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Evaluation with Practical Prevention of Rainwater and Environmental Pollution in Agri-Food Industries: The Case of Cameroon Beverage Company

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Abstract

This work aimed to evaluate the management of rainwater within the Cameroon beverage company. The compliance of the rainwater management policy within the factory with designated norms was first evaluated. Furthermore, the presence of pollutants in the surface water of the nearest river, which directly adjoins the plant, was assessed to identify areas at risk in the production plant. It was observed that all activities carried out in the workshops, such as handling, transferring products from one workshop to another, washing (bottles, bins, and tanks), and waste management, all contribute to polluting the rainwater. Results showed that solid wastes account for 39% of potential plant pollutants, followed by fermentable products and waste (29%), chemicals (21%), metals (6%), bacteria (5%), organic products (3%), oils and fats (3%). These pollutants degraded the water quality of the nearest river, as proven by several tests. The chemical demand for dissolved oxygen (COD) reached a maximum value of 860 mg/l at the grain distribution station. Suspended materials with a maximum value of 600 mg/l were measured at the pipe exit, which drains water coming from the wastewater treatment plant. A phosphate level of 100 mg/l was also obtained from the packaging unit during the rainy season. Overall, 50% of the plant's areas are at critical risk for stormwater management, 37.5% are labeled as catastrophic risk areas, and 12.5% are areas of tolerable risk. An innovative, practical corrective action plan has been suggested and could be adopted in any similar agro-industry in the world.

Keywords

Assessment, Management, Stormwater, Agribusiness, Beverage

1. Introduction

Stormwater is runoff that comes from rain, melting snow, hail, or ice (Mbog, 2013). When stormwater drains urban infrastructures and passes through works of human activity, it causes significant damage to continental freshwater and coastal shores (Anonymous, 2007). Since 2007, the US Environmental Protection Agency (EPA) has provided economic operators with a guide that enables them to develop their stormwater pollution prevention plan (SWPPP). Thus, this plan recommends that potential companies set up a stormwater management team, identify potential pollutants of rainwater, and adopt control measures that will minimize the release of these pollutants into nature. To date, those measures are well implemented in American industries, cities, and universities (Anonymous, 2016).

In Cameroon, as in several developing countries, fresh waters in urban areas are exposed to aggression by pollutants that degrade water quality while modifying the ecosystems (Winter & Duties, 1998; Beyene et al., 2009; Tchinda et al., 2018). To protect itself against the pollution of waterways, the State of Cameroon has adopted and promulgated Law No. 96/12 of August 5, 1996, on the management of the environment in Cameroon. Article 4 of the law stipulates that: "Are forbidden: Spills, flows, jets, infiltrations, burials, spreading, direct or indirect deposits in water, of any solid, liquid or gaseous matter and in particular industrial, agricultural and atomic waste likely to alter the quality of surface or ground water, or sea waters within the territorial limits; harm public health and the aquatic or underwater fauna and flora; to call into question the economic and tourist development of the regions" (Djomo, 2000).

The brewing industry in Cameroon produces solid wastes of mineral and organic nature, as well as liquid effluents. Some of these wastes are commercialized (drippings, yeasts, and packaging), and others are treated by fermentation techniques before being discharged into nature (wastewater) (Leclercq et al., 1985). However, until now, a good number of industrial products and waste, including brewery waste, still exists in nature without being treated. Soil leaching and storage places not protected against rainwater are the main causes of their presence in nature (Mbog, 2013).

To comply with Cameroon's regulations on environmental protection, and in view of its status as a major consumer of water (Meyengue, 2018), a company in Cameroon commonly named "Les Boissons du Cameroun," meaning the Cameroon beverage company, has set up an environmental management plan that would now make it possible to control the increase in pollution due to its activities in terms of solid, liquid, and gaseous discharges. Thus, the company invested in building a modern wastewater treatment plant for its liquid effluents in its factory located in the capital city (Yaoundé) (Wabo, 2014). With this in mind, it has provided systems for recovering hazardous waste (caustic soda, used oils) and fermentable waste (drippings, yeast) to its various workshops in order to reduce any discharge of factory effluents into nature without treatment. However, so far, nearly 65% of the factory's wastewater has still not been sent to the wastewater treatment plant (STEP) (Magang, 2017). Some hazardous products, waste, and fermentable waste are still found in stormwater pipes despite the company's investment in environmental preservation (ISO, 2010). It is important to note that the Cameroon beverage company is the biggest brewery company in Central Africa.

Thus, this study sets the general objective of evaluating the management of rainwater by the Cameroon Beverage Company in its production plant located in the center region. More specifically, we first made an inventory of the management of rainwater within the plant; next, we have characterized surface water pollutants in the nearest stream; and finally, we have mapped risk areas within the plant.

2. Materials and Methods

2.1. Inspection of Rainwater Management within the Factory

To achieve this objective, it was necessary to verify the existence of a rainwater pollution prevention team and identify the factory's potential pollutants according to the manufacturing processes conducted there. This was done using the Stormwater Pollution Prevention Plan Development Guide for Industrial Operators proposed by the United States Environmental Protection Agency in 2009, and revised by the Department of Environmental Sciences of Christopher Newport University in the United States in 2016 (Christopher Newport University, 2016).

