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Diagnosis of Lead Pollution of Surface Waters of a River: Case of the Djiri River in the Republic of Congo

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Abstract

This research work focuses on the physico-chemical analysis of surface water from the Djiri River with the aim of preventing the population against possible water pollution. The analysis of samples taken from the Djiri river revealed the presence of lead in these waters at levels exceeding the WHO guideline values: an average annual pollution (0.93 mg/l) which is visibly higher than the value. WHO guide (0.01 mg/l) in situ data from the Djiri River revealed a significant drop in flow between the 2016 period characterized by a divergence index of 0.82344, thus highlighting a hydrological situation for which national hydrological stakeholders will absolutely have to implement measures, remedial measures or mechanisms to protect this river against possible disappearance by elimination of lead in the water.

Keywords

Metallic Pollution, Water Quality Standards, Indicators and Degree of Pollution

1. Introduction

The Djiri river is located in the 8th arrondissement of Brazzaville, with a flow of 25 m^3/s, it flows into the Congo river. The demographic growth of the city of Brazzaville has pushed many populations to occupy plots of land over the past ten years and to live in the Djiri district, so all around the Djiri river are dwellings where Socioeconomic activities are carried out.

The riparian populations use the waters of the Djiri for various uses like

Swimming; Laundry; Washing up; Food washing.

An electric steelworks is erected 1km from the Djiri bridge (1st exit). It is likely to release toxic particles into the waters of the Djiri River that can cause damage to the environment in general and to human health in particular.

This work is part of the protection of the water ecosystem and the health risk coverage of neighboring populations.

Indeed, the problem of water pollution is closely linked to that of water quality and requires special attention in the Congo as in most developing countries; the faster a diagnosis of poor quality of water for use is made, the quicker the means can be implemented to provide solutions to cover health and environmental risks.

During this study, we estimated the physico-chemical and metallic quality of Djiri's surface water from two sampling points: Djiri Station (Upstream Point) and Old Djiri Manianga Bridge (Downstream Point).

Twelve months of sampling and physicochemical analyses have made it possible to demonstrate overall the pollutant nature of lead, the relative values of which for the monthly in situ measurement excess are strictly positive and consequently of the values of the pollution index strictly higher than the unit characterizing an exceeding of the WHO guide values for this metal [1]. Lead is a point source of pollution.

2. Materials and Methodologies

2.1. Materials

The reagents, hardware and software requirements necessary for the implementation of the sampling process, physico-chemical analyzes and analysis of the data resulting from the physico-chemical characterization of the water are summarized in **Table 1**.

Table 1. Equipment, Product and Software for the acquisition of data from physico-chemical analyzes of water.

N˚	Product/Software	Material type	Goal
1	Precision scale	Measuring device	Mass measurement in other words the concentration of sand, suspended matter, dry residue and empty beaker
2	PH meter		Automatic in situ pH measurement of water
3	Conductivity meter		Determination of the in situ electrical conductivity of water
4	Spectrometer		Determination of the concentrations of elements dissolved in a given sample
5	Sieve		Filtering the samples in their raw state and collecting the sand before any other handling
6	GPS	Sampling Equipment	Acquisition of the geographical coordinates of the sampling points
7	Plastic Bottles		Water withdrawal from the river
8	MapInfo	Software	Realization of the GIS
9	MS EXCEL 2016		Realization of statistical data aggregates
10	XLSTAT		Data analysis
11	MS ACCESS 2016		Realization of the database
12	Chemical Product	Chemical Reagents	To assess the levels of chemical species in water (Copper, Lead, Chromium, Iron, etc.)

Source: Field data (Physico-chemical Analysis Laboratory, IRSEN).

Table 1 summarizes the chemicals, hardware and software allowing the acquisition of physico-chemical analysis data and data to be estimated from the algorithms for predicting experimental data.

2.2. Methodologies

2.2.1. Location of Sampling Points

The study takes place on the Djiri river and two sampling points were chosen based on their accessibility for sampling on the Djiri river (**Table 2**). The geographic coordinates of the upstream (S1) and downstream (S2) points are shown in **Table 2**.

All samples were taken over 12 months between May 2016 and December 2017 at two points (Upstream and Downstream) chosen because of their accessibility and their proximity to the target industrial site.

2.2.2. Physico-Chemical Analysis Methodology

During our study and using plastic bottles of 1.5l liter capacity, washed and rinsed beforehand with demineralized water, the sample is taken by immersing the bottle 25 cm from the free surface. The water samples, taken, are transported to the laboratory immediately for analysis. 20 physico-chemical parameters were measured to characterize the environment studied between May 2016 and December 2017.

Samples of the water to be analyzed were taken in plastic bottles in areas where water is not stagnant at the upstream point and downstream point from the plant chosen for the study.

