Assessment of Physic-chemical Quality of the Water of the River Moulouya at the Region Outat El Haj and Missour

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Abstract

Objectives: To evaluate the physical and chemical quality of groundwater in the medium Moulouya, to identify the sources of pollution of the OuedMoulouya waters and to detect the corrélation between the physico-chemical contents. Methods/Analysis: Some physicochemical parameters change during transport and storage of samples of the sampling site (Ground) to the laboratory; therefore it is always better to make on-site measurements. The measurements of all physical and chemical parameters are performed within 48 hours after the sampling, with the standard methods usually adopted by this type of analysis. In this work, we applied the statistical methods and in particular, the Principal Component Analysis (PCA) on the XLSTAT software. Findings: The analysis of results show that the water of stations are BICARBONATED with CALCICUM and magnesium and they also show that in the stations, where the wastewater are discharged from the cities of Missour and OUTAT EL HAJ, there is an increase in the levels of Biochemical Oxygen Demand (BOD5), Orthophosphate, chlorides, Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), Organic Matter (MO), and a decrease in the dissolved oxygen levels. Analyses of nitrates and orthophosphates of the water give very low values. These waters are fairly loaded with organic matter, especially near the urban discharges from the cities of Missour and OUTAT EL HAJ (BOD5 = 27.2 mg/1, OM = 47.09 mg/l, O2 = 4.8 mg O2/l) in dissolved salts (chloride, sulphate). The temperature (T = 20.9 °C) is related to the arid local climate. The values of certain parameters such as temperature, the potential of hydrogen, conductivity, alkalis, sulphates and chlorides generally testify that the waters of the OUED are of good quality according to Moroccan standards. Furthermore, the pollution degree differs from one site to another depending on the distance and the remoteness of the source of pollution. Application: The protection of the receiving environment, installation and dimensioning of a STEP at the level of the Missouri city and upgrading and renewal of the STEP of OUTAT EL HAJ.

Keywords: Morocco, Physical Chemistry, Pollution, Outat El Haj, Oued Moulouya, Water Quality

1. Introduction

The quality of water in the world has experienced in

recent years deterioration because of uncontrolled both domestic and industrial wastes and the intensive use of chemical fertilizers in agriculture. They produce a chemi-

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cal change in the water and make it unsuitable for desired uses 1.2. Many studies have also been reported on the study of different effects of industrial and urban wastes on the evolution of the quality of surface water and the pollution of inland aquatic ecosystems^{3,4}.

Moulouya is the only river flowing into the Mediterranean. Along more than 500 km, it drains almost all of eastern Morocco, and it is particularly affected by pollution due to the growing population of the coastal centers, the continuous development of industry and agriculture and the presence of mineral deposit⁵. Indeed, liquid domestic and industrial waste sources generated by the cities of TOUNFITE, BOUMIA, ZAIDA MISSOUR, OUTAT EL HAJ, TINDIT AND GUERCIF are dumped directly into the river from a precarious and without any prior treatment. Moreover, there are mining waste, laundry waste and metal residues which can be a major source of contamination of the aquatic ecosystem of the river⁶.

The city of Missour located 205 km from Fez in the province of BOULMANE is one of those centers. The presence of the Middle Atlas chain in its northwest boundary, the High Atlas in south and the remoteness of the Mediterranean mitigates the marine influences like rain and gives the region a semi-arid climate accompanied by long periods of drought (waters resources in Morocco) which has a direct impact on the water level in the region. This work is a contribution to the evolution of the quality of surface water in that region by a space-time monitoring of the evolution of a number of physical and chemical parameters listed above.