Animated interviews and inspections of all the company work units were conducted. During the field visit, it appeared necessary to have an interview with the head of the Health, Safety, Workplace Safety, and Environment (HSSTE) department. The latter presented the stormwater management system put in place by his department, and the stormwater prevention team that is under his responsibility. Interviews were also conducted with the heads of other departments and with employees in the workshops. These surveys made it possible to find out if the staff is involved in the management of rainwater through training and to find out the origin of eventual pollution of the Aké River (name of the nearest river) caused by the plant.

These interviews specifically checked the training of employees, the sites, and activities at the origin of the potential pollution of rainwater. More specifically, the waste management method, with particular emphasis on the management of liquid waste (wastewater and specials), storage of hazardous products (chemicals, hydrocarbons, etc.), and measures to control rainwater pollution, were checked.

Once the employees were informed, we inspected all the workshops to check the veracity of the answers obtained during the interviews. To this end, a checklist was designed to facilitate observation of all the points highlighted during the interviews.

2.2. Characterization of Surface Water Pollutants Surrounding the Plant

The objective was to assess the effect of the plant's activities on the quality of surface water in the nearest river, named the Aké River. Thus, it was necessary to collect samples of surface water along this watercourse and analyze their physicochemical parameters during rainy and dry periods, in order to characterize the pollutants coming from the plant.

Taking into account the fact that part of the plant is crossed by a river (the Aké River), and that another part discharges its effluent directly into the Mfoundi River, four sampling stations were targeted and classified as stations A1, A2, A3, and A4. Those four sampling stations were retained because of their proximity to a potential or observable waste discharge point in the factory. Station A1: Point on the river located before crossing the packaging plant (PP); Station A2: Point on the river located at the crossing of the PP; Station A3: Point on the river located after the WWTP discharges; Station A4: Point located near the spent grain distribution.

Station A1 03.84156˚N 11.51762˚E at an altitude of 697 m is located approximately 100 m from the plant. It is located in the district of Yaoundé 4, in a marshy area of cultivation which is being transformed into a residential area. This area also houses a beauty salon. The vegetation there is quite abundant and dominated by species such as Acroceras zyzanoides, tithonia diversifolia on the right bank, and Acroceras zyzanoides and Echinochloa pyramidalis on the left bank. Station A1 is located upstream from the plant. It receives only domestic wastewater from the home gardens and the beauty institute which is near the river. Station A2 with coordinates 03˚84017'N, 011˚51339'E is located approximately 30 m from the packing area, at an altitude of 647 m. The vegetation is dominated on the right bank by Setaria barbata, Tithonia diversifolia, and on the left bank by Echinochloa pyramidalis. Station A2 is located downstream of the beer packaging plant. The water from station 2, which crosses this zone of the plant mixes with the effluents that come out of it. These effluents are mainly made up of water from the bottle washer and debris from Kieselghur.

Coordinate station A3 03˚84031'N, 011˚51339'E; is located about 100 m from the source, at an altitude of 713 m. Located after the WWTP discharges, effluents from station A3 are those from the hot syrup plant and part of the pipes from the Liquids and Fluids Production Center (CP), which mix with those from stations A1 and A2. The A4 station, with coordinates 03˚84151'N and 011˚515388'E at an altitude of 634 m, is located 5 m from the yeast and spent grain distribution zone, as well as 50 m from the Tank Out Doors (TOD). The effluents sampled mainly come from the pipes in the cellars, the machine rooms, and the spent grain distribution area.

The water samples were collected using clean polyethylene bottles of 1.5 L and 1 L in volume. These were taken to the laboratory for physico-chemical analyses. The parameters of the water samples to be analyzed in this study were: pH, electrical conductivity, temperature, water turbidity, COD, BOD5, and traces of certain ions present in the water.

Measurements of pH and redox potential (Eh) were determined using a WTW brand pH meter. After prior calibration of the pH meter using buffers with values of 7.00 and 4.01, the glass electrode was introduced into 100 ml of the sample, and the values were read on the digital display screen (Djomo, 2000). The electrical conductivity measurements were made using a WTW brand conductivity meter. This apparatus is fitted with a standard probe which is plunged vertically into the solution whose concentration is to be determined. The conductivity value is read on a digital display screen. This conductivity is expressed in µS/cm or in mS/cm depending on the concentration of the sample (Djomo, 2000). Turbidity is an organoleptic parameter of water. It was measured by an Eutch TN-100 Thermo Scientific turbidimeter. The measurements read by the turbidimeter in this study are in NTU (Nephelometric Turbidity Unit) (Djomo, 2000). The suspended solids induced on Ø90 mm fiberglass filter paper are weighed using an AG 204 Analytical Balance and dried in an oven at a temperature of 105˚C (Djomo, 2000).

The measurement of the chemical oxygen demand was made by the so-called "reactor digestion" method. After homogenization of the wastewater samples, 2 ml is taken and introduced into COD tubes, then incubated in the presence of a witness at 150˚C for 2 hours in a Hach brand COD reactor (multi-tube heater). After the tubes have cooled, the COD value of the sample is read in mg/l, using a Hach DR/890 colorimeter, at a wavelength of 600 nm (Metcalf & Eddy Inc., 1991). The nitrate ions were determined by the cadmium reduction method using a Hach DR/890 spectrophotometer. After introducing 10 ml of wastewater sample into a spectrophotometric cell, a sachet of Nitraver 5 reagent is added thereto. The mixture is then homogenized and left to stand for 5 minutes (reaction time). The color developed in the presence of NO_3^- is then read with a spectrophotometer at a wavelength of 500 nm. The content of the parameter considered is read on the digital display screen of the device by reference to a control consisting of 25 ml of the wastewater sample, and the result is expressed in mg/l (De Villers et al., 2005).

