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Characterization of Wastewater Used for Irrigation and Other Purposes in Chad

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Abstract: This research work was based on recommendations of a number of researchers stating that pollution has appeared in the Chadian capital, N'Djamena, as a result of the liquid waste being thrown out from some private and public sectors before being treated. This study is a follow-up to research, some of which have been published and some not yet completed. The current article was focused on the determination of some physicochemical characteristics of wastewater in the capital of Chad N'Djamena and to assess their environmental impact. These characteristics were: Temperature, pH, electrical conductivity, TDS, Cu, Zn, Al, Fe, Mn, NO_3^-, PO_4^{3-}, HCO_3^-, chemical oxygen demand (COD), biological oxygen demand (BOD) and total dissolved solids. Samples were taken from four different effluent streams and analyzed according to the standard methods. The results of the evaluation were: pH (4.26 ± 0.06 - 8.57 ± 0.06), temperature (23.17 ± 0.21 - 33.60 ± 0.10°C), electrical conductivity [EC] (212 ± 0.01 - 1997 ± 10 µs/cm), the total dissolved solids TDS (1.42 ± 0.01 - 906.63 ± 1.21 mg/l), chemical oxygen demand COD (30 - 1170 mg/L), biological oxygen demand BOD (26 - 228 mg/L), Cu (0.11 - 6.20 mg/L), Zn (0.02 - 3.53 mg/L), Mn (0.003 - 6.77 mg/L), Al (0.10 -1.12 mg/L), Fe (0.39 - 3.43 mg/L), bicarbonate (23.67 - 853.33 mg/L), phosphate (0.023 - 333.67 mg/L) and nitrate (0.98 - 127.0 mg/L). These results revealed that the values of some parameters are exceeded the limit recommended by the World Health Organization for wastewater discharge. We conclude that this untreated wastewater are sources of pollution to the daily consumed legumes and vegetables.

Keywords: Effluent, Wastewater, Physicochemical Characteristics, Pollution, Chad

1. Introduction

Wastewater generally contains liquid wastes produced by households, hospitals, restaurants, industries, etc., as a result of daily activities. Municipal treatment facilities are designed to treat raw wastewater to produce a liquid effluent of suitable quality that can be disposed to the natural surface waters with minimum impact on environment and human health. In developed countries, much of the wastewater is treated prior to use for irrigation of fodder, fiber, and other crops. Meanwhile, though standards are set in developing countries, they are not always respected [1-3].

Pollution caused by wastewater represents the greatest threat to the sustainable use of ground and surface water.

Waste effluents and raw untreated sewage are often discharged into an open and fresh water sources. In most of developing countries, majority of rural and urban peoples discharge their raw domestic wastewater directly into the water streams without any- reservations [4]. This practice constitutes pools of wastewater in open gutters and on roads often provides breeding conditions for mosquitoes and medium for several bacteria and viruses. These observations were also reported by some authors in Chad [5-8]. Wastewater pools, contain hazardous contaminants such as oil and grease, pesticides, ammonia, and heavy metals [9]. Global climate change impacts also could tend to increase the diffuse pollution in an urban or agricultural area. The climate change determinants affecting water quality are mainly the ambient temperature and the increase

of extreme hydrological events. Moreover, drying-rewetting soil cycles and the increase in solar radiation also could be considered [10].

Nowadays, the availability of good quality water even for human uses is threatened in many places. Consequently, irrigated agriculture faces the problem of using water of poor quality to irrigate lands that provide food for an expanding population [11]. The use of untreated wastewater in irrigated agriculture has potential for both positive and negative environmental consequences [12]. However, irrigation of agriculture with treated municipal wastewater is highly encouraged [13] and is considered as an environmentally wastewater disposal practice compared to its direct disposal to the surface or ground water. Although wastewater is a suitable source of plant nutrients and organic matter, it could contain undesirable chemical compounds and pathogens that cause negative environmental and health problem [14]. A number of risk factors have been identified in wastewater reuse, like microbial pathogens and the salinity of soil. For optimum use of wastewater for irrigation purposes, many guidelines have been developed to give a quality criteria and treatment guidance [15-16].

