International Journal of Environmental Monitoring and Analysis
2015; 3(5): 238-244
Published online September 2, 2015 (http://www.sciencepublishinggroup.com/j/ijema)
doi: 10.11648/j.ijema.20150305.11
ISSN: 2328-7659 (Print); ISSN: 2328-7667 (Online)

Evaluation of the Physico-Chemical and Bacteriological Quality of Surface Waters in Guelma Basin, Algeria

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To cite this article:
Nora Kachi, Slimane Kachi, Houria Bousnoubra. Evaluation of the Physico-Chemical and Bacteriological Quality of Surface Waters in Guelma Basin, Algeria. *International Journal of Environmental Monitoring and Analysis*. Vol. 3, No. 5, 2015, pp. 238-244.
doi: 10.11648/j.ijema.20150305.11

Abstract: In order to evaluate the influence of human activities on the quality of surface waters of Guelma basin, physicochemical parameters (T°, pH, EC, TSS, DO, BOD_5 COD, $PO4^-$, $NH4^+$, $NO2^-$ and NO_3^-) and bacteriological (TG, TC, FC and FS) of waters of Maiz and Zimba river have been followed on three sites starting from upstream to downstream during the flood and dry period. The parameters showed a significant influence of leaching from agricultural soils, urban and industrial discharges on the physico-chemical and bacteriological composition of water. The nitrogen and phosphate compounds are more important during the flood period and the high densities of bacteria were observed in dry period. The results indicate that surface waters of Maiz and Zimba river revealed a signs of degradation whatever the sampling period, since the majority of the analyzed parameters show higher levels of contamination to Algerian standards.

Keywords: Pollution, Physicochemical Parameters, Bacteriology, Surface Water, Guelma, Algeria

1. Introduction

Currently, the surface waters of the catchment area of Guelma are threatened by intensive pollution due to the socio-economic and demographic development which is always accompanied by rapid urbanization and the implementation of an industrial fabric. The irrational use of fertilizers and pesticides within the perimeter of Guelma and intensive irrigation exacerbates the situation. All these activities generate significant mineral and organic levels of pollution susceptible to distort the quality of surface waters in the basin. Thus, a general diagnosis of the current situation of pollution and rigorous monitoring of its evolution, prove of great necessity to protect the environment and water resources.

It is in this perspective that this work was conducted to assessing for the first time the physicochemical and bacteriological quality in flood and dry period of surface waters of Zimba and Maiz river, a major tributary of the Seybouse river in the alluvial plain of Guelma.

2. Material and Methods

2.1. Presentation of the Study Zone

The Guelma basin is located at the North-East of Algeria. It has a form lengthened from east to west on 20 km length and from 3 to 10 km wide, crossed by the river Seybouse which constitutes the main superficial stream. In the alluvial plain of Guelma, the Seybouse receives the Maiz and Zimba rivers which drain all wastewaters, urban, industrial and agricultural water without preliminary treatment over a length of 6 and 9 km respectively (fig.1). This zone corresponds to a basin of collapse in which piled up a set of sediments going from Miocène to Quaternary [1]. The climate is sub-wet with an average precipitation of 600 mm/year and a temperature of 18.5°C. It has a big fertility due to Seybouse river and to a large dam which assures a vast irrigated perimeter of 9650 ha. From a hydrogeological point of view, the alluvial aquifer of Guelma is the most important within the region with a total discharge of 385 l/s [2]. It is fed by seepage and runoff water from rainfall and irrigation.

