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POTENTIAL IMPACT OF ANTHROPOGENIC ACTIVITIES ON GROUNDWATER IN THE TANGIER-TETOUAN-ALHOCEIMA REGION (MOROCCO)

IMPACT POTENTIEL DES ACTIVITES ANTHROPIQUES SUR LES EAUX SOUTERRAINES DANS LA REGION DE TANGER-TETOUAN-ALHOCEIMA (MAROC*)*

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ABSTRACT

The protection and preservation of natural environments, especially water resources, is a primary objective for national and global water services. The deterioration in groundwater quality is due to the effects of human activities: in particular industrial, agricultural and domestic activities. These anthropogenic activities release dangerous products and substances into the environment. The presence of these pollutants in groundwater poses a problem with the balance of water resources and poses a risk to human health, especially when it comes to the consumption of spring water in rural areas where the majority of the population obtains its water directly from the aquifer. The water table of the Tangiers-Tetouan-Alhoceima basin - the study area - is the most heavily used and its overexploitation is due to numerous individual motor pumps. Groundwater withdrawals are concentrated in rural areas and therefore cause

groundwater levels to drop. This slick has also been strongly affected by climate change.

Keywords: Human activities*;* Water resources; Deterioration; Groundwater; Human health; Tangier-Tétouan-Hoceima.

RESUME

La protection et la préservation des milieux naturels, en particulier les ressources hydriques, est un objectif primordial pour les services de l'eau au niveau national et mondial. En effet, la détérioration de la qualité des eaux souterraines est due aux effets des activités humaines : en particulier les activités industrielles, agricoles et domestiques. Ces activités anthropiques libèrent dans l'environnement des produits et des substances dangereux. La présence de ces polluants dans les eaux souterraines pose un problème sur l'équilibre des ressources hydriques et engendre un risque pour la santé humaine surtout lorsqu'il s'agit de la consommation des eaux de sources dans le milieu rural où la majorité de la population s'approvisionne directement de l'aquifère. La nappe phréatique du bassin de Tanger-Tétouan-Alhoceima, - la zone d'étude - est la plus sollicitée et son surexploitation est due à de nombreuses motopompes individuelles. Les prélèvements des eaux souterraines sont concentrés dans le milieu rural, ils provoquent par conséquent le rabattement des niveaux piézométriques de la nappe. Cette nappe a été également fortement affectée par les changements climatiques.

Mots clés : Activités anthropiques, Ressources hydriques, Détérioration, Eaux souterraines, Santé humaine, Tanger-Tétouan-Hoceima.

INTRODUCTION

Morocco's natural water resources are among the weakest in the world. Indeed, the potential of natural water resources is estimated at 22 billion m^3 per year, equivalent to 750 m^3/inhabitant/year, commonly accepted as a critical threshold indicating the appearance of shortages and latent water crises. More than half of these resources are concentrated in the northern basins covering nearly 7% of the national territory. This limitation of water resources is compounded by the deterioration in water quality as a result of increased pollution (MATEE, 2007).

However, the water sector still faces challenges related mainly to the scarcity of water resources due to climate change, the overexploitation of groundwater

resources, the low value of water resources, particularly in agriculture, and the deterioration of water quality due to delays in sanitation, wastewater treatment and the reuse of treated wastewater (DRPE, 2014).

The water table of the study area is the most stressed and overexploitation is due to numerous individual motor pumps. Groundwater withdrawals are concentrated in rural areas and therefore cause groundwater levels to drop. This slick has also been strongly affected by climate change (Soudi et al., 2002).

The Tangiers-Tetouan basin, where the study area is located, has attracted the attention of many researchers due to its geographical location and the importance of these water resources (El Gharbaoui, 1981; El Talibi et al. 2016; Saadi et al., 1999; Amharref et al.2006; Assine et al., 2006). In this article, we seek to complement previous work already carried out by posing as an objective to study the impact of anthropogenic activities on groundwater in the Tangiers-Tetouan region 5(Er-Raioui et al., 2012 ; Laghzal et al., 2016).

MATERIAL AND METHODS

Study Area

The region of Tangier-Tetouan (Figure 1), the capital city of Tangier covers an area of 11,570 km², representing 1.6% of the total area of the Moroccan Kingdom. It is bordered by the Mediterranean Sea to the north, the Atlantic Ocean to the west, the region of Taza-Al Hoceima-Taounate to the east and the Gharb-Chrarda-Beni Hssen South. From the geographical point of view, the Tingitane Peninsula is characterized by a structural entity that is the Rif area according to (APDN, 2007). Indeed, and outside the coastal plains areas geomorphology steep or heavily corrugated cover more than 80% of the region.