Contaminants in domestic wastewaters can be divided into three categories: suspended solids, organic matters (chemical oxygen demand, biochemical oxygen demand) and nutrients (nitrogen and phosphorus) [17]. A conventional wastewater treatment processes often begin by physical process and followed by biological one. In general, organic and inorganic substances in the domestic sewage may include both suspended and dissolved fractions. Suspended fraction can be easily removed by physical or physiochemical processes under most conditions. However, some dissolved substances may attach on to the suspended particles. Therefore, as long as the suspended particles can be effectively removed, the originally dissolved matter may also be removed substantially [18].

Since different water quality parameters need to be considered when evaluating wastewater effluents as a potential irrigation water source than those considered for its direct discharge into a receiving stream, a specific set of wastewater quality reporting requirements must be outlined and defined. Therefore, before using wastewater for irrigation as a means of increasing water supply for agriculture, a thorough analysis must be undertaken for a sustainable development strategy [19].

Although many research efforts have been reported in wastewater in Chad [20-21], untreated municipal wastewater in many quarters of N'Djamena city still used carelessly for the irrigation of daily consumed legumes and vegetables without any official awareness. How safe is this practice? Hence, the objective of this paper is to provide a review of the characteristics of wastewater used for irrigation and to carry out some physical and chemical characterizations of wastewater used to irrigate legumes and vegetables consumed daily in N'Djamena and evaluate their environmental impact.

2. Materials and Methods

2.1. Study Location

The location of study is N'Djamena, the capital of Chad. N'Djamena locates at latitude 12.8° N and 15.2° E longitudinal at an elevation of 295 m above the mean sea level. The main discharge channel "*la Cevette de Saint Martin*" is located in the middle of the town, it is a wide but not deep, it runs from northeast to southwest and drains into Chari River. The population of N'Djamena is about 993492 habitats, distributed in 10 municipals. The study site included 4 locations; Diguel Ryad (DR) quarter in the municipal number 8 (Site 1), Paris Congo (PC) quarter in the municipal number 7 (Site 2), General Hospital channel (HGRN) in the municipal number 3 (Site 3) and the Chadian Brewery Company (STB) channel, Farcha quarter, in the municipal number 1 (Site 4).

2.2. Water Sampling and Analysis

The wastewater samples were collected during the season of 2014 from the 4 locations. Three samples per month from each location were collected at the same time (8:00 to 10:00 am) in a clean sterile plastic container and stored at 4°C in the Laboratory of Analysis of Water and Environment, Faculty of Pure and Applied Science, University of N'Djamena.

2.3. Methodology

Temperature (°C) and electrical conductivity (μm/S) were measured using multifunction apparatus (WTW 315 i/SET) [22]. pH was measured using pH meter (ECOSCAN pH 6), ISO (2006) [23]. Total Dissolved Solids (mg/l) were measured following the standard method [24]. Biological Oxygen Demand (BOD) (mg/l) and Chemical Oxygen Demand (COD) (mg/l) were estimated form incubation at 20°C for 5 days. Five heavy metal (Cu, Zn, Al, Fe, Mn) and three ions (NO_3^-, PO_4^{3-}, HCO_3^-) were analyzed using a spectrophotometer of mark (HACH DR/2400) at different wavelengths [25].

2.4. Statistical Analysis of Data

The data obtained were analysed using the analyses of variance (ANOVA) at a probability (*P*) of 0.01 and 0.05 confidence level. SPSS was used for the one-way analysis of variance (SPSS). Figures were plotted applying multiple regression analysis in Sigmaplot software (Sigmaplot ®, 2010).

