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# Monitoring the Mnasra groundwater quality regarding nitrate-related pollution. Gharb region-Morocco. 2011-2012.

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## Abstract
Water pollution by nitrate has become increasingly a serious problem in Mediterranean countries. Agricultural activities are probably the most significant anthropogenic sources of nitrate contamination in groundwater. Irrigation system is among the causes behind leaching of nitrate from soil surface to groundwater. Gharb plain is the largest agriculture irrigated zone in northwest of Morocco, well known for its intensive agricultural activities. The excessive use of fertilizers and manure under gravity irrigation system, presents a huge risk to groundwater quality especially for sandy-loam soils similar to those of the area. The purpose of the present study was the evaluation of the level of nitrate contamination in groundwater, and the attempt to relate it to the irrigation system adopted in Gharb area. A total of 90 water samples were collected and analyzed by ionic chromatography. Results showed that 86.7% of water samples have exceeded (54 – 400 mg/L) the limit of nitrate concentration (50 mg/L) fixed by World Health Organization (WHO). Attempts to focus on the main physical and chemical factors behind the magnitude of contamination are discussed.

***Keywords:*** *Gharb zone; groundwater; irrigation; nitrate; pollution; field condition*

## 1. Introduction
Pollution of groundwater by nitrate becomes a major challenge in Mediterranean countries. Mediterranean regions share common features such as arid and semi-arid climates, hot and dry summers, and mild and rainy winters. Actually, about 75% of the available water in the Mediterranean area is used for agricultural purposes [1]. Groundwater contamination by nitrates in areas of intensive agriculture has been largely discussed. According to the European Environment Agency, 20 % of European Union stations had wells with an annual mean in $NO^{-}_{3}$ concentration above the maximum allowable concentration (50 mg/L) [2]. In Africa, 50% of wells exceed the critical limit, and in some

cases it could contain higher than several hundred milligrams per liter [3]. In Gharb region of Morocco, nitrate concentration in some wells reach 119 mg/L due to intensive agricultural practices [4-5]. Crop irrigation is likely to promote groundwater nitrate pollution [6-7]. Irrigation consumes 64% of water in the region, being even close to 90% in many aquifers and basins [8]. Vulnerable aquifers are frequently located in zones of high water demand, such as coastal areas (Algeria, Italy, France, Morocco, Tunisia…). Besides, irrigated farming accounts for a large share of total water withdrawals: 83% in Greece, 68% in Spain, 57% in Italy, and 52% in Portugal [9]. In 2003, the total Moroccan irrigated area was 1 664 000 ha, of which 334 130 ha is served by perennial irrigation and 300 000 ha by seasonal one [10]. The drip by drip system is more and more encouraged by the Moroccan government via 80% of subvention. The mismanagement of irrigation can result in water misuse and also in strong negative impacts on the environment, such as nitrate pollution and eutrophication.

The objective of this work was to monitor the groundwater quality regarding nitrate pollution, in Mnasra groundwater over two agricultural seasons 2011 and 2012, and to study the impact of irrigation system on the quality of groundwater.

## 2. Materials and methods

### *2.1. Locality of the Field Sites*

The field sites are located in Mnasra area in Gharb region-Morocco, which is an important agricultural zone along Atlantic coast, with intensive usage of mineral and organic fertilizers. The surface area is of 600 $Km^2$, dominated by sandy and clay soils. The climate is Mediterranean with annual precipitations ranging between 480 and 600 mm, and the average temperature is 27°C in summer and 13°C in winter (Office Régional de Mise en Valeur Agricole du Gharb).

### *2.2. Sampling of Water*

Sampled wells were chosen at the proximity of farmer’s houses in the fields chosen randomly in the area (Fig. 1). Ten wells were chosen and sampled on February, March, April, May and July 2011, and March, April, May and September 2012. The well-waters are used for irrigation and human consumption.

A total of 90 samples of water were collected in clean plastic bottles. Samples were stored in the freezer (-20°C) until their analysis.

### *2.3. Analysis*

#### *2.3.1 pH and electrical conductivity measurements*

pH at laboratory and conductivity at 25°C were measured 24h after the sampling with a pH-meter Basic 20 and Cyberscan 510 conductomer respectively.