Tangiers, located in the Strait of Gibraltar between the Mediterranean and the Atlantic Ocean, approximately coincides with the basin of the river M'harhar and presents an alternation of valleys, covered mainly Quaternary alluvium, marl and sandstone hills.

Lower Basin Loukkos constituting the countryside the most developed in the region, thanks to good soils and abundant water and covering the clay alluvial plains and the sandy plateau of Larache.

Tangiers Peninsula is characterized by a dense hydrographic network in the form of Oueds with low and unsteady flow (El Yaouti et al., 2009).

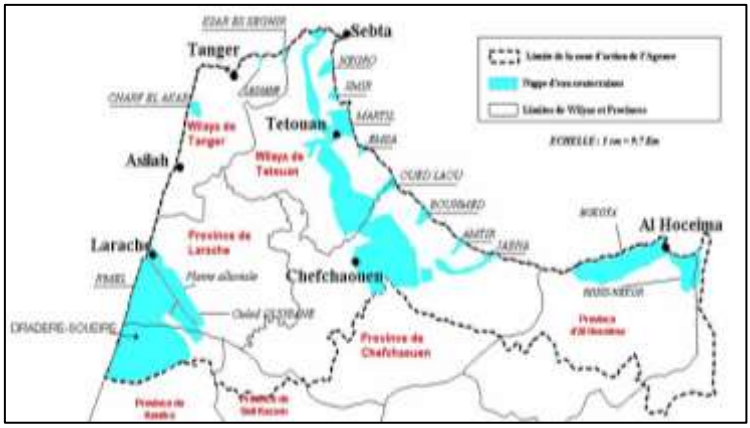

Figure 1: Map of groundwater tables in the area

Identification of different types of water pollution in the study area

Main sources of pollution

The diagnosis in the field made it possible to draw up an inventory of the various sources of pollution, which can be summarised as follows:

- Intensification of breeding operations (sheep and cattle),
- Market gardening, which uses large quantities of fertilizers in the form of manure and fertilizer,
- Rural discharges, which discharge domestic wastewater into the environment without prior treatment,
- Wild household garbage dumps,
- Domestic and industrial effluents,
- Poor waste management and household behaviour,
- Poor management of water points by households,
- The presence of small farms close to water points.

Pollution treatment

All these sources of contamination pose a threat to the water table in general and to the water points studied in particular. These sources, created in particular by anthropogenic activities, contribute to the pollution of surface waters (receiving environment of waste water and waste) and consequently promote the pollution of groundwater by different types of pollutants. These different

sources of pollution increase with demographic, economic and agricultural development.

The study of different sources of water pollution in the study area is also based on the activity reports of the Loukkos Hydraulic Basin Agency (ABHL, 2014 ; ABHL, 2010).

Statistical tool

The physico-chemical and bacteriological parameters were analyzed by the software used is the version Diagramme 9 and Geographic Information System (GIS).

RESULTS AND DISCUSSION

Pollution from domestic activities

The wastewater in the study area contains more than 99% water, with the remainder consisting of dissolved and suspended organic and inorganic matter and microorganisms (UNEP, 1999). It is these materials that give municipal wastewater its physical, chemical and biological characteristics. In addition, the quality of wastewater is marked by seasonal, daily and hourly variations. Concentrations also vary depending on whether the weather is dry or wet. It is also noted that these wastewater are urban in nature, rich in nitrogen and phosphorus, elements contributing to eutrophication on the one hand, and on the other hand, they offer favorable conditions for denitrification and dephosphatation.

It should be noted that a significant part of the raw wastewater discharged by the city of Tetouan is reused in agriculture. It is used to irrigate 70 ha in market gardening areas for forage crops (SEC, 1992). Such wastewater, when used in its raw state, constitutes a serious danger to public health, especially when harvested products are in the state (REEM, 2015).

The pollution loads found in the study area vary according to the volumes of wastewater discharged into the environment. The annual evolution of these pollutant loads is shown in Figure 2. The urban centre of the study area discharges a total annual volume of wastewater estimated for 1995 at 58 million m^3, in 2030 this volume would be estimated at 97 million m^3, of which about 90% is discharged into rivers. Indeed, pollutant loads discharged into the natural environment contribute to surface water pollution and consequently promote

groundwater pollution by different types of pollutants (Keddal, Yao N'dri. 2007).