2. Materials and Methods

2.1 Overview of the Study Area

The study area is part of the watershed of Moulouya; middle Moulouya is located between latitudes 32 ° 50

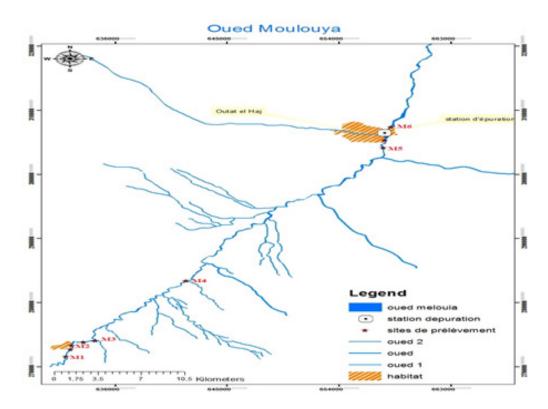


Figure 1. Location of the study area and sampling sites.

'N and 33 ° 50' S and either side of longitude4th W. For the total area of 16,800 km³, middle Moulouya has 6% of mountains (medium and high Atlas), 55% of plateaus (REKKAME) and 39% of plains which form the valley itself^z. It is located between Missour and OUTAT EL HAJ and lies between the latitudes 32 ° 50'N and 33 ° 50'N (Figure 1).

2.2 Methods of Water Analysis

Along the middle Moulouya (study area), twelve monthly samples of samples were carried out during the period from November 2014 to October 2015. Some physicochemical parameters change during transport and

storage of samples of the sampling site (Ground) to the laboratory therefore it is always better to make on-site measurements. In situ measurements of temperature, pH, electrical conductivity, dissolved oxygen and turbidity were conducted respectively by a mercury thermometer, a pH meter PH-2006, a conductivity meter WTW (COND 315i), an OXIMETER EUTCH (CYBERSCAN DO300) and TURBIDIMETER HACH 2100N.

The measurements of all physical and chemical parameters are performed within 48 hours after the sampling, with the standard methods usually adopted by this type of analysis^{8.9}. The type of method, the device used as well as the reference method is summarized in Table 1.

Table 1. Physico chemical Parameters and the reference of the Method of analysis

Paramètre	Unité	Référence	Méthodes
MES	mg/l	AFNOR	Filtration Weighing
HCO ₃ -	mg/l	Rodier	Volumetric dosing with HCl (0.1N)
Chlorides	mg/l	Rodier	Volumetric Method Mohr
Sulphates	mg/l	Rodier	Methods Néphérométrique
Nitrates	mg/l	Rodier	Method to Salicylates Sodium
Nitrites	mg/l	AFNOR	Method to Reagent Zambelli
Total phosphorus	mg/l	AFNOR	Dosage after persulfate oxidation
Ortho phosphate	mg/l	AFNOR	Method Ammonium Molybdate
COD	mg d'O ₂ /l	AFNOR	Oxidation with potassium dichromate
BOD ₅	mg d'O ₂ /l	AFNOR	Methods Oxyton

2.3 Statistique Data Processing

In this work, we applied the statistical methods and in particular, the PCA on the XLSTAT software (Trial Version).

3. Results and Discussion

3.1 The Water Temperature and Potential of Hydrogen (PH)

The average water temperature has a significant spatial variation from upstream to downstream, and it depends on climatic variations and not on the studied stations of watercourses¹⁰.

The recorded results show that the temperature is between 19.6 ° C and 21.3 ° C (Figure 2); these values are considered limits ranging from 20 to 30 ° C. This is a favorable temperature for bacterial growth (assimilative phenomenon), parasites, mosquito larvae and other microbial germs.

In our case, the temperature is not substantially high because the measurements were performed in the morning and water regularly flows from the mountains to the mouth.

Figure 2 shows the spatial variation in pH at the various studied stations. The analysis shows that the measured average of pH range between 7.36 and 7.51 and show no significant variation. They remain somewhat neutral and express alkalinity of different stations (upstream-downstream).

The minimum values are recorded in summer while the maximum values are recorded in winter.

The pH increase during the winter period (flood period) may be due to the abundance of carbonate formations at the middle Moulouya watershed and are washed out by rain and flood of the OUED.

