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Long-term assessment of surface and groundwater quality in Tensift region, Morocco

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Abstract
In this study, the assessment of surface and ground waters quality in Tensift region during the period of 2003 to 2012 (9 years) was investigated. For surface waters, the results show that the five dams in the study area are distributed mainly in three facies, Ca-Na-HCO_3-Cl-SO_4, Ca-HCO_3-SO_4 and Ca-HCO_3-Mg facies. According to Moroccan water quality evaluation systems of 2002 and 2008, the quality is generally medium and good respectively. The trophic status of dams' waters studied is relatively varied, this variation shows a tendency to eutrophication. In most dams, Chlorophyceae, Diatoms, Cyanophyceae and Dinophyceae classes are the most dominant. These classes exhibit high algal production. During the investigation period, water quality of six treatment plants studied is consistent with the Moroccan standard of water quality for human consumption. For ground waters, the majority facies are Ca-Na-HCO_3-Cl-SO_4 facies. Excellent and good classes are the dominant quality classes for these waters in the study area.

Keywords: Tensift, Surface Water, Groundwater, Trophic status, Quality assessment, Cartography.

1. Introduction
Water is the principal constituent of living beings and the indispensable element to any form of life. Without water, no organization, whether it be plant or animal, cannot live. Therefore, water is indispensable to the existence, development and the life of man. From its design to the realization of its activities as the industry or agriculture, the man has need of water. The depletion of the quantity and quality of available water resources can make the water resources for human needs unnecessary and damage simultaneously the environment [1]. Water quality is assessed by physico-chemical, biological and hydromorphological controls of waters bodies [2-6]. This concept is used for some uses that require water to the particular characteristics (for example, drinking water).
The main purpose of quality monitoring of waters intended for the production of drinking water is to ensure the chemical and biological quality of produced and distributed water. The knowledge of water quality is essential to ensure the conformity of drinking waters. It gives a global vision on the risks in order to ensure the protection of resources and to determine the possible sources of water quality alteration [7-11].
The objective of this study is to assess the physico-chemical, biological and hydrochemical quality of surface and ground waters in Tensift region during 9 years, in agreement with Moroccan and French regulatory texts.

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2. Materials and methods

2.1 Study area

Tensift region is located in the center west of Morocco and extends over an area of 32114 km^2 which equivalent to 4.5% of the national territory. It is limited to the north by the region of Chaouia Ouardigha, to the north-west by the region of Doukkala-Abda, to the east by the region of Tadla Azilal, on the south by the region of Souss-Massa-Draa and to the west by the Atlantic Ocean. The region is composed of six provinces (Essaouira, Chichaoua, Al Haouz, El Kelâa des Sraghna, Rhamna, Safi) and a prefecture (Marrakech). The climate of the region is distinguished by an apparent variability of temperature, humidity and rainfall (low and uneven). It influenced by the Atlantic Ocean and high altitudes of High Atlas. The character arid and semi-arid dominated in the whole region, by against the wet character appears only in the High Atlas Mountains at altitudes above 2500 m [12].

Geological formations of Tensift basin are various. Al Haouz plain is formed by the deposits of Neogene and quaternary alluvial. The layer of limestone exists around Chichaoua and High Atlas Mountains. A few Paleozoic deposits are scattered in the south of the center of the plain. These formations are composed of schist, quartzite and limestone. The deposits ranging from Cretaceous and Eocene form Essaouira-Chichaoua basin. These formations consist in dolomite and limestone Marne. The Jbilet mountains belong to the Paleozoic era are composed of schist, mica-schist, quartzite, and limestone. High Atlas mountains in Tensift basin belong mainly to Paleozoic and partly in Precambrian eras [13].

The hydrographic network of Tensift basin comprises primarily the Tensift River, which flows from east to west from its source and receives many tributaries (Figure 1). The main tributaries of Tensift River are localized in Al Haouz, and take birth from the High Atlas. The flow regime of Tensift River is irregular. It is a function of the rainfall in the basin and of the melting of snow in the High Atlas. In addition, the basin has benefited from a transfer of the order of 300 mm^3/year from Oum Er Rbia basin, via Rocade channel. Ground waters in the region are characterized by an uneven geographical distribution due to the unequal geographical distribution of the rainfall and surface waters, as well as the presence of a diverse geology. The major aquifers are those of Al Haouz plain, the Mejjate, Bahira and Essaouira basin (Meskala-Korimate) [14].