The presence of the phosphomolybdate complex was determined by the so-called "*molybdovanadate*". 0.5 ml of the molybdovanadate reagent is added to each wastewater sample as well as to a control (distilled water). If orthophosphate molecules are present, they will react with molybdate in an acid medium to form the phosphomolybdate complex. In the presence of vanadium, vanadomolybdophosphoric acid, which has a yellow color, will be formed. The intensity of the color is proportional to the concentration of phosphates present in the medium. The reading is done with a Hach DR/890 spectrophotometer at a wavelength of 430 nm, and the values are displayed in the form of orthophosphates (PO_4^{3-}) and expressed in mg/l (De Villers et al., 2005).

Their presence in water is generally linked to the presence of gypsum in the soil. It is a natural compound that corresponds to the presence of sulfur in the water. Maximum presence is limited to 250 mg/l in drinking water (De Villers et al., 2005).

2.3. Characterization Mapping of Risk Areas for Rainwater within the Plant

Through mapping, we seek to identify areas of major risks and present them in a synthetic way, that is, in a more hierarchical form (Mbog, 2013). The objectives of risk zone mapping are to set up an adequate internal control or risk management process; assist management in the development of its strategic plan and its decision-making; guide the internal audit plan by highlighting the processes in which the major risks are concentrated; and finally, to ensure the good image of the organization.

Mapping risk areas is a tool in the risk management process that enables a sound plan for the first three phases of a Risk Management Plan, namely: identifying and assessing risks; treating them; and monitoring their progress. The mission of the mapping is to identify and prioritize the risk factors (or benchmarks) and to draw up a complete inventory of the vulnerabilities. More specifically, the identification of risk in our case study consisted of dividing the company into work units and brainstorming to establish cause-and-effect diagrams that may have impacts on stormwater in each workshop.

Evaluation and ranking of all the risks identified prompted their classification in terms of priorities for their treatment. The assessment was based on two parameters: the probability or frequency of occurrence of a risk (F) and the impact or severity (G), which represents the consequences of this event. The assessed risks are placed in a matrix with the frequency of occurrence of the risk as the ordinate and the severity of the risk as the abscissa. They evolve on scales numbered from 1 to 4. The frequencies of appearance of the risk are qualified as low, average, strong, and very strong, corresponding to scales 1, 2, 3, and 4, respectively. The same ratings are assigned to gravity. Similarly, the dangerousness of the risk is categorized as minor, moderate, important, and very important, which are assigned to scales 1, 2, 3, and 4, respectively. The combination of these two events, known as frequency and severity of the risk, determines the criticality (C) of the risk as the product of frequency and gravity, $C = F \times G$. It is from this criticality that the priority ranking in taking actions is set up (**Figure 1**). When the frequency-gravity combination gives 1, 2, or 3, the risk is tolerable. For a combination of 4, 6, or 8, the risk is critical. The risk is stated as catastrophic for a combination of 9, 12, or 16.

It is from the risk assessment matrix (**Figure 1**) that the risk zoning map for the plant's stormwater is drawn up. From the zoning map, the criticality is given by looking at the color used to locate an area, as the same color is used in the risk assessment matrix. It should be remembered that the form of risk mapping facilitates its appropriation as a tool for managing the risks of rainwater pollution. Documentation can be organized by work unit, workshop, activities, or process (Toukak, 2017).

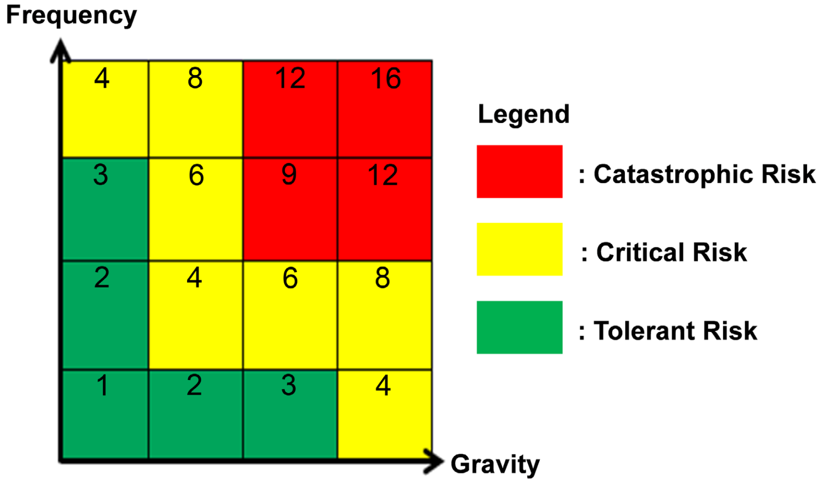

Figure 1. Risk assessment matrix (Mbog, 2013).

3. Results and Discussion

3.1. Rainwater Management within the Factory

The process of making beer requires the use of various substances that are very often inert or dangerous to the environment. The resulting potential pollutants are: organic matter, waste, metals, bacteria, oils and greases, biological products, and chemical/hazardous substances (**Figure 2**).

