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Full Length Research Paper

Evaluation of quality of irrigation water used for vegetables crops in the agricultural zone of Zbara (south-west of Algeria).

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In the agricultural region of Zbara (South - West of Algeria), under a very stern arid climate, with a strong evapotranspiration and a drought that last for years, the need to the irrigation is unavoidable for most crops, especially for vegetable growing reputed for their big requirements in water. The objective of the present work is to introduce a qualitative survey of vegetable crops irrigation water for the agricultural zone of Zbara. This can be done, by a physico-chemical and microbiological assessment of water for five wells and five basins with accumulation capacity of 100m^3. The physico-chemical analyses reveal neutral or slightly basic, not turbid water, mineralized fairly and rich in fertilizing elements (calcium, magnesium, potassium). The values of electric conductivity and the middle contents of the toxic elements (chloride and sodium) comply with the guides of the international regulation of irrigation water, with a Sodium Adsorption Ratio (SAR) lower than 1; however; this water can be dangerous on the long-term. The bacteriological assessment affirms the existence of the total germs (to 22 and 37°C) and of the total coliforms in the wells and the basins with a rate that passes the norms for the more part of these last. The research of the fecal contamination indicators shows the presence of *E. coli* in the accumulation of basins. Finally, we can say that the irrigation water of Zbara region are of medium to low quality and must be used with precaution.

Keywords: Irrigation water, vegetable crops, agricultural zone of Zbara, physico-chemical analysis, microbiological analysis.

INTRODUCTION

Water is life, as one has the habit to say. Indeed, this universal solvent is indispensable to the cellular formation seen its wealth in oxygen, in hydrogen and especially in carbon. Besides, by its role of vital interface between the biosphere, the man and the environment, on the one hand and it's practically renewable character with the passing of

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the generations, on the other hand, the lasting management and reasoned of this heritage imposes itself like a primordial preoccupation (Hertig and Fallot, 2006).

The underground water of the arid regions of Algeria is, generally, threatened qualitatively and quantitatively. Indeed, it is exposed to the pollutions from the surface (Degremont, 1989) and is damaged irreversibly by the saline water intrusion and the excessive exploitation of the water-bearing coats that excite the capacity of this one to keep water provoking, so, the forcing of the underlying layers (Remini, 2010).

While knowing that the underground water of Zbara zone, situated to the level of Bechar (Algerian southwest), represent the only water source of provision in drinking water and irrigation of the agricultural perimeters (FAO, 2005) and that this water is overexploited by the farmers whom has neither knowledge on the quantity of the groundwater nor on its quality, we judged the importance to measure and to characterize this water in order to define its role on the long-term, to maintain the viability and the productivity of the agricultural exploitations for vegetable farms vocation.

However, it is important to recall that irrigation in agriculture consists of controlling the supply of good quality water in sufficient quantity to the different crops in order to maximize yields (FAO, 2003). It also permits to assure the maintenance of the crops under intensive conditions, particularly when the local market permits to sell the production easily (FAO, 2005). For this fact, the irrigation requires a permanent provision for water quality and an equitable and lasting distribution system.

The objective of the present work is to study the physico-chemical and microbiological characterization of the irrigation water for vegetable production in the agricultural region of Zbara. The analyses have been done on a certain number of wells and accumulation basins that are open to air. The choice of the vegetable crops is on one hand, to their large consumption by the local population and their demand in water and their fragility to pathogenic microorganisms recovered potentially in a water of irrigation, on the other hand.

MATERIAL AND METHODS

Presentation of the study area

The region targeted for the present survey is the agricultural area of Zbara that is located in the Daïra of Lahmar in the north of Becharat 31°56'53.05 '' N of latitude and 2014'43.23 '' W of longitude. It is situated between the township of Lahmar to the south, the township of Mougheul to the north, the one of Sfisifa to the East and the local road of Lahmar-Mougheul to the west (Figure 1).

This zone is characterized by a desert climate, a strong aridity represented by a weak pluviometry that doesn't pass the 200 mm/year and a too elevated temperature during summer period as well as a cold winter season (Malki, 2013). The agricultural zone of Zbara is characterized by a considerable number of farmers in vegetable production, they occupy the surrounding of 150 ha, either 37.5 % of the total cultivate surface (estimated to 400 ha), and that since 1990. The farmers of Zbara provide 60 % of the local market in fruits and vegetables.