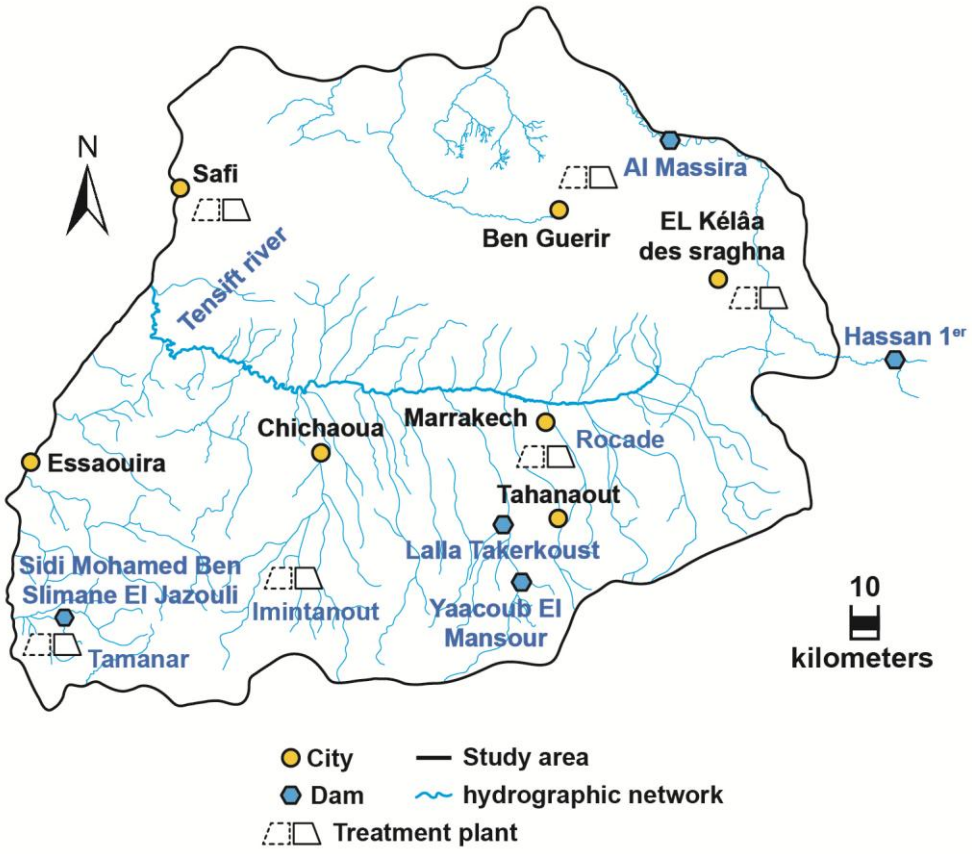


Figure 1 : Hydrographic network, dams and treatment plants studied in Tensift region.

Monitoring network of surface water is composed of five dams and six treatment plants (Figure 1), dams are, Al Massira, Hassan 1er, Lalla Takerkoust, Yaacoub El Mansour and Sidi Mohamed Ben Slimane El Jazouli. Treatment plants monitored are the plant of Safi, Ben guerir, El Kelaa des Sraghna, Rocade, Imintanout and Tamanar. For groundwater, the monitoring of the quality is realized for 128 samples.

2.2 Methodology

Regulatory texts adopted as reference in this study are: Moroccan water Act 10-95, Moroccan waters decree for food use (No. 2-05-1326), Moroccan standard of water quality for human consumption (NM 03.7.001 (2006)) and water quality evaluation systems (WQES) of Morocco (2002 (applicable) and 2008) and of France (2003). Parameters used in this study are those fixed by water quality evaluation systems. The quality of treated water is evaluated according to Moroccan standard of water quality for human consumption (NM 7.03.001 (2006)).

The first step in the realization of this study is the collection and the constitution of the analytical database relating to the Tensift region. This step is followed by a statistical treatment of water quality data using the Microsoft Excel software. The next step is the evaluation of hydrochemical, physico-chemical and biological quality of surface and groundwater as well as of treated water quality. The hydrochemical quality is assessed by the determination of the mineralization of these waters through Piper and Schöeller-Berkaloff diagrams using Aquachem V2012 software. By contrast, the physico-chemical quality is determined by the classification of each type of waters according to WQES of corresponding waters. Surface waters biological quality is determined by the analysis of chlorophyll (a), phytoplankton and the study of trophic status probability according to the trophic index OECD (1982) [15]. The last step is devoted to the realization of quality classes cartography.

3. Results and discussion

3.1 Hydrochemical quality

Piper and Schöeller-Berkaloff diagrams of surface water samples which are presented in (Figure 2) and (Figure 3) respectively, show that the set of the five dams in the region of Tensift are distributed predominantly in three facies. The first facies, Ca-Na-HCO_3-Cl-SO_4, is dominant in Al Massira dam. The Hassan 1er dam is well characterized by the second facies, Ca-HCO_3-SO_4. However, for Lalla Takerkoust, Yaacoub El Mansour and Sidi Mohamed Ben Slimane El Jazouli dams, the facies Ca-HCO_3-Mg is the most dominant.