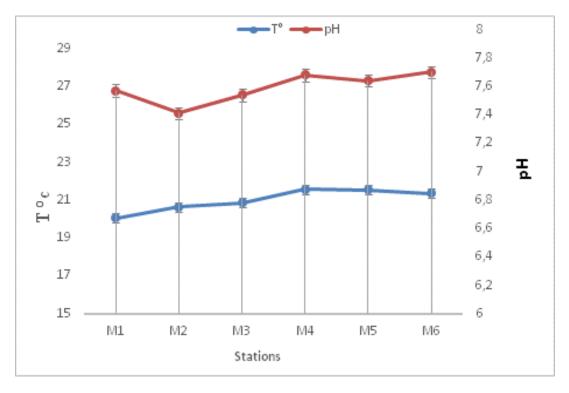


Figure 2. Spatial variation of temperature and pH.

3.2 The Electrical Conductivity (EC) and **Turbidity**

The conductivity measurement is a good assessment of the degree of mineralization of water in which each ion acts by its concentration and its specific conductivity. The reported average values show small variations. They fluctuate between 115µs/cm at the M6 station and 1387 µs/ cm in the M4 station with an average of 1256 µs/ cm in surface waters of the OUED of Moulouya, not exceeding the Moroccan standards of surface water (2700 µs/cm)11, which classifies these waters in the right grid of surface water.

Turbidity measures the water content of the particles in suspensions, associated with the transport of water which is of a mineral nature and by the presence of microorganism¹². The latter increases from the upstream to downstream of 175.1 to 277.2 NTU. These recorded turbidity levels well above the acceptable limits intended for water of human consumption that is 5 NTU¹² (Figure 3).

3.3 TSS, Bicarbonate (HCO3-), Chlorides (Cl-) and Total Hardness (TH)

The spatial average of total suspended solids (TSS) increased in parallel with the turbidity from the upstream to downstream of the discharge of the town of Missour, OUTAT EL HAJ and which are driven by heavy rains varying from 356.8 to 411.2 mg/l. the TSS recorded values exceed the standard of surface water which is 50 mg/l. The suspended solids levels are proportional to the flow and reach their greatest values during the flood periods, resulting in bacterial contamination in summer with an increased capacity of drop¹³. It is noteworthy that the high values recorded at stations are due to industrial and domestic waste.

In Figure 4, we notice that the recorded levels in the studied stations remains almost constant with an average of 132.5 mg/l, and we notice that the variations in alkalinity between the different date's samples are mainly related to variations in precipitation. This is explained by

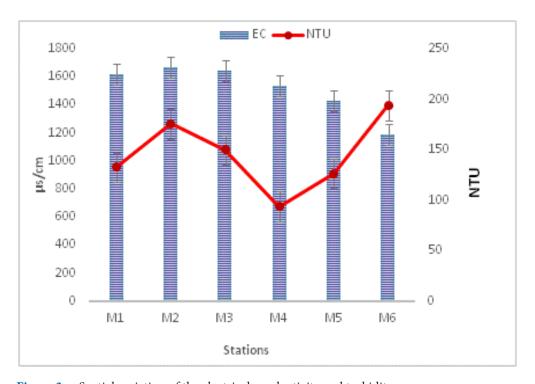


Figure 3. Spatial variation of the electrical conductivity and turbidity.

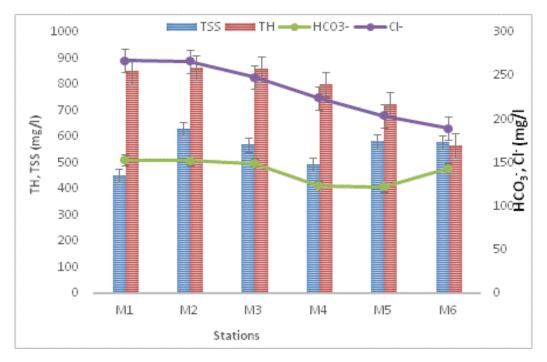


Figure 4. Spatial variation of TSS, TH, bicarbonate and chloride.

the significant dissolution of calcite in the watershed of Moulouya during the winter period, which is attributed to the increased flow in various tributaries of the mold¹⁴. The concentrations of chloride in the OUED of Moulouya vary in the same direction as the total water of mineralization. The concentrations of chloride ions found in the waters of the Moulouya (Figure 4) ranged from 158.9 mg/l in the M6 station and 176.8 mg/l in the M4 station.