Sampling sites

The points of water collection have been chosen at random from five vegetable farms. We did two sampling for every point of water, the first to the level of the wells (underground water) and the second to the level of the basins (superficial water for the microbiological analyses) with a capacity of 100 m^3.

Sampling

The samples of water intended to the different microbiological and physico-chemical analyses have been collected in small bottles in glass sterile with a capacity of 500 ml and 1500 ml, respectively.
The samplings have been achieved according to the modes described by Theirrin et al, (2003) and Rodier et al. (2009). Note that the collection samples from the wells are taken directly from the source, on the other hand for the case of the accumulation basins, the bottle is immersed to a depth of 50 cm far from the sides (Rodier, 1984,; Rodier et al., 2005).

Physico-chemical Analyses

The physico-chemical profile of the different water samples have been determined by measuring some parameters: the pH, the electric conductivity to 20°C, the turbidity, and the global mineralization (Rodier et al., 2009).

The different anions and cations pressed: $\sqrt{Ca^{2+}, K^+, Na^+,}$ Cl -, CaCO3, Mg2+, SO4-2 have been determined according to the methods of chemical standards (French Association of Normalization, 1986,; Rodier et al., 2009; Ladjel, 2009). Whereas the sodium adsorption ratio (SAR) has been calculated by the following formula: SAR = $Na^+/(Ca^{2+}+Mg^{2+})/2$(Maynard and al., 1997).

Microbiological analyses

The microbiological characterization of the different samples of collected water has been measured by the numbering of the total germs and the research of the fecal contamination indicators (coliforms, *E. colis*, fecal

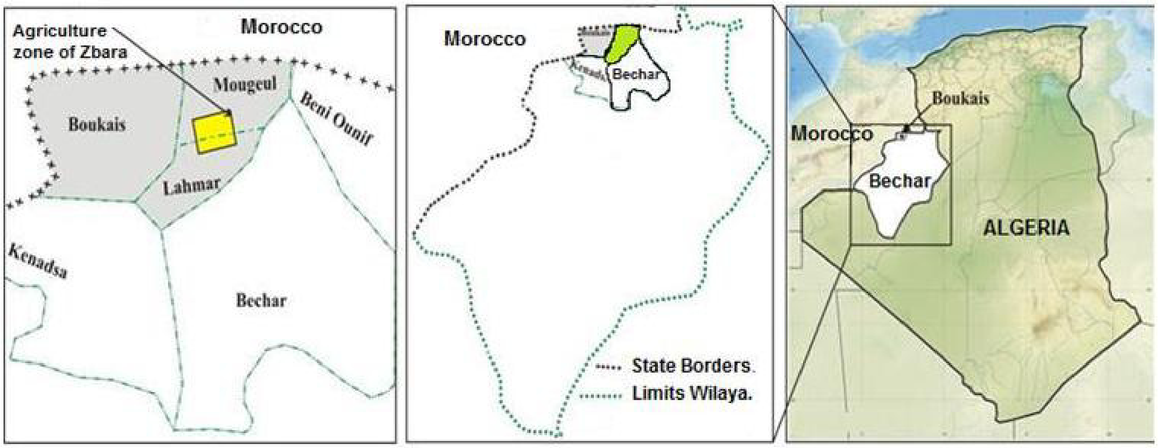

Figure 1: Location of the study area.

Table 1: Physico-chemical results of wells water.

	pH	E.C (µs.cm^{-1})	Mineralization (mg.l^{-1})	Solubility (NTU)	Ca^{+2}mg .l^{-1}.	K^{+} mg.l^{-1}.	Na^{+} mg.l^{-1}.	Cl^{-} mg.l^{-1}.	Mg^{+2} mg.l^{-1}.	SO_4^{-2} mg.l^{-1}.	SAR
E 1	7.58	712	509.73	0.625	98.35	1	20	71	27.74	134.58	0.45
E 2	7.43	1128	855.63	0.09	114.5	1	35.9	142	56.81	275.75	0.68
E 3	7.53	776	555.55	0.648	84.65	1	20	106.5	43.35	111.53	0.43
E 4	7.55	964	733.23	0.15	112.05	1	17.7	71	24.27	80	0.38
E 5	7.49	1008	764.61	5.92	139.45	1	26.81	142	24.64	114.41	0.54

streptococci and the *Clostridiums sulfatereducing*). The numberings as well as the presumptive tests have been achieved according to the classic methods described by Rodier et al. in 2009.