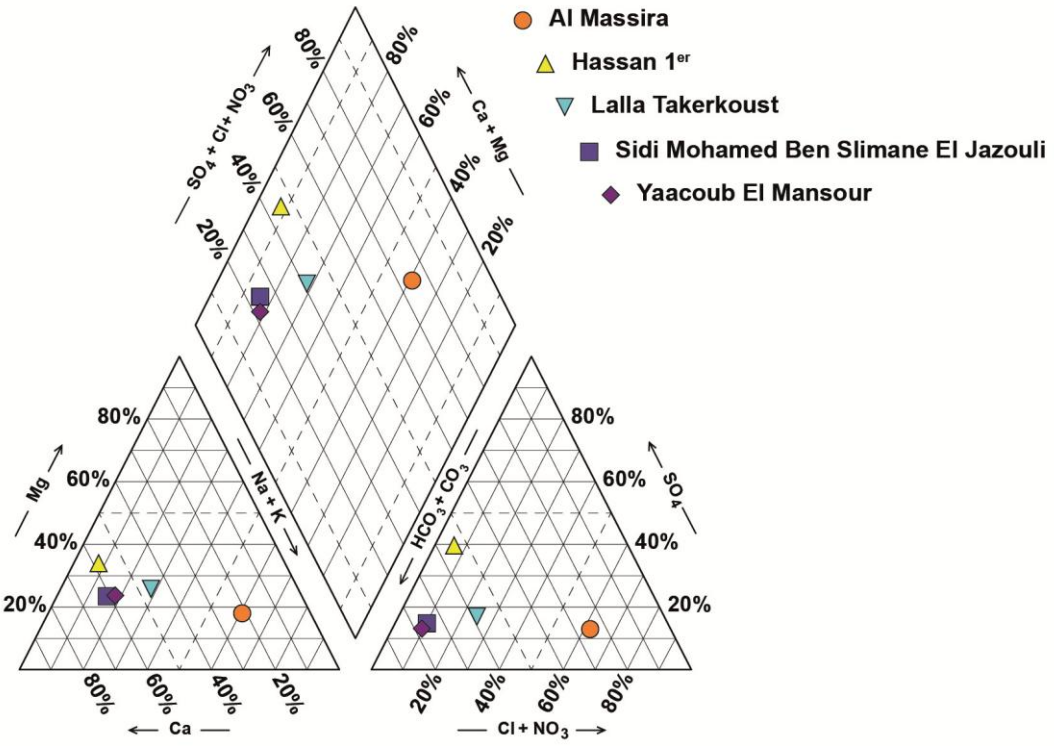


Figure 2 : Facies of surface water according to Piper diagram.