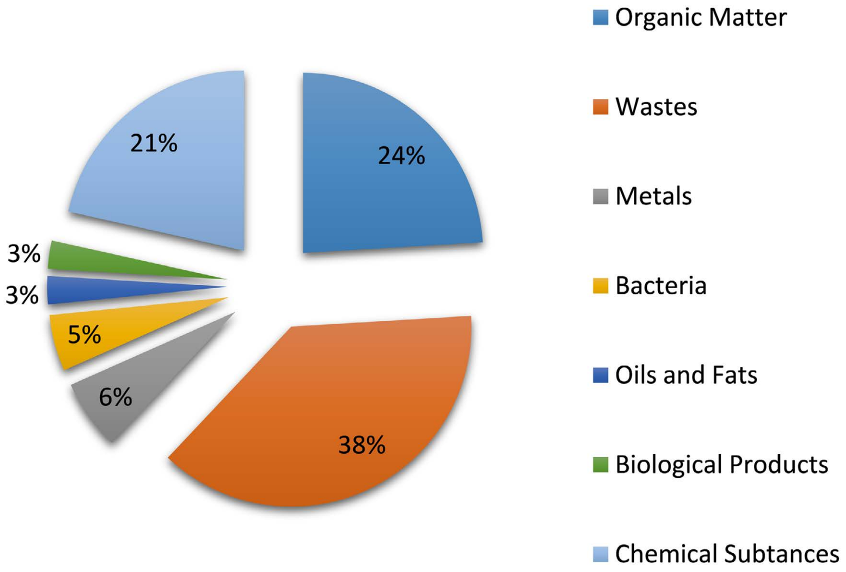

Figure 2. Summary diagram of the potential pollutants found in the various workshops of the plant.

Accidental and voluntary spills are observed in stormwater gutters. This is the case with dead yeasts dumped out of the retention or at the thermolysis station (**Figure 3**), or spent grain deposited around the rainwater pipes in the distribution area.

Figure 3. An incident occurred during the transfer of the yeast to the various thermolysis tanks. The red arrow indicates a deposit of spent grain around the rainwater pipe.

The retention basins available in the factory are mainly made of plastic and metal. The capacities of these retentions vary between 250 L and 1000 L. **Figure 4(a)** shows that, out of 83% of workshops that use retention tanks, only 56% have compliant retention basins (**Figure 4(b)**). These same results show that 7% of the workshops and storage areas visited do not have any (**Figure 4(a)**).

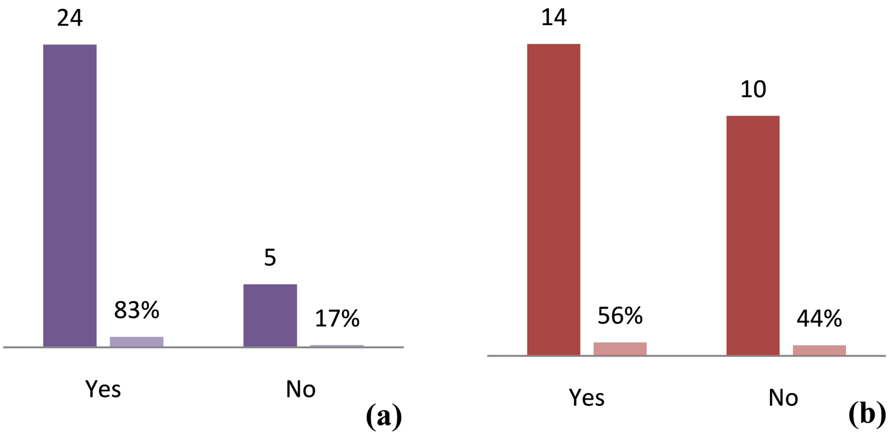

Figure 4. Condition of retention basins: (a) Availability of retention basins; (b) Conformity of retention basins.

The hazardous waste collected in the factory workshops are: used oils, soiled rags, hoses, date-stamp ink cartridges, electronic waste, and laboratory waste. These wastes are collected and stored sheltered from bad weather and separately from other solid waste of the plant. When improperly collected, they can spill into the factory yard (**Figure 5**).

Figure 5. Case of spillage of used oil from a container still containing the remains of chemicals.

Both the factory's garbage bins and the kieselguhr bins are placed on the floor. The nature of the waste (wet labels, household waste) they contain facilitates the formation of leachate. The leachate percolates under the tanks and subsequently transfers its pollutants to the rainwater pipes during both the dry and rainy seasons (**Figure 6**).

Figure 6. Casting leachate under the garbage bins.

3.2. Characterization of Surface Water Pollutants Surrounding the Plant

The water discharged by the plant does not have a considerable influence on the temperature of the receiving environment in the first three sampling stations during the two seasons, with the exception of sampling station number 4 (draff storage area), where the temperature rises to 38.5˚C (The temperature is not shown in the figure) in the dry season. This temperature is significantly higher than the discharge standard authorized by the Ministry of Water and Energy of Cameroon, which is on average 30˚C (MINEE) (**Figure 7**).

The COD results are very remarkable. The effluents sampled during the dry season show satisfactory results in relation to the requirements of the discharge standard in Cameroon, that is to say, between 29 and 55 mg/l. Conversely, in the rainy season, this curve is much above the normal curve. These values reached 730 mg/l at the WWTP (station 3) and 860 mg/l at the spent grain distribution zone (station 4) (**Figure 8**).