3. Results and Discussion

3.1. Hydrogen Ion (pH)

The results in figure 1 showed that all the values of pH of wastewater in the 4 locations aren't exceed the limits (6-9) recommended by WHO [14]. In location 3 (HGRN), for example, the pH range between 4.40 ± 0.13 in November to 8.40 ± 0.08 in September. In location 4 (STB) the highest pH (8.57 ± 0.06) was recorded in September, while the lowest was found to be 4.26 ± 0.06 in November. The high value of pH in location 4 could be attributed to the nature of the
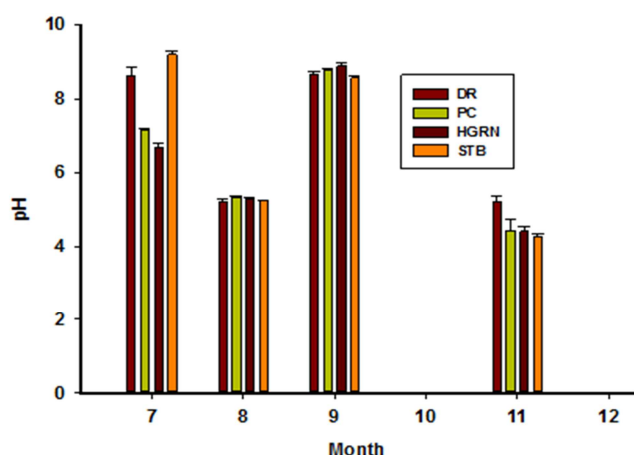
wastewater of the Chadian Brewery Company.

Figure 1. PH of wastewater from four differents sites in N'Djamena.

*DR: Diguel Ryad effluent, PC: Paris Congo effluent, HGRN: General Hospital effluent and STB: Chadian Brewery Company effluent.

3.2. Temperature (°C)

The results in figure 2 revealed that the wastewater has a temperature ranged on average between (23.2-33.60°C). Temperatures higher than 30°C are not in accordance with wastewater discharging standards [26]. At location 1 (DR) and 2 (PC) temperatures ranged on average between $23.17 \pm 0.21°C$ in November to $32.27 \pm 0.40°C$ in July, while in site 3 (HGRN) and 4 (STB) the values were found to be $27.8 \pm 0.57°C$ in September and $33.60 \pm 0.10°C$ in July. The lowest temperature (23.2°C) was recorded at location 2 in November, while the highest (33.60°C) was recorded in July at location 4.
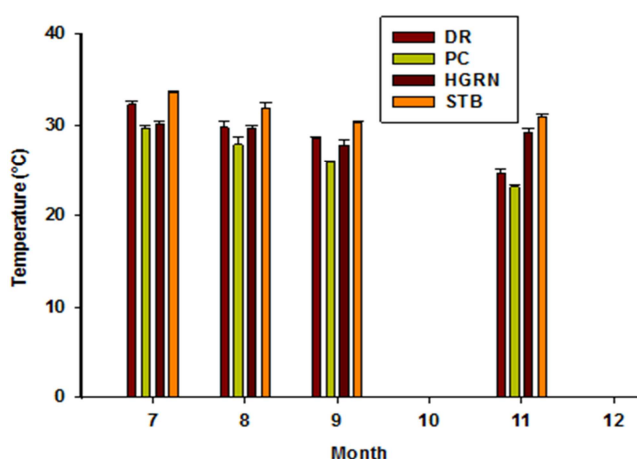

Figure 2. Temperature of wastewater from four different sites in N'Djamena.