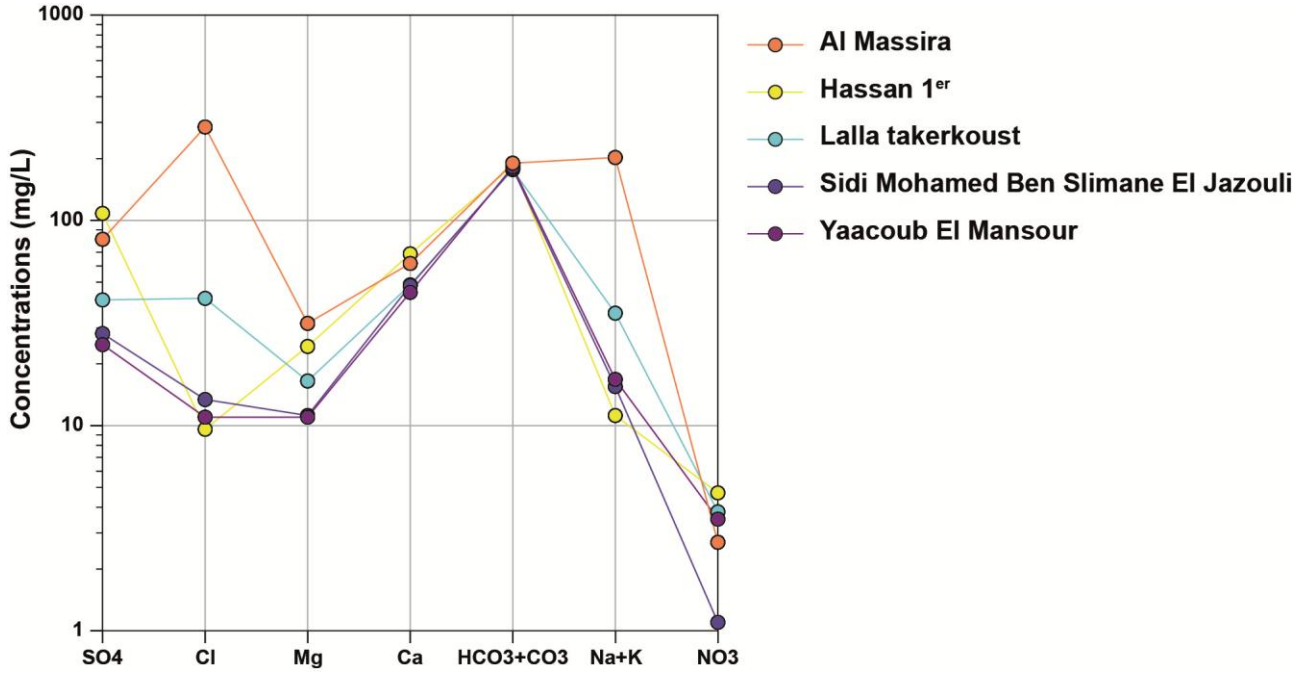


Figure 3 : Facies of surface water according to Schoeller-Berkaloff diagram.

The comparison of the concentration of hydrochemical parameters of the five dams has shown that the classification of these dams' waters, from the highest mineralization to the lowest, is, Al Massira, Hassan 1er, Lalla Takerkoust, Sidi Mohamed Ben Slimane El Jazouli and Yaacoub El Mansour. For groundwater samples, the facies Ca-Na-HCO_3-Cl-SO_4 is abundant according to Piper (Figure 4) and Schöeller-Berkaloff (Figure 5) diagrams.

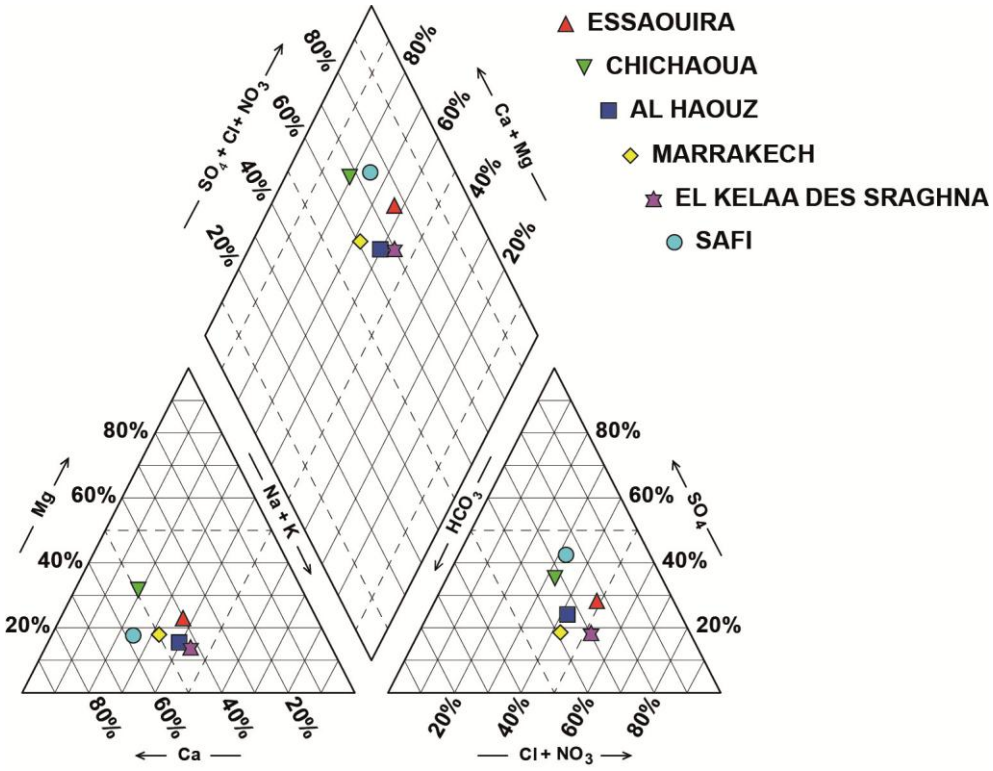


Figure 4 : Facies of groundwater according to the Piper diagram.