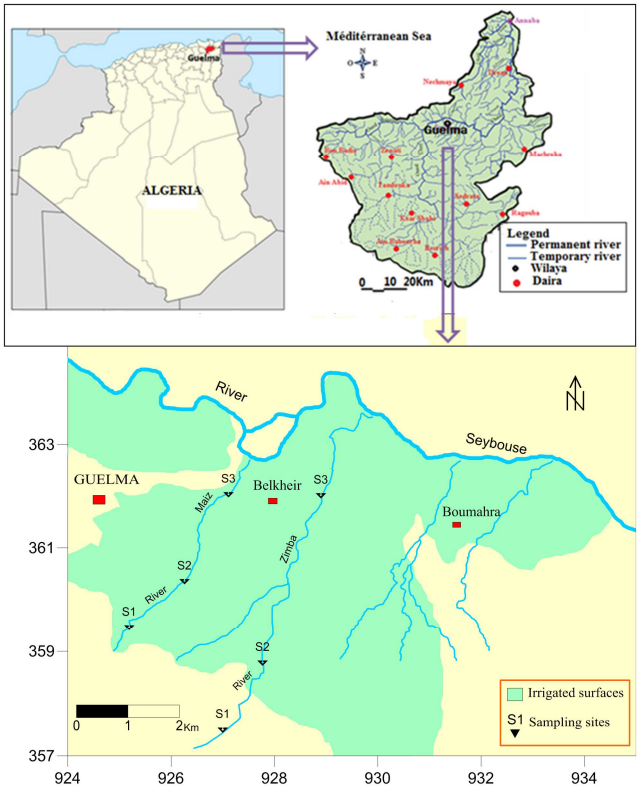

Figure 1. *Guelma basin and sampling sites (Maiz and Zimba river).*

2.2. Samples and Analyzes

We carried out two sampling campaigns at the rate of one sample per period. To follow the temporal variability of the studied parameters, we selected six sampling sites that distributed along Maiz and Zimba rivers (Figure 1). The samples were taken in wet period (in March, 2015); this period shows an intense rain with violent floods and in dry period (in May, 2015). For each sample, analyzes were focused on the physico-chemical and bacteriological parameters which are: temperature, pH, electrical conductivity and dissolved oxygen are measured in situ using a multi-parameter type Hanna-Model 9828. Polyethylene bottles of 1 liter are used for taking samples for physic-chemical analysis at the laboratory (TSS, COD, BOD5, $PO4^{-}$, $NO3^{-}$, $NO2^{-}$ and $NH4^{+}$).

Other glass bottles, carefully washed, rinsed six times at bidistilled water (1.8 µS/cm) and sterilized (120 ºC, 15 min) are used to take samples for bacteriological analysis (TG, FC, TC and FS) according to the most probable number [3]. The samples are collected in the middle of the river, halfway between the water columns according to a direction opposite to the water flow direction [4].

3. Results and Discussion

3.1. Physico-Chemical Characterization

3.1.1. Temperature (T°)

The temperature of surface waters of Maiz and Zimba rivers is variable according to period of sampling wet or dry and increases from upstream to downstream (fig. 2). According to the Algerian standards set by [5] to surface water, these waters are of excellent quality because their temperatures are below 20 °C. *3.1.2 pH* The pH in flood period is alkaline for all samples and varies from 10.85 to 12.43 and becomes weakly alkaline in dry period (7.77 to 9.97). The increase of the pH in flood period would be related to the dissolution of limestone travertine carbonates which limits the southern edge of the Guelma basin (fig. 3). According to the grid of appreciation of the quality of surface water (NAWR, 2012), these rivers present an excessive pollution in wet period and tends to attenuate in dry period with a passable to poor appreciation. *3.1.3 Electric conductivity (EC)* The electric conductivity of water increases from upstream to downstream in times of rain and dry, this increase is greater in dry period with up to 1145 µS/cm at Maiz river and of 1045 µS/cm at Zimba river (Figure 4). In flood period, the high values of the conductivity indicating a continuous supply of mineral salts from outside all along the rivers. However, in dry period, the increase of the conductivity is mainly attributed to the domestic and industrial wastewater discharges [6]. *3.1.4 Total suspended solids (TSS)* The highest values of total dissolved solids are observed in dry period. The water surface of Maiz river is more charged in TSS (396-1500 mg/l) than that of Zimba river (108-140 mg/l) (fig. 5). These high contents in TSS are due to the important domestic discharges rich in mineral and organic particles, on the other hand the low contents can be allotted to the heavy density of the vegetable cover in wet period which slows down the erosion of the soil.