3.3. Electrical Conductivity

Electrical conductivity is an important parameter used to evaluate pollution level in waste water. It depends on temperature and dissolved ions. From figure 3, highest and lowest values of electrical conductivity (1997 ± 10 - 212 ± 0.01 μs/cm) were recorded in September at location 4 (STB),

and 2 (PC) respectively. The elevated values of electrical conductivity might be due to the presence of high soluble salts in the wastewater of Chadian Brewery Company, enhanced by the evaporation process. The death and migration of fishes at the wastewater discharge area of the Chadian Brewery Company into Chari River were reported [21].
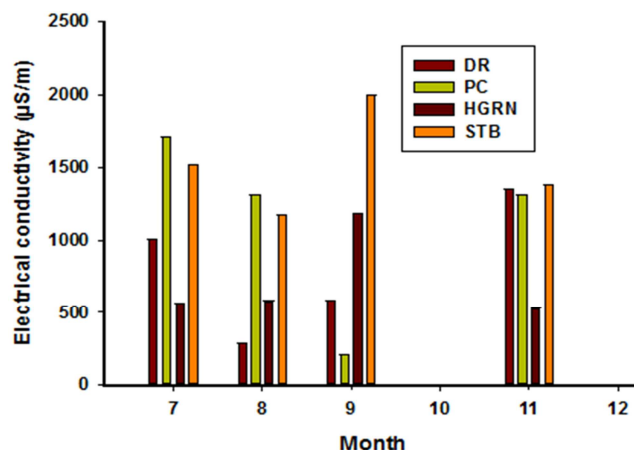

Figure 3. Electrical conductivity of wastewater from four different sites in N'Djamena.

3.4. Total Dissolved Solids

The total dissolved solids (TDS) represent the amount of organic and inorganic materials in a liquid in an ionic or molecular form. From figure 4, the highest average value (906.63 ± 1.21 mg/l) of TDS in location 1 (DR) was recorded in November, while in location 2 (PC) was recorded in August (877.48 ± 2.35 mg/l). Locations 3 (HGRN) and 4 (STB), scored the highest average values in September (791.82 ± 0.68, 1338.1 ± 0.84 mg/l respectively). The lowest value (1.42 ± 0.01 mg/l) was recorded at locations 2 These results showed that site 4 record the highest value (1338.1 ± 0.84 mg/l) of total dissolved solids. This high value could be attributed to the concentration of soluble salts in the water exchange unit of the Chadian Brewery Company due to evaporation process.
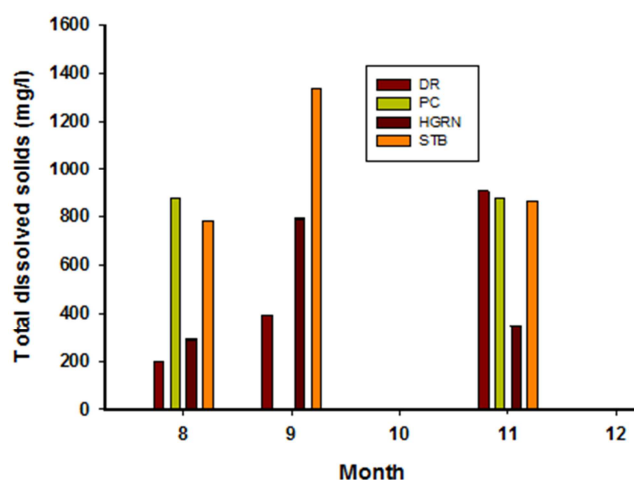

Figure 4. Total dissolved solids in wastewater from four different sites in N'Djamena.