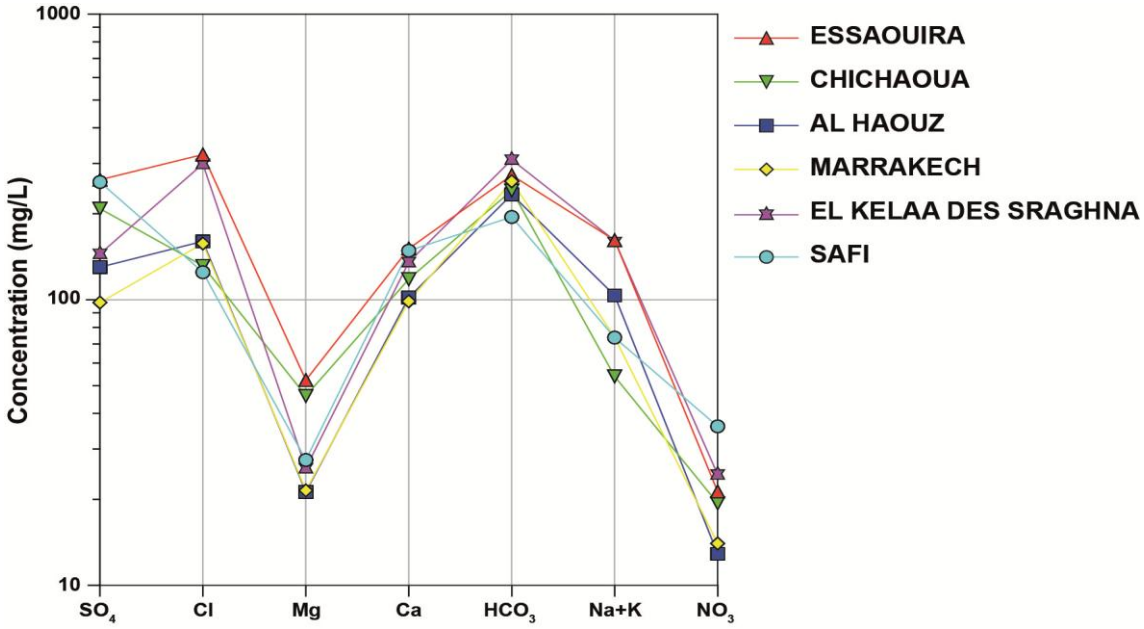


Figure 5 : Facies of groundwater according to the Schöeller-Berkaloff diagram.

3.2 Physico-chemical quality

The classification of surface water in agreement with Moroccan water quality evaluation system of 2002 (WQES 2002) has shown that waters of Al Massira, Hassan 1er, Lalla Takerkoust and Yaacoub El Mansour dams are characterized by a good quality, in contrast, Sidi Mohamed Ben Slimane El Jazouli is of medium quality. The class good represents 80% of dams' waters quality. By contrast, the medium class represents only 20 %. On the other hand, and in consonance with Moroccan water quality evaluation system of 2008 (WQES 2008), Al Massira and Sidi Mohamed Ben Slimane El Jazouli dams are of medium quality, however, Hassan 1er, Yaacoub El Mansour and Lalla Takerkoust dams are characterized by a good quality. The class good represents 60% and the medium class represents only 40% of the quality of dams' waters. These results show that the quality of surface waters according to the Moroccan water quality evaluation system of 2002 and 2008 is generally good.

The comparison between the results of the classification determined by the two Moroccan systems WQES 2002 and 2008, shows that the quality of Al Massira dam waters is decreased from a good quality according to the WQES 2002 to the medium quality according WQES 2008. This change is due to the addition of new parameters in WQES 2008 that can downgrade the quality of waters; in our case it is the conductivity (0.137 S/m). For the other dams (Hassan 1er, Lalla Takerkoust and Sidi Mohamed Ben Slimane El Jazouli) the quality remains the same for the two systems.

For ground waters, the classification according to Moroccan WQES 2002 reveals that physico-chemical quality has a deteriorating trend, this is due to the high content of mineralization parameters, conductivity, chlorides and nitrates. The water quality degradation classes of samples studied are, the medium class for 13 % of samples and the bad class corresponds to 1% of the samples. The class very bad is not observable under this system. In contrast, according to Moroccan WQES 2008, and saw the addition of new parameters, we note the emergence of the class very bad. This class corresponds to 1% of the samples studied. For the other classes, it is found that the bad and medium classes characterize respectively 4% and 7% of the samples. Nonetheless, in agreement with French WQES 2003, 7% of samples are characterized by the bad class and 3% of the samples to medium class, the comparison between the three systems shows that French WQES 2003 and Moroccan WQES 2008 are more penalizing than Moroccan WQES 2002.