Monthly water samples are taken from two selected points on the Djiri River:

- Djiri station (Near Old Djiri Bridge 1st North Exit);
- Manianga (Djiri Bridge 2nd North Exit);

The old Djiri bridge taken as the point of origin;

- Frequency: one sample per month and per sampling point;
- Physico-chemical analyzes at the IRSEN Analysis Laboratory: for the identification of pollutants;
- Concentration of sand by sifting through a 0.0065 mm sieve;
- Material in suspension by filtration through a 0.45 micrometer filter;
- Dry residue by evaporation at 105˚C in an oven;
- Ion concentration by a direct spectrometer and palintest.

Sampling marks the starting point of the process of acquiring experimental data.

Table 2. Geographic coordinates of points.

SITES	POSITION	LONGITUDE IN DECIMAL DEGREES	LATITUDE IN DECIMAL DEGREES
S1	UPSTREAM	15.3123	−4.1475
S2	DOWNSTREAM	15.4445	−4.1615

S1: Old Djiri Bridge 1st Exit (Station); S2: Old Djiri Bridge 2nd Exit; The upstream point (S1) is located 1km away from the electric steelworks.

Sampling consists of carrying out a series of water samples from the Djiri river once a month at each point chosen in order to carry out physicochemical analyzes leading to the qualitative state of the waters of the Djiri; These physico-chemical analyzes will take place in the IRSEN's physico-chemical analysis laboratory.

The protocol adopted for the analysis of the samples is spectrophotometry and the spectrophotometric analysis is based on the following parameters.

PH, T˚C, CE, Ca^{2+}, Mg^{2+}, K^+, TAC, NH_4^+, Cu^{2+}, Al^{3+}, Mn^{2+}, SO_4^{2-}, PO_4^{3-}, Fe^{tot}, NO_3^-, Cr, Cl^-, Sand, Suspended matter, Dry residue.

The principle of this protocol is described as follows.

For each parameter, the sample is calibrated *i.e.* the measurement of the wavelength of each parameter in the sample is determined;

With the 10 ml water cuvettes, add the reagents (crush the reagent tablets and mix with 10 ml of water);

The mixture obtained by putting together the crushed pellets and 10 ml of water, is placed in a direct spectrophotometer and the measurements immediately appear on the screen of the spectrophotometer (Table 3).

Table 3. Codes used for the physico-chemical and metallic parameters evaluated.

SYMBOL	DESIGNATION
Al^{3+}	Aluminium
Ca^{2+}	Calcium
CE	electrical conductivity
Cl^-	chlorine
Cr	Chromium
Cu^{2+}	Copper
Fe^{tot}	Total iron
K^+	Potassium
MES	Suspended matter
Mg^{2+}	Magnesium
Mn^{2+}	Manganese
NH_4^+	Ammonium
NO_3^-	Nitrate
Pb^{2+}	Lead
PH	Hydrogen potential
PO_4^{3-}	Phosphate
RS	Dry residue
sables	Sand
SO_4^{2-}	Sulfate
T˚C	Temperature in degrees Celcius
TAC	Full alkalimetric titer

2.2.3. Metallic Pollution Assessment Methodology

- Determination of the in situ measurement excess Δ_C between the downstream point and the upstream point for each physico-chemical, chemical or metallic parameter at each point and at each moment:

$$\Delta_C = \text{Measured}_{\text{Downstream}} - \text{Measured}_{\text{Upstream}} \tag{1}$$

- **Indice de Pollution IP** pour chaque paramètre en chaque point et à chaque instant:

$$\text{IP} = \frac{\Delta_C}{\text{Guide}_{\text{Value}}} \tag{2}$$

If IP > 1 Then the OMS guide value has been exceeded for the parameter analyzed otherwise no exceedance is observed.

- **Pollution degree** for each parameter at each point and at each moment:

Pollution degree for each parameter at each point and at each moment:

$$\text{D}^{\circ}\text{P} = \text{Measured}_{\text{Downstream}} - \text{Guide}_{\text{GuidValue}} \tag{3}$$

If D˚P > Measured_Upstream Then there is pollution otherwise no pollution observed.

- **Evaluation of the metal flux:**

The flux is defined as the mass of the pollutant flowing over a surface in one year, it is expressed in tonnes per year.

$$\text{Metallic}_{\text{Flux}} = 31.536 * \text{Average}_{\text{Daily}_{\text{Flux}}} * \text{Over}_{\text{measurement}} \tag{4}$$

Minimum metal Flux:

If IP > 1 then $\Delta_C > \text{WHO}_{\text{Guide}_{\text{Value}}}$

THE FOLLOWINGINEQUALITY IS OBTAINED:

$$\text{Average}_{\text{Daily}_{\text{Flux}}} * \Delta_C > \text{Average}_{\text{Daily}_{\text{Flux}}} * \text{WHO}_{\text{Guide}_{\text{Value}}}$$

MINIMUM FLOW DEDUCTION:

$$\text{Minimum}_{\text{metallic}_{\text{Flux}}} = \text{Average}_{\text{Daily}_{\text{Flow}}} * \text{WHO}_{\text{Guide}_{\text{Value}}} \tag{5}$$

The minimum flux is the flux corresponding to a pollutant concentration equivalent to the WHO guideline value.

