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IMPACT OF WASTEWATER DISCHARGES ON SOME TOXIC METAL CONCENTRATIONS IN THE WATER AND SEDIMENTS OF THE AIN DALLIA DAM, SOUK AHRAS, ALGERIA

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ABSTRACT

The current study aims to assess the impact of wastewater discharges from the Hanancha region on the physico-chemical quality of the Ain Dallia dam's waters and sediments. Water and sediment samples were collected and analyzed for this purpose between December 2015 and April 2016. TME pollution (Cu, Zn, Fe, and Pb) is assessed using relatively simple principles of measuring concentrations, calculating indices, and comparing them to established standards that vary depending on the element, its toxicity, and the receiving environment. The results show extremely high levels of Cu, Fe, and Pb contamination in the waters of the two dam sites. They clearly show the influence of anthropogenic inputs through the use of domestic wastewater discharges. However, an examination of the results of the three indices of the sediments, namely contamination factor (CF), degree of contamination (DC), and pollution load index (PLI), reveals very high poly metallic contamination. This pollution is caused mainly by zinc and copper.

KEY WORDS : Water, Sediment, Heavy metals, Pollution

INTRODUCTION

Wadis are ecologically and economically significant environments. They are the sites of intense human activity that results in pollutant discharges of different types that destabilize the natural functioning of these ecosystems (Amiard-Triquet, 1989; Bryan and Langoston, 1992). This is the case with discharges from domestic duties, which most of the time end up in watercourses after partial depollution treatment in wastewater treatment plants. Sediments are studied in these wadis for their involvement as environmental indicators due to their ability to fix pollutants, particularly trace metals (TMEs), and thus serve as a reservoir and then a potential source of contamination for the water (Tessier, 2012). Several studies have been conducted around the world to demonstrate the effect of anthropogenic discharges on the degradation of river water physicochemical quality (Jarvie *et al.,* 2003; Baran *et al*., 2007; Duh *et al.,* 2008; Manjusha-Bhor *et al.,* 2013; Sharma *et al*., 2014; and Chandra *et al.,* 2017). Several authors have highlighted such contamination in Algerian wadis (Cheggour, 1988; Dahbi 1989; Bouachrine, 1995; Serghouchni, 1995; Belbachir, 1997; Tahiri, 2005; Debieche *et al.,* 2003; Benrabah *et al*., 2013; Zenati *et al.,* 2010; Bougherira *et al*., 2014 and Bellazi *et al.,* 2020). To evaluate the quality, preservation, and maintenance of the Ain Dallia Dam, we proposed in this work to quantify the contents of four metallic trace elements (Cu, Fe, Pb, and Zn) in the water and surface sediments, and to measure the degree of metallic contamination/pollution using the contamination factor (CF), degree of contamination (DC), and sedimentary pollution index (SPI) indices.

MATERIALS AND METHODS

The region's presentation

Hanancha is a municipality in the wilaya of Souk Ahras, about 20 kilometers south-west of the wilaya's capital. The wilaya of Guelma borders it on the north; Tiffeche and Zarouria on the south, Khemissa on the west; and Souk-Ahras on the east.The region has a lot of agricultural potential, so that's what they do. The region's flat geomorphological configuration favors extensive agriculture (cereals, fodder,..) and sheep breeding. Its hydrographic network is connected to the vast Medjerda watershed. It is distinguished by sedimentary formations ranging in age from the Triassic to the Quaternary. It is composed primarily of limestone, clay, marl, sandstone, gravel, and alluvium (Louis David, 1959). The annual rainfall recorded at the Ain Dalia station between 2009 and 2016 ranged between 519 mm in 2016 and 1200 mm in 2014. The wettest months are February and March, with rainfall totaling 134.9 mm and 148.53 mm, respectively. August, on the other hand, is the driest month of the year, with 3.7 mm. The Ain Dallia structure is the most significant in this basin. It is located downstream of the Medjerda wadi in a 193-square-kilometer sub-basin. It mobilizes 82 Mm^3, with a variable volume of 45 Hm^3. This dam serves as the primary source of drinking water for Souk Ahras, the Wilaya's capital. In October 1994, a wastewater treatment plant with a nominal flow of 200 m3/day went into operation. It is a low-load activated sludge treatment plant with a capacity of 2000 equivalent residents. It is currently treating domestic wastewater from Hanancha. The WWTP's discharge point is Oued Medjerda, and its official purpose is to protect the Ain Dallia dam.