#### *2.3.2 Water analysis for nitrate*

Two mL of each sample were filtered through 0.45 µm polytetrafluoroethylene (PTFE) membrane, and were diluted 10-folds in order to avoid column obstruction. Then, nitrate analysis was carried out using ion chromatography Dionex ICS-3000 equipped with an AS11HC column (250 × 4 mm, i.d.) and conductometric detector. The mobile phase was KOH (25 mM) and flow rate was 1.3 mL/min. Method limit quantification was 100 µg/L. The analyses were done in Laboratory Interdisciplinary of

Environmental Continental – University of Lorraine- Nancy-France. The results are expressed as $NO^-_3$ mg/L.

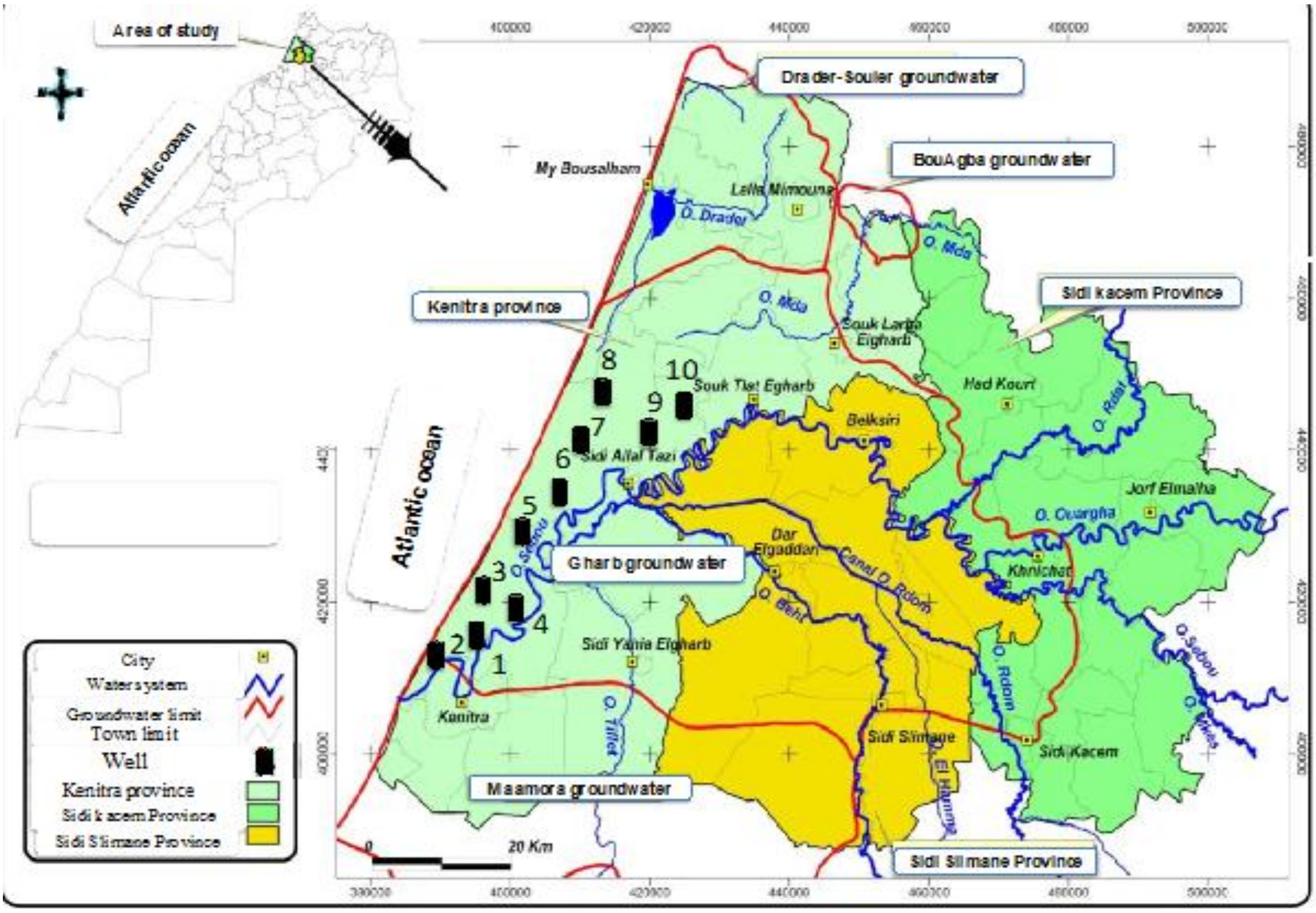


**Figure 1.** Location of the studied site and monitored wells

## 3. Results and Discussions

### *3.1. Agricultural Practices in Gharb Area*

Table 1 summarizes the main figures revealed by our survey related to different cultivation encountered in terms of production, and the quantity of N–fertilizer applied in Gharb. Actually, this region is well known by industrial crops: such as sugar beet, sugar cane, in addition to conventional crops such as cereals, and vegetables due to the appropriate climate and soil properties. The farms investigated are of small to medium size (3 to 10 ha), and are mainly active in livestock (sheep and cattle). During the agricultural season (February to July), 2 to 6 crops are encountered in the area cultivated depending of each field as consequence of rotation practices generally adopted by the farmers: Most fertilizers used in surveyed farms are ammonitrate 33.5%, NPK, urea (24 N Kg/ha/application), further livestock manure used (cattle and poultry) amounted to 33 tons/ha/year. The survey revealed also that during 2009, 27 000 ha of the area have been irrigated by gravity system irrigation, and 3 770 ha by drip by drip one [11]. All surveyed farms were equipped with drip by drip irrigation system. The volume of irrigation depends on climate. In winter period, the mean volume is 0.5 L/hour at 10 cm distance between drippers during 2 hours per day, while in summer period; the volume is 1 L/hour for each 10 cm during 2 hours per day.