3. Results and Discussion

3.1. Results

3.1.1. Characterization of the Waters of the Djiri River

The physico-chemical analyzes of the samples collected enabled the following results to be obtained.

Table 4 illustrates a summary of in situ measurements resulting from sampling carried out on the Djiri river at the downstream point.

Table 4. Summary of downstream observations [MG/L].

DOWNSTREAM												
Physico	**TIME [Month]**											
Chemical	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Parameter												
Al^{3+}	0.001	0.03	0.12	1.75	0.08	0.8	0.9	0.9	0.7	0.9	0.9	0.13
Ca^{2+}	9	15	18	21	16	12	13	10	12	13	12	16
CE	7.58	7.17	8.14	9.1	8	8	10.2	8.22	9.33	10.1	6.4	5.99
Cl^{-}	8.4	2.02	3	2.11	2.97	1.7	2.32	2	2.25	3.08	3.67	4.18
Cr	2.05	0.08	0.09	0.15	0.09	0.08	0.09	0.09	0.06	0.08	0.06	0.07
Cu^{2+}	0.3	0.9	0.17	0.21	0.15	0.9	0.1	0.11	0.8	0.9	0.8	0.11
Fe^{tot}	4.1	0.016	0.022	0.022	0.026	0.014	0.018	0.01	0.09	0.01	0.08	0.09
K^{+}	3.7	4.2	4.1	4.7	4	2.9	2.8	2.7	3.4	2	1.8	2
MES	8.4	13.25	18.08	24.7	22.08	9.13	7.22	13	14.4	13.3	10.22	12.2
Mg^{2+}	11	11	13	11	12	10	10	10	14	12	11	11
Mn^{2+}	1.77	1.7	1.76	2.01	1.81	1.15	2.18	1.12	0.99	1.66	0.98	0.98
NH_4^{+}	0.002	0.09	0.18	0.19	0.08	0.1	0.12	0.9	0.09	0.08	0.06	0.09
NO_3^{-}	0.06	2.86	3.04	3.75	3.07	3.02	2.99	4.44	6.07	6.22	8.55	9.76
Pb^{2+}	2.8	0.77	1.07	1.13	0.62	0.9	0.27	0.5	0.8	0.73	0.9	0.83
PH	5.16	6.73	6.15	6.22	6.08	6.17	6.22	6.19	6.08	6.18	6.32	6.24
PO_4^{3-}	0.01	0.3	0.28	0.28	0.22	0.16	0.2	0.19	0.13	0.14	0.13	0.15
RS	0.62	31	37.5	40.2	37.5	20.4	18.9	25.6	28.4	35	39.2	42.9
sables	5.78	2.12	9.7	10.6	9.7	2.13	3.01	7.55	11.5	15.7	13.7	16.4
SO_4^{2-}	0.14	21	25	27	9.3	18	29	13	10	13	12	17
T˚C	28.2	28.2	27.7	27	27	27.8	27.9	27	27	26.8	26.8	26.4
TAC	179	199	201	187	187	150	158	110	99	99	94	101

Table 5 illustrates a summary of the in situ measurements resulting from the sampling carried out on the Djiri river at the upstream point.

Table 6 presents the extreme and average values of the upstream observations:

- The PH oscillates between 5.14 and 6.7, which means that the studied medium is acidic
  (PH < 7);
- The electrical conductivity EC oscillates between 4.18 µS/cm and 11.2 µS/cm therefore EC < 100 µS/cm which implies low mineralization of the water and does not promote the movement of electrical charges in the water, in particular ions Pb^{2+};
- The temperature fluctuates between 26.1˚C and 28.4˚C;

- The lead content varies between 0.17 mg/l and 1.42 mg/l.

Table 7 shows extreme and mean values of downstream observations;

- The PH oscillates between 5.16 and 6.73, which means that the studied medium is acidic (PH < 7);
- The electrical conductivity EC oscillates between 5.99 μS/cm and 10.7 μS/cm, therefore EC < 100 μS/cm which implies a low mineralization of the water and does not promote the movement of electrical charges in the water, in particular ions Pb^{2+};
- The temperature oscillates between 26.4˚C and 28.2˚C;
- The lead content varies between 0.27 mg/l and 2.8 mg/l.

Table 5. Summary of upstream observations [MG/L].

