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Assessment of the surface water suitability for irrigation purposes: Case of the Guenitra dam watershed (Skikda, NE Algeria)

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Abstract

This paper aims to determine the water suitability for irrigation purposes originated from the Guenitra dam and its tributaries. This dam is located downstream of the Guenitra watershed (sub-catchment from the Guebli watershed). This watershed is considered among the highly influenced areas by anthropogenic activities including mostly urban wastes and leachate products of the abandoned polymetallic sulphide mine of SidiKamber. Two water sampling campaigns were carried out, during rainy and dry seasons, namely December 2017 and September 2019 respectively. The Physico-chemical parameters (hydrogen potential (pH) and electrical conductivity (EC) were measured in-situ while the major elements were analysed in the laboratory. The obtained results have been interpreted and evaluated by using indicators of water irrigation quality such as sodium absorption ratio (SAR) and percentage of sodium (%Na), in combination with electrical conductivity, in addition, the residual sodium carbonate (RSC) and the permeability index (PI). As a result, the water of Guenitra dam and its tributaries exhibit good to admissible quality for irrigation, excluding the waters of wadi Essouk tributary those are of poor quality due to direct discharge of the leachate product of SidiKamber abandoned mine, causing acidic character (3.09 to 5.30) as well as an important mineralization content (2550 to 2900 µS/cm) of water.

Keywords: water quality, irrigation, surface water, Guenitra dam, Skikda, Algeria.

1. Introduction

Algeria, similar to all the countries of the Mediterranean basin, has suffered water stress due to climate change, urban and demographic growth (Touati, 2010). Since the beginning of the 21st century, a new water policy has been undertaken by the Algerian government to mobilize new water resources by building dams. Currently, Algeria accounts for about 83 dams, which are an important source for drinking water supply, irrigation and industrial purposes (Allalgua et al., 2017; Touhari et al., 2018). The physicochemical composition of dam waters is mainly related to the nature of the geological formations crossed by the draining tributaries of the watershed (Lakhili et al., 2015; Ouhmidou et al., 20015; Bouguerne et al., 2017) and to the influence of anthropogenic discharges that lead to the degradation of the surface waters quality makes the wadi and dams water useless. Since 1980, the Skikda region has experienced several problems regarding water quality, in response to population growth, industrial and agricultural development (Bahroun et al., 2017). Urban and industrial discharges are the main causes, they are often dumped into rivers without any prior treatment (Belhadj and Boudoukha, 2014). The Guenitra dam watershed is considered among the influenced areas by anthropogenic activities, mainly the leachate product impact from the SidiKamberabandoned mine (Issaad et al., 2019). Previous studies carried out on the SidiKamberabandoned mine by (Boukhalfa, 2007; Medjram and Khalfaoui, 2014; Gherib et al., 2017; Issaad et al., 2019; Charchar et al., 2020) have been focused on acid mine waste in addition to the effects of heavy metals on the microbial quality of soils and surface waters of wadi Essouk, which drains the abandoned mine and discharges directly into the Guenitra dam. In this study, we report Physico-chemical data of the Guenitra dam water and its tributaries to shed the light on their suitability for irrigation, to qualify the possible risks of its waters on soil degradation, the effect of rainy and dry periods as well as the leachate product impact on surface water quality.

2. Materials and methods

2.1. Study area

The Guenitra dam, the studied area, is in the northeast of Algeria (Figure 1a), about 30 km south of Collo town (Wilaya of Skikda) (Figure 1b). It occupies the downstream part of its watershed (202 km2 of surface area) which is characterised by a dense hydrographic network. The main wadis that feed the Guenitra dam are wadi Fessa, wadi Charfa, wadi Magramene, wadi Malouh and wadi Essouk (Figure 1c). The dam (120 hm3of total capacity) ensures drinking water supply to Skikda city (37000 m3), the surrounding towns, the industrial zone (16000 m3) (Medjram and Khalfaoui, 2014) and the irrigation of EmdjezEdechich and the Saf-Saf valley perimeters (area of 5650 hectares) (Boukhalfa, 2007; Mecibah, 2017). Surface waters of Guenitra dam watershed are subjected to nocive anthropogenic activities such as, discharges of wastewater from OumToub and BeniOulbane townships and agricultural water as well as leachates product from SidiKamberabandoned mine, which could cause

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deterioration of the dam water quality.

According to the weather station of Guenitra dam, the mean annual rainfall in the study area is 650 mm/year (1989-2004) (Issaad et al., 2019). It is characterised by a Mediterranean climate with two distinct seasons;(i) rainy humid season extending from October to April with a maximum rainfall average of 78 mm/month and a minimum temperature average of 13.5°C/month; (ii) Dryless rainy season extending from May to September with low monthly average rainfall (20 mm/month) and relatively high monthly temperatures (≈ 25°C/month) (Mecibah, 2017).