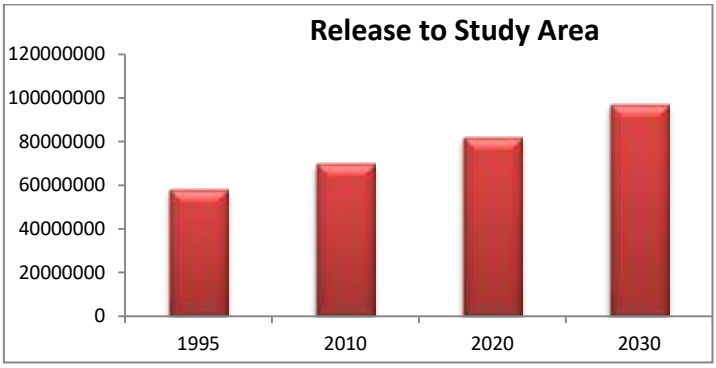

Figure 2: Evolution of wastewater discharges in the study area (ABHL, 2014)

A quantitative and qualitative assessment of the domestic effluents generated by the main urban centres of the Loukkos, Tangier and Mediterranean coastal basins is presented in Table 1.

Table 1: Estimated domestic pollution of cities with more than 10,000 inhabitants 2005 (Mehdioui, 2009).

Bassin	Volume_of wastewater m^3/j	DCO t/j	DBO_5 t/j	Phosphorous Materials t/j	Nitrogenous substances t/j
Tangérois	104013	51,6	17,2	0,86	8,6
Mediterranean Coastal	50159	27,4	9,2	0,46	4,6
Loukkos	5107	2,8	0,9	0,5	0,5

According to the ABHL (Agence du bassin Hydraulique de Loukkos 2010), this pollution can be considered low importance. Furthermore, its diffuse nature makes it difficult to treat and has a negligible impact on water quality due to the absence of direct discharge in most cases.

Industrial pollution

The assessment of industrial pollution is based on the determination of the characteristic parameters of the polluting activity for the different types of industry (ABHL, 2010). On the basis of the summary of all the documents

collected relating to industrial pollution in the study area, we identified the following sources of emissions: textiles, tanneries, paper mills, abattoirs, breweries, dairies and canneries.

The effluents generated by industrial activities are discharged directly into the three basins: Tangérois, Loukkos and Côtiers Méditerranéens. The waters contain concentrations of COD, BOD5, BOD5, TSS, PT, NTK (Table 2).

Table 2: Industrial pollutant load generated by industrial activities (REEM 2015)

	Tangérois	Loukkos	Mediterranean Coastal
Industrial pollution load (T of Organic Matter/year)	9 715	1 737	15 036

All these polluting activities for the different types of industries contribute to surface water pollution and consequently promote the deterioration of groundwater resources by different types of pollutants. The analysis of pollution in the region shows that the pollutant load is very high. Figure 3 gives an overall picture of the pollution loads generated by industrial activities.

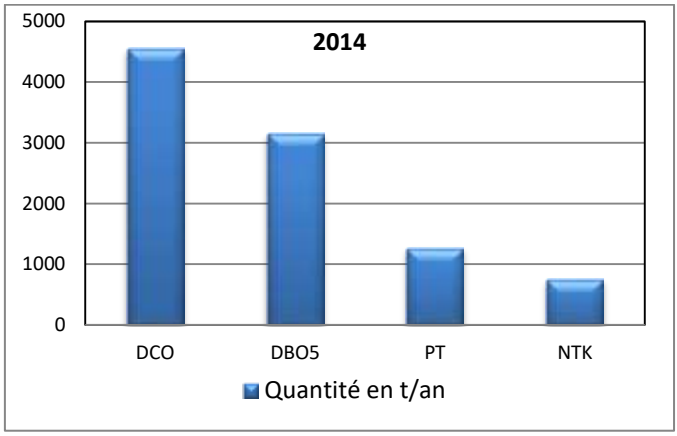

Figure 3: Polluting loads generated by industrial activities in the study area

The area most affected by industrial pollution in the Mediterranean coastal basins is the Martil river basin which receives 10375T Mo / year. This charge affects both rivers and the Martil aquifer. The pollutant load represents 56.76% of the overall pollutant load of the Mediterranean coastal basins.

The pollutant load emitted by isolated industrial units was estimated in 2004 at around 7,000 tonnes of oxidizable materials, more than half of which is directly in the natural environment, particularly in the subsoil (68%) and wadis (32%). If no action is taken, this pollution will reach 9,000 tonnes by 2020 and will irreversibly affect the quality of the receiving environments (Table 3).