UPSTREAM												
Physico	TIME [MG/L]											
Chemical	1	2	3	4	5	6	7	8	9	10	11	12
Parameter												
Al^{3+}	0.001	0.01	0.9	1.2	0.06	0.6	0.7	0.5	0.5	0.8	0.7	0.1
Ca^{2+}	4	40	14	16	6	10	11	9	11	10	11	14
CE	7.12	9.14	9.4	11.2	9.75	7.7	8.4	7.18	8.88	9.05	4.18	4.7
Cl^-	4.5	2.26	1.8	1.87	1.3	1	2.1	17	2.1	1.75	2.11	3.44
Cr	1.6	0.06	0.08	0.09	0.09	0.06	0.08	0.05	0.04	0.06	0.05	0.06
Cu^{2+}	0.3	0.6	0.15	0.17	0.9	0.8	0.9	0.6	0.5	0.6	0.6	0.8
Fe^{tot}	2.5	0.1	0.016	0.021	0.08	0.012	0.01	0.09	0.08	0.07	0.06	0.09
K^+	6	2.1	3.9	3.5	44	2.2	2.7	2.1	3	1.9	1.2	1.8
MES	4.5	14.9	13	15.2	2.76	9	11.1	10.9	11.14	10.5	8.44	11
Mg^{2+}	7	9	10	9	10	8	9	8	10	12	8	9
Mn^{2+}	1.64	0.75	1.55	1.17	1.17	1.1	2.14	1.07	0.97	0.98	0.95	0.82
NH_4^+	0.42	0.04	0.09	0.12	0.48	0.07	0.06	0.08	0.07	0.06	0.05	0.07
NO_3^-	0.04	3.18	2.77	3.14	3.7	2.05	4.17	3.18	4.6	4.51	5.01	8.96
Pb^{2+}	1.42	0.36	0.8	0.83	0.44	0.5	0.17	0.3	0.7	0.6	0.5	0.7
PH	5.14	5.75	6.05	6.7	5.4	6.04	6.13	6.17	5.97	6	6.25	6.17
PO_4^{3-}	0.01	0.17	0.16	0.28	0.18	0.14	0.18	0.16	0.1	0.8	0.5	0.17
RS	0.45	33.1	23.3	37.7	28.7	20	27	22.9	25.7	30.1	33.7	41
sables	9.91	5.5	8.2	9.12	4.79	7.4	8.04	7.12	9.18	8.5	10	15
SO_4^{2-}	0.13	3.12	20	23	8.4	13	8.75	11	9	11	10	14
T˚C	28.4	28	27.9	27.2	26.4	27	27.4	26.2	26.7	26.9	26.4	26.1
TAC	95	187	175	122	95	100	105	99	97	88	84	92

Table 6. Extreme and average values of upstream in situ measurements [MG/L].

UPSTREAM			
Physico			
Chemical			
Parameter	**MIN [MG/L]**	**MAX [MG/L]**	**AVERAGE [MG/L]**
Al^{3+}	0.001	1.2	0.505916667
Ca^{2+}	4	40	13
CE	4.18	11.2	8.058333333
Cl^-	1	17	3.435833333
Cr	0.04	1.6	0.193333333
Cu^{2+}	0.15	0.9	0.576666667
Fe^{tot}	0.01	2.5	0.26075
K^+	1.2	44	6.2
MES	2.76	15.2	10.20333333
Mg^{2+}	7	12	9.083333333
Mn^{2+}	0.75	2.14	1.1925
NH_4^+	0.04	0.48	0.134166667
NO_3^-	0.04	8.96	3.775833333
Pb^{2+}	0.17	1.42	0.61
PH	5.14	6.7	5.980833333
PO_4^{3-}	0.01	0.8	0.2375
RS	0.45	41	26.97083333
sables	4.79	15	8.563333333
SO_4^{2-}	0.13	23	10.95
T°C	26.1	28.4	27.05
TAC	84	187	111.5833333

Table 7. Extreme and average values of downstream in situ measurements [MG/L].

DOWNSTREAM			
Physico			
Chemical			
Parameter	**MIN [MG/L]**	**MAX [MG/L]**	**AVERAGE [MG/L]**
Al^{3+}	0.001	1.75	0.600916667
Ca^{2+}	9	21	13.91666667
CE	5.99	10.2	8.185833333
Cl^-	1.7	8.4	3.141666667
Cr	0.06	2.05	0.249166667
Cu^{2+}	0.1	0.9	0.454166667

Continued

Fe^{tot}	0.01	4.1	0.374833333
K^+	1.8	4.7	3.191666667
MES	7.22	24.7	13.83166667
Mg^{2+}	10	14	11.33333333
Mn^{2+}	0.98	2.18	1.509166667
NH_4^+	0.002	0.9	0.165166667
NO_3^-	0.06	9.76	4.485833333
Pb^{2+}	0.27	2.8	0.943333333
PH	5.16	6.73	6.145
PO_4^{3-}	0.01	0.3	0.1825
RS	0.62	42.9	29.76833333
sables	2.12	16.4	8.990833333
SO_4^{2-}	0.14	29	16.20333333
T˚C	26.4	28.2	27.31666667
TAC	94	201	147

3.1.2. Water Pollution Assessment

- **Spatial variation of experimental measurement**

Table 8 illustrates the in situ measurement differences between the downstream point and the upstream point. It emerges from this illustration that three parameters have strictly positive measurement deviations on all the measurements: lead, magnesium and manganese.

- **Metal Pollution Index**

Applying the method described in 3.2.2 gives results listed in the following table.

The 2006 WHO standards do not define a guide value for magnesium because it is considered a trace element.