RESULTS AND DISCUSSION

Physico-Chemical Results

The obtained results are summarized in table 1.

The results of the pH for different samples of water don't show any meaningful difference. The measured pH is slightly neutral alkaline (7.43 to 7.58). These results are in adequacy with those of Tabouche and Achour that affirmed in 2004 that the underground waters of the Algerian Sahara have a pH neighboring of the neutrality of alkaline nature. The pH of the ground water of Zbara is within the normal range for irrigation water, which according to the international regulation, should be between 6.5 and 8.4 (Agbossou et al., 2003; Kessera, 2005).

The values recorded for the set of points of water show an electric conductivity underneath (712 to 1128µS.cm^{-1}) of those fixed by the Algerian norms for the consumption water (2800µS/cm), and by the Moroccan norms for irrigation water (1200µS.cm^{-1}) (Algerian Official Journal, 2011,; D.R.P.W, 2007).On the other hand, the obtained results for the global mineralization (rate of saltiness) (509.73 and 855.63 mg.l^{-1}) show superior values or even twice the quality of the one required by the FAO(450 mg.l^{-1}) for water destined to the irrigation.

The exploitation of the electric conductivity results and those of the global mineralization proof that the ground water of the agricultural zone of Zbara is slightly salted, although the values recorded of the conductivity are below the advisable values. It can be considered slightly dangerous (Maynard and Hochmuth, 1997,; Doucet, 2006) but its use would be possible with precaution (Ayers and Westcot, 1989,; Kessera, 2005) for some non-sensitive crops, with the condition that the drainage of soil is excellent to preserve the underlying ground water and to avoid the accumulation of salts at the level of soil (Ayers and Westcot, 1989,; Maynard and Hochmuth, 1997,; Boeglin, 2000,; Kessera, 2005,; Doucet, 2006,; USAFID, 2015).Also the quantity of irrigation water should exceed the need of the crops to drag the salts below the root zone.

The obtained results show a weak turbidity to the level of the first four points of water collected with one interval of 0.09 and 0.648 NTU; however, we record a value of 5.92 NTU to the fifth point of water. Values are extensively lower than those required by the Moroccan regulation for the water of irrigation by sprinkling and gravity that are of 11 NTU and 21 NTU, respectively (D.R.P.W, 2007). According to Desjardins (1990); Kettab (1992) and Boeling (2000), among the general features of the underground water, it is necessary to keep its very weak turbidity.

The concentration of $Ca^{2+}$for the different analyzed samples, vary between a minimum of 84.65 mg.l^{-1} and a maximum of 139.45 mg.l^{-1}. Whereas the one of the Mg^{2+} varies between 24.27 mg.l^{-1} and 56.81 mg.l^{-1}. The obtained values are in adequacy with those required by the norms of the irrigation water that is fixed, according to Kessera (2005), between 0 and 20 me.l^{-1} for Ca^{2+} and between 0 and 5 me.l^{-1} for Mg^{2+}; while the FAO requires stricter thresholds (enters 0 and 400 mg.l^{-1}pour the Ca^{2+} and between 0 and 60 mg.l^{-1} for the Mg^{2+}) (Agbossou et al., 2003).

The calcium especially exists to the state of hydrogénocarbonates and in least quantity as sulphate, Chloride,… etc. We can consider that a water having content lower than 75 mg/l of CaCO3 or 30 mg.l^{-1} of Calcium, is a soft water, and if above these values, it is hard water (Rodier et al., 1996). According to the obtained results, we can conclude that the water of the region of Zbara is hard water (350 mg.l^{-1}<CaCO3 <650 mg.l^{-1} with a concentration in Ca^{2+} that varies between 84.65 mg.l^{-1} and 139.45 mg.l^{-1}). In this same sense, the calculation of the water toughness [TH = ($Ca2^{++}$ $Mg2^{+}$)*5 with 1°F = 10 mg.l^{-1} of CaCo3], allows us to confirm that it is a hard water (min 17.95 <TH>25.9 max, interval being located between 15 and 30.