3.5. Chemical Oxygen Demand (COD)

As shown in Figure 5, the chemical oxygen demand (COD) was found to be 30.00 mg/l in August and 5380 mg/l in September in location 1 (DR). The rest of COD values fall within this range in locations 2 (PC), 3 (HGRN) and 4 (STB). The lowest values were recorded in August in locations 1, 2, 3 and 4 (30, 358, 110, 110 mg/L respectively), while the highest ones in locations 4, 3 and 2 were reported in July (1170 mg/L), September (1120 mg/L), and November (709 mg/L) respectively. From these results, it observed the majority of COD values reported are beyond the allowable limit (75 mg/L) recommended by World Health Organization standards for wastewater [27].
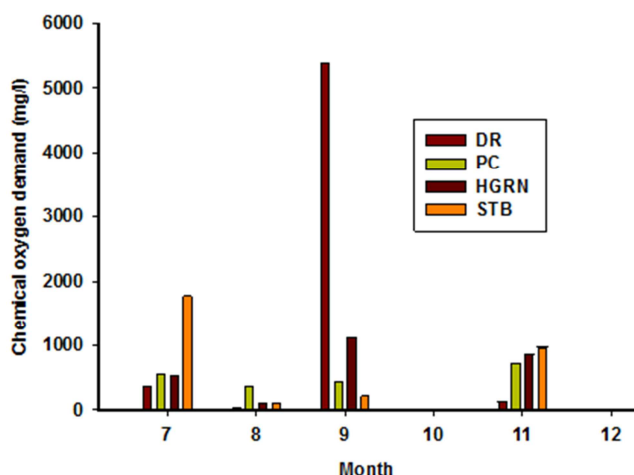

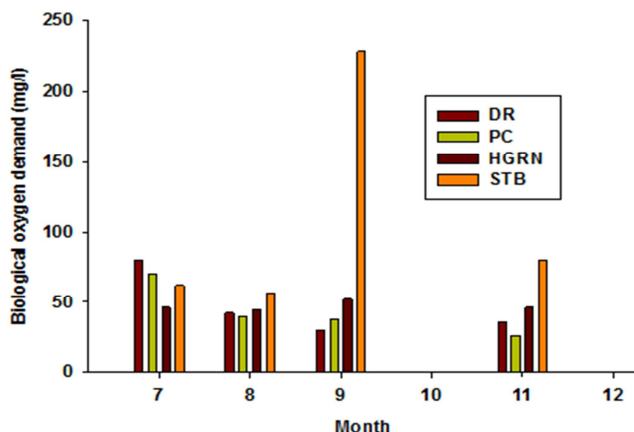*Figure 5. Chemical oxygen demand in wastewater from four different sites in N'Djamena.*

Figure 6. Biological oxygen demandin wastewater from four different sites in N'Djamena.

3.6. Biological Oxygen Demand (BOD)

As shown in Figure 6, the results of BOD showed varying concentrations in the four samples. The highest values recorded in July at locations 1 (80.00 mg/L) and 2 (70.00 mg/L), and in September at locations 3 (52 mg/L) and 4 (228 mg/L). While the lowest values for locations 1, 2, 3 and 4 were found to be 30 mg/L in September mg/L, 26 mg/L in November, 44 mg/L in August and 56 mg/L in August respectively. These results

suggested that the values of BOD during the study period were in the range of 26 - 228 mg/L. However, the recommended limit of BOD in wastewater is 50 mg/L [28].

3.7. Heavy Metals and Ions

3.7.1. Copper

The copper content of wastewater samples varies dramatically in the 4 locations from 0.11 mg/L to 6.20 mg/L. The result was shown in tables 1, 2, 3 and 4. In location 1 (DR) varied from 1.07 mg/L in July to 2.77 mg/L in November, in location 2 (PC) from 0.80 mg/L in August to 4.01 mg/L in September, in location 3 (HGRN) from 0.11 mg/L in November to 1.06 mg/L in July and in location 4 (STB) from 1.41 mg/L in July to 6.20 mg/L in August. All these values of copper content are exceeded the WHO limit for irrigation water (0.01 - 1.0 mg/L). The elevated value of copper content in location 4 could be attributed to degradation of copper pipes used for the disposal of wastewater from Chadian Brewery Company directly into the Chari river.

3.7.2. Zinc

The results of analyzes of zinc concentration in the 4 samples are shown in the tables 1, 2, 3 and 4. The minimum values were recorded in November in location 1, 2, 3 and 4 as 0.02, 0.31, 0.02, and 0.59 mg/L respectively, while the maximum concentrations were 1.01 mg/L (July), 2.65 mg/L (September), 0.89 mg/L (July) and 3. 53 mg/L (August) in location 1, 2, 3 and 4 respectively. except the result of location 4 (3.53 mg/L), these results showed that the zinc content in the 4 samples are not exceed the limit permitted in wastewater (3 mg/L) [28].