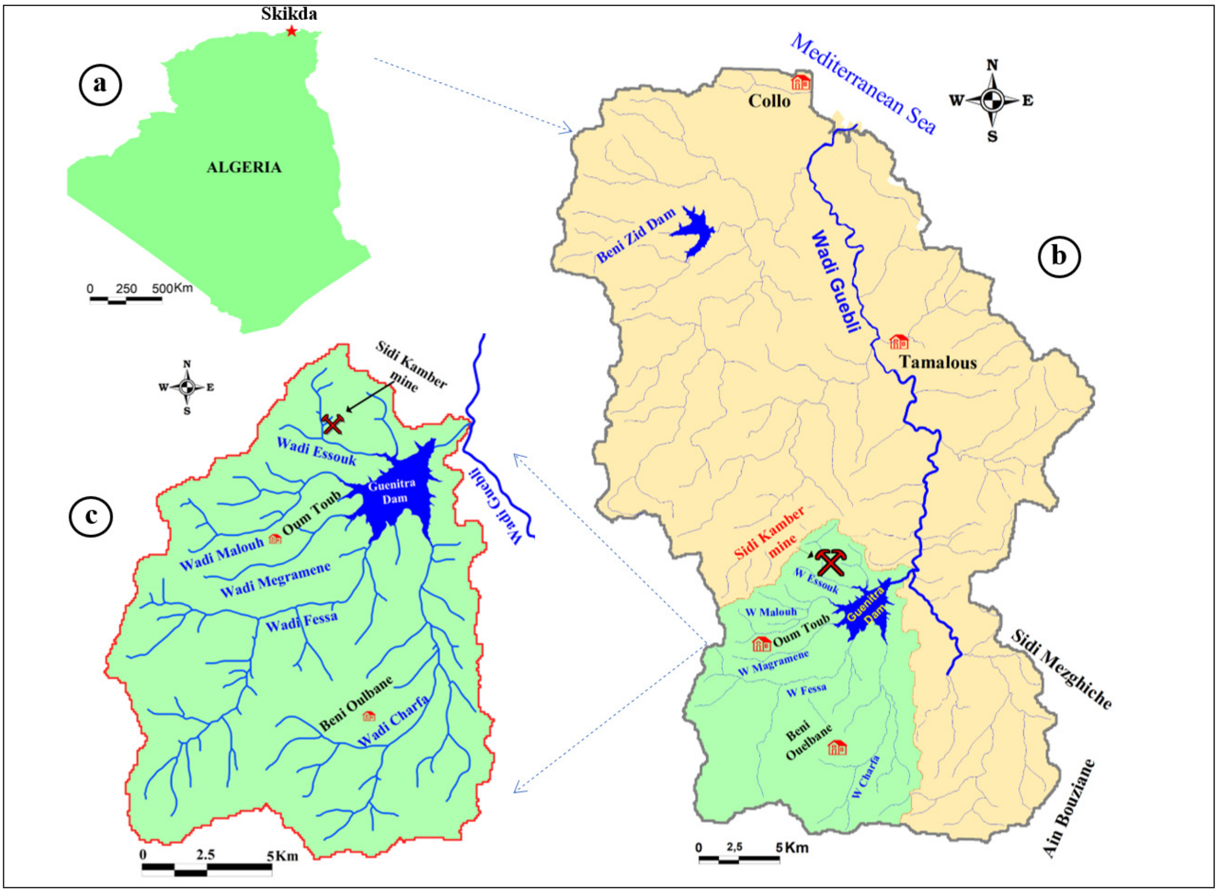

Figure 1. The geographical location of the Guenitra watershed; a. Map of Algeria, b. wadi Guebli watershed area, c. Guenitra watershed.

The Geology of the Guenitra watershed comprises different structural domains that belong to the so-called "internal zones" of the Maghrebid chain (Figure 2). According to Mahdjoub (1991) metamorphic rocks (Kabyle basement) of the Proterozoic to Lower Palaeozoic age are the most widespread and are surmounted by their Mesozoic calcareous cover (calcareous chain). In addition, Tellian units and flysch formation could also be present with a lesser importance. The Kabyle basement formations, mainly represented by gneisses and different types of schists, outcrops in the northwestern part (Figure2). Although, in the best part of the area, it outcrops as tectonic windows (Mahdjoub, 1991). These metamorphic formations host the Pb-Zn-Fe-Ba sulphide mineralization of SidiKamber Igneous rocks, solely represented by microgranites, are less widespread and are intruded in the Kabyle basement as a dyke shape. The Flysch formations of cretaceous ageoccupy the core of the watershed while the upstream part is dominated by carbonate formations (marl, limestone, marly limestone) of the Tellian units. The Numidian nappe of Miocene age is the most recent formation, it occupies the upper parts, therefore it covers all the older formations mentioned above.

The SidiKamber abandoned mine (North-West of the Guenitra dam) has been installed above the Kabyle basement. It should be noted that the deposit is composed of a series of massive sulphide veins scattered on both sides of the Essouk wadi. The sulphide mineralization is represented by galena (PbS), sphalerite (ZnS), pyrite-marcasite (FeS_2) and barite ($BaSO_4$) (Issaad et al., 2019). In 1976, mining activities of the Pb-Zn deposit have been ceased, since the only barite has been mined by open-pit until 1984, when the mine was definitively closed, however, the resulted leachate products have continued to flow into watercourses without prior treatment (Boukhalfa, 2007).