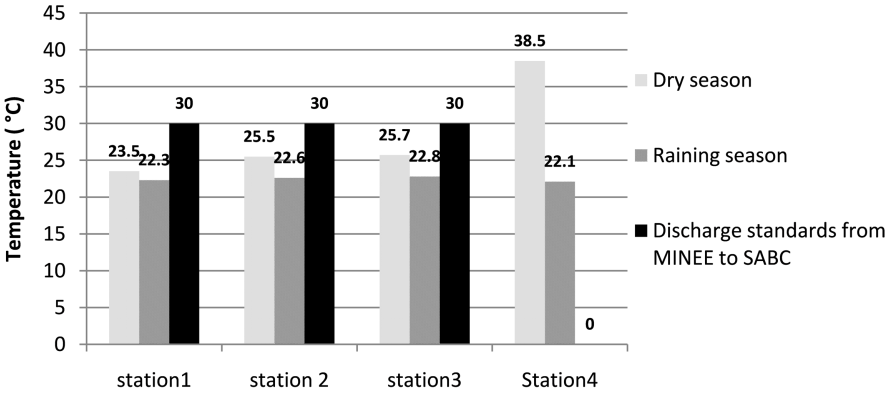

Figure 7. Evolution of the temperature in the four sampling stations during the two seasons.

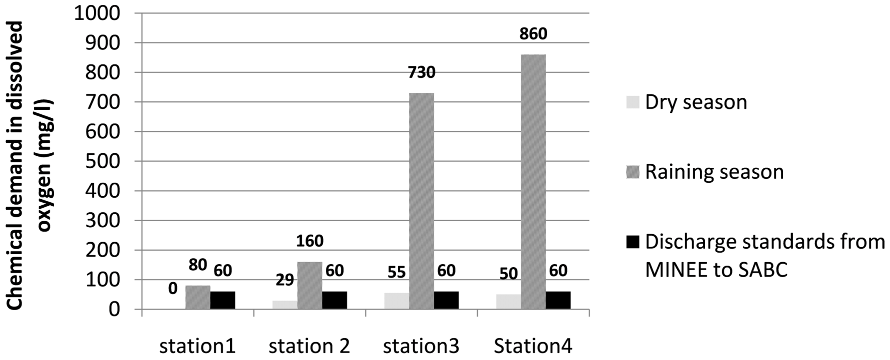

Figure 8. Evolution of the Chemical Oxygen Demand (COD) in milligrams per liter at the four stations during the two seasons during which the samples were taken.

The SS variation curves in **Figure 9** show that the waters are very stable during the dry season and very turbid during the rainy season. The values of the concentration of suspended matter in the water sampled during the rainy season are much higher than the discharge standard authorized by the MINEE for all the sampling points. A maximum value of 600 mg/l was recorded at stations 2 and 3 (**Figure 9**).

The evolution curves of phosphate concentrations in the dry season showed that they are lower than the value authorized by the discharge standard authorized by the MINEE (**Figure 10**). However, those in the rainy season reached a peak of 100 mg/l at sampling station number 2 and were above the standard at the three other stations (**Figure 10**).

The values of sulfate concentrations oscillated between 250 mg/l and 270 mg/l in sampling stations 1, 2, and 3 during the rainy season (**Figure 11**) and were almost zero in the dry season.

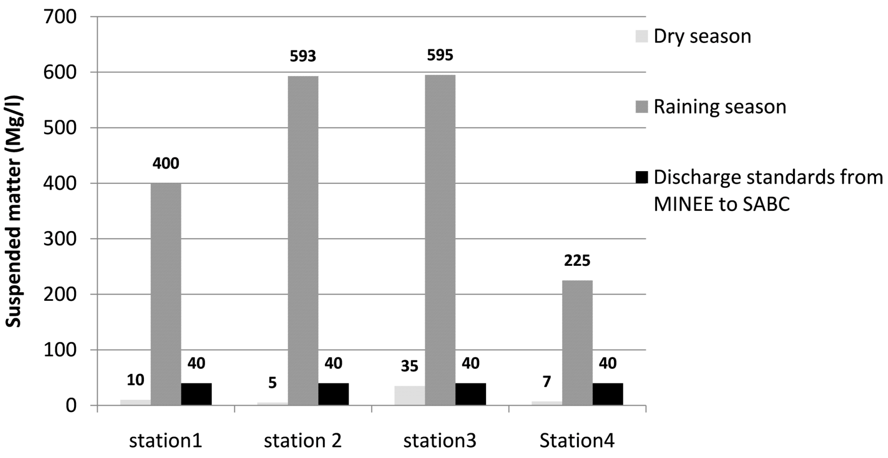

Figure 9. Evolution of suspended solids (SS).