For the six stations of the study area, chlorides record some levels that are lower than the Moroccan standards set at 750 mg/l, which classifies these waters in the excellent class of grid quality of surface water¹¹.

The total water hardness (TH) is a parameter directly connected to the amount of calcium and magnesium in water⁸. The waters of the OUED of Moulouya are characterized by a total hardness especially at the studied stations. These high values (> 30 ° F) could be explained

by the disposal of domestic and industrial wastewater and the nature of sedimentary rocks through which water runoff. The hardness varies between 410.3 ° F recorded at the M6 station and 594.5 ° F recorded at the M4 station (Figure 4).

3.4 Biochemical Oxygen Demand (BOD₅), Chemical Oxygen Demand (COD), Dissolved Oxygen (O₂) and Organic Matter (OM)

Figure 5 shows an increase of BOD_5 of the Moulouya river waters from its upstream to its downstream reflecting the river's pollution effect. Indeed, the mean values of BOD_5 vary between 17.5 mg/l at the station M1, and 46.2 mg/l in the station M2. The downstream portion of the study area (M2, M6) receives raw sewage with rich organic matter and nutrients from urban agglomerations of Missour

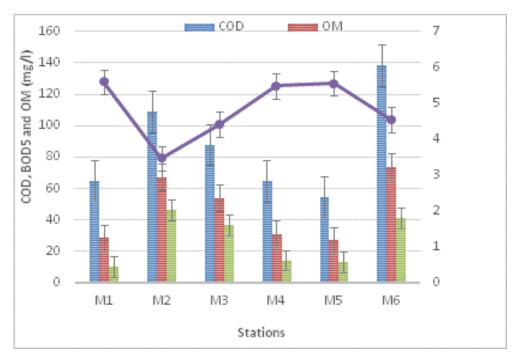


Figure 5. Spatial variation of BOD5, COD, OM and dissolved oxygen.

and OUTAT EL HAJ, causing a considerable increase in the organic load of surface water in a small space.

At the OUED Moulouya (M4 and M5 stations), we can notice a decreasing gradient of BOD_5 , reflecting the self-purifying effect of the river. The average of the values is recorded at the study sites above the standard set for the surface water which is 10 mg/l^{11} .

The pattern of evolution of the COD and the MO is identical to that of BOD₅. The contents of COD and MO recorded at the level of the studied waters are respectively between 73.8 mg/l, 37.7 mg/l in the M4 station and 141.6 mg/l, 74.9 mg/l in M6, Figure 5. All rates based on organic materials and COD exceed the values indicated by the surface water quality grid estimated at 5 mg/l for the MO and 40 mg/l for COD¹¹, this could be explained firstly by the direct result of discharges of sewage and secondly by the creation of conditions of the organic matter degrada-

tion by microorganisms whose activity and multiplication require oxygen.

Oxygen is a particularly useful parameter for water and is an excellent indicator of its quality. This is one of the most sensitive parameters to pollution. Its value provides information on the degree of pollution and therefore the degree of self-purification of rivers¹⁵.

Space consumption from upstream to downstream of the dissolved oxygen result in excessive consumption of organic matter and microorganisms in the environment¹⁶ with an average of dissolved oxygen which varies from 5.42 to 3.82 mg/l.

