21].

Total Phosphate Analysis

Phosphate comes from fertilizers, pesticides, industry and cleaning compounds. Natural sources include phosphate containing rocks and solid or liquid wastes. The lowest value of phosphate was recorded as 1.0 mg/L and the highest value was 19.6 mg/L (Table 2). Nearly all these values (except September) were higher than the permissible limit of 5 mg/L ([10]. Phosphates favors the growth of microalgae that develop at the expense of other plants, asphyxiate aquatic fauna, can produce toxins and disrupt the production of drinking water. These high values originate from the fact that Maroua is characterized by rainy period from May to about October accompanied by different agricultural activities using fertilizers and pesticides, and the cotton plant uses borehole water. The phosphorus in the wastewater is also probably from the phosphorus detergents used in rinsing operations and poorly treated borehole water.

Electrical Conductivity

The mineral constituents of effluents (including the ions or charge carrying substances) are generally indicated by the electrical conductivity [22]. High electrical conductivity affects plants by causing damage to root system with consequent prejudice in nutrient and water absorption process. All the values obtained were extremely higher (Table 3) than permissible limits of 250 mg/L [23]. This probably originated from borehole water and the chemicals used in the different operations on the cotton processing.

Total Dissolved Solids (TDS)

TDS values greater than 500 mg/L are not good for potable water, however, values of 1500 mg/L may be tolerated in unavoidable circumstances [24]. Jain (2002) [25], reported that mineral-rich water can be used in the absence of quality water. This study showed TDS values ranging from 1700 mg/L to 6000 mg/L (Table 3) and are all above allowed limits [23]. High TDS in cotton wastewater originates from bleaching, rinsing, scouring, slashing and resizing operations as illustrated in Figure 1 as they use different chemicals that are discharged in wastewaters. Leaves, silt, industrial waste sewage and pesticides and inorganic materials, industrial waste, sewage, pesticides and inorganic materials may raise the level of TDS in the water bodies [26]. The town of Maroua has a Sudan-Sahelian climate with temperatures averaging 35°C on average. This water sources, especially for drinking purposes, are very scarce (with no rivers), and parts of the population depends on borehole water (the cotton plant also uses borehole water that they do a pretreatment prior to use due to lack of other sources), thus further contamination of underground water with industrial effluents put the lives of many people who depend on already poor water quality at additional risk. High values of TDS in groundwater are generally not harmful to human beings but the high concentration may affect people suffering from kidney and other diseases. High levels may also produce undesirable taste.

Total Suspended Solids (TSS)

Total suspended solids comprised carbonates, bicarbonates, chlorides, phosphates and nitrates of Ca, Mg, Na, K, Mn organic matter, salt and other particles. The values of TSS from August to December (Table 3) were above the permissible limit of 200 mg/L [17]. The bleaching operation uses principally chemicals such as sodium hypochlorite, Cl_2, NaOH, H_2O_2, acids, surfactants, $NaSiO_3$, sodium phosphate, short cotton fiber which are discharged in wastewater and contribute in raising TSS value. This period involves rainy and windy conditions and contributing to the pollution of groundwater used by the cotton plant. High TSS and TDS value could also be associated with the presence of high color and they may be the major sources of the heavy metals [10]. The total suspended solids may be caused by suspended particle inside the water body affecting turbidity and transparency.

Biological Oxygen Demand (BOD)

The organic pollution of effluents is generally indicated by the BOD measurements. It is the amount of oxygen required for microorganisms to accomplish the biological decomposition of dissolved solids or organic matter in effluents under aerobic conditions [27]. The low BOD level is an indicator of good quality water, while a high BOD level indicates polluted water. BOD directly affects the amount of dissolved oxygen (DO) in rivers and streams. The higher BOD level, tend to increase the oxygen-depleted in the water. The consequences of high BOD are equivalent with those for low DO, such as bad impact for aquatic organisms that cause stressed, suffocate, and die. Except for January and February (Table 3), the values were all higher than the permissible limit of 300 mg/L in Cameroon [17]. These high values of BOD indicate the extent of biodegradable substances present in the effluents as compared to raw water. The high BOD in cotton industry effluents originates from operations such as sizing, resizing, and dyeing which use compounds such as starch, waxes, carboxymethyl cellulose (CMC), gums, oils, binders, acids, thickeners, cross-linkers, fats, and pectins as presented in Table 1.

The increasing of BOD can be caused by the discharge of industrial wastewater effluent, animal and crop wastes and domestic sewage in huge amounts. Moreover, BOD sources in the aquatic environment are composed of leaves and woody debris, dead plants and animals, animal manure, industrial waste, wastewater treatment plants, feedlots, and food-processing plants, the breakdowns of septic systems, and urban stormwater[28]. All of these are characteristics of our zone study. Correspondingly, effluent samples obtained from engineering, dyes and paint industries also show significantly high BOD levels of 604.8 mg/L, 776.2 mg/L, and 535.8 mg/L respectively [28].

Chemical Oxygen Demand

The Chemical Oxygen Demand (COD) is the measurement of the oxygen equivalent of the organic matter in a sample which is affected by oxidation of a strong chemical oxidant [28]. Like BOD, COD also measures the amount of organic matter in effluents. They both determine the oxygen depletion effect of waste contaminant. Apart from January, February and March (absence of rainfall period) (Table 3), all the values were higher than recommended values in Cameroon of 600 mg/L[17] during the rainfall period. Thus, these high levels of COD imply toxic conditions and the presence of biologically resistant organic substances in SODECOTON wastewater [28].

Biodegradability of SODECOTON wastewater Discharges

The biodegradability factors (COD/BOD5) of SODECOTON effluents that it has a COD/BOD_5 ratio ranging between 1.73 to 2.00 mg/L (Table 3), with the values being higher in the rainy season (June–December). These results show that these effluents are not difficult to biodegrade with chemical-dominant pollution (COD/BOD_5 <3)[29].

CONCLUSION

The Maroua cotton processing plant (SODECOTON) has no treatment systems for their effluents. The present study was aimed at analyzing the physicochemical characteristics of the wastewater of this plant. The characteristics of the effluents studied were grossly above the set limits by the Cameroon government and some world bodies like the World Health Organization, particularly during the rainy season. The cotton processing plant has many economic advantages; nevertheless, the need to apply specific objectives relative to good practices in the treatment of its wastewater effluents before discharge should not be compromised. Results of this study highlight the need for the company and the government to adopt and implement international practices in the management of industrial effluents. Thus, the negative environmental impact of this plant effluent should weigh over the short term economic benefits. We thus conclude that due to the high pollution of SODECOTON wastewater, it is highly recommended that its disposal without proper treatment should be discouraged as BF analysis shows that this wastewater can easily be treated with physico-chemical methods and continuous monitoring of the quality of its discharged wastewater is imperative to ensure the protection of water resources from further degradation and improvement of hygiene and sanitation of Maroua. This will contribute significantly to reducing the different epidemics linked to water quality in Maroua.

ACKNOWLEDGMENT

The authors sincerely thank the management of Centre Pasteur du Cameroun agency of Garoua (PCC) where measurements and analysis were carried out.

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