Sampling site and materials

The Ain Dallia dam has two water quality monitoring points: one after the discharge, respecting the mixing distance (St1), and the other at the dam (St2). They provide information on the dam's water quality along the discharge path (Figure 1).

During the water sampling campaigns, which lasted from December 2015 to April 2016, we adhered to the "filtration, acidification, and conservation" sampling standards. A WTW Multi 340i/SET multi-parameter instrument was used to measure the physicochemical parameters (pH, temperature, salinity, conductivity, Eh, dissolved oxygen) in situ. Major chemical elements (Cl^-, HCO_3^-, SO_4^{2-}, Na^+, K^+, Mg^{2+}, Ca^{2+}) were analyzed using volumetry, flame atomic absorption, and colorimetry. Volumetry, flame atomic absorption, and colorimetry

At each site, only the surface sediments were sampled. This horizon is critical because it is in constant contact with water and contains the most recent deposits. The sediments were collected in a stainless steel container to avoid contamination.

Methodology

Water quality

The water quality assessment system is developed and promoted by the French Ministry of Land Use and Environment and the water agencies (Zenati

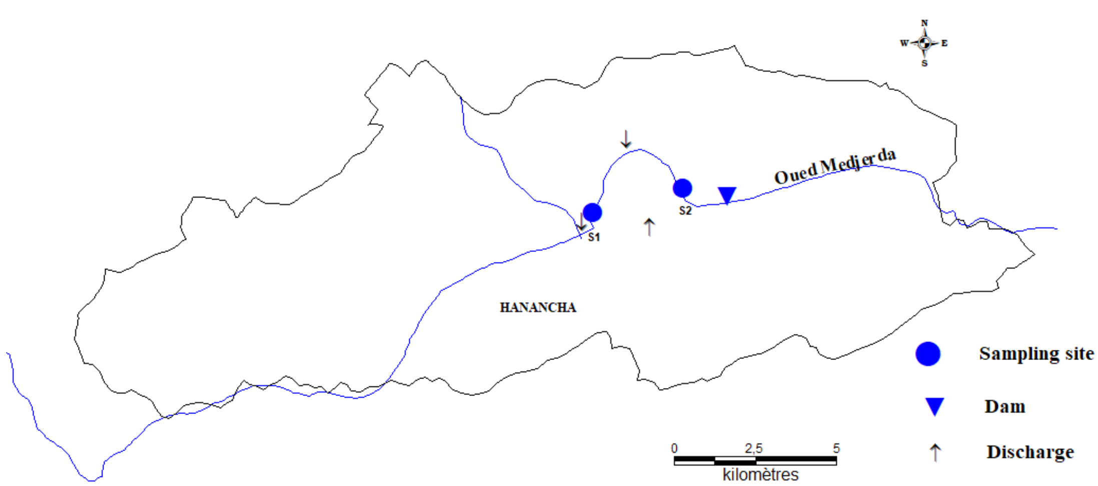

Fig. 1. Study area and sampling sites

and Messadi, 2009). Fifteen types of water alteration have been selected. Each refers to a list of parameters whose measurement makes it possible to calculate an alteration quality index:

- For each parameter, four threshold values are defined and an interpolation curve is used to associate a quality index value with each sample.
- For an alteration, the alteration quality index is the minimum quality index calculated from the list of parameters.

This taint quality index ranges from 0 (worst) to 100 (best) and is divided into five classes (00 - 19: very poor, 20 - 39: poor, 40 - 59: fair, 60 - 79: good, 80 - 100: very good). In 90% of cases, the number of samples taken must be greater than a fixed number for each parameter.

Soil quality

The TME concentrations obtained in the soil samples are interpreted using three contamination indices that can help to better distinguish the respective contributions of the anthropic and natural sources that may be present at the Ain Dallia dam. It should be noted that the calculation of these indices requires the use of geochemical background, which is typically obtained through bibliographic research.