3.5 Nitrate (NO₃-) and Nitrite (NO₂-)

The levels of nitrate increase from the upstream to the downstream from 13.6 to 17.9 mg/l, which is below the

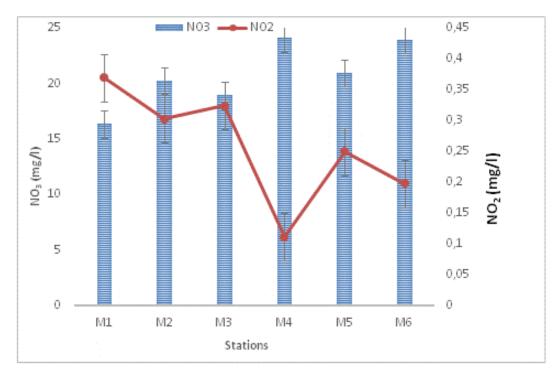


Figure 6. Spatial variation of nitrate and nitrite.

WHO standards that are 50 mg/l; the maximum values are obtained at the M2 and M6 stations (Figure 6).

Nitrite levels evolve inversely with values ranging from 0.16 to 0.37 mg/l; this could be explained by gentrification of nitrate to nitrite by bacteria autotrophic NITROSOMONAS AND NITROBACTERS which respectively realize the oxidation of ammonium in nitrite and the oxidation of nitrite in nitrate. This justifies the consumption of dissolved oxygen from upstream to downstream¹².

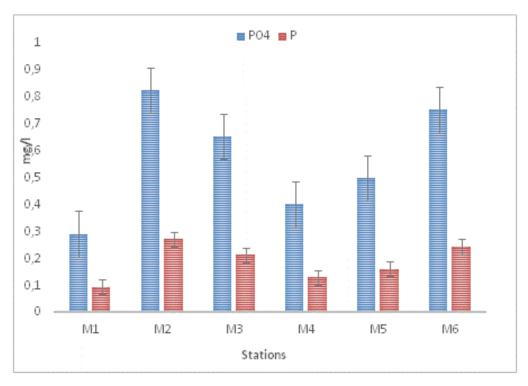
3.6 Orthophosphate (PO₄³-)

Phosphorus is one of the most important nutrients in nature. It is a biogenic element essential to the growth of algae, bacteria and protozoa¹⁸. The elevated levels of this element in surface waters can cause eutrophication¹⁹.

The Levels found in the river are low, and the concentrations in PO_4^{3-} of different water stations range around 0.3 mg / 1 and 0.8 mg / 1 (Figure 7). The highest values are displayed in the stations M2 and M6 and this can be explained by the proximity of the latter to the discharges of domestic sewage²⁰. Phosphate levels are proportionally increasing in orthophosphate whose values are ranging from 0.12 to 0.26 mg/l.

3.7 Sulfates

Sulfur is a non metallic element that exists naturally in soils and rocks in organic forms (proteinaceous sulfur) and mineral status (sulfides, sulfates and elemental sulfur). Sulfur combines with oxygen to form sulfate ion which is present in certain minerals: gypsum, barite...



Spatial variation of the phosphorus and orthophosphate. Figure 7.

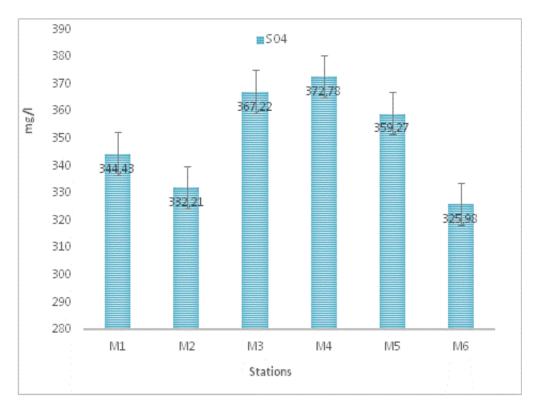


Figure 8. Spatial variation of sulfate.

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The reversible transformation of sulfates into sulfides is done through the sulfur cycle^{21,22}. Surface waters contain varying levels of sulfates and their concentration is generally between 2.2 and 58 mg/l²³.

The evolution of the sulphate content displays important values which are stored for six stations (Figure 8). This is due to leaching of evaporate deposits from gypsiferous formations, mainly gypsum (CaSO4 2H2O) and anhydrite (CaSO4).