3.7.3. Manganese

As shown in tables 1, 2, 3 and 4, the lowest manganese concentration was recorded in November. The lowest value (0.003 mg/L) was reported in September in location 1, while the highest reported values in the location 1, 2, 3 and 4 in August were 5.13, 6.77, 3.37 and 3.58 mg/L respectively. The maximum limit allowed of heavy metals in waste water is 6.61 mg/L [28].

3.7.4. Aluminum

The result of aluminum concentration in the different samples studied were figured in the tables 1, 2, 3 and 4. The lowest values (0.10, 0.00 and 0.13 mg/L) were recorded in November in locations 2, 3 and 4 respectively, all of which are within the allowable limit for drinking water (0. 2 mg/L) [29-30], while the result in location 1 (0.98 mg/L) in September was beyond this limit. The highest values in positions 1, 2, 3 and 4 were: 1.11 mg/L in November, 1.11 mg/L in July, 0.28 mg/L in August and 0.51 mg/L in September respectively, all of which are exceed the allowable limit, except in Location 3 (0.18 mg/L). The highest value of aluminum concentration (1.12 mg/L) was recorded in July in Location 2. The elevated concentration of aluminum could be attributed to accumulation of waste water from traditional fabrication of kitchen aluminum tools in location 1.

3.7.5. Iron

The results of analyzes of iron concentration in the samples are shown in the tables 1, 2, 3 and 4. All readings recorded are exceeded the allowable limit in drinking water (0.05 - 0.20 mg/L) [31] as well as in wastewater (0.3 mg/L) [27]. In location 1 (DR) the readings are varied from 1.90 mg/L in August to 4.20 mg/L in November, while in location 2 (PC) from 5.92 mg/L in July to 0.90 mg/L in November. In location 3 (HGRN) and 4 (STB) the lowest values were recorded in September (0.39, 2.30 mg/L) and the highest ones were recorded in July and August (3.43, 3.11 mg/L) respectively. The elevated value of ion content in location 2 could be attributed to degradation of useless iron pots thrown without any health control.

3.8. Dissolved Ions

3.8.1. Bicarbonate

The results of analyzes of bicarbonate concentrations in all samples studied are shown in the tables (1, 2, 3 and 4). The lowest bicarbonate concentration (23.67 mg/L) was recorded at location 3 (HGRN) in August, while highest one (853.33 mg/L) was recorded at the same location in September. At location 1 (DR) the values are varied from 203.33 mg/L in July to 363.00 mg/L in November, whereas at location 2 (PC) the readings varied from 344.00 mg/L in August to 750.33 mg/L in September. At location 4 (STB) the highest value (646.67 ± 2.89 mg/L) was recorded in September and the lowest one (307.00 ± 2.65 mg/L) was recorded in November. Most of these results are exceeded the recommended limit (130 mg/L) for drinking water [27]. These high bicarbonate concentrations in the samples studied could be attributed to the concentration of bicarbonate salts due to evaporation of water in hot season.

3.8.2. Phosphate

As shown in tables 1, 2, 3 and 4, the phosphate profile ranged from 0.023 to 333.67 mg/L at the four study locations. At location 1 (DR) the values are varied from 0.399 mg/L in November to 45.97 mg/L in August, while in location 2 (PC) from 0.023 mg/L in November to 333.67 mg/L in September. At location 3 (HGRN) and 4 (STB) the lowest values were recorded in November (0.05, 0.67 mg/L) and the highest ones were recorded in July as 66.00 and 213.33 mg/L respectively. These results showed that the phosphate concentrations in wastewater are exceeded the recommended limit (10 mg/L) [32], and this could be due to the relatively acidic nature of wastewater in the mentioned period. This acidic medium does not favorize the deposition of phosphate ions in form of calcium, magnesium or generally heavy metals phosphate, which are slightly soluble in water [33]. The increase of phosphor in wastewater encourages the growth of algae and hence increases the percentage of plant nutrients in water [34].