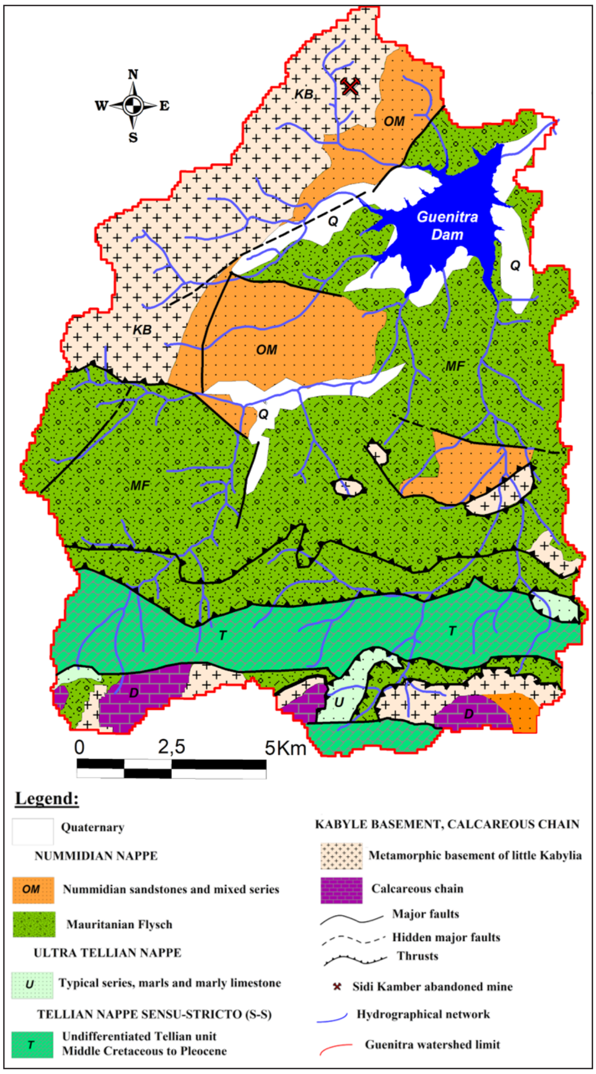

Figure 2. Geological map of the study area (Vila, 1980).

2.2. Sampling and analysis methods

For a good spatio-temporal characterization of Guenitra watershed water chemistry and its dam, two water sampling campaigns were carried out; (1) during the rainy season (December 2017) where the effect of dilution is important, and (2) during the dry season (September 2019) where the effect of dilution is negligible. During the two campaigns, 17 samples were collected from 10 sampling sites (Figure 3) where: eight (08)sites are located in the dam's tributaries to characterize the water inflows from the dam, one (01) site located in the dam lake (near the dam seawall) to evaluate the quality of the dam water which is used for irrigation purposes, and the last station located in the downstream (after the dam) to evaluate the quality of the dam water discharged into wadi Guebli (Figure 1b). Three (3) samples were not collected: one (O2) during the September 2019 campaign and two (O9 and B1) during the December 2017 campaign.

The samples were preserved according to Rodier et al. (2009). In-situ measurements of the physico-chemical parameters (hydrogen potential (pH) and electrical conductivity (EC)) were done using the Hanna portable pH-metre (HI 8424) and conductivity metre (HI-8733).

The major chemical elements analysis (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, HCO_3^{-} and NO_3) was carried out at the Geological Engineering Laboratory (LGG) of Mohamed Seddik Benyahia-Jijel University using a spectrophotometer (UV 1600 PC), flame spectrophotometry (AFP 100) and volumetric titration. The protocols and methods of chemical analysis are done according to Rodier et al. (2009). The verification of analytical error of analysed ions concentration was done by the electro neutrality (charge-balance error) according to the following equation:

$$CBE = \frac{\sum cations - \sum anions}{\sum cations + \sum anions} \ x\ 100$$

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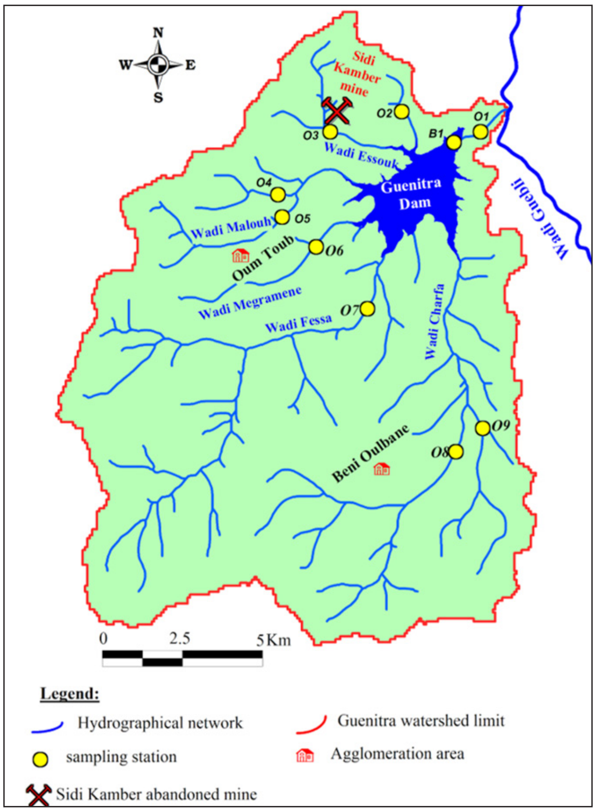

Figure 3. Water sampling map in Guenitra watershed.