The obtained results vary between a minimum of 80 mg.l^{-1}and a maximum of 275.75 mg.l^{-1}, this concentrations respect the recommended norms. Some authors notably, Couture (2006) and Doucet (2006) raise some problematic associated to the presence or the absence of the sulfate in the irrigation water. Couture (2006) indicates, also, that the irrigation of the crops with waters having some concentrations in sulphate inferior to 48 mg.l^{-1} can entail some deficiencies in this element. On the other hand, a quantity above 300 mg.l^{-1} can lead to some conditions, such as the change of the construction materials (corrosion of the storage reservoirs) and to accelerate the corrosion of iron (Rodier et al., 1996).

The recommendations for concentrations of the sulfates in the irrigation water according to Kessera (2005) are0 to 20 me.l^{-1} and 0 to 960 mg.l^{-1} for the FAO (Agbossou et al., 2003).

Potassium is one of the major elements that are necessary to the fertility of soil to assure good development of vegetables. The irrigation water must have, according to the FAO, a concentration in the range between 0 and 2 me.l^{-1} of K^{+} (Agbossou et al., 2003; Kessera, 2005). The analyzed samples present a concentration of 1 mg.l^{-1}, this concentration respect the norm.

Sodium is one of the most undesirable elements in irrigation water. This element originates from the change of the rock and the soil of the irrigation systems especially affects the permeability of soil and the infiltration of water when it is in large quantity (Saucier and al, 2008). Indeed, this element replaces the calcium and the magnesium adsorbed by the particles of clay and provokes the scattering of the soil particles. As a result of this fact, the bursting of the aggregated soil provokes a hard and compact soil that is dry and resistive to water (Couture, 2006).

Otherwise, although the permeability of the sandy soils cannot be affected as quickly as the one of the heavier soils when irrigated with a water of strong content in sodium, a potential problem due to this element can exist and persist with time (Saucier and al, 2008).

It is important to underline that a strong absorption of sodium, provokes the burning of plants and the singeing of foliage as well as a necrosis of tissue situated on the side of the leaves (Couture, 2006).

The obtained results of the assessment of sodium rate reveal that irrigation water contains between a minimum of 17.7 mg.l^{-1} and a maximum of 35.9 mg.l^{-1} of Na^{+}. These numbers don't pass the norms that require69 mg.l^{-1} for irrigation water of (D.R.P.W 2007). Kessera (2005) reported that the concentration of the Na^{+} must be between 0 and 40 me.l^{-1}.While the FAO declares active concentrations of 0 to 1062 mg.l^{-1} (Agbossou et al., 2003).

It is admitted that a water that contains high concentrations of sodium, calcium and magnesium should have a SAR<10 and do not pose a danger for any type of soils. On the other hand, for too weak concentrations of sodium, the SAR could be >10 and water will be prejudicial for soils and the crops, in this case, vegetables, if the concentrations in calcium and magnesium are very weak (Couture, 2006). The values of SAR for the different samples are between 0.38 and 0.68, these values respect the norms required by the FAO that is from 0 to 15. However, according to Kessera (2005), when the SAR is between 0 and 3 and that the electric conductivity is understood between 700 and 2000 µS.cm^{-1}s, the irrigation water must be used with a light restriction and moderation.

According to the diagram of Riverside (Figure 2), the irrigation water of Zbara is classified in the C3-S1 class; it is considered to be middle to low quality. Such water must be used with precaution and the drainage with suitable quantity of gypsum are obligatory.

It is well known that when present in the irrigation water, the chlorides can be absorbed by the roots of the plants and accumulate in the leaves to damage them while provoking some burns. When the irrigation is done by aspersion, the chlorides can damage the leaves by direct