According to the Algerian standards [5], the quality of surface waters is poor in flood period and are excessively polluted in dry period *3.1.5 Dissolved oxygen (DO)* The oxygen content obtained during the two periods considered is ranged between 5.45 and 11.5 mg/l for all analyzed water samples and decreases from upstream to downstream (fig. 6). The highest values were recorded in flood period in both rivers, Zimba (9.84-11.5 mg/l) and Maiz (7.62-10.33 mg/l). This is due to the recorded cold temperatures and to the important flow caused by the heavy rains [4]. However, during the dry period, the warming of water and low flow rate cause a decrease in the dissolved oxygen, aggravated by an increase in oxygen consumption by the bacteria by decomposing the organic matter. According to the grid of the NAWR (2012), water is of excellent quality in floods and high quality in dry periods [7].

3.1.2. Phosphate

Phosphates come mainly from domestic and industrial activities but also from agricultural activities via the erosion of soil [8]. The surface water of the river Zimba has contents very close to 1 mg/l whatever the sampling period (fig. 7). However, at river Maiz, the phosphates follow a spatial variation marked by a clear increase in dry period and vary between 5.16 (S1) and 8.44 mg/l (S2). This situation can be explained by the significant releases of urban waste which are very charged with phosphate compounds. These values

are used to quality the water of passable quality Zimba river and passable to very polluted for Maiz river [5].