3. Results and discussion

Results of physico-chemical analyses of Guenitra Dam surface waters and its tributaries of the two campaigns (December 2017 and September 2019), as well as the irrigation water quality indicators (SAR, %Na, RSC and IP) are shown in Table 1.

Table 1. Physico-chemical parameters of surface waters of Guenitra watershed.

Campaign	Samples	EC	pH	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl-	SO_4^{2-}	HCO_3^{-}	CO_3^{2-}	NO_3^{-}	SAR	%Na	RSC	IP
		µS/cm	/	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L	/	%	meq/L	%
First Campaign (December 2017)	O1	740	7.95	1.60	3.65	2.87	0.12	3.20	1.23	2.8	0	0.01	1.77	36.33	-2.45	55.16
	O2	896	7.93	1.60	4.78	3.28	0.12	3.70	1.14	3.08	0	0.17	1.84	34.71	-3.30	51.48
	O3	2550	5.30	10.42	12.56	4.88	0.16	6.35	1.35	0.16	0	0.09	1.44	17.99	-22.82	18.84
	O4	1856	7.81	2.24	9.88	3.43	0.07	9.50	3.11	4.00	0	0.21	1.40	22.43	-8.13	34.76
	O5	1160	7.8	3.21	3.89	3.83	0.34	3.60	0.76	5.64	0	0.01	2.03	36.99	-1.46	55.07
	O6	1604	7.85	3.29	4.13	6.62	0.44	6.30	2.48	6.24	0	0.01	3.44	48.77	-1.18	62.98
	O7	1008	8.39	3.77	4.94	2.53	0.08	1.90	2.72	3.92	0.1	0.19	1.21	23.06	-4.69	39.80
	O8	1750	7.72	8.82	5.51	4.96	0.32	6.30	2.97	6.48	0	0.17	1.85	26.90	-7.85	38.28
Second Campaign (September 2019)	O1	653	7.64	2.57	3.04	1.72	0.12	2.90	0.81	3.16	0	0.02	1.03	24.64	-2.45	46.99
	O3	2900	3.09	11.86	1.68	4.31	0.20	4.70	12.98	0.00	0	0.01	1.66	24.98	-13.54	23.89
	O4	2900	7.62	5.21	15.28	7.48	0.26	14.20	2.12	11.2	0	0.01	2.34	27.42	-9.29	38.35
	O5	1400	7.88	3.37	5.68	5.52	0.55	4.10	1.21	9.2	0	0.01	2.60	40.18	0.15	56.57
	O6	2190	7.70	4.09	4.16	6.59	0.78	10.00	1.03	5.12	0	0.01	3.25	47.19	-3.13	56.69
	O7	1200	7.73	2.32	6.16	3.06	0.13	3.60	2.54	5.00	0	0.01	1.49	27.35	-3.48	45.35
	O8	800	7.85	2.24	2.40	2.84	0.07	2.50	0.63	4.2	0	0.01	1.87	38.58	-0.44	64.70
	O9	830	7.80	2.97	2.72	2.77	0.21	2.70	1.13	4.28	0	0.01	1.64	34.38	-1.41	55.84
	B1	620	8.69	1.76	2.32	1.73	0.13	2.80	1.26	2.32	0.2	0.01	1.21	31.26	-1.56	54.70

3.1. Physico-chemical parameters of surface waters

Statistical analysis of surface waters of Guenitra watershed in terms of maximum (max), minimum (min), standard deviation (ST.D.) and mean values are shown in Table 2.

pH values of waters for all tributaries of the dam's watershed range from 7.62 to 8.39 (avg. 7.83), which is acceptable compared to the acceptable pH limit for irrigation water (6.5to 8.5) according to the Food and Agriculture Organization of the United Nations (FAO,1985). The dam water is slightly alkaline (pH of 8.69). However, the pH of wadi Essouk waters, which drains the abandoned mining area of SidiKamber, is very acidic (3.09 to 5.3) due to the oxidation of the sulphide minerals and the generation of the acid mine drainage (Issaad et al., 2019). Irrigation with acid and mineralized water leads to the degradation of soil structure, the reduction of biological activities and an increase in the risks of induced toxicity (Lal, 2015). Besides, when the pH values exceed 6.0 the repulsive force generated by the negative charges on soil particles decrease the permeability index resulting in accelerated erosion by water (Matsumoto et al., 2018).