**Table 1.** Main crop installed quantity of production and quantity of N-fertilizer used in Gharb perimeter-Morocco. 2004-2005

| Crop | Area of production (ha) | Quantity of production (T/ha) | Quantity of N-fertilizer (Kg/ha) |
|---|---|---|---|
| Cereals | 326000 | 1.6 | 155 |
| Leguminous | 41800 | 0.4 | 28 |
| Sugar beet & sugar cane | 26400 | 39.3 | 180 |
| Oleaginous | 36800 | 1.8 | 240 |
| Vegetable | 27096 | 36.1 | 80 |

[a] Gharb Agribusiness 2011

**Table 2.** The main properties of the studied wells. Gharb region-Morocco 2011-2012

| Wells | X-Lambert | Y-Lambert | Nature of water | Depth (m) | Manure (t/ha) | Irrigation L/ha | pHLab | Conductivity (µS/cm) at 25°C | Mean & SD[c] of $NO^-_3$ |
|---|---|---|---|---|---|---|---|---|---|
| W1 | 391991.161 | 409067.949 | Not drinking | 2 | - | - | 7.7 | 8642 | 319±51 |
| W2 | 390071.599 | 413337.873 | Drinking | 36 | 4 | $1^a/2.5^b$ | 7.6 | 541 | 68±14 |
| W3 | 391771.783 | 413614.739 | Drinking | 12 | 24 | $0.5^a/1^b$ | 7.6 | 674 | 125±13 |
| W4 | 394168.215 | 417554.849 | Drinking | 9 | 36 | $0.5^a/1^b$ | 7.4 | 759 | 110±16 |
| W5 | 395491.923 | 418874.323 | Drinking | 9 | 18 | $0.5^a/1^b$ | 7.5 | 656 | 86±10 |
| W6 | 398691.504 | 428781.736 | Drinking | 16 | 30 | $0.5^a/1^b$ | 7.5 | 594 | 105±14 |
| W7 | 402499.953 | 439314.801 | Drinking | 7 | 91 | $0.5^a/2^b$ | 7.3 | 1897 | 85±22 |
| W8 | 406584.485 | 447916.419 | Not drinking | 13 | - | - | 7.4 | 1583 | 39±12 |
| W9 | 412033.626 | 439619.244 | Drinking | 6 | 30 | $0.5^a/1^b$ | 7.4 | 1148 | 128±17 |
| W10 | 413982.935 | 441733.8 | Drinking | 4 | 30 | $0.5^a/0.5^b$ | 7.7 | 760 | 136±37 |