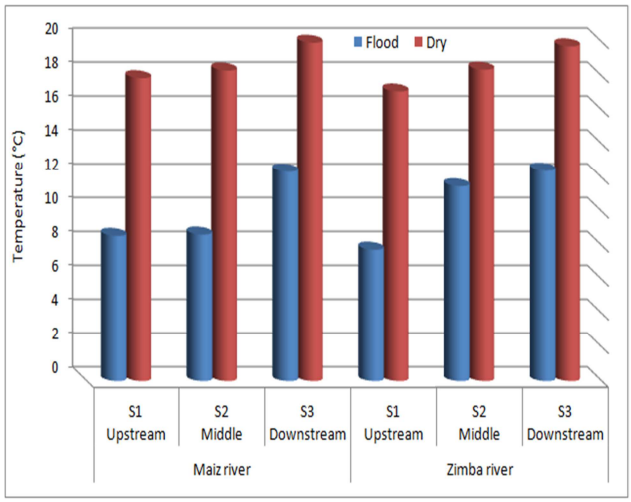

Figure 2. *Variation of temperature in flood and dry period.*

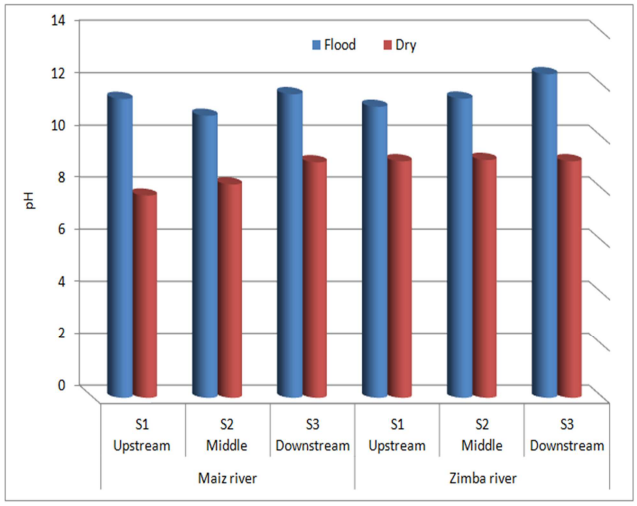

Figure 3. *Variation of pH in flood and dry period.*

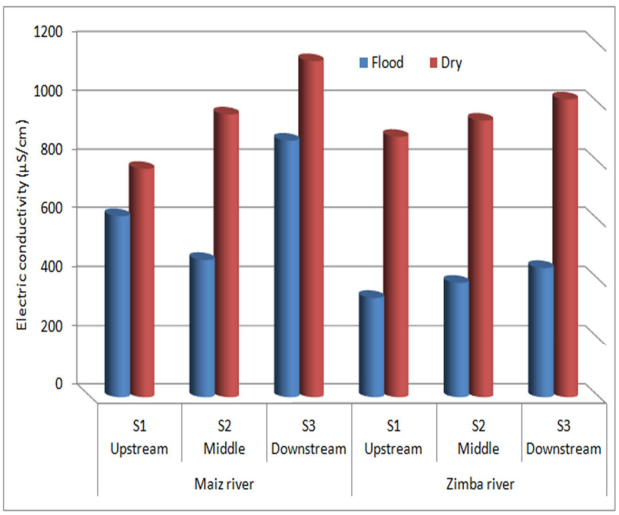

Figure 4. *Variation of electric conductivity in flood and dry period.*

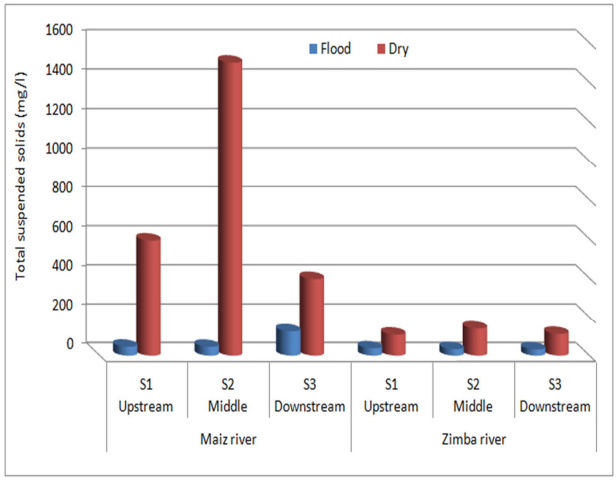

Figure 5. *Variation of total suspended solids in flood and dry period.*

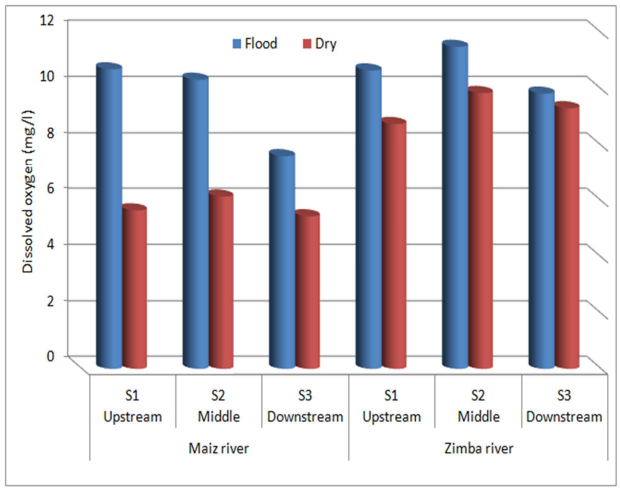

Figure 6. *Variation of dissolved oxygen in flood and dry period.*

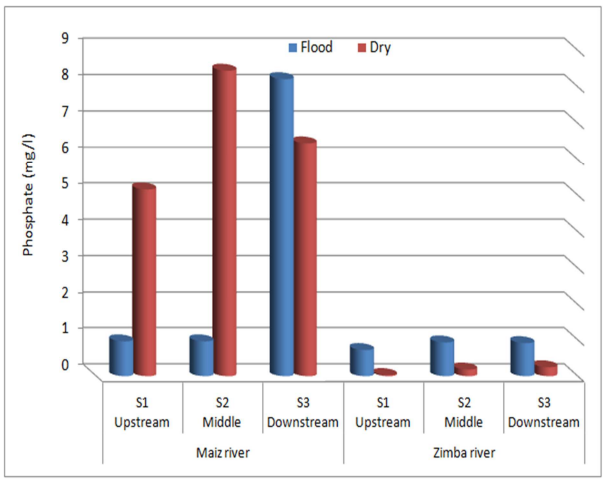

Figure 7. *Variation of phosphate in flood and dry period.*

3.1.3. Nitrogen Compounds

(i). Nitrate

The histogram of the nitrate contents in surface waters of Zimba and Maiz river (fig. 8), shows a slight variation of these contents which oscillate between 2.14 and 3.26 mg/l in

dry time, however high concentrations are recorded in flood period ranging from 78 to 76 mg/l (Zimba river) and from 89 to 115 mg/l (Maiz river). The increase in nitrate levels in water during the flood season comes from the leaching of fertilizers used in irrigated soils of the perimeter of Guelma which are very rich in nitrate. However, the low values during the dry season could be attributed to the recent releases of wastewater which have not undergone any degradation of organic matter. Thus, according to the Algerian and international standards of the quality of surface water, these rivers are of excellent quality (<5 mg/l) in dry time and poor quality (50 to 100 mg/l) to excessively polluted (>100 mg/l) in flood time.