3.8 Principal Component Analysis PCA

We conducted a PCA to study the interactions of the spatiotemporal variations of physicochemical parameters. The CPA has been one of the most used methods by other authors^{24,25}. Thus, we used XLSTAT 2014 software (Trial Version).

This statistical method allows transforming the initial quantitative variables correlated all over them in new quantitative variables, uncorrelated, called principal components²⁶.

The examination of the numerical results of the proper values of this ACP (Figure 9) indicates that the axis F1 explains 84.57% of the total variance of the data. The F2 axis represents 8.39% of the total variability in the data. Thus, 92.97% of the variability of the table data is extracted by factorial plan F1 X F2. Therefore, the analysis of PCA results will be made limited to the first two axes.

The correlation circle Figure 9 shows that sixteen of the twenty variables included in the ACP contribute to the definition of factorial plan F1 x F2.

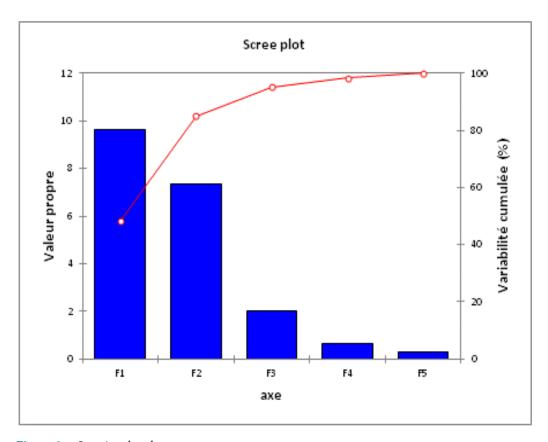


Figure 9. Inertia related vectors.

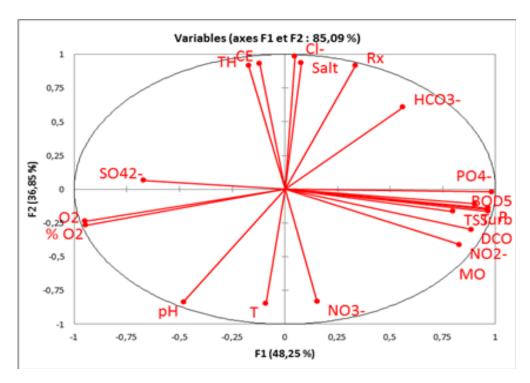


Figure 10. Correlations circle of variable physicochemical.

The alkalinity of water is expressed by the strong correlation between the EC, OM, COD, BOD, P, NO,, and PO₄ according to the axis F1, the highly mineralized waters are rich in chlorides and it is associated with variables such as MO, BOD₅, Nitrates and PO₄ which are domestic pollution indicators opposed to the dissolved oxygen. It defines an increasing gradient from left to right pollution, which results in a decrease in oxygen and increase in COD, BOD₅, and nitrites, hardness, turbidity, chlorides, phosphates. The latter leads to a strong mineralization8, which explains the increase in conductivity from left to right along the axis F2.

Based on the factorial plan F1 x F2 (Figure 10), the PCA results show that the various stations are positioning (F1) according to the degree of pollution of their waters.

Thus, the most polluted stations (C1, C2 and C3) are the positive side of F1, while the least polluted stations from M1 to M6 are on the negative side.

On the Moulouya river, stations C1, C2 and C3 are characterized by high levels of BOD, and COD, OM, high enough PO_4^{3-} and NO_2 , low O_2 , Cl^2 , SO_4^{2-} , and NO_3^{-1} . This is due to pollution from discharges of domestic and industrial waters of Missour (Figure 11).

The overall analysis defines a typology dominated by the individualization of two groups of stations:

*Group I includes the resorts of wastewater from the area (M2 and M3) characterized by high domestic pollution. The stations are loaded with organic pollutants leading to low dissolved oxygen concentrations.