Contamination factor (CF)

TMEs are mainly associated with sediment particles (clays, carbonates, iron oxides and hydroxides, organic matter, etc.), so TME concentrations must be expressed as a function of a parameter related to the nature of the sediment (Sahli *et al.,* 2014). This normalisation, which consists in expressing the ratio of a given substance's content to that of the normalising factor, enables the contamination factor "CF" of a given trace element in the sediment to be defined. This contamination factor is expressed using the formula:

$CF = Cs/Bg$ (1)

With :

- Cx: Measured concentration for an element x,
- Bg: Background for an element x,

CF contamination classes are defined (Hakanson, 1980; Förstner *et al.,* 1981; Carballeira *et al.,* 1997 in Rubio *et al.,* 2000): CF<1 (absent to low contamination), $1 \leq CF < 3$ (moderate contamination), $3 \leq CF < 6$ (considerable contamination), $6 \leq CF$ (extreme contamination) and very high contamination).

Degree of contamination

The degree of contamination (DC) is the sum of the CFs, allowing the a priori polymetallic contamination for each sampling point to be estimated. It is computed using the following formula:

$$DC = \sum_{i}^{n} CiF \quad .. (2)$$

This index is associated with four quality classes (Hakanson, 1980): DC < 6 (low contamination), 6 ≤ DC < 12 (moderate contamination), 12 ≤ DC < 24 (considerable contamination), 24 ≤ DC (very high contamination).

Pollution load index

The pollution loading index (PLI) introduced by TOMLINSON *et al,* (1980) is determined according to the following relationship to highlight the impact of urban activities on sediment quality:

$PLI = \Sigma (C1F*C2F*C3F.......CnF)$(3)

Where :

C F is the contamination factor, n is the number of elements analysed, C metal is the concentration of the element in the sediment sample and Cbacground is the geochemical background value of the element.

RESULTS AND DISCUSSION

The chemistry of the water in the Ain Dallia Dam is naturally influenced by the matrix composition, but it is also influenced by domestic wastewater. During the failure of the wastewater treatment plant, the dam receives more than 570 m^3/day of wastewater, which is discharged directly without any prior treatment. The pollution of raw wastewater is evaluated based on the determination of a number of physicochemical parameters that characterize this wastewater. The temperature of the wastewater in the urban collector, which drains the agglomeration, ranges between 7.5 °C and 18.1 °C as the minimum and maximum extreme values, respectively, with an average temperature of 12.85 °C. In summary, the pH of the wastewater samples tested was relatively basic. The chloride values in the wastewater range from 227 $mg.L^{-1}$ to 794 $mg.L^{-1}$with a 436 $mg.L^{-1}$as the mean value. While the alkalinity values found show that the wastewater from this collector is characterised by an average bicarbonate concentration of around 685 $mg.L^{-1}$. During the study period, the copper values in the discharges varied significantly. The copper content of urban wastewater is approximately 2.38 $mg.L^{-1}$ on average. In contrast, the iron levels in the wastewater show no significant variation. The average iron content of the wastewater tested was 3.69 $mg.L^{-1}$. Similarly, the Pb contents recorded show significant variations during the sampling cycle, with an average value of 1.41 $mg.L^{-1}$ recorded. The evolution of Zn concentrations in discharge over the study period shows that these raw effluents are less concentrated, with an average concentration of 0.17 $mg.L^{-1}$.