3.3 Surface water biological quality

The determination of chlorophyll (a) concentration allows the estimation of the biomass and the intensity of the algal activity in the waters. Average concentrations of chlorophyll (a) in Al Massira (6µg/L) and Lalla Takerkoust (5µg/L) dams' waters are higher than those in Hassan 1er (3µg/L), Yaacoub El Mansour (2µg/L) and

Sidi Mohamed Ben Slimane El Jazouli (2µg/L) dams. During the study period from 2003 to 2012, the planktonic classes: Chlorophyceae, Diatoms, Cyanophyceae and Dinophyceae are always present in all the retention of dams, with a dominance of Chlorophyceae and Diatoms classes. In Al Massira, Hassan 1er, Lalla Takerkoust and Yaacoub El Mansour dams Cryptophyceae class is presented with a low percentage. However, In Sidi Mohamed Ben Slimane El Jazouli dam, we noted the absence of this class. In Al Massira, Hassan 1er and Sidi Mohamed Ben Slimane El Jazouli, we noted the presence of Chrysophyceae class with a low percentage. The Euglenophyceae class is present only in the Al Massira dam (Figure 6).

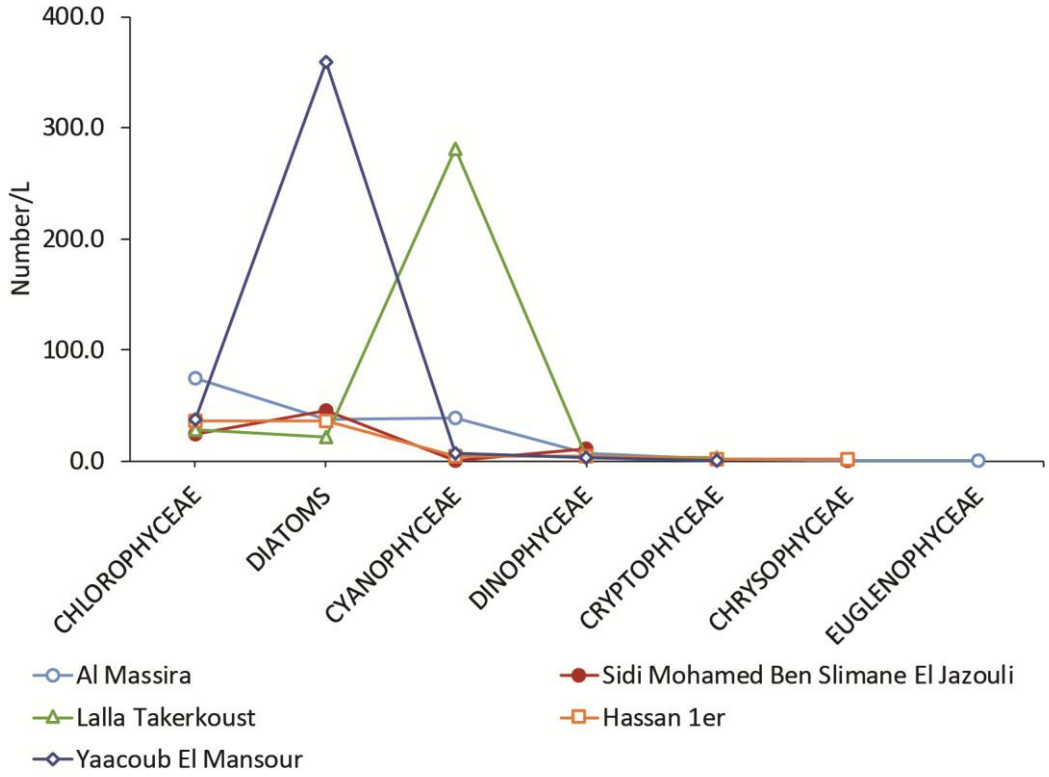


Figure 6 : Evolution of planktonic number in dams' waters.

Chlorophyceae, Diatoms, Cyanophyceae and Dinophyceae classes have a high algal production in Al Massira, Lalla Takerkoust and Hassan 1er dams with the dominance of Chlorophyceae and Dinophyceae classes. In Hassan 1er dam, the dominant classes are Diatoms, Cyanophyceae and Dinophycees. For Sidi Mohamed Ben Slimane El Jazouli dam Chlorophyceae, Diatoms and Dinophyceae classes represent the highest algal production, with the dominance of the Dinophyceae class. In Yaacoub El Mansour dam, Chlorophyceae and Diatoms classes represent the highest values of the production algal. In this dam waters the Diatoms class is the more dominant.