Electrical Conductivity (salinity) values range between 620 to 2900 µS/cm (avg. 1474 µS/cm) (Table 2) indicating that the waters are lightly mineralized to mineralized. The high electrical conductivity values were recorded in the main wadis; wadi Charfa (1750 µS/cm), wadi Magramene (2160 µS/cm), wadi Malouh (2900 µS/cm) and wadi Essouk (2550 to 2900 µS/cm). They are more mineralized in the dry season (September 2019) than in the rainy season (December 2017). According to FAO (1985), the dam waters and their tributaries are acceptable for irrigation (EC < 3000 µS/cm as limit value).

Table 2. Statistical analysis of surface waters of Guenitra watershed.

Parameters	Units	December 2017(8 samples)				September 2019(9 samples)				Mean
		Min	Max	Mean	ST.D	Min	Max	Mean	ST.D	
EC	µS/cm	740	2550	1485	606	620	2900	1546	930	1473
pH	/	5.30	8.39	7.44	0.95	3.09	8.69	7.07	1.62	7.46
Ca^{2+}	meq/L	1.60	10.42	4.37	3.36	1.76	11.86	4.04	3.12	4.21
Mg^{2+}	meq/L	3.65	12.56	6.17	3.26	1.68	15.28	4.83	4.21	5.50
Na^{+}	meq/L	2.53	6.62	4.05	1.35	1.72	7.48	4.00	2.10	4.03
K^{+}	meq/L	0.07	0.44	0.21	0.14	0.07	0.78	0.27	0.24	0.24
Cl^{-}	meq/L	1.90	9.50	5.11	2.45	2.50	14.20	5.28	4.07	5.20
SO_4^{2-}	meq/L	0.76	11.35	3.47	4.09	0.63	12.98	2.63	3.93	3.05
HCO_3^{-}	meq/L	0.16	6.48	4.04	2.10	00.00	11.20	4.94	3.41	4.49
CO_3^{2-}	meq/L	00.00	00.10	00.01	00.04	00.00	00.20	00.02	00.07	00.05
NO_3^{-}	meq/L	0.01	0.21	0.12	0.09	0.01	0.02	0.01	00.00	0.07
SAR	/	1.21	3.438	1.96	0.69	1.03	3.25	1.94	0.71	1.89
%Na	%	17.99	48.77	31.40	10.12	24.64	47.19	33.44	7.8	31.95
RSC	meq/L	-22.82	-1.18	-6.50	7.11	-13.54	0,15	-3.93	4.53	-5.14
IP	%	18.84	62.98	44.55	14.29	23.89	64.70	49.23	12.26	47.03

Chloride and bicarbonate ions are present in most samples, the average chloride and bicarbonate contents varied respectively from 5.11 to 5.28 meq/L and from 4.04 to 4.94 meq/L, particularly recorded in the wadis Fessa, Charfa, Magramene and Malouh. On the other hand, sulphate ions are dominant especially in the water of Essouk wadi with average contents oscillating between 2.63 to 3.47 meq/L. Regarding cations, magnesium is the most important element with average concentrations ranging between 4.83 and 6.17 meq/L (Table 2). While calcium and sodium contents varied from 4.04 to 4.37 meq/L and from 4.00 to 4.05 meq/L respectively.

The nitrate concentrations recorded in this study are low and range between 0.01 meq/L and 0.21 meq/L (avg. 0.06meq/L) (Table 2). While carbonate ions are present only in wadi Fessa water (0.1 meq/L) during the first campaign (December 2017) and in the dam water (0.2 meq/L) during the second campaign (September 2019) (Table 2).

3.2. Hydrogeochemical facies

To know the hydrogeochemical regime of the studied area, analytical data obtained from the hydrochemical analysis are plotted on the Piper tri-linear diagram (Piper, 1944) to deduce the hydrogeochemical facies.

This diagram reveals a variability of chemical facies relative to the Guenitra watershed waters with three distinct groups (Figure 4). This variability could be explained, in part by the geological nature of the terrains crossed and also to anthropogenic pollution : (i) calcium-magnesium bicarbonate facies (G1: wadi Fessa and wadi Charfa) due to the dissolution of carbonate formations of SidiDriss mountains; (ii) sodium-calcium chloride sulphate facies (G2: wadi Magramene, wadi Malouh and Guenitra dam) linked to urban discharges from neighbouring towns (OumToub and BeniOulbane); (iii) calcium sulphate facies at wadi Essouk (G3) linked to acid mine drainage (AMD) from the SidiKamber mine and the oxidation of its metallic sulphide minerals contained in the mine discharges, in particular iron disulphide pyrite (Boukhalfa, 2007; Issaad et al., 2019).