3.8.3. Nitrate

Generally, the nitrate concentrations in the four samples studied are ranged from 0.98 to 127.0 mg/L. The lowest values at locations 1 (DR), 2 (PC) and 3 (HGRN) were recorded in July as 0.98, 2.92 and 1.98 mg/L respectively, while at location 4 (STB), the lowest value (8.40 mg/L) was recorded in November. The highest values of nitrate concentrations at locations 1, 2, 3 and 4 were found to be 23.0 mg/L in August, 38.27 mg/L in September, 31.70 mg/L in August, and 127.0 mg/L in July mg/L respectively, all of which are exceeded the recommended limit (1-10 mg/L) in drinking water [35] as well as in wastewater (15 mg/L) [27]. This highest nitrate concentration recorded in the sample of Beverage plant (location 4) could be attributed to the presence of organic and inorganic nitrogenic maters in the sewage, as well as dust and other substances that could reach the drainage channel of the plant. Also, this high nitrate concentration could be due to the lack of oxygen content of organic matter in wastewater [36].

Table 1. Heavy metals and dissolved ions in wastewater of Diguel Ryad (DR) channel.

Heavy metals and ions (mg/l)							
Month	Cu	Zn	Al	Fe	Mn	NO_3^-	PO_4^{3-}	HCO_3^-
July	1.07 ± 0.02	1.01 ± 0.01	0.21 ± 0.02	2.56 ± 0.02	0.01 ± 0.001	1.98 ± 0.02	2.80 ± 0.44	203.33 ± 2.89
August	1.25 ± 0.04	0.91 ± 0.03	0.22 ± 0.01	1.90 ± 0.01	5.13 ± 0.80	23.00 ± 1.41	45.97 ± 0.52	207.67 ± 1.25
September	1.10 ± 0.04	0.60 ± 0.07	007 ± 0.01	1.99 ± 0.02	0.003 ± 0.00	18.10 ± 0.70	33.50 ± 1.15	300.33 ± 0.58
November	2.77 ± 0.04	0.02 ± 0.01	0.20 ± 0.01	4.20 ± 0.10	0.004 ± 0.00	6.93 ± 0.06	0.67 ± 0.03	363.00 ± 2.65
Average	1.55	0.64	0.16	2.66	1.29	12.50	20.74	268.58

Table 2. Heavy metals and dissolved ions in wastewater of Paris Congo (PC) channel.

Heavy metals and ions (mg/l)							
Month	Cu	Zn	Al	Fe	Mn	NO_3^-	PO_4^{3-}	HCO_3^-
July	2.57 ± 0.02	1.01 ± 0.01	1.12 ± 0.02	5.92 ± 0.02	0.02 ± 0.002	2.92± 0.02	225.33 ± 0.58	339.67 ± 0.58
August	0.80 ± 0.01	1.23 ± 0.04	1.11 ± 0.03	2.72 ± 0.01	6.77 ± 0.42	24.90 ± 0.10	44.13± 0.61	344.00 ± 1.73
September	4.01 ± 0.01	2.65 ± 0.03	0.44 ± 0.01	4.73 ± 0.02	0.012 ± 0.001	38.27 ± 0.05	333.67 ± 1.25	750.33 ± 0.47
November	1.21 ± 0.01	0.31 ± 0.01	0.10 ± 0.01	0.92 ± 0.02	0.00 ± 0.00	6.33 ± 0.31	0.05 ± 0.01	403.67 ± 2.62
Average	2.15	1.30	0.70	3.56	1.70	18.11	150.80	459.42

Table 3. *Heavy metals and dissolved ions in wastewater of Reference General Hospital (HGRN) channel.*