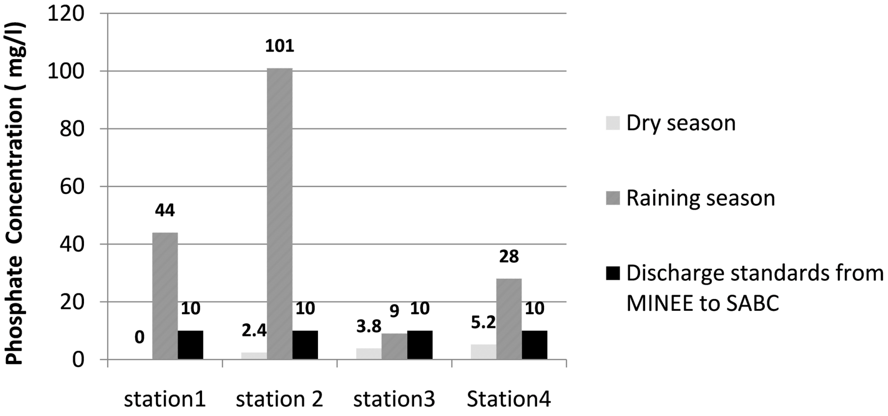

Figure 10. Evolution of phosphate at the four sampling stations during the two seasons.

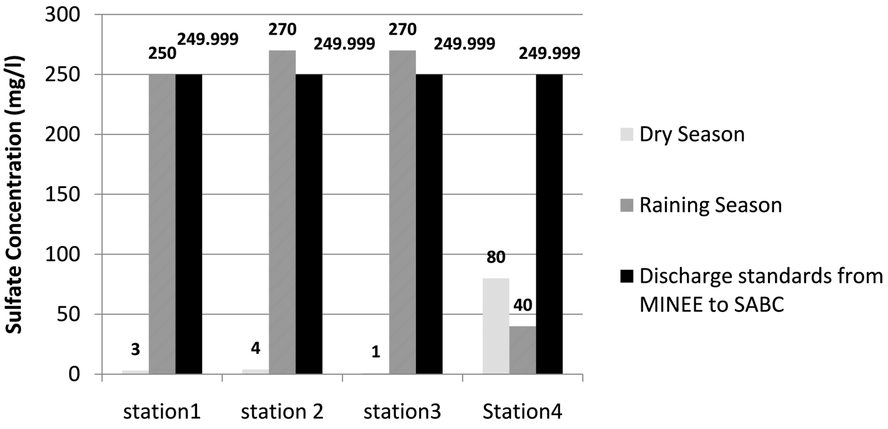

Figure 11. Evolution of sulfate at the four sampling stations during the two seasons.

The pH concentration curves show progressive increases in their values at stations 1, 2, and 3 during the dry season, unlike the rainy season, where they are rather decreasing. This trend of pH variation is also observed at station 4, which is a station that is isolated from the other 4. At this point, the pH is neutral in the dry season and is basic in the rainy season. Despite variations in the hydrogen potential of the effluents, they still remain within the standards authorized by the MINEE, between 08 and 09 (Figure 12).

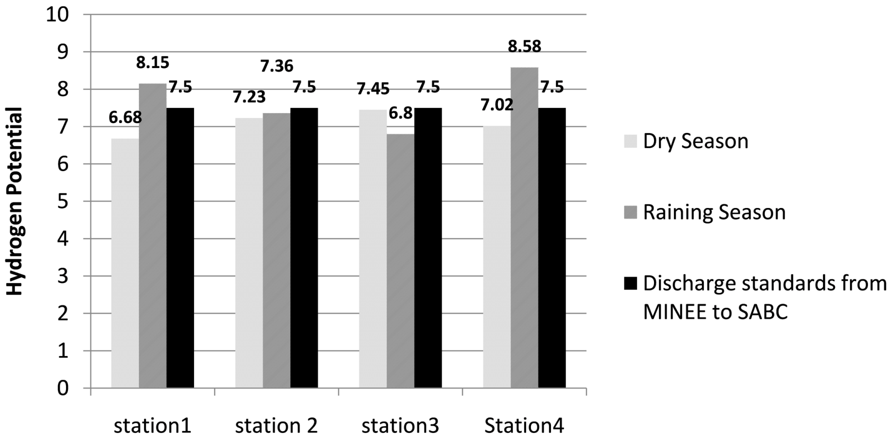

Figure 12. Evolution of the hydrogen potential at the four stations during the four seasons.

3.3. Mapping of Risk Areas in the Factory

The stormwater pollution risk assessment grid shows that the plant records several observations (Figure 13). First of all, fifteen (15) areas are at catastrophic or major risk for rainwater, or 37.5% of the study area in total. They are divided into six (06) at the Liquids and Fluids Production Center (CP) and nine (09) at the Courtyard (TC) (Figure 13 and Figure 14); Twenty (20) medium risk areas for stormwater pollution, that is, 50% of the total areas of the study area. To this end, eight (08) medium risk areas are counted at the CP level and ten (10) areas are identified at the TC level (Figure 13 and Figure 14); Finally, five (05) zones with tolerant or minor risks, i.e., 12.5% of the total of the two zones.