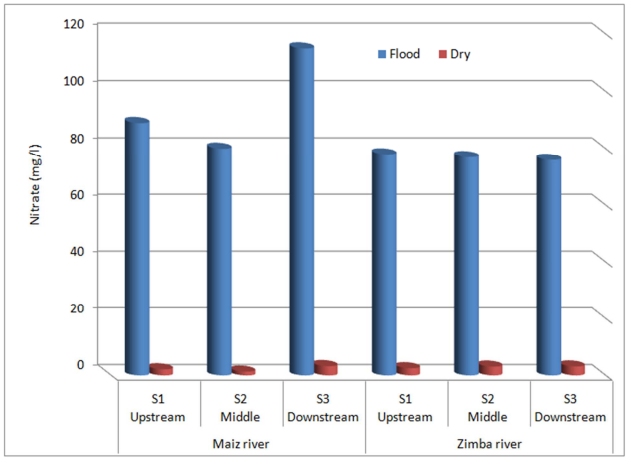

Figure 8. *Variation of nitrate in flood and dry period.*

(ii). Nitrite

The high nitrite concentrations are recorded in dry period for both rivers and increase from upstream to downstream of 0.31 to 1.26 mg/l for Maiz river and from 0.15 to 1.35 mg/l for Zimba river. This increase results from the progressive accumulation of organic pollutants in urban discharges. During flood time, the nitrite concentration is slightly higher than that of the dry period and ranges from 0.61 to 1.02 mg/l for Maiz river and from 0.42 to 0.53 mg/l for Zimba river (fig. 9). The quality of the surface waters is poor (0.1 to 3 mg/l) regardless of the sampling period [5].

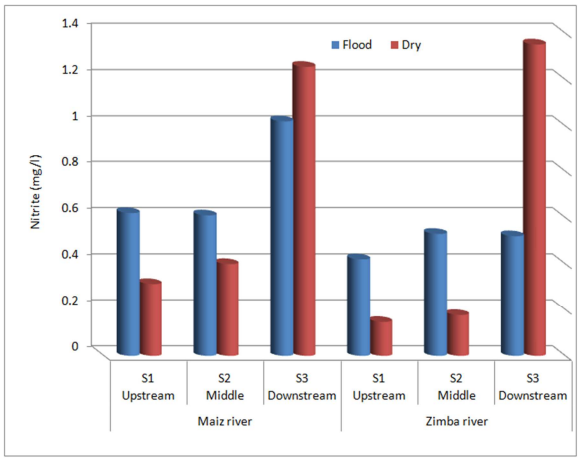

Figure 9. *Variation of nitrite in flood and dry period.*

(iii). Ammonium

Analysis of ammonium profile during floods (fig. 10) shows that the levels vary between 1.24 and 1.68 mg / l with a peak of 25.75 recorded at S3 (Maiz river).

The ammonium values obtained in dry period show that the waters of zimba river are of good quality (<0.2 mg / l), however, for the Maiz river, the water quality is a poor in the middle (7.22 mg/l) and excessive pollution at upstream and downstream (> 8 mg/l).