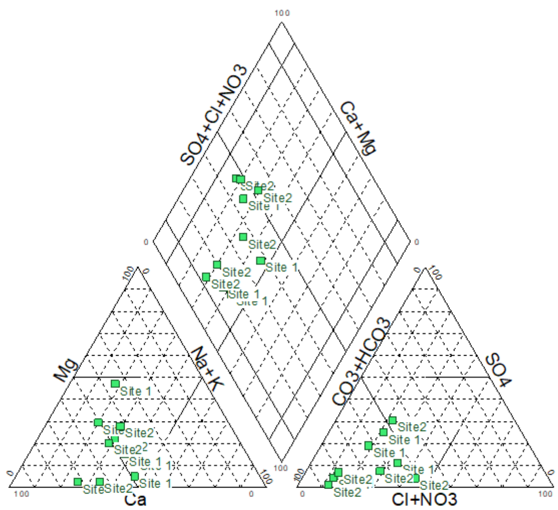

Fig. 2. Piper diagram

TSS concentrations in the wastewater tested ranged between 153 $mg.L^{-1}$ and 337 $mg.L^{-1}$, with a mean of 245 $mg.L^{-1}$. The organic pollution values expressed in BOD5 differ considerably between sampling campaigns. The BOD5 values recorded range from 159 $mg.L^{-1}$ to 460 $mg.L^{-1}$(minimum value). (maximum value) with a mean of 309.5 $mg.L^{-1}$. COD values vary considerably during the study period, ranging from 307 $mg.L^{-1}$ to 688 $mg.L^{-1}$ and with a mean of 397.5 $mg.L^{-1}$. The Oued Medjerda, represented by the Ain Dallia Dam, has long been used as a dumping ground for domestic waste. This has only gotten worse as the urban population has grown.

Table 1 shows that bicarbonates dominate the anions, with average concentrations of 468 $mg.L^{-1}$at the two sites, and calcium is the dominant cation, with the highest value recorded being of the order of 142 $mg.L^{-1}$in site 1 and the lowest value observed being of the order of 50 $mg.L^{-1}$at the same site.

Figure 02 depicts the facies of the sampled waters, which are dominated by HCO_3^- and Ca^{2+}. In the cation plot, all of the points are in the central zone, with a strong preference for the calcium pole. The points in the anion diagram form a cloud near the bicarbonate pole.

The concentrations of labile trace elements in aquatic ecosystems are affected by pH and suspended matter content. Thus, the copper trapped by the particulate phase, for example, is desorbed at acidic pH, becoming labile and bioavailable to aquatic life. At high pH, dissolved copper associates with the particulate phase, causing the opposite effect.

Salinity controls dissolved heavy element levels in addition to pH and suspended matter levels.

Table 2. Indices of alterations of the waters of Ain Dallia dam

Date of samples	Indices of alterations	
	Site 1	Site 2
Décembre 2015	46	44
Janvier 2016	68	62
Février 2016	37	34
Mars 2016	37	37
Avril 2016	25	24

Table 1. Physico-chemical characteristics of Ain Dallia dam water

	Site 1				Site 2			
Parameter	Max	Min	Moy	Écart type	Max	Min	Moy	Écart type
T °C	21.3	9.3	13	4.79	20	10.3	13.14	3.90
pH	9.35	3.84	7.476	2.11	9.4	3.92	7.626	2.13
Cond $Us.cm^{-1}$	1360	640	931.6	268.43	770	520	606.8	100.41
Cl^- $mg.L^{-1}$	82.92	54.16	68.06	12.30	79	50.56	58.76	11.85
HCO_3^- $mg.L^{-1}$	732	257.42	470.43	229.07	945.5	198.86	465.55	308.24
SO_4^{2-} $mg.L^{-1}$	91.29	23.42	50.05	25.03	70.32	25.39	49.34	19.57
Ca^{2+} $mg.L^{-1}$	142.75	50.32	83.64	35.50	140.95	56.14	93.95	36.24
Na^+ $mg.L^{-1}$	100	35	74.6	26.14	66	30	50.6	16.38
Mg^{2+} $mg.L^{-1}$	69.25	14.58	39.77	20.93	112.99	21.62	50.73	35.85
K^+ $mg.L^{-1}$	0.39	0.06	0.26	0.14	0.82	0.12	0.42	0.25

Contaminant emissions in cities are frequently localized and variable in quantity over time. As a result, pollution levels vary from negligible to extremely high.

Lead 0.0161mg.$L^{-1}$and Zinc 0.0077mg.L^{-1} concentrations are higher in the analyses, with a difference of 0.00048, 0.00554 mg.L^{-1} at site 1, in comparison to site 2. Copper 0.00612 mg.$L^{-1}$and iron 0.03068 mg.L^{-1} has lower concentrations than site 2, with a difference of 0.00262, 0.00464 mg.L^{-1}, correspondingly, at site 1.

The alteration of micro pollutants in the dam's waters varies greatly between the two sites, according to the "SEQ EAU" water quality assessment system. This is influenced by the season, rainfall, and discharges. The two sites have poor quality for the remaining sampling months, with the exception of January and February, when the quality is passable and good (Table 2).