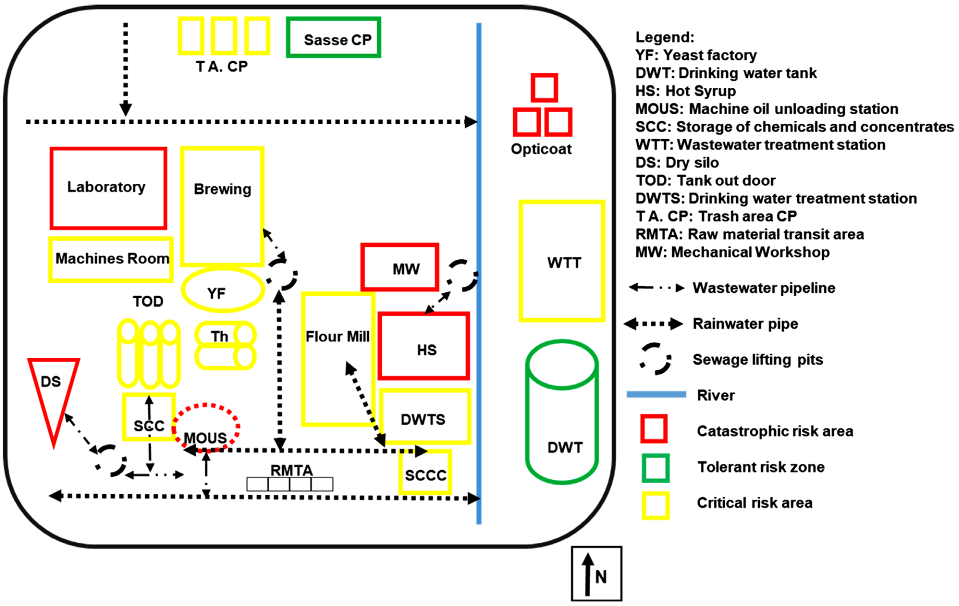

Figure 13. Mapping of risk areas in the liquids and fluids production center (CP).

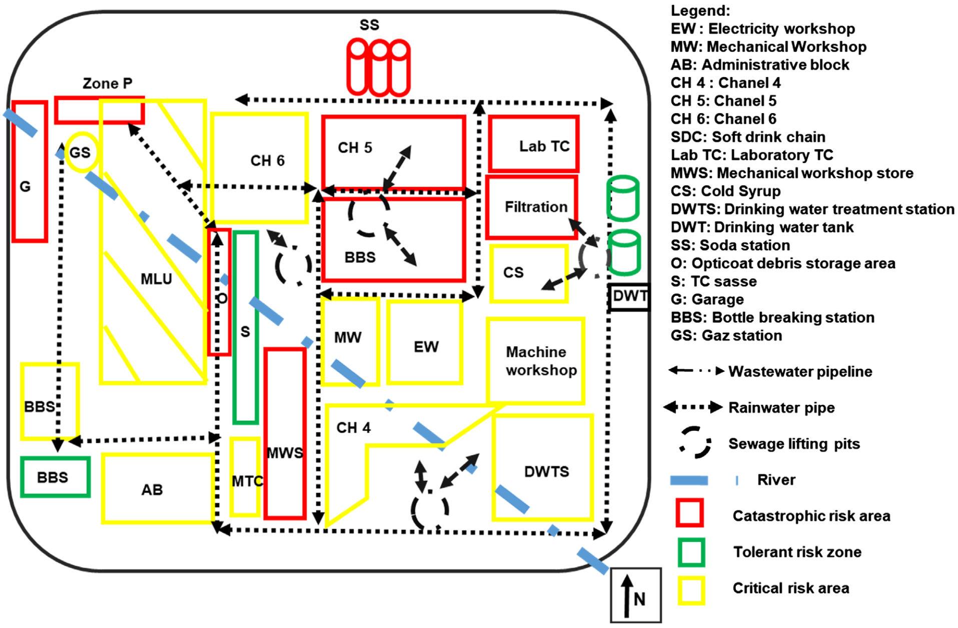

Figure 14. Mapping of the risk areas of the terrain court (TC).

4. Discussion

In general, this work shows that all the activities in the factory workshops are potential sources of rainwater pollution because each workshop contains at least one pollutant. The results of the identification of potential pollutants showed that waste (solid waste and liquid waste) is the main pollutant in the factory, followed by fermentable products or brewery by-products (yeast and spent grains) and chemicals. To avoid spills of these pollutants in rainwater, a system for managing the pollution of these waters, made up of retention tanks for products and hazardous waste, a separative network of rainwater and wastewater drainage, and absorbent sponges, has been set up. This system has flaws.

Failures of this system are due to: non-compliance with good environmental practices by plant employees; the incapacity of workers in certain workshops; and the non-compliance of retention basins. These failures were observed due to several reasons: spillage that occurred during yeast thermolysis as a result of the incompetence of the agents responsible; runoff of wastewater in the stormwater channels for conditioning and mixing caused by the malfunction of the secondary treatment of the WWTP. The malfunctions were mainly due to the fact that the filtration grids, pits, and valves were clogged with solid waste. This result corroborates those of Ayina in 2018, who worked on the impact of the use of soda in the brewing industry and was able to demonstrate that nearly 21.60% of the caustic soda used in the plant is lost every year. Similarly, those of Magang in 2017, who conducted a study on improving the rate of recovery of wastewater at the SABC group purification station in Yaoundé, from which it emerged that the rate of recovery of wastewater is an average of 35% per month at the WWTP of the Center Region plant.

The analysis of the waters around the site revealed that the physicochemical parameters, such as the temperature of the Aké River stream, are ambient, with the exception of that of station 4, which is beyond the normal and is equal to 38.5˚C. This rise in temperature at this sampling point is caused by the hot water from the closed circuit washes (CIP).