a: in winter period, b: in summer period
SD: standard deviation

Table 2 shows the mean values of pH, conductivity and quantities of manure used by field. The site 1 is located near of a waste deposit, which explains its high conductivity value. The depth of wells is ranging from 2 to 16 m, except for well 2 (36 m). pH of water is slightly basic (7.5±0.1) and the values of conductivity are high (957±483 µS/cm). This situation is likely related to the proximity of the coast to the studied area. Liu et al. [12] found that three independent variables–well depth, cropping activity, and water pH–have significant influence on $NO_3$–N concentration. They indicated that well water was more likely to have lower $NO_3$–N concentration when water pH was higher. However, our results didn't show any significant relationship between high pH at laboratory and low nitrate concentration. In fact, for same pH the amount of nitrate varied between sampling sites. This situation could be explained by the influence of other parameters such as localization and agricultural practices.

Bouarfa et al. [13] demonstrated that the distribution of salinity was mainly located in the groundwater, and confirmed by the evolution of the drainage water salinity during rainfall events

### *3.2 Irrigation System and Concentration of Nitrates*

The mean concentration of nitrate for the period covered during 2011 and 2012 are shown in figure 2. The values have exceed the limit of nitrate concentration (50 mg/L as $NO_3^-$), a health-based guideline fixed by World Health Organization (WHO), in 86.7% of water samples. In 2011, 84% of samples revealed high amount of nitrates, and only 16% respected the critical limit. In 2012, 90% of samples presented values above the guideline value. From December to February 2012, the area have known a period of frost, during which, the farms have lost their crops and, as a consequence, have reinstalled new crops. This situation could explain why nitrate concentrations were higher in 2012.

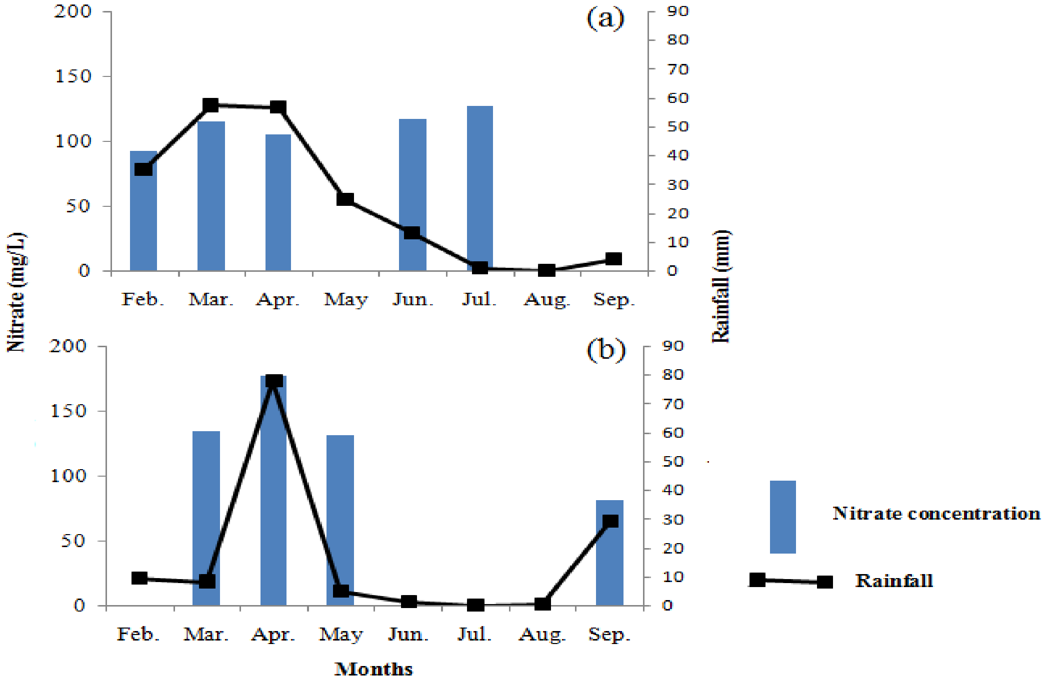


**Figure 2.** Mean values of nitrate concentration in wells (mg/L) and rainfall of 2011 (a) and 2012. (b)

The results demonstrated that nitrate concentration was high during the spring and summer periods. Similar results were found by Rutkoviene et al. [14] who reported higher nitrate concentration in the water of shallow wells in March to July period, and lower in September to February period. It is well documented that spring precipitation could carry the pollutants to the deeper layers of the soil. In summer, the high air temperature could create more favorable conditions to convert N-ammonia to N-nitrate [14]. There is the potential for nitrification/denitrification which may be enhanced by the temperature and increased bacterial activity in the soils and thus enhance nitrate leaching.