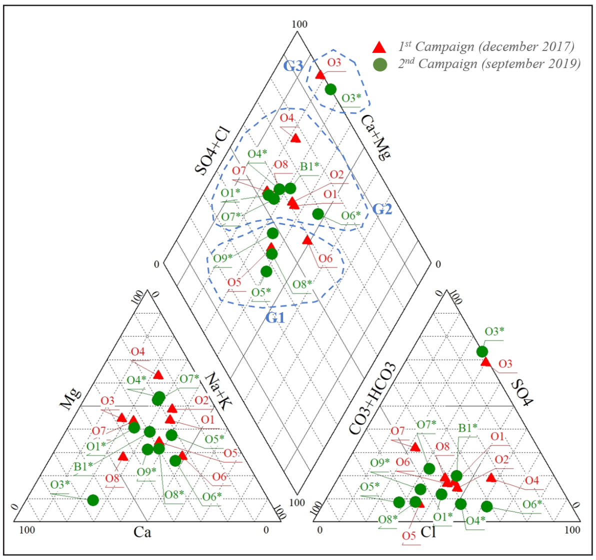

Figure 4. Piper diagram showing surface water samples from the watershed of Guenitra

3.3. Suitability of water irrigation

Water quality, soil types and agricultural activities are determinable factors for an appropriate irrigation practice (Kaka et al., 2011). For the water quality assessment in terms of irrigation, several criteria were used to monitoring the water quality intended for agricultural activity, namely; sodium absorption ratio(SAR) and percentage of sodium (%Na) in combination with electrical conductivity (EC); residual sodium carbonate index (RSC) and permeability index (PI). These methods describe the potential risk of soil salinization and the negative effects of irrigation on soils and plants (Rouabhia and Djabri , 2010; Kaka et al., 2011; Li et al., 2016; Li et al., 2019; Orou et al., 2016; Towfiqul Islam et al., 2017; Safiur Rahman et al., 2017; Singh et al., 2019; Saadali et al., 2019).

3.3.1. Sodium absorption ratio (SAR): it measures the relative proportion of sodium ions of water compared to calcium and magnesium ions. It can be calculated according to the equation of Richards (1954), where all ion contents are expressed in meq/L:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

Indeed, high sodium water is generally unsuitable for soil irrigation due to deterioration of soil characteristics, such as clays dispersion, structure degradation, permeability diminution and plants asphyxiation (Richards, 1954; Orou et al., 2016). SAR has been plotted versus EC (µS/cm) on the Richards'united States salinity diagram to graphically demonstrate the suitability of this water for irrigation purposes in terms of quality. Five water classes were defined: excellent, good, acceptable, poor and bad (Table 2).

Table 2. Classification of water by degree of irrigation ability using the SAR method (Richards, 1954)

Degree	Quality	Class	State of use
1	Excellent	C1-S1 C1-S2	Safe use for irrigation of most crops on most soils.
2	Good	C2-S1 C2-S2	Suitable for plants that have the tolerance to salts, however, its use can cause problems for clays.
3	Acceptable	C3-S1 C2-S3 C3-S2	Salinity must be controlled, irrigation of tolerable crops to salts on well-drained soils.
4	Poor	C4-S1 C4-S2 C3-S3	Highly mineralized water, used only for very salt-resistant plants with good soil permeability.
5	Bad	C3-S4 C4-S3 C4-S4	Unsuitable

Obtained results of calculated SAR of surface waters vary from 1.21 to 3.44 (avg. 1.96) for the first campaign (December 2017) while for the second campaign (September 2019) it varies between 1.03 and 3.25 (avg. 1.94) (Table 2). According to Richards diagram (SAR vs EC), the water of the majority of tributaries in the watershed is mainly in classes C2S1 and C3S1 (Figure 5), which correspond respectively to a low and medium water salinity (good to acceptable quality). These waters are suitable for irrigation of salt-tolerant crops on well-drained soils with continuous control of the salinity evolution. However, waters of wadi Malouh (O4) and wadi Magramene (O6) in September 2019 and wadi Essouk (O3 and O3*) for both campaigns correspond to a poor-quality class (C4S1) (Figure 5), these mineralized waters are only authorized for the irrigation of certain salt-tolerant species and on well-drained and leached soils (Richards, 1954).

3.3.2. Percentage of sodium (%Na): Sodium is one of the most undesirable elements in irrigation water due to its effect on soil permeability and water infiltration. It substitutes calcium and magnesium adsorbed on clay particles and causes soil particles dispersion, making consequently the soil hard and compact when it's dry and excessively water-impermeable (Kaka et al., 2011; Singha, 2017; Singh et al., 2019). The percentage of sodium is calculated according to the following formula (Todd, 1980), where all ion contents are expressed in meq/L:

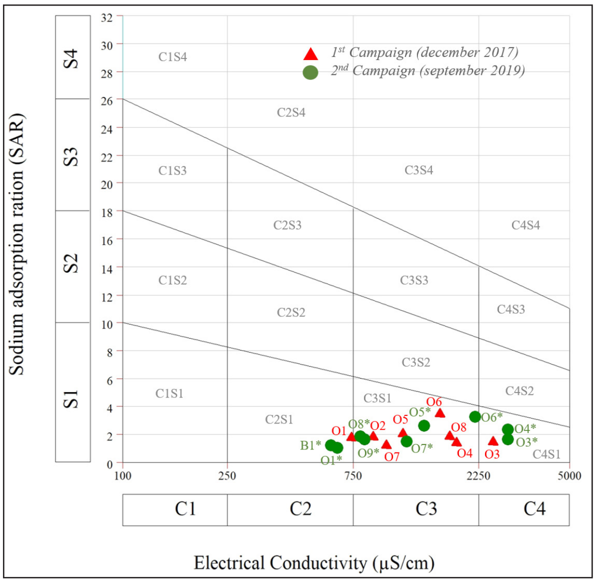

Figure 5. Irrigation water suitability of Guenitra watershed according to Richards (1954).