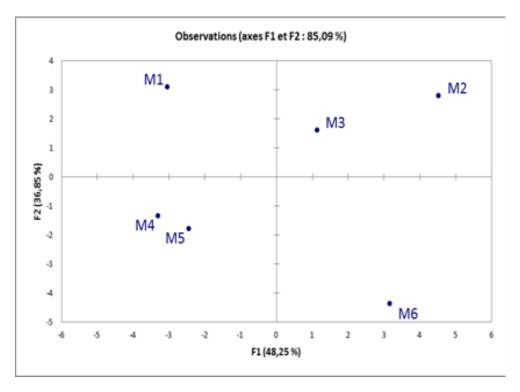


Figure 11. Projected stations on the factorial plane $F1 \times F2$.

- *Group II is represented by M4 and M5 stations; it shows average quality water rich in oxygen, through self-purification phenomenon.
- * Group III includes the resorts of wastewater of our city (M6) characterized by high domestic pollution.

4. Conclusions

This work forms part of the evaluation of the physicochemical quality of the water of the OUED Moulouya that receives discharges of domestic and industrial sewage of OUTAT EL HAJ and Misssour without any treatment.

The quality of surface waters in the region of OUTAT EL HAJ and Missour depends on litho logy drained by the waters of the Moulouya, and the significant influence of domestic sewage and farming on the two banks of Moulouya. However, the levels observed in some physicochemical parameters (EC, chloride, sulphate) do not exceed the Moroccan standards presented in the quality of surface water (Moroccan Standards, Morocco's Official Gazette", No. 5062 of 30 Ramadan 1423. Rabat, 2002). There is a degradation of water quality particularly in the area which is subject to the wastewater discharges from cities of Missour and OUTAT EL HAJ respectively at the stations M2, M5. However, this contamination tends to decrease in the stations located far from urban wastes and this decrease could be related to self-purification phenomenon.

Comparing the physicochemical contamination of Moulouya with other courses of Moroccan (Sebou) and global (Seine) water shows that it remains within tolerable limits in relation to the low socio-economic development of cities installed in the area of the Moulouya.

5. References

- 1. Rouabhia A, Baali F, Kherici N, Djabri L. Vulnérabilité et risque de pollution des eaux souterraines de la nappe des sables miocènes de la plaine d'El-Ma El-Abiod (Algérie). Sécheresse. 2004; 15(4):347-52.
- 2. Rouabhia AEK, Djabri L. L'irrigation et le risque de pollution saline. Exemple des eaux souterraines de l'aquifère miocène de la plaine d'el ma el abiod. Larhyss Journal. 2010:55-67.
- 3. Djabri L. Mécanismes de la pollution et vulnérabilité des eaux de la Seybouse. Origines éologique, industrielles, agricoles et urbaines. Thèse de doctorat. De l'Université d'Annaba. 1996:1-261.
- 4. Walling DE, Russell MA, Webb BW. Control on the nutrient content of suspended sediment transported by British rivers. The Science of the Total Environment. 2001; 266(1):113-23. Crossref.
- 5. Doubi M, Dermaj A, Ait Hadou B, Chebabe D, Erramli H, Hajjaji N, Srhiri A. Contribution à l'étude Physicochimique de l'oued Moulouya et un affluent au niveau de la région d'Outat El Haj. Larhyss Journal. 2013; 16:91-104.
- 6. Belghyti D, EL Kharrim K, Guamri Y, Loukili A, Lamri D, Hrach-rass A, Tahoum M. Etude préliminaire physicochimique et biotypologique de la Moulouya, Rapport I, Projet (PBERM). Méditerranée. 2006:1-153.
- 7. Coulibaly P, Bobée AB. Prévision hydrologique par réseaux de neurones artificiels : état de l'art. Revue canadienne de génie civil. 1999; 26(3):293-304.
- 8. Rodier J. L'analyse de l'eau naturelle, eaux résiduaires, eau de mer. 9th Edition Dunod, Paris; 2009.
- 9. Office national de l'eau potable (ONEP)-GTZ. Dossier technique relatif à la détermination des zones de protection rapprochées et éloignées du champ captant Ahmed Taleb. Office national de l'Eau Potable; 1995. p. 1-61.
- 10. Aboulkacem A, Chahlaoui A, Soulaymani A, Rhazi-filali F, Benali D. Etude comparative de la qualité bactériologique des eaux des oueds Boufekrane et Ouislane à la traversée de la ville de Meknès (Maroc). Review of Industrial Microbiologiy Sanitary and Environnemental. 2007; 11(1):1-13.