Table 9 indicates that only lead has pollution indices strictly greater than unity at all times and implies as the choice of pollutant to follow: Lead.

- **Determination of the Pollution Index, Pollution Degree on Lead.**

The results on the assessment of water pollution come from the application of the assessment method adopted in 3.2.2. The result of this evaluation is that only lead has a pollution index strictly greater than unity, a degree of pollution (pollution indicator) above the experimental measurement upstream and a metal flow transported above the flow Medium at all times.

Table 10 presents, on the one hand, pollution indices above the WHO guide value for lead and, on the other hand, pollution degrees above in situ measurements downstream, which indicates water pollution with lead.

- **Seasonal variation of experimental measurement**

Seasonally, there are variations in the average measurement between the rainy season and the dry season upstream and downstream, indicating the pollution is more evident in the rainy season than in the dry season (Table 11).

Table 8. Measurement excess between the upstream point and the downstream point.

Over measurement	[MG/L]											
Physico-Chemical	TIME [Month]											
Parameter	1	2	3	4	5	6	7	8	9	10	11	12
Al^{3+}	0	0.02	−0.78	0.55	0.02	0.2	0.2	0.4	0.2	0.1	0.2	0.03
Ca^{2+}	5	−25	4	5	10	2	2	1	1	3	1	2
CE	0.46	−1.97	−1.26	−2.1	−1.75	0.3	1.8	1.04	0.45	1.05	2.22	1.29
Cl^-	3.9	−0.24	1.2	0.24	1.67	0.7	0.22	−15	0.15	1.33	1.56	0.74
Cr	0.45	0.02	0.01	0.06	0	0.02	0.01	0.04	0.02	0.02	0.01	0.01
Cu^{2+}	0	0.3	0.02	0.04	−0.75	0.1	−0.8	−0.49	0.3	0.3	0.2	−0.69
Fe^{tot}	1.6	−0.08	0.006	0.001	−0.054	0.002	0.008	−0.08	0.01	−0.06	0.02	0
K^+	−2.3	2.1	0.2	1.2	−40	0.7	0.1	0.6	0.4	0.1	0.6	0.2
MES	3.9	−1.65	5.08	9.5	19.32	0.13	−3.88	2.1	3.26	2.8	1.78	1.2
Mg^{2+}	**4**	**2**	**3**	**2**	**2**	**2**	**1**	**2**	**4**	**0**	**3**	**2**
Mn^{2+}	**0.13**	**0.95**	**0.21**	**0.84**	**0.64**	**0.05**	**0.04**	**0.05**	**0.02**	**0.68**	**0.03**	**0.16**
NH_4^+	−0.42	0.05	0.09	0.07	−0.4	0.03	0.06	0.82	0.02	0.02	0.01	0.02
NO_3^-	0.02	−0.32	0.27	0.61	−0.63	0.97	−1.18	1.26	1.47	1.71	3.54	0.8
Pb^{2+}	**1.38**	**0.41**	**0.27**	**0.3**	**0.18**	**0.4**	**0.1**	**0.2**	**0.1**	**0.13**	**0.4**	**0.13**
PH	0.02	0.98	0.1	−0.48	0.68	0.13	0.09	0.02	0.11	0.18	0.07	0.07
PO_4^{3-}	0	0.13	0.12	0	0.04	0.02	0.02	0.03	0.03	−0.66	−0.37	−0.02
RS	0.17	−2.1	14.2	2.5	8.8	0.4	−8.1	2.7	2.7	4.9	5.5	1.9
sables	−4.13	−3.38	1.5	1.48	4.91	−5.27	−5.03	0.43	2.32	7.2	3.7	1.4
SO_4^{2-}	0.01	17.88	5	4	0.9	5	20.25	2	1	2	2	3
T˚C	−0.2	0.2	−0.2	−0.2	0.6	0.8	0.5	0.8	0.3	−0.1	0.4	0.3
TAC	84	12	26	65	92	50	53	11	2	11	10	9

Source: Physico-chemical analysis laboratory, IRSEN.

Table 9. Determination of the pollution index.

Mg^{2+}	Mn^{2+}	Pb^{2+}	WHO Guide Value	WHO Guide Value	IP-Mn	IP-Pb
[MG/L]	[MG/L]	[MG/L]	Mn [mg/l]	OMS du Pb [mg/l]		
4	0.13	1.38	0.4	0.01	0.325	138
2	0.95	0.41	0.4	0.01	2.375	41
3	0.21	0.27	0.4	0.01	0.525	27
2	0.84	0.3	0.4	0.01	2.1	30
2	0.64	0.18	0.4	0.01	1.6	18
2	0.05	0.4	0.4	0.01	0.125	40
1	0.04	0.1	0.4	0.01	0.1	10
2	0.05	0.2	0.4	0.01	0.125	20
4	0.02	0.1	0.4	0.01	0.05	10
0	0.68	0.13	0.4	0.01	1.7	13
3	0.03	0.4	0.4	0.01	0.075	40
2	0.16	0.13	0.4	0.01	0.4	13

Table 10. Determination of the pollution index, pollution degree.