To assess the water quality in terms of the toxic elements Cu, Fe, Zn, and Pb, we established a contamination factor classification for the two sites. Based on the results (Table 3), we can divide metal concentrations into three categories:

The very high contamination factor is observed at both sites during the months of December and April, while the zero contamination gradient is observed during the months of January and March.

Violations of water quality in the Ain Dallia dam have an immediate impact on the soil, which can be hazardous to human health. The fate of heavy metals is determined by a variety of factors, including the type of soil and its acidity.

Table 4 presents the average concentrations of TMEs measured in the sediment samples collected during the study period.

These results demonstrate that the sediment samples collected at the two sites have high concentrations of Zn (6.4261 and 7.6814 mg.kg^{-1}) and Fe at the local geochemical background (3.8068 and 3.9167mg.kg^{-1}). However, the sediment sample collected from site 2 reveals a high concentration of Cu in the local geochemical background (0.0367 mg.kg^{-1}). Untreated wastewater discharges into the

Table 3. Contamination factors of the Ain Dallia dam waters

Site	Elts	Background	Déc 2015		Jan 2016		Fev 2016		Mar 2016		Avr 2016	
		noisemg.L^{-1}	[ ] mg.L^{-1}	CF	[ ] mg.L^{-1}	CF	[ ] mg.L^{-1}	CF	[ ] mg.L^{-1}	CF	[ ] mg.L^{-1}	CF
Site 1	Cu	0.0015	0,003	M	0,0078	C	0,0059	C	0,0067	C	0,0072	C
	Zn	0.03	0,0246	N	0,0018	N	0,0031	N	0	N	0,0093	N
	Fe	0.01	0,038	C	0,0254	M	0,0413	C	0	N	0,0487	C
	Pb	0.0001	0,0561	T	0	N	0	N	0	N	0,0244	T
Site 2	Cu	0.0015	0,0048	C	0,0113	T	0,0102	T	0,0102	T	0,0072	C
	Zn	0.03	0,0009	N	0,0016	N	0,0004	N	0	N	0,0082	N
	Fe	0.01	0,041	C	0,0279	M	0,0454	C	0	N	0,0623	T
	Pb	0.0001	0,0464	T	0	N	0	N	0	N	0,0317	T

Table 4. Average concentrations of TMEs measured in the sediments of Ain Dallia dam

Site Elements	Cu mg.g^{-1}	Fe mg.g^{-1}	Pb mg.g^{-1}	Zn mg.g^{-1}
Site 1	0,0071	3,9167	0,0028	6,4261
Site 2	0,0367	3,8068	0,0029	7,6814

Table 5. Contamination indices of the sediments of the Ain Dallia dam

Site	Elements	Background noise (u.g^{-1})	Concentration ($mg.g^{-1}$)	CF	PLI	DC
Site 1	Cu	14.3	0,0071	0,49	1,13	124,36
	Zn	52	6,4261	123,57		
	Fe	30890	3,9167	0,12		
	Pb	17	0,0028	0,16		
Site 2	Cu	14.3	0,0367	2,56	2,82	150,57
	Zn	52	7,6814	147,71		
	Fe	30890	3,8068	0,12		
	Pb	17	0,0029	0,17		

dam can explain these concentrations. The calculated contamination indices confirm the presence of anthropogenic metal contamination in the sediments (Table 5).

Table 5. Contamination indices of the sediments of the Ain Dallia dam

The sediments from the two sampling sites have FCs in Fe and Pb of less than 1, indicating a lack of these elements, which are extremely toxic to benthic fauna. Contamination is nil to moderate for copper at both sites, and very significant for zinc at both sites.

The results show a polymetallic contamination dominated by one or two elements. The average DCs exceed the maximum threshold of Hakanson's (1980) third class, indicating very high contamination. Zinc and copper are primarily responsible for this critical value.

The pollution load index (PLI) of the sediments from both sites is calculated to better understand the differing degrees of contamination of the sediments at each site. Lower PLI values (1) indicate that there is no discernible anthropogenic effect. PLI values greater than one, on the other hand, indicate anthropogenic pollution. The calculated PLI values exceeded one, allowing the two sites to be ranked in increasing pollution order: S2> S1.

CONCLUSION

The Ain Dallia dam, which represents Oued Medjerda, has long been used as a receptacle for the dilution and dispersion of domestic waste. With the growth of the urban population, this has only gotten worse.