- 11. Ministère de l'environnement du MAROC. Normes marocaines, Bulletin officiel du Maroc, N° 5062 du 30 ramadan 1423, Rabat; 2002. p. 1-18.
- 12. Rapport sur la santé dans le monde, résumé d'orientation. Organisation mondiale de la sante [Internet]. [cited 2017 Aug 07]. Available from: www.who.int/whr/2007/fr/.
- 13. Gourari L, Alaoui-Mhidi M, Fedan B. Physico-chemical parameter variations of water from Wadi Aggai waters: geo-environnemental significance and consequences for travertines precipitation [Middle Atlas, Morocco]. Journal of African Earth Sciences (and the Middle East). 2000; 30(2):283-93. Crossref.
- 14. Kolbe HJ. Neuroptera aus Marocco, gesammelt von Herrn Prem.-Lieut. M. Quedenfeldt. Berl. Ent. Zeitschr. 1884; 28(1):132-6.
- 15. Oumlouki EK, Moussadek R, Zouahri A, Dakak H, Chati M, El amrani M. Study of physic-chemical quality of water and soil in the region Souss Massa (Case perimeter Issen), Morocco. Journal of Materials and Environmental Science. 2014; 5(2):2365-74.
- 16. Vilain M. La production végétale: la maitrise de technique de la production. College Agriculture d'Aujourd'hui, in-8, broché; 1989. p. 361.
- 17. Makhoukh M, Sbaa M, Berrahou A, Van Clooster M. Contribution to the Physicochemical study of water surface of the Oued Moulouya (Morocco oriental). Larhyss Journal. 2011; 9:149-69.
- 18. Brahimi A, Chafi A. Ecotoxicological study of Oued Za and its tributary Oued Tizeghrane (Lower Moulouya, Eastern Morocco). Journal of Materials and Environmental Science. 2014; 5(5):1671-82.
- 19. Abba E, Nassali H, Benabid M, EL Ayadi R et EL Ibaoui H. contribution to the physicochemical study of lake ecosystem dayet aoua morocco. Afrique Science. 2008; 4(2):306-17.
- 20. Pauwels H. Mineralogical Magazine. Minerals Science. 1996; 60(399):696-7.
- 21. Peck HD. Sulphur requirements and metabolism of microorganisms. Proceedings of a symposium on sulphur in nutrium. Ari Publishing Co, Wespost, CT; 1970. p. 1-12.
- 22. Abboudi A, Tabyaoui H, El Hamichi F, Benaabidate L, Lahrach A. Etude de la qualité physico-chimique et contamination métallique des eaux de surface du bassin

- versant de Guigou. Maroc. European Scientific Journal. 2014; 10(23):1857-7881.
- 23. Meybeck M, Friedrich G, Thomas R, Chapman D. Rivers. Water quality assessments: A guide to the use of biota, sediments and water in environment monitoring. 2nd Edition. Published by E&FN Spon, an imprint of Chapman & Hall; 1996. p. 59-126.
- 24. Orloci L. On information flow in ordination. Vegetatio. 1974; 29(1):11-16. Crossref.
- 25. Giraudel J, Lek S. A comparison of self-organizing map algorithm and some conventional statistical methods for ecological community ordination. Ecological Modelling. 2001; 146(13):329-39. Crossref.
- 26. Davis JC. Statistics and data analysis in geology. 2nd Edition. WILEY New-York, Chi-chester, Brisbane, Toronto, Singapore; 1984. p. 1-7.