Table 3: Distribution of industrial, connected and unconnected pollution (ABHL, 2010)

Junction	Reject (m^3)	%	Org.M (kg)	%
Pollution of "connected" Industrial Units	7.092.762	82%	3.691	52%
Pollution of the Industrial Units "running connected"	285.671	3%	259	4%
Pollution of Industrial Units "not connected"	1.236.463	15%	3.101	44%
Total	8.614.896	100%	7.052	100%

More than 50% of the organic load is released by the agri-food sector, mainly by sugar factories (45%). The rest is generated by slaughterhouses (13%), dairies (12%), cheese factories (9%) and oil mills (9%). The latter are concentrated in the Loukkos basin upstream of the Oued El Makhazine dam and constitute a real threat to the water quality of this dam.

The textile and leather sector is the second most polluting industry in the study area. This sector generates approximately 42% of the overall pollutant load released at the study area level. It is mainly concentrated in the city of Tangier.

In terms of chemical pollution, ceramic, surface treatment and chemical manufacturing units generate more than 80% of this pollution.

In 2011, approximately 88 modern and semi-modern units and 2,168 traditional units generate pollution from marine pollution. These oil mills are mainly concentrated between Chefchaouen and Ouazzane and at the level of Larache and Ksar El Kébir.

Agricultural pollution

Agricultural activities are a fairly important source of contamination of water resources. Pollution of waters of agricultural origin is generally linked to nitrates and/or phosphates (Hamzaoui et al., 2011). Agricultural intensification

is generally accompanied by a significant increase in fertilization, defined as the totality of amendments (farm and chemical fertilizers) made to land to provide plants with the additional nutrients necessary for their growth in order to improve and increase crop yield and quality (Keddal et al., 2007).

Nitrogen inputs come from several sources: soil organic matter through mineralization, organic amendments such as manure and other wastes, and nitrogen fertilizers.

The agricultural activity in our study area is concentrated at the level of the irrigated perimeter of Loukkos where the irrigated area is approximately 40,000 ha, of which nearly 30,000 ha are currently being developed into large hydropower plants.

The slick most affected by nitrogen pollution is the R' mel slick (Figure 4). This area is undergoing an intensive development of irrigation for market gardening crops that consume large quantities of fertilizer. The impacts of this pollution on water are usually manifested by an increase in nitrate content and salinity.

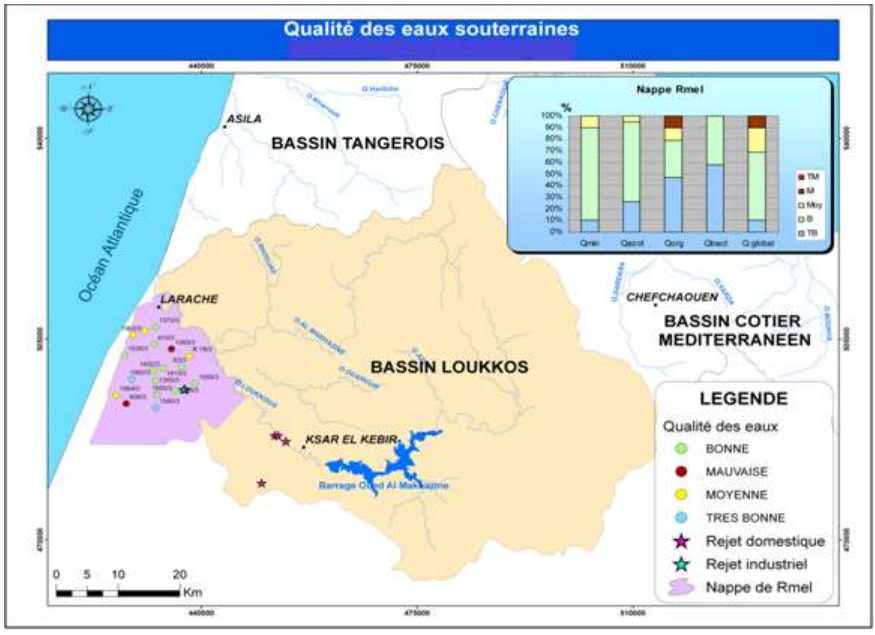

Figure 4: Quality status of the R' mel slick (Lukkos Basin) (Keddal, 2007)

Intensification of agriculture induces more or less nutrient losses and micropollutants through leaching or soil erosion, leading to degradations in the quality of groundwater and surface water, which are often worrying.

Some pesticides are characterized by their widespread toxicity spectra, bioaccumulation and persistence in different natural environments and food chains.

CONCLUSION

The diagnosis of the results reported in this article revealed that landfills are at the origin of surface water contamination and therefore leachate (ingression phenomenon) in groundwater, as well as disease spread and landscape degradation. The poor management of this human waste produced in the study area is likely to contribute to groundwater pollution and consequently to the deterioration of groundwater quality.

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