The water analysis reveals higher lead (0.016 $mg.L^{-1}$) and zinc concentrations (0.0077 $mg.L^{-1}$). 0.00048 and 0.00554 $mg.L^{-1}$in comparison to site 2. Copper is 0.00612 $mg.L^{-1}$, and iron is 0.03068 $mg.L^{-1}$ has lower concentrations than site 2, with a difference of 0.00262, 0.00464 $mg.L^{-1}$respectively, at site 1.

Even at trace levels, heavy metals are very dangerous, causing waterborne diseases in humans and the environment because toxicity can develop through bioaccumulation in organisms.

Impaired water quality in the Ain Dallia dam has an immediate impact on the soil, which can be detrimental to human health. The fate of heavy metals is determined by a variety of factors, including the type of soil and its acidity.

The results show that the sediment samples taken at the two sites have high concentrations of Zn (6.4261 and 7.6814 $mg.kg^{-1}$) and Fe at the local geochemical background (3.8068 and 3.9167 $mg.kg^{-1}$). However, the sediment sample collected from site 2 reveals a high concentration of Cu in the local geochemical background (0.0367 $mg.kg^{-1}$). Untreated wastewater discharges into the dam can explain these concentrations. The calculation of the three contamination indices confirms the presence of anthropogenic metal contamination in the sediments.

REFERENCES

Amiard-Triquet, C. 1989. Bioaccumulation and relative harmfulness of some metal pollutants to marine species. *Bull. Ecol. T.* 20 (2) : 129-151.

Baran, N., Mouvet, C. and Négrel, P. 2007. Hydrodynamic and geochemical constraints on pesticide concentrations in the groundwater of an agricultural catchment (Brévilles, France). *Environmental Pollution.* 148(3) : 729-738

Belbachir, C. 1997. Contribution à l'étude de la pollution bactérienne et métallique du littoral méditerranéen du Maroc oriental. Cas de l'embouchure de la Moulouya (Doctoral dissertation, Thèse 3 cycle, Univ. Mohammed 1er, Fac. Sci. Oujda).

Bellazi, M. A., Zenati, N., Belahcene, N., Samer, F., Berredjem, Y. and Gheid, A. 2020. Spatio-Temporal Variability of Water Pollution in the Watershed of Wadi Echaref, Sedrata, Algeria. *Pollution Research.* 39 (February Supplement Issue) : S20-S27.

Benrabah, S., Bousnoubra, H., Kherici, N. and Cote, M. 2013. Characterization of the water quality of the West Kebirwadi (Northeast Algeria). *Rev. Sci. Technol. Synthesis.* 26: 30-39.

Bouachrine, M., Fekhaoui, M., Bennasser, L. and Idrissi, L. 1998. Distribution of selected metals in tissue samples of fish from an industrially contaminated stream (The River Sebou, Morocco). *Acta Hydrobiologica.* 40(3).

Bouachrine, M., Fekhaoui, M., Bennasser, L. and Mokhtar, N. 1995. Evaluation du degré de la contamination de la faune ichtyologique du bas Sebou. *Premier Congrès nat. limnologie,* 21-22.

Bougherira, N., Hani, A., Djabri, L., Toumi, F., Chaffai, H., Haied, N. and Sedrati, N. 2014. Impact of the urban and industrial waste water on surface and groundwater, in the region of Annaba, (Algeria). *Energy Procedia.* 50 : 692-701.

Bryan, G. W. and Langston, W. J. 1992. Bioavailability, accumulation and effects of heavy metals in sediments with special reference to United Kingdom estuaries: a review. *Environmental Pollution.* 76(2) : 89-131.

Chandra, D. S., Asadi, S. S. and Raju, M. V. S. 2017.

Estimation of water quality index by weighted arithmetic water quality index method: A model study. *International Journal of Civil Engineering and Technology.* 8(4) : 1215-1222.

Cheggour, M. 1988. Contribution to the study of a paralicenvironment: the Bouregregestuary (Moroccan Atlantic coast); global ecological conditions and study of metallic contamination. 3rd cycle thesis, E.N.S. Takadoum- Rabat, p 337.