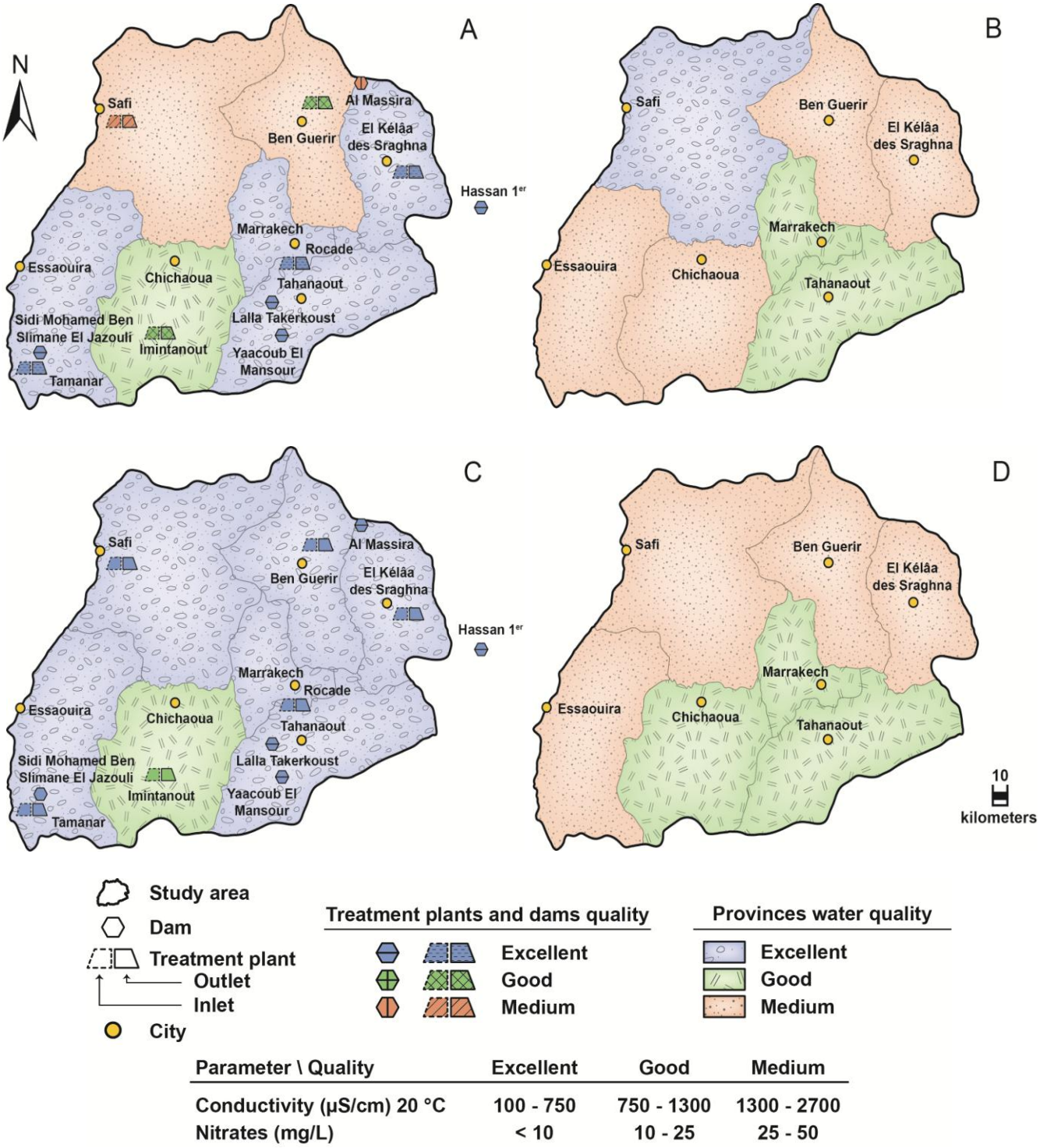
To assess the trophic status of dams' waters using the mathematical model of the OECD (1982), the average concentration of chlorophyll (a), total phosphorus and transparency, measured with the Secchi disc, are used. In this study, the trophic status of dams' waters studied in accordance with the OECD model (1982) has shown a tendency to eutrophication, which is in relationship with the intense activity of planktonic algae and the high content of the chlorophyll (a) [16].

3.4 Treated water Quality

Monitoring of treated water quality in Tensift region is done for six treatment plants, Ben guerir, Imintanout, El Kelaa des Sraghna, Rocade, Safi and of Tamanar. Parameters monitored during the period from 2003 to 2012 for each station are the Temperature, pH, conductivity, dissolved oxygen, Oxidability and nitrates. The evolution of these parameters at the inlet and the outlet of the six treatment plants during the period 2003 to 2012 has shown that water quality at the outlet of these plants is consistent with the Moroccan standard of water quality for human consumption (NM 03.7.001 (2006)).