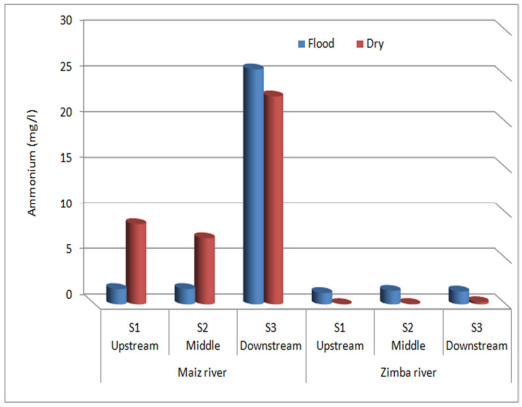

Figure 10. *Variation of ammonium in flood and dry period.*

3.2. Organic Matter

3.2.1. Chemical Oxygen Demand (COD)

The contents of the COD recorded at the surface waters are between 35 and 41.25 mg/l in flood period, except at the station (S3) of Maiz river which shows a maximum content of 189.25 mg/l (fig. 11). The increase of COD at this station reflects the presence of an important polluting load resulting from the accumulation of urban and industrial wastes. In dry period, a net increase of COD is observed to reach a peak in S3 of 1730.8 mg/l (river Maiz) and 47.6 mg/l (river Zimba). The increase in the concentrations of the COD in dry time could be attributed to an increase in the organic and inorganic substances in the receiving environment [9]. During floods, the quality of surface waters is passable because of the dilution of the load in organic matter by rainwater except at S3 (Maiz river) where still shows a rather high content.

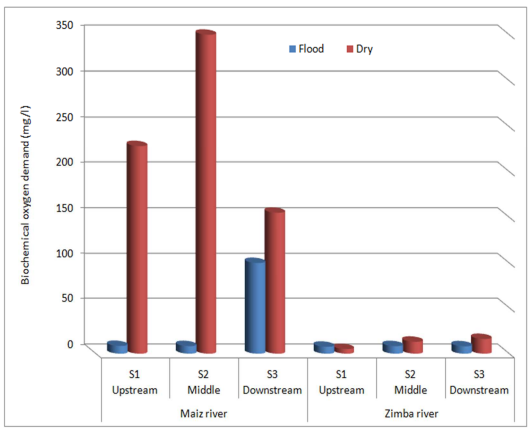

Figure 11. *Variation of chemical oxygen demand in flood and dry period.*

3.2.2. Biochemical Oxygen Demand (BOD_5)

In flood period, the concentrations of water BOD5 vary between 7.54 and 8.41 mg / l, qualifying these waters of passable quality except at the station (S3) of Maiz river where waters quality is very bad (BOD5 > 25 mg /l). However, in dry period, the biodegradable organic matter is very important in particular at Maiz river (fig. 12) where the water quality is very bad and poor for Zimba river (S2 and S3). The results obtained show that there is high groundwater pollution by organic matter which is very important in dry periods compared to the floods.

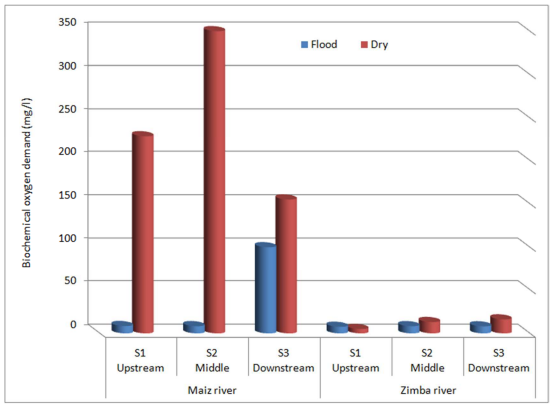

Figure 12. *Variation of biochemical oxygen demand in flood and dry period.*

3.3. Bacteriological Characterization

3.3.1. Total Germs (TG)

The total germs constitute the whole of the microorganisms (indicators of pollution and pathogenic….) susceptible to develop at 22 °C and 37 °C. Its contents inform us about the state of water pollution. The surface waters of Maiz river are very contaminated compared to Zimba river regardless of the sampling period (fig. 13). We also note that the level of contamination of the water increases from upstream to downstream with an excessive development of germs at 37° C in flood period and at 22 °C in dry period. The change of the degree of contamination during the flood time is mainly due to the effects of the dilution.