Nitrogen pollution could also be generated from intensive livestock breeding. Thus, Laftouhi et al. [15] had estimated the amount of nitrate generated by livestock in Essaouira basin (174 km west of Marrakech- Morocco). They reported that 40 470 of ovine and 4 270 of bovine in 75 000 ha generate a mean amount of 1.09 and 0.83 tons per day of nitrates respectively. In Gharb region, ovine and bovine represented 588 000 and 231 260 animals, which could generate a mean amount of 15.87 and 45.09 tons N per day respectively. Those values are 54 and 14 time higher than those of Essaouira due to the difference of livestock size.

As shown in table 1, the main crop installed in the area could also favorite the leaching of nitrate to groundwater. Indeed, Ju et al. [16] found that nitrate concentration in water samples exceed 50 mg/L under wheat-maize, apple orchard, and greenhouse vegetable system (especially in the last one 53%). They also reported that the majority of farmers do not take account of N inputs from manure and irrigation water when they decide how much fertilizer N to apply. Sign et al. [17] reported that the amount of N leached (18-81% of applied N under maize and 71-94% of applied N under wheat) depended on amount of N fertilizer. The same behavior could be expected from growers due to high level of illiteracy and low technical assistance.

Many studies demonstrated that irrigation had an important impact on nitrate pollution. Thus, a study performed by Burkrat and Kolpin [18] showed that the frequency of excess nitrate in a well is higher when irrigation was used, even at 3.2 Km distance from a well (41%), than when no irrigation was used (24%).

Accumulated nitrate is prone to leaching into the subsoil after high irrigation rates or heavy rainfall [16], and thus irrigation agriculture poses a high risk of groundwater nitrate contamination when combined with high fertilizer and water inputs [19-20]. Xiloyannis et al. [1] indicated that irrigation may pollute surface and subsurface waters through the transport, by surface runoff or deep percolation, of mineral elements (nitrates in particular), that have been applied to the soil surface.

In a study realized by Singh et al. [17] based on seven representative soil units under different crop rotations in the Kopias area of Greece, it was found that N was leached to deeper soil layers and to the unsaturated zone by both excess winter rainfall and spring irrigation of different crops. Semaan et al. [21] found that nitrate leaching always increases with decreasing values of water application efficiency and rapidly increases with the increase in water applied. Numerous studies reported that a part of the N applied as organic or chemical fertilizers is not consumed by crops, and a quantity of this unused N enters rivers and aquifers, this is due to intensive irrigation coupled with intensive fertilization and sandy soils are the important causes for nitrate leaching [22-23]. Vegetable crops have shallow root systems and are sensitive to water and nutrient supply; therefore farmers readily apply large amounts of fertilizer and frequently irrigate the fields, leading to leaching of $NO_3^-$N out of the root zone and into the subsoil or shallow groundwater [16]. The high nitrate concentration could present a serious threat of eutrophication for rivers and aquifers [24-25]. However, our results did not show close links between irrigation and this level of contamination. Indeed, table 2 shows no correlation between nitrate and irrigation (a) (p-Value at 95%=0.398), but there is a correlation between nitrate and irrigation (b) (p-Value=0.014), which may support our statement about irrigation. No statistical correlation was observed between nitrate levels and manure use (p-Value at 95%= 0.55). Other parameters could be considered including mainly hydrogeological properties of the area, climate change and bacterial activity.

## 4. Conclusion

Our Results showed that 86.7% of water samples from Mnasra groundwater have exceeded the limit of nitrate concentration (50 mg/L) fixed by World Health Organization (WHO). A total of ninety water samples were collected from 10 randomly wells and analyzed by ionic chromatography. The monitoring of groundwater quality demonstrated that the area is contaminated with nitrates (54 – 400 mg/L).

Irrigation system in Mnasra area doesn't appear the main cause for nitrate pollution. However, in many Mediterranean countries, irrigation requires special attention in order to increase water use efficiency and reduce environmental impacts.

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