Although the pH values conformed to those of the guidelines proposed by the MINEE (values between 6 and 9), they nevertheless showed a variation in water quality. In the dry season, the water withdrawn tends to become more basic as it passes through the plant. This change in water quality is caused by the caustic soda contained in the conditioning effluents (Ayina, 2018). These waters tend to become increasingly acidic during the rainy season. This acidity is due to the concentration of the optical coating in the water being dominant.

The difference in suspended solids values showed that these waters are very stable in the dry season and very turbid, on the other hand, in the rainy season. The concentration difference of 200 mg/l observed at stations 1 and 2 is due to the leaching of pollutants from the plant by rainwater. This shows that the plant's stormwater drainage network is clogged with pollutants. The COD values, meanwhile, lead to the conclusion that these pollutants are of organic nature (degraded spent grains and yeast) as the peaks of the COD concentration curves are high in the rainy season in stations 3 and 4. The values of phosphates and sulfates showed that they are present in the washing water with regard to the values obtained at station 4 (sulfates) in the dry season and the modifications of the value of phosphate in stations 2 and 3 in the rainy season. The spatio-temporal variations of the waters of the Aké River led to the conclusion that the effluents from the plant have a negative influence on the quality of this watercourse. This conclusion is in agreement with the results of Makhoukh et al. (2011) who noted the degradation of water quality in the area subject to domestic, industrial, and agricultural wastewater discharges from the cities of Missour, Outat El Haj, and Guercif in Morocco.

The results of the mapping of risk areas in the plant show that 50% of the areas of the plant are at critical or medium risk. This criticality is due to the nature of the potential pollutants, whose dangerousness is very serious for nature, but the frequency of discharge is lower. This is the case with the raw material of breweries, which is fermentable and is a serious danger to the aquatic environment. In addition to this raw material, there are hazardous substances from the ancillary activities of breweries (engine oils from machines, chemical substances (beer additives, caustic soda, optical coating, dater anchor, analysis reagents), and concentrated solutions) and all resulting waste. 37.5% of the study area is at catastrophic risk or at major risk. The catastrophic nature of these areas is due to the very high dangerousness of these risks and the repeated frequency of their discharge into the rainwater drainage network without corrective action. The remaining 12.5% of the areas are those where the impact on rainwater is tolerated or are minor risk areas. The risk tolerance in the case of this study is due to the fact that the nature of the pollutants in these areas has characteristics similar to those of households.

This is the case for hand washing products in sasses. The results of the mapping of risk areas in this study are contrary to those of Toukak (2017), who counted areas of minor or tolerable risk much higher than areas of medium and major risk during the assessment of industrial risks at the industrial level of the BOCOM industry in Douala. 5% of the remaining areas are those where the impact on stormwater is tolerated or are minor risk areas. The risk tolerance in the case of this study is due to the fact that the nature of the pollutants in these areas has characteristics similar to those of households. This is the case for hand washing products in sasses. The results of the mapping of risk areas in this study are contrary to those of Toukak (2017), who counted areas of minor or tolerable risk much higher than areas of medium and major risk during the assessment of industrial risks at the industrial level. BOCOM industry in Douala. Overall, in order to significantly reduce or eliminate the occurrence of critical and medium risk areas, manual handling should be eliminated. Transfer of materials should be done through an automatic, leakage-free conveying apparatus. Disposal of wastes should be done with convenient containers and stored in a dry and secure place. The company should comply with modern practices of waste disposal in garbage bins. This will protect the environment even more.

5. Conclusion

The objective of this study was to assess the management of rainwater by the Société Anonyme des Boissons du Cameroun at its capital center plant. To achieve this objective, a general inventory of the factory was conducted in order to verify the rainwater management system that exists there. This was done with the help of the rainwater pollution prevention method proposed by the United States Environmental Protection Agency in 2009, revised by Christopher Newport University in 2016 in the United States. Next, it was important to diagnose the state of surface water pollution on the Aké River, which is the plant's direct tributary. This diagnosis facilitated the development of a mapping of the zones at risk of pollution of the factory's rainwater.

The general observation made is that all the activities carried out within the workshops, such as handling, transfer of products from one workshop to another, washing (bottles, racks, and tanks), and waste management, are risks of rainwater pollution. Thus, solid waste constitutes 39% of the plant's potential pollutants, followed by fermentable products or waste (29%), chemical substances (21%), metals (6%), bacteria (5%), organic (3%), oils, and fats (3%). Despite the rainwater pollution control and prevention measures implemented by the SSSTE service, these pollutants degrade the quality of the water in the Aké tributary.

To this end, 50% of the plant areas are critical risk areas for stormwater management, 37.5% are catastrophic risk areas, and 12.5% are tolerable risk areas. In view of the above, a corrective action plan worth 8,889,250 FCFA has been proposed. So far, 75% of the corrective actions have already been carried out and monitored by the SSSTE service.

Authors' Contributions

Joel Renaud Ngouanom Gnidakouong: Analysis and interpretation of data, critical revision of the manuscript for intellectual content, correspondence, and supervision. Séverin Mbog Mbog: Conception and design, analysis, and interpretation of the data. Ernestine Kemmoe Kountchie Nzadi: Experimental work, drafting of the paper, interpretation of data. Seukou Njabo Marie Therese: Drawings and design. Dieudonne Bitondo: Conception and design, general supervision. All authors agree to be accountable for all aspects of the work.

Data Availability Statement

Data will be made available on reasonable request, in compliance with the Taylor & Francis data sharing policy.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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