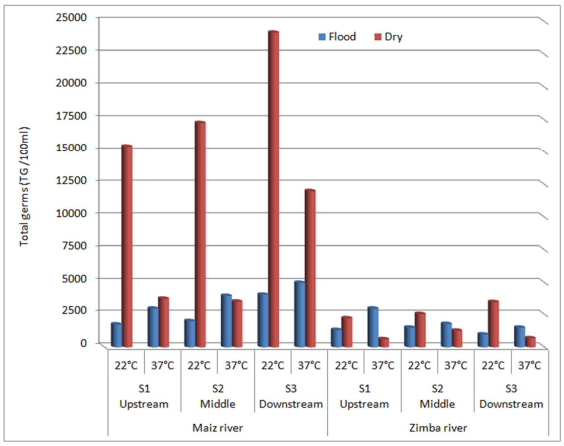

Figure 13. *Variation of total germs in flood and dry period 4.*

3.3.2. Total Coliforms (TC)

The results obtained show that Maiz river presents a permanent contamination whatever the sampling periods with contents ranging between 1400 and 1100 TC/100 ml. For Zimba river, there is an increase from upstream to downstream and the highest densities are recorded in S2 (1100 TC/100 ml) and S3 (1400 TC/100 ml) in flood time. In the dry period, the opposite phenomenon is observed with a maximum at S1 (1400 TC/100 ml). The high concentrations in total coliforms are due to domestic wastewaters in dry time and leaching from agricultural soils and to urban releases in floods (fig. 14). The Algerian standards for surface waters in TC class the waters of Maiz and Zimba river of passable quality.

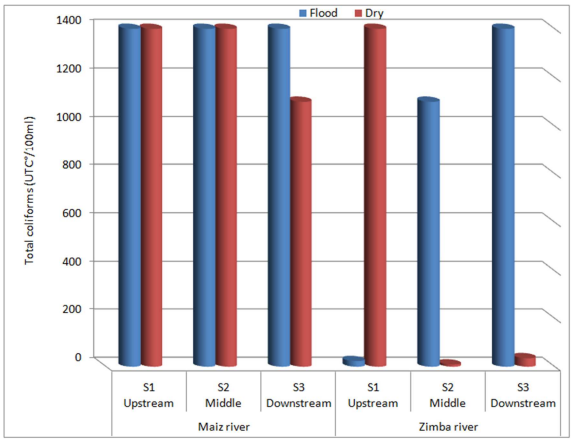

Figure 14. *Variation of total coliforms in flood and dry period.*

3.3.3. Fecal Colifzorms (FC)

As regards the concentrations in fecal coliforms, river Zimba is more contaminated than Maiz river and the high values are observed during floods with a maximum of 460 FC/100 ml (S1) (fig. 15). The peak observed in dry time at S1 (Maiz river) results from discharges of urban wastewater of Maiz area which are very loaded in fecal matter. Thus, with regard to the assessment grid [5], the water quality is generally good (<200 FC/100 ml) for Maiz river and z passable (> 200 FC/100 ml) for Zimba river.