3.5 Cartography

Cartography representation provides a quick overview and effective as well as the simplification of the phenomenon being studied. According to Moroccan WQES 2008 and during the period 2003 to 2012, the mean values of the classification results of conductivity (Figure 7-A,B) and nitrate (Figure 7-C,D) parameters are used to represent the quality of surface water and groundwater, respectively.



Parameter \ Quality	Excellent	Good	Medium
Conductivity (µS/cm) 20 °C	100 - 750	750 - 1300	1300 - 2700
Nitrates (mg/L)	< 10	10 - 25	25 - 50

Figure 7 : Cartography of water quality for, A : Surface water conductivity, B : Groundwater conductivity, C : Surface water nitrates, D : Groundwater nitrates

Conclusion

The study of surface and ground waters quality from 2003 to 2012, has allowed the determination of the overall quality status of surface and ground waters in Tensift region. The mineralization results have showed that the surface waters are characterized by Ca-Na-HCO_3-Cl-SO_4, Ca-HCO_3-SO_4 and Ca-HCO_3-Mg facies. In contrast, the mineralization of groundwater is characterized by the Ca-Na-HCO_3-Cl-SO_4 facies. The overall status of surface waters quality is generally good to medium, despite the trend to the degradation manifested by the high content of the chlorophyll (a) and the intense activity of planktonic algae, which requires the implementation of solutions to avoid the eutrophication risks on the quality and biodiversity in these waters.
The planktonic classes predominate in these dams are Chlorophyceae, Diatoms, Cyanophyceae and Dinophyceae. Trophic status results obtained using OECD (1982) model have shown that dams' waters have a tendency to eutrophication. The monitoring of treated water quality has confirmed that the quality at the outlet of these plants is consistent with the Moroccan standard of water quality for human consumption (NM 03.7.001 (2006)). The overall status of ground waters quality according to the three waters quality evaluation systems is generally excellent to good. Elsewhere, it is noted that there is a degradation tendency of approximately 12% of samples according to the three systems.

References

1. Momblanch A., Paredes-Arquiola J., Munné A., Manzano A., Arnau J., Andreu J., *Sci. Total Environ.* 503-504 (2015) 300-318.
2. Bernatowicz W., Wei A., Matschullat J., *Environ. Monit. Assess.* 159 (2009) 311-330.
3. Ballesteros E., Torras X., Pinedo S., García M., Mangialajo L., de Torres M., *Mar. Pollut. Bull.* 55 (2007) 172-180.
4. Bald J., Borja a., Muxika I., Franco J., Valencia V., *Mar. Pollut. Bull.* 50 (2005) 1508-1522.
5. Borja Á., Franco J., Valencia V., Bald J., Muxika I., Belzunce M. J., Solaun O., *Mar. Pollut. Bull.* 48 (2004) 209-218.
6. Vlachopoulou M., Coughlin D., Forrow D., Kirk S., Logan P., Voulvoulis N., *Sci. Total Environ.* 470-471 (2014) 684-694.
7. Myers D. N., Foundations of Water Quality Monitoring and Assessment in the United States. Elsevier Inc. (2015) 21-92.
8. Teixeira Z., Teixeira H., Marques J. C., *Sci. Total Environ.* 470-471 (2014) 1320-1335.
9. Xiao G., Feng M., Cheng Z., Zhao M., Mao J., Mirowski L., *Ecotox. Environ. Safe.* 111 (2015) 185-191.
10. Ishii S., Nakamura T., Ozawa S., Kobayashi A., Sano D., Okabe S., *Environ. Sci. Technol.* 48 (2014) 4744-4749.
11. Normatov P. I., Armstrong R., Normatov I. S., Narzulloev N., *Russ. Meteorol. Hydro+*. 40 (2015) 347-354.
12. High Commission for Planning, report on: Monographie de la Région Marrakech Tensift Al Haouz (2009) 130.
13. Japan International Cooperation Agency, Ministry of Territorial Development, Water and Environment, Hydraulic Basin Agency of Tensift, report on: Etude du plan de gestion intégrée des ressources en eau dans la plaine d'Al Haouz (2007) 138.
14. Ministry of Energy, Mines, Water and Environment, Hydraulic basin agency of Tensift, report on: Ressource en eau (2014) 183-204.
15. Cooperative Programme for Monitoring of Inland Waters (Eutrophication Control). Book on: Eutrophication of Waters: Monitoring, Assessment and Control. OECD. (1982) 154.
16. Blache U., Jakob T., Su W., Wilhelm C., *Plant Physiol. Bioch.* 49 (2011) 801-808.