	TIME [Month]	DOWNSTREAM MEASURE [MG/L]	UPSTREAM MEASURE [MG/L]	WHO Guide Value OMS Pb [MG/L]	Average Excess measurement [MG/L]	Pollution Index	Pollution degree [MG/L]	Observation
LEAD	1	2.8	1.42	0.01	1.38	**138**	**2.79**	**Pollution**
	2	0.77	0.36	0.01	0.41	**41**	**0.76**	**Pollution**
	3	1.07	0.8	0.01	0.27	**27**	**1.06**	**Pollution**
	4	1.13	0.83	0.01	0.3	**30**	**1.12**	**Pollution**
	5	0.62	0.44	0.01	0.18	**18**	**0.61**	**Pollution**
	6	0.9	0.5	0.01	0.4	**40**	**0.89**	**Pollution**
	7	0.27	0.17	0.01	0.1	**10**	**0.26**	**Pollution**
	8	0.5	0.3	0.01	0.2	**20**	**0.49**	**Pollution**
	9	0.8	0.7	0.01	0.1	**10**	**0.79**	**Pollution**
	10	0.73	0.6	0.01	0.13	**13**	**0.72**	**Pollution**
	11	0.9	0.5	0.01	0.4	**40**	**0.89**	**Pollution**
	12	0.83	0.7	0.01	0.13	**13**	**0.82**	**Pollution**
						Average Pollution Degree	**0.93333**	

Table 11. Seasonal measure excess.

	SEASON			WHO Guide	
	SP	**SS**	**Variation**	**Value**	**OBSERVATION**
AVERAGE DOWNSTREAM MEASUREMENT	**1.2875**	**0.77125**	**0.51625**	**0.01**	**overtaking**
	SP	**SS**	**Variation**	**Value**	**OBSERVATION**
AVERAGE UPSTREAM MEASUREMENT	**0.765**	**0.5325**	**0.2325**	**0.01**	**overtaking**

SS: Rainy season, SP: Dry season.

- **Flux variation**

Table 12 shows that the variations in measurements and lead flow between the downstream and upstream of the river are respectively above the WHO guide value and the average flow as illustrated in Figures 1-3.

The quantity of pollutant transported is above the minimum quantity of the identified pollutant (Figure 4) and this confirms the result of Figure 3.

3.2. Discussion

The analysis of the physicochemistry data of the surface water of the Djiri river revealed for these waters a temperature ranging from 26.1˚C to 28.4˚C, an electrical conductivity between 4.18 and 11.2, a pH between 5.14 and 6.7.

Table 12. Determination of flux.

	TIME	AVERAGE DAILY FLOW	METAL FLUX	WHO Guide Value	Average Measurement Excess	MINIMUM FLUX
LEAD	1	20.76	903.4685568	0.01	1.38	0.2076
	2	20.7	267.646032	0.01	0.41	0.207
	3	20.73	176.5101456	0.01	0.27	0.2073
	4	20.52	194.135616	0.01	0.3	0.2052
	5	20.73	117.6734304	0.01	0.18	0.2073
	6	20.73	261.496512	0.01	0.4	0.2073
	7	20.71	65.311056	0.01	0.1	0.2071
	8	20.73	130.748256	0.01	0.2	0.2073
	9	20.73	65.374128	0.01	0.1	0.2073
	10	20.71	84.9043728	0.01	0.13	0.2071
	11	20.7	261.11808	0.01	0.4	0.207
	12	20.7	84.863376	0.01	0.13	0.207

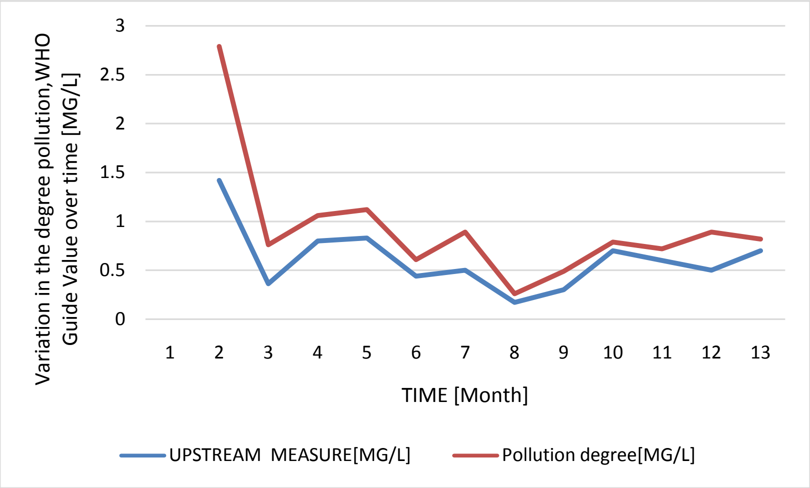

Figure 1. Comparison of Pollution Degree and Measurement upstream of the river.