Dahbi, N. 1989. Contribution to the study of a paralicenvironment: the Bouregregestuary (Moroccan Atlantic coast); Hydrology, Hydrodynamics and metallic pollution. 3rd cycle thesis, *E.N.S. Takadoum- Rabat,* p 150.

David, L. 1956. Étude des monts de la haute Medjerda: Publications du service de la carte géologique de l'Agérie. Buttetin N°11. Alger.

Debieche, T. H., Mania, J. and Mudry, J. 2003. Species and mobility of phosphorus and nitrogen in a wadi-aquifer relationship. *Journal of African Earth Sciences.* 37(1-2) : 47-57.

Duh, J. D., Shandas, V., Chang, H. and George, L.A. 2008. Rates of urbanisation and the resiliency of air and water quality. *Science of the Total Environment.* 400(1-3) : 238-256.

Duman, F., Aksoy, A. and Demirezen, D. 2007. Seasonal variability of heavy metals in surface sediment of Lake Sapanca, Turkey. *Environmental Monitoring and Assessment.* 133(1) : 277-283.

Förstner, U. and Wittmann, G.T.W. 1981. *Metal Pollution in the Aquatic Environment*. Springer-Verlag, Belin Heidelberg New York, 486 p.

Hakanson, L. 1980. An ecological risk index for aquatic pollution control. A sedimentological approach. *Water Research.* 14(8) : 975-1001.

Jarvie, H. P., Neal, C., Withers, P. J., Robinson, A. and Salter, N. 2003. Nutrient water quality of the Wye catchment, UK: exploring patterns and fluxes using the Environment Agency data archives. *Hydrology and Earth System Sciences.* 7(5) : 722-743.

Katyal, D. 2011. Water quality indices used for surface water vulnerability assessment. *International Journal of Environmental Sciences.* 2(1).

Manjusha, B., Prakash, K., Abhijit, B., Sheetal, Manisha, B. and Bholay, A.D. 2013. Water quality Assessmet of the River Godavari, A Ramkund, Nashik, (Maharashtra), India. *International Journal of Engineering and Science.* 2(2) : 64-68.

Rubio, B., Nombela, M.A. and Vilas, F. 2000. Geochemistry of major and trace elements in sediments of the Ria de Vigo (NW Spain): an assessment of metal pollution. *Marine Pollution Bulletin.* 40(11) : 968-980.

Sahli, L., El Okki, M. E. H., Afri-Mehennaoui, F. Z. and Mehennaoui, S. 2014. Utilisation d'indices pour l'évaluation de la qualité des sédiments: cas du bassin Boumerzoug (Algérie). *European Scientific Journal.* 10(35).

Serghouchni, M. 1995. *Contribution à l'étude écologique et toxicologique des civelles d'Anguilla anguilla de la basse Moulouya* (Doctoral dissertation, Thèse 3ème cycle, Univ. Mohammed 1er, Fac. Sci. Oujda).

Sharma, M. K., Jain, C.K. and Singh, O. 2014. Characterization of point sources and water quality assessment of river Hindon using water quality index. *Journal of Indian Water Resources Society.* 34(1) : 53-64.

Tahiri, L., Bennasser, L., Idrissi, L., Fekhaoui, M., Abidi, A. E. and Mouradi, A. 2005. Contamination métallique de Mytilus galloprovincialis et des sédiments au niveau de l'estuaire de Bouregreg (Maroc). *Water Quality Research Journal.* 40(1) : 111-119.

Tessier, E. 2012. *Diagnostic de la contamination sédimentaire par les métaux/métalloïdes dans la rade de Toulon et mécanismes contrôlant leur mobilité* (Doctoral dissertation, Université de Toulon).

Thomilson, D. C., Wilson, D. J., Harris, C. R. and Jeffrey, D.W. 1980. Problem in heavy metals in estuaries and the formation of pollution index. *Helgol. Wiss. Meeresunlter.* 33(1-4) : 566-575.

Zenati, N. 2010. *Pollution of the Aquatic Environment: Diagnosis and Proposal*. Annaba region. Doctoral thesis. Department of Geology, Badji Mokhtar Annaba University. p. 289.

Zenati, N. and Messadi, D. 2009. Système d'évaluation de la qualité des eaux superficielles. Application au bassin versant côtier Constantinois Est. *Le Journal de l'Eau et de l'Environnement.* N° 15 : 120-133.