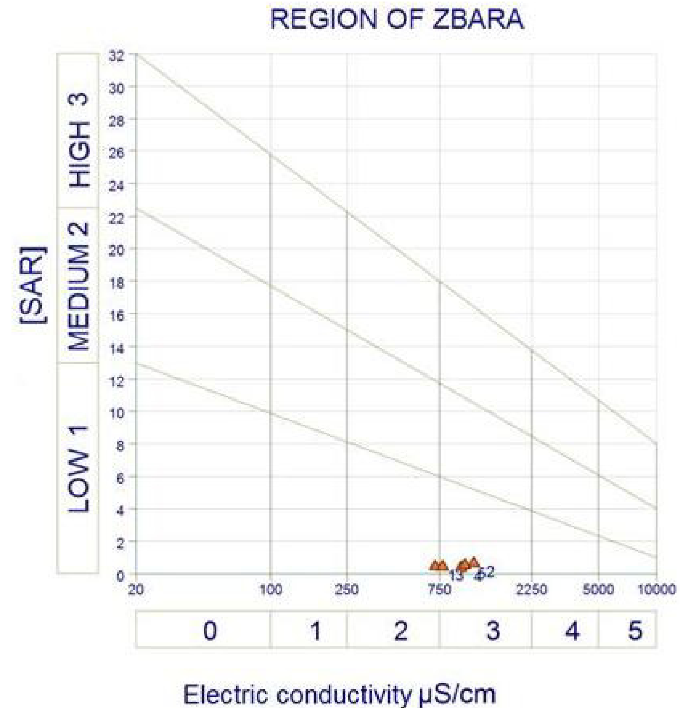

Figure 2: Diagramme de Riverside (Zbara).

absorption(Couture, 2006). For the set of the samples, the contents in Chlorides are to the norms: between 0 and 30 me.l^{-1} (Kessera, 2005) and/or 0 and 10 mg.l^{-1} for the FAO (Agbossou et al., 2003).

The obtained results for the dosage of the anions and cations in ground water of Zbara, allowed us to establish its chemical facies. The diagram of Piper allows us to confirm that this water is hyper chlorinated calcic.

Microbiological Results

The obtained results are summarized in table 2.

To value the microbiological quality of the irrigation waters of the region of Zbara better, we did the microbiological analyses for the wells and the basins. This in order to discover the possible contaminations caused by the environment and/or the staff of the exploitation or by animals.

The microorganisms developing at 20°C±2 are naturally present saprophytes in water; while, those developing at 37°C come from the fecal contamination of the warm-blooded live being (Figarella et al., 2007).

The exploitation of the different results shown in Table 2,reveal the presence of variable germs aerobes developing at 22 and 37°C. It is necessary to underline that the wells and the basin n° 05 presented the rates respectively most elevated 2.2×102 and 2.8×102 CFU.ml^{-1}s. These same points also presented contents of germs aerobes developing at 37°C passing the required norms. It is necessary to specify that the norm guides indicates that the rate of these germs must be lower or equal to 10 CFU.ml^{-1}s in 37°C and 100 CFU.ml^{-1}s to 22°C (Algerian Official Journal, 2000).

The total coliforms are used since a very long time as indicators of the microbial quality of water because of their indirect association to the pollutions of fecal origin. Most species of this group exist naturally in soil or in vegetation (Edberg and al., 2000). The sanitary risk that is directly related to the presence the group of total coliforms is therefore weak (El haissoufi et al., 2011).

The results displayed in the Table 2 record an important number of total coliforms and fecal coliforms in the water of the basins in relation to the one of the wells (ground water). The two elevated values of the total and fecal coliforms recorded for the basins in relation to those obtained for the wells are due to the stagnation of water in the basins, the exposure to the free air and its use for bathing in summer. These bad practices can entail a spectacular increase of total bacteria that are able to go from 10 to 10000 times of the initial number. The irrigation of vegetables from contaminated water with fecal coliforms poses a potential risk to the human health (Saucier and al, 2008).

The Algerian norms require the absence of the total coliforms, except in exceptional cases, but never in consecutive samples, can be tolerated a number lower

Table 2: Microbiological results of wells water and the basins of accumulation.

		Total germs *at 22°C (CFU/ml)*	*Total* germs *at 37°C (CFU/ml)*	total coliforms *(CFU/100ml)*	fecal coliforms *(CFU/100ml)*	*Streptococcifecal* D *(CFU/100ml)*	*Clostridiums sulfatereducing (CFU/20ml)*
E 1	Wells	10	3	0	0	0	0
	Basins	14	9	75	75	15	0
E 2	Wells	64	12	450	75	5	0
	Basins	90	80	1100	250	15	2
E 3	Wells	6	1	11	0	0	4
	Basins	20	12	1100	9	5	11
E4	Wells	10	8	4	4	2	5
	Basins	11	10	1400	300	8.8	7
E 5	Wells	220	180	39	36	2.2	0
	Basins	280	170	1100	150	2.2	2