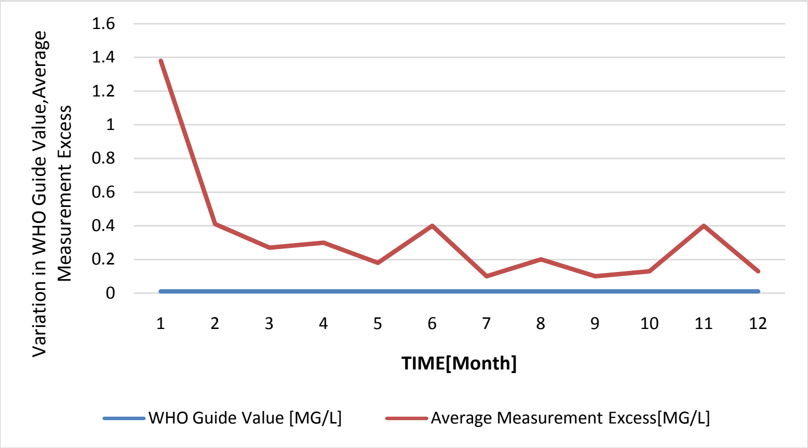

Figure 2. Comparison of in situ measurement excess vs WHO guideline value.

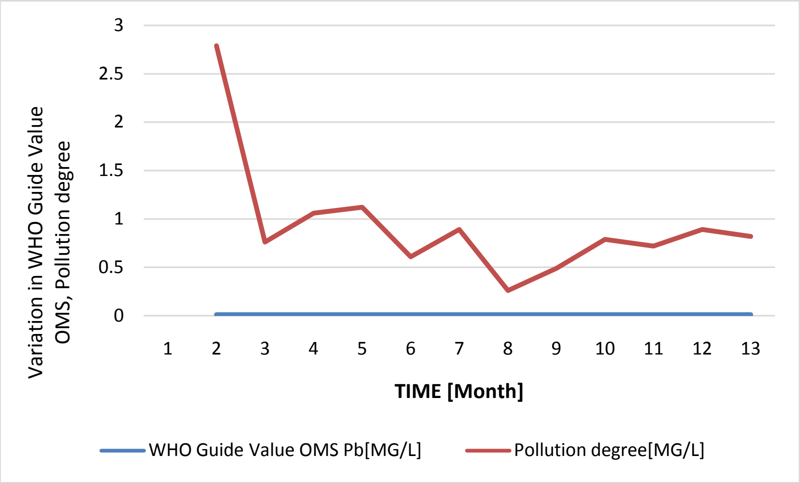

Figure 3. WHO guide value vs Pollution Degree comparison graph.

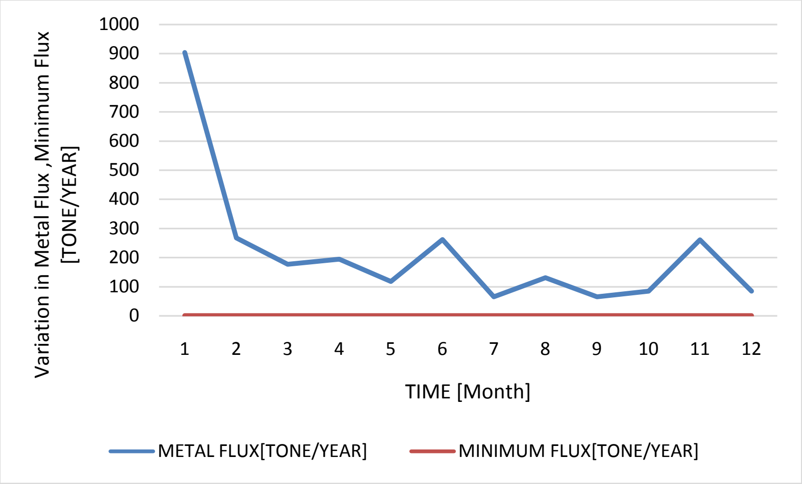

Figure 4. METAL FLUX vs MINIMUM FLUX comparison graph.

The observed pH values imply a pH < 7 and therefore an acidic environment and this increases the risk of the presence of lead in a more toxic ionic form [2]. The values of electrical conductivity observed indicate a weak mineralization of water compared to the conductivity of natural water which is between 50 and 1500 µS/cm and this does not favor the movement of electrical charges, in particular metal ions (lead) which are in principle good conductors of electricity and this induces their accumulation in water;

The methodology used in our study to estimate the metal pollution indices of the surface water of the Djiri river as described in sub-paragraph 3.1.2 makes it possible to verify both that the pollution index (PI) is strictly greater than unity, this implies that the excess measurement is strictly greater than the WHO guideline value and that, consequently, the degree of pollution is greater than the in situ measurement upstream of the river;

It therefore emerges from this pollution assessment that only lead gives, at any time and at each sampling point, monthly excess measurements in situ above the

WHO water potability standard, which implies a source of metallic lead pollution between downstream and upstream of the Djiri river. This pollution identified in the surface waters of the Djiri river is similar to the results of the pollution study observed in African rivers and in other continents. As the geology of the Djiri watershed is essentially made up of sands, the existence of a source of lead emissions other than the electric steelworks which is installed upstream of the river 1 km from the upstream sampling point is excluded.