Heavy metals and ions (mg/l)								
Month	Cu	Zn	Al	Fe	Mn	NO_3^-	PO_4^{3-}	HCO_3^-
July	1.06 ± 0.01	0.89 ± 0.01	0.28 ± 0.01	3.43 ± 0.03	0.010 ± 0.001	0.98 ± 0.02	66.00 ± 0.87	29.67 ± 0.58
August	0.66 ± 0.02	0.26 ± 0.01	0.18 ± 0.01	0.54 ± 0.01	3.37 ± 0.30	31.70 ± 0.10	34.56 ± 0.46	23.67 ± 1.15
September	0.52 ± 0.01	0.17 ± 0.01	0.013 ± 0.01	0.39 ± 0.01	0.000 ± 0.00	9.47 ± 0.38	18.17 ± 0.19	853.00 ± 1.63
November	0.11 ± 0.01	0.02 ± 0.01	0.00 ± 0.00	0.47 ± 0.02	0.000 ± 0.00	3.57 ± 0.24	0.023 ± 0.01	305.67 ± 2.62
Average	0.59	0.34	0.09	1.21	0.85	11.43	29.69	303.00

Table 4. *Heavy metals and dissolved ions in wastewater of Chadian Brewery Company (STB) channel.*

Heavy metals and ions (mg/l)								
Month	Cu	Zn	Al	Fe	Mn	NO_3^-	PO_4^{3-}	HCO_3^-
July	1.41 ± 0.01	0.76 ± 0.01	0.21 ± 0.02	3.11 ± 0.01	0.01 ± 0.001	127.00 ± 1.00	213.33 ± 2.89	351.67 ± 1.53
August	6.20 ± 0.27	3.53 ± 0.06	0.22 ± 0.01	13.11 ± 0.01	3.58 ± 0.04	64.43 ± 0.51	139.00 ± 1.00	353.33 ± 1.53
September	1.67 ± 0.01	0.73 ± 0.02	0.51 ± 0.02	2.30 ± 0.01	0.003 ± 0.001	10.67 ± 0.15	78.67 ± 0.58	646.67 ± 2.89
November	3.70 ± 0.30	0.58 ± 0.01	0.13 ± 0.01	3.38 ± 0.03	0.0	8.40 ± 0.44	0.39 ± 0.03	307.00 ± 2.65
Average	3.25	1.40	0.27	5.48	0.90	52.63	107.85	435.11

4. Conclusion

The production of healthy agricultural vegetables remains challenge in parts of the capital of Chad, N'Djamena. The irrigation of the mentioned products by untreated wastewater become habitual practice without any a warning from the concerned officers. The current study assessed some physical and chemical characteristics of wastewater used to irrigate legumes and vegetables consumed daily in N'Djamena city in Chad and evaluate their environmental impact. The results revealed that the values of pH, Zn and Mn were within the recommended limits for most of the sampling period and ranged between 4.26 - 8.57, 0.02 - 3.53 mg/L and 0.003 - 6.77 mg/L, respectively, while the values of temperature, electrical conductivity EC, total dissolved solids TDS, chemical oxygen demand COD, biological oxygen demand BOD, Cu, Al, Fe, bicarbonate, phosphate and nitrate, were exceeded the recommended limits. These results confirmed the deterioration of physicochemical qualities of the discharged wastewater effluents (Diguel Ryad (DR) quarter in the municipal 8, Site 1; Paris Congo (PC) quarter in the municipal 7, Site 2; General Hospital Channel (HGRN) in the municipal 3, Site 3 and the Chadian Brewery Company Channel (STB) Farcha quarter, in the municipal 1, Site 4). Our findings require urgent intervention of the Chadian government to reduce the risk of indiscriminate pollution of environments through the continuous and irresponsible release of untreated effluents from different private and public sectors in the N'Djamena city in order to avoid public health concerns associated with environmental pollution.

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