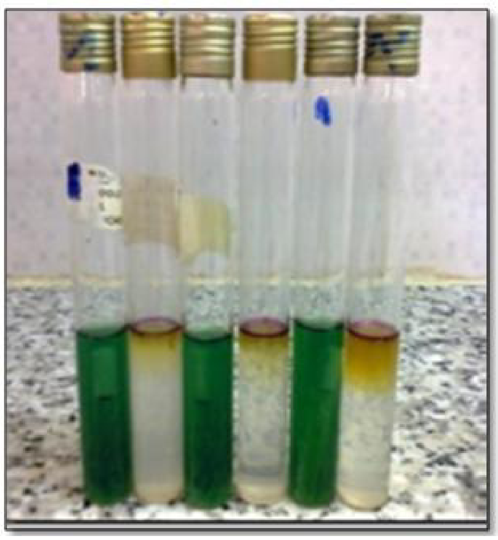

Figure 3: confirmatory test for the presence of *E. coli* on *EPT growth medium*

than 10 $CFU.100ml^{-1}$s in the non-treated water (Algerian Official Journal, 2000); while the Moroccan norm suggests a value limits 5000 of fecal coliforms in 100 ml of water destinies to the irrigation (USAID, 2015); whereas the WHO (2000) and USEPA (1973) require 1000 $CFU.100ml^{-1}$s.

Among the most dangerous fecal coliforms, *E. coli* must not be present in any irrigation water. The results of confirmatory test reveal a contamination of the water for all accumulation basins with this species (Figure 3). The question on the impact of the irrigation of vegetables with water that contains some *E. coli*, on the human health is very complex. Because only presence of these species doesn't indicate that it will be transmitted by the crops to human beings and that it represent a risk on their health. Besides, according to a survey made by the institute of research and development in agro environment (IRDA), it has been demonstrated that several factors enter in interaction and can influence this risk, either positively (to decrease the risk of *E. coli*) or negatively (persistence of the *E. coli*on vegetables). These factors are: the irrigation mode (aspersion, versus drip), the morphology of fruit or the vegetable irrigated (smooths or to complex surface), the delay between the moment of the last irrigation and the harvest, the meteorological conditions preceding the irrigation and the degree of contamination of the irrigation water in *E. coli* (Cote and al., 2007). According to Couture (2004), the irrigation of the crops with dripping system will prevent water to be in direct contact with the plantation which will reduce considerably, the risks of contamination of the crops.

Concerning the *Streptococci fecal* D in 100 ml of waters, their presence has been detected to the level of the wells 3 and 5 and in all accumulation basins (Figure 2). Specifying that the Algerian regulation requires the total absence of the *Streptococci fecal* D in 100 ml of waters (Algerian Official Journal, 2000) and that according to Rodier et al. (1996) the presence of *Streptococci fecal* D must accompanied with the presence of fecal coliforms to be certain of a fecal contamination of water.

Finally, the *Clostridium sulfate reducing* (CSR), the obtained results are in acceptable majority and that, in relation to the Algerian norms that tolerate a spore of Sulfate Reducing anaerobe (SRA) in20 ml of analyzed sample (Algerian Official Journal, 2000). Several authors, notably Ladjel (2009); El haissoufi et al. (2011) had reported that the spores of *clostridium sulfate reducing* contain a big variety of *Clostridium* as *C. perfringens*, *C. sporogenes*, *C. fallax*, *C. septicum*, *C. bifermentans*, *C. roseum*,…et that it is necessary to signal that the sulfate reducing anaerobic bacteria are often considered like witnesses of fecal pollution and their spores are spilled extensively in the environment.

CONCLUSION

In this survey, we measured and characterized water used in irrigation by the agricultures of the region of Zbara (South - West of Algeria). This issue represent a big importance because of the problems that the region have such as drought, non-availability of superficial water and the strong demand of water resulting from the agricultural activities. The assessment of the water quality by classic methods revealed a relatively middle saltiness. It remains however moderate for most wells situated in the studied agricultural perimeter, of which the water can be used for irrigation but with a light restriction. The data collected during this survey enabled us to collect a large amount of information about the microbiological quality of the irrigation water used in the region of Zbara. Although in general, the quality of water is acceptable, some cases justify that more attention is needed.

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