In December 2017, the sodium percentage in water oscillates between 17.99% and 48.77% (avg. 31.40%) (Table 2).In September 2019, it varies from 24.64% to 47.19% (avg. 33.44%).Wilcox's diagram (1948), sodium percentage versus electrical conductivity (Figure 6) shows that the waters of the majority of tributaries belong to the "excellent, good to permissible" quality during both campaigns (20% < %Na < 50% and EC < 2000 µS/cm), excluding the waters of wadi Malouh (O4*) and wadi Magramene (O6*) in September 2019 and wadi Essouk (O3 and O3*) for the two campaigns (December 2017 and September 2019) which correspond to Doubtful to Unsuitable quality for irrigation (EC > 2000 µS/cm) (Figure 6).

Generally, there is a slight deterioration in water quality during the second campaign (Low-water period; September 2019), this reflects the increase of salinity due to temperature increasing due to the surface water evaporation.

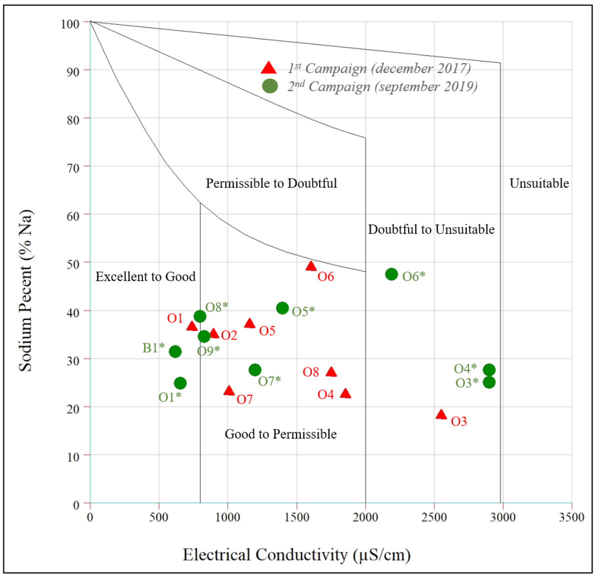

Figure 6. Irrigation water suitability of Guenitra watershed according to Wilcox's(1948).

3.3.3. Residual Sodium Carbonate (RSC): Residual sodium carbonate has been calculated to determine the hazardous effect of carbonate and bicarbonates on irrigation water quality. It is calculated according to the following formula (Kaka et al., 2011; Li et al., 2016; Li et al., 2019), where all ion contents are expressed in meq/L:

$$RSC = \left(CO_3^{2-} + HCO_3^{-}\right) - \left(Ca^{2+} + Mg^{2+}\right)$$

Bicarbonate is an important constituent during the assessment of irrigation water quality. The RSC is used to quantify the impact of water with high carbonate content on soil and plant growth. An excess of RSC sterilises soils due to the deposition of sodium carbonate (Joshi et al., 2009). Water with an RSC < 1.25 is safe for irrigation, and an RSC> 2.5 is considered unsuitable for irrigation (Richards, 1954; Kaka et al., 2011; Towfiqul Islam et al., 2017; Safiur Rahman et al., 2017; Li et al., 2016, 2019; Singh et al., 2019).

In our case, the RSC of Guenitra dam water and its tributaries varies from -9.29 to 0.15 (avg. -3.39), except wadi Essouk waters those are influenced by acid mine drainage from SidiKamber abandoned mine (3.09 < pH < 5.3) where the RSC is about -22.82 and -13.54 for December 2017 and September 2019 respectively (Table 2). All values indicate that the waters of the study area are suitable for irrigation.