In addition, the seasonal analysis of the average excess lead measurement shows upstream and downstream variations exceeding the WHO guideline value applied and indicating that during the rainy season, the use of recycled scrap metal debris in the study area to compensate for landslides contributes more to the pollution of the waters of the Djiri river than in the dry season (**Table 11**): 1.28 mg/l in the rainy season compared to 0.77 mg/l downstream dry season, *i.e.* a variation of 0.51 mg/l and 0.76 mg/l in the wet season and 0.53 mg/l in the upstream dry season, *i.e.* a variation of 0.23 mg/l.

The results of our study in terms of diagnosis of metallic pollution are in line with those of other studies of metallic pollution of water carried out in other rivers of the world and in particular.

- The study of pollution by heavy metals and metalloids and which revealed the pollution by lead on certain stations (lead content exceeding the admissible standards) of the waters of the Bou Regreg estuary (coast Atlantic, Morocco), pollution of an anthropogenic nature, with high pollution indices. In fact, exceeding the WHO guideline value at certain stations implies, in the case of our study, strictly positive in situ excess measurements and higher pollution degrees than downstream in situ measurements [3];
- On our study, the point measurements (concentration) of lead or the excess measurements (variation in concentration) between downstream and upstream are strictly positive and above the WHO standard (0.01 mg/l) involving thus higher degrees of pollution measurements in situ downstream, this joins the study entitled Contribution to the analytical study of pollutants (in particular of heavy metal type) in the waters of the Chari river during its crossing of the city of N 'Djamena' which revealed anthropogenic lead pollution of the waters of the Chari River (lead content exceeding acceptable standards) [4];
- The study of the quality of surface water and its impact on the environment in the Wilaya of Skikda in Algeria revealed the significant presence of toxic metallic trace elements in the water, in particular the levels lead found in this surface water exceeds the WHO acceptable standard, indicating contamination of the water; the results of our study also reveal the exceedances at each sampling point of the admissible WHO standard and confirm, through the indices and the estimated degree of pollution, values showing lead contamination of the waters of the Djiri river [5];
- Assessment of the risks of pollution by heavy metals (Hg, Cd, Pb, Co, Ni, Zn)

of the waters and sediments of the Konkouré river estuary in the Republic of Guinea found on some stations levels of trace metal elements, in particular lead, exceeding WHO standards in terms of concentration at the time and point of sampling and this describes the same scenario observed in the results of our study because at any point and at the time of sampling, the lead in situ measurement exceeds permissible WHO standard [6];

- The study entitled "Contribution of the physico-chemical analysis to the evaluation of metallic contamination of seawater on the coast of Agadir, 2016 (southern Morocco)" showed that the metallic contents of seawater show significant variations depending on the sampling areas and seasons, *i.e.* levels exceeding the acceptable metal contents of the WHO, our study revealed a seasonal variation in water pollution by lead [7].

The pollution of the waters of the Djiri river with lead confirms many cases of pollution observed in Africa and in other continents [8]-[13].

4. Conclusions

The physico-chemical analyses carried out on all the samples taken from the Djiri River have revealed a source of lead contamination in the water.

This contamination is linked to the presence of an industrial installation located 1km from the selected sampling point upstream of the Djiri watershed, in particular the point located on the old bridge over the Djiri river (Djiri station).

This study is a prelude to the design and production of a tool for valuing hydrological data which will be equipped with the following features.

- Storage of sampling data and physico-chemical analyzes of water;
- Management of hydrometric stations (gauging data, control of stations;
- Support for the scale for monitoring the flows of rivers;
- Have the physico-chemical state of a river at a given period;
- Monitor water pollutants in general;
- Integration of environmental water standards into the system.

This work perspective will greatly contribute to the establishment of a national observatory of hydrological data from rivers with a view to facilitating analyzes related to water quality in order to provide the necessary explanation in the face of the resurgence of water pathologies observed in these watercourses.

5. Recommendation

The study recommends that it is essential to set up and apply a mechanism for monitoring the quality of water in rivers at the national level.

Good quality water, that is to say water that meets WHO drinking water standards, will ensure the good health of those who use it.

To guarantee the protection of watercourses or that of the population against possible pollution, the operationality of the monitoring of the water quality of watercourses is required of the bodies responsible for issues of protection of water ecosystems. Thus, to ensure the coverage of water pollution risks and ensure the good health of the populations, it is advisable to conceptualize and implement the hydrological data observatory in order to make available the analysis data of water quality and alert from time to time on any exceptions highlighted to make possible corrections.

Recognition

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Data Availability

The data used to support the conclusions of this study are included in the article.

Conflicts of Interest

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

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