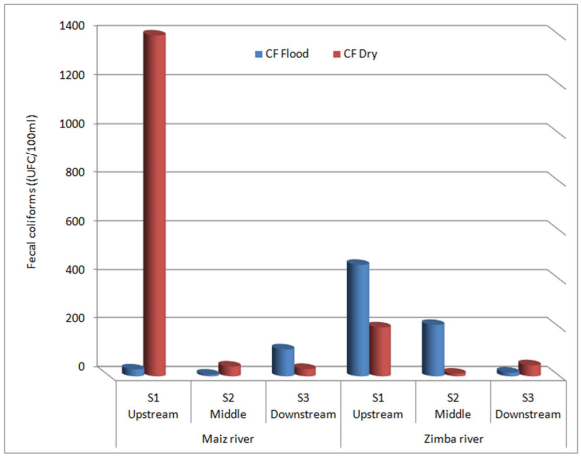

Figure 15. *Variation of fecal coliforms in flood and dry period.*

3.3.4. Fecal streptococci (SF)

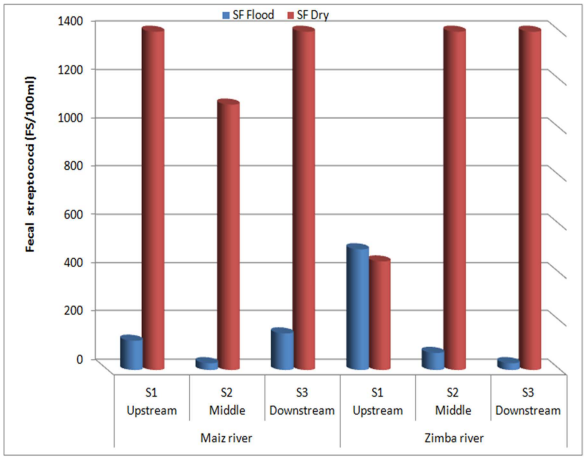

Figure 16. *Variation of fecal streptoccoci in flood and dry period.*

The presence of fecal streptococci in water indicates fecal contamination because the streptococci are typical of animal and human excrement [10]. The highest concentrations are recorded during dry period compared to the flood period [11], ranging from 450-1400 germs/100 ml (fig. 16) and therefore, much superior to the guide value fixed to 100 germs/100 ml according to the executive decree No. 93-164 of 10/07/1993 JORA 46. During floods, higher fecal contents in streptococci are observed at stations S1 and S3 (Maiz river) and S1 (Zimba river) is the consequences of urban waste and leaching of animals excrement.

3.4. Comparison Between Flood and Dry Period

At the majority of sampling stations, the abundance of total germs, total coliforms, fecal coliforms and fecal streptococci increases generally in flood time for Zimba river and in dry period for Maiz river (Table 1). The floods play a decisive role in the process of water contamination of Zimba river through the leaching of the agricultural soils by runoff [12]. However in Maiz river, the bacteriological contamination is much more dominated by the wastewater discharges.

Table 1. *Comparison of bacteriological contamination of surface waters of Maiz and Zimba river in flood and dry period.*

Period	Maiz river				Zimba river			
Flood	TG	TC	FC	FS	TG	TC	FC	FS
		S1, S2, S3	S3		S1, S2, S3	S2, S3	S1, S2	S1
Dry	S1, S2, S3	S1, S2	S1	S1, S2, S3	S1, S2, S3	S1	S1	S2, S3

(i). Origin of the Contamination

When the ratio of fecal coliform over fecal streptococcus (CF/SF) is greater than 4 is exclusively human pollution (wastewater discharge). When it is less than 0.7, the origin is mainly animal [13]. In this case, cattle and in particular sheeps appear to play a predominant role in the contamination of water. During the periods of study, the spatiotemporal variation of the ratio (Table 2) at Maiz and Zimba river showed that:

Table 2. *Origin of the contamination according to the report CF/SF in flood and dry period.*

Surface water	Ratio FC/FS	Sampling stations		
		S1	S2	S3
Maiz river	Flood	0.23	0.25	0.73
	Dry	1	0.03	0.02
Zimba river	Flood	0.92	3	0.53
	Dry	0.04	0.007	0.03

(ii). Flood Period

In Maiz river, the contamination is animal in stations S1 and S2 and mixed with animal predominance in S3. However, in Zimba river, it is mixed with animal predominance in S1, mixed with human dominance in S2 and of animal origin in S3.

(iii). Dry Period

For Maiz river, the contamination is mixed with animal predominance in S1 and animal for other stations, on the other side, the contamination of animal origin for all stations of Zimba river.

According to this ratio, the contamination is of animal origin in dry period and mixed with animal predominance in flood period.

4. Conclusion

At the end of this study relative to surface waters of Guelma basin, the exploitation of the analyzed data of samples taken from upstream to downstream of Maiz and Zimba river during flood and dry period showed that: The dissolved oxygen and pH records the highest values in flood time. As for the electric conductivity and the total suspended solids, the highest values are observed in dry time. These results are due to the effect of the dilution, period of sampling and to the load in organic matter; For nutritive elements, it is noted that nitrogen and phosphate compounds are more important during flood period and mainly come from the leaching of agricultural soils (rich in fertilizers and organic matter) and wastewater; The high densities of bacteria were observed in both periods. The origin of this contamination is animal in dry period and mixed with animal predominance in flood period; Finally, the results obtained show that surface waters of Maiz and Zimba river present signs of degradation whatever the period of sampling, because most of the analyzed parameters revealed contents that exceed the Algerian standards. Therefore, the conservation of their quality requires the implementation of water-treatment plants and to monitor the use of fertilizers within the irrigated perimeter of Guelma.

Acknowledgments

The authors thank all the staff of the wastewater treatment plant of Guelma in particularly Mr. Boudjahem Façyal and laboratory (LGCH) for their collaboration.

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