3.3.4. Permeability index (PI): Soil permeability is also affected by the continuous use of irrigation water with the influence of Ca^{2+}, Mg^{2+}, $Na^{+}$and HCO_3^{-} contained in the soil. Doneen (1964) and Ragunath (1987) developed a criterion for assessing water suitability for irrigation based on a permeability index (Figure 7).Accordingly, water can be classified into three classes; Class I (water excellent quality for irrigation), class II (water of acceptable quality) and class III (water unsuitable for irrigation) (Kaka et al., 2011; Li et al., 2016; Singha, 2017; Safiur Rahman et al., 2017; Towfiqul Islam et al., 2017; Singh et al., 2019). The permeability index (PI) can be written according to the following equation, where all ion contents are expressed in meq/L:

$$PI = \frac{Na^{+} + \sqrt{HCO_3^{-}}}{Ca^{2+} + Mg^{2+} + Na^{+}} \times 100$$

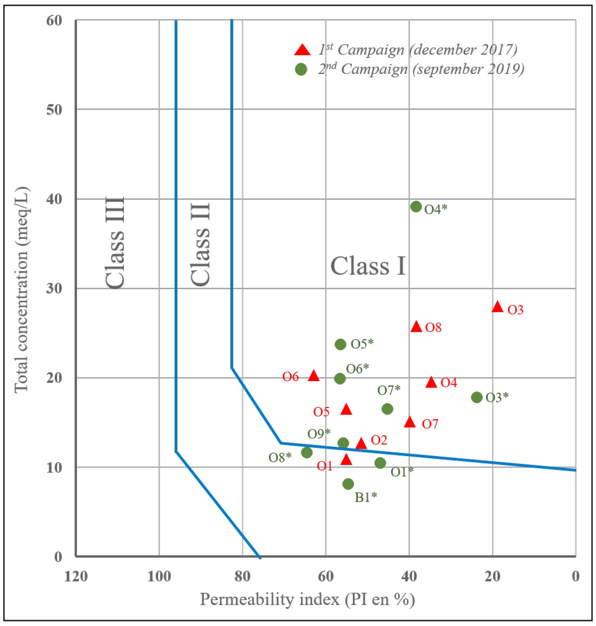

Figure 7. Classification of irrigation water based on permeability index.

Permeability index (PI)of waters of the Guenitra watershed varies between 18.84% and 62.98% (avg. 44.55%) during the first campaign (December 2017) and oscillates between 23.89% and 64.70% (avg. 49.23%) during the second campaign (September 2019) (Table 2). the results show that 76.47% of water samples plot in class I (Figure7), corresponds to all tributaries of the dam's watershed. 23.53% of water samples plot in class II, corresponding to the dam (B1) and its outlet (O1). In resume, the waters of the study area are suitable for irrigation (excellent to acceptable water for irrigation) without any effect on soil properties.

3.4. Discussion

pH values of waters for all tributaries of the dam's watershed range from 7.62 to 8.39 which is acceptable compared to the acceptable pH limit for irrigation water (6.0 to 8.5) according to FAO (1985). However, the pH of wadi Essouk water is very acidic (3.09 to 5.3) influenced by the oxidation of the sulphide minerals and the generation of the acid mine drainage. Electrical Conductivity values range between 620 to 2900 µS/cm, according to FAO (1985), the dam waters and its tributaries are acceptable for irrigation (EC < 3000 µS/cm as limit value).

Piper diagram reveals a variability of chemical facies relative to the Guenitra watershed waters with three distinct groups (calcium-magnesium bicarbonate facies, sodium-calcium chloride sulphate facies and calcium sulphate facies). This variability could be explained, in part by the geological nature of the terrains crossed and also by anthropogenic pollution.

Irrigation water quality indicators (SAR, %Na, RSC and PI) show that the water from the dam and most tributaries of the watershed display good to admissible quality and suitable for irrigation of most crops, excluding wadi Essouk tributary waters which drain the SidiKamber abandoned mining area (acidic and important mineralized water) those are of poor quality, influenced by the acid leachate product, Therefore, continuous monitoring of the impact of the wadi Essouk pollution on the dam water quality is necessary. The wadi Essouk waters could be only intended for irrigation of salt-tolerant crops on well-drained soils. Waters of the wadis Malouh and Magramene have undergone very remarkable quality degradation during the second campaign (September 2019); they were changed from good to poor quality due to the low-water period (negligible dilution effect) and high temperatures (high evaporation effect) which cause an increase in water salinity.

4. Conclusions

This study highlighted the devastating effect of acid leachate products from the abandoned mine on surface water quality and their presumed risk for irrigation as well as the effect of dry periods on the deterioration of surface water quality. This situation becomes seriously worrying in the presence of anthropogenic discharges of acidic nature and/or with high mineralization (rich in chemical elements undesirable for agriculture). The hydrodynamic exchange between surface water (wadi or dam) and groundwater by the over-pumping for irrigation will cause the drainage of polluted water from the wadis, which could lead to the water contamination from wells, intended mostly for drinking water supply, hence the direct risk on human health.

The water chemistry of Guenitra dam and its tributaries is mainly affected by the geological formations (mostly carbonate); particularly, carbonate formations occupy the southern and south-western parts of the watershed. On the other hand, discharges from urban areas (OumToub and BeniOulbane townships) as well as acid mine discharges fromSidiKamber mine through the oxidation of metallic sulphide minerals, in particular iron disulphide pyrite, have played a major role in deteriorating the water quality.

Finally, to protect water resources, particularly dams, against all types of water pollution, either for drinking water supply or for irrigation, it's well recommended to manage contaminated sites, especially abandoned mining areas, and to pre-treat its mining discharges, as well as the purification of wastewater discharges from urban areas located upstream of dams.

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