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Research Note

Survey of the Physico-chemical and Parasitological Quality of the Wastewaters Used in Irrigation (Souk Ahras, North-East of Algeria)

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A B S T R A C T

The reuse of wastewaters of urban communes of Khmissa (Site 1), Hannancha (Site 2) and Souk Ahras (Site 3) rejected in the Medjerda wadi of Souk Ahras region (North-East Algeria) for agricultural purposes in the far North-East of Algeria is accompanied by health and environmental risks, the evaluation of which requires physico-chemical and parasitological characterization. Biweekly samples were taken from March to August 2019 at the three studied sites wastewaters discharges. The results revealed that the waters studied are characterized by high salt contents, negative redox potential and high levels of turbidity (97.28 ± 18.12 to 111.57 ± 13.11 NTU), suspended matter (TSS) (351.6 ± 15.52 to 397.33 ± 20.6 $mg{\cdot}L^{-1}$), ammonium (8.51 ± 1.94 to 11.19 ± 3.18 $mg{\cdot}L^{-1}$) and orthophosphates (3.69 ± 1.40 to 5.29 ± 1.78 $mg{\cdot}L^{-1}$), high values in BOD_5 (120.62 ± 43.17 to 170.25 ± 32.34 $mg{\cdot}L^{-1}$of O_2), and COD (286.73 ± 39.65 to 358.9 ± 32.81 $mg{\cdot}L^{-1}$of O_2) as well as the presence of some metallic trace elements such as cobalt (Co) and cadmium (Cd). Parasitological analysis shows high contamination of these irrigation waters by helminthes eggs, which exceed widely the standards of use of waste water in agriculture. The application of Principal Component Analysis (PCA) allowed to conclude that the waters of Medjerda wadi receive urban wastewater from surrounding areas and should not be reused directly in agriculture before being subjected to a processing, in order to improve their quality by meeting the required standards.

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INTRODUCTION

The availability of good quality water is an essential element to prevent disease and improve quality of life [1]. Currently, the situation in Algeria is characterised by a growing demand for water, while hydric resources are becoming scarce in a permanent way [2]. To this end, the discharge of wastewater into the wadis is a problem which results in an imbalance of the ecological environment on the one hand and the loss of these waters without recovery [3]. These wastewaters have an important part in the degradation of the receiving environment and are likely to constitute the essential cause of water scarcity and public health problems in the future [4].

Thus, the reuse of wastewater in agriculture is becoming more common practice in Algeria; due to the increasing scarcity of water resources [5]. Farmers are required to use different water sources to meet the needs of their crops [6]. In many cases, they are obliged to use untreated urban or industrial wastewater, coming from the wadis; this water represents an important resource, but also a serious risk for the environment and the human health [7]. The Medjerda wadi is one of the most important wadis in eastern Algeria [8]. This watercourse is exposed to significant domestic, agricultural and industrial discharges from urban agricultural areas of the city of Souk Ahras (North-East Algeria) [9]. Many studies have reported that water in the wadi is subject to intensified pollution by urban effluents [8-10]. The mixed wastewater from this region (mixed with the waters of the Medjerda wadi) is used for irrigation of land located downstream of the dump sites.

The present study has two main objectives:
- First of all, the characterization of the nature of wastewater from the three discharge sites : Khmissa (Site 1), Hannancha (Site 2) and Souk Ahras city (Site 3), we are interested in monitoring the quality of wastewater reused for irrigation by spatio-temporal monitoring of the physico-chemical

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parameters of the sampled water, in order to specify the importance of this pollution.

- The second objective is devoted to the assessment of the pathogenic microbiological load by analysing their parasitological parameters in these waste waters in order to show whether or not they need to be recycled before being reused in agriculture.

MATERIALS AND METHODS

Description of the study sites

The study area is located in the extreme east of Algeria in the territory of the city of Souk Ahras, more exactly in the Medjerda wadi. This wadi ranks among the range wadis international [8], it takes its source of Rass-El-Alia (Khmissa) in the north west of Souk Ahras (Algeria) then flows towards the East, before flowing into the Mediterranean sea Tunis Golf. Extending over 416 km are 106.16 km under the Souk Ahras city [11].

This region is characterized by a sub-humid climate. This wadi is a receiving environment for wastewater from the urban commune of Khmissa, Hannancha and Souk Ahras of the city of Souk Ahras, through several urban collectors (Figure 1). It is important to emphasize that this wadi is an important source of irrigation water in these agricultural areas [9]. Three wastewater discharges in the Medjerda wadi reused in irrigation were explored in this study: the rejection of the commune of Khmissa (Site 1), the rejection of the commune of Hannanche (Site 2) and the rejection of the commune of Souk Ahras (Site 3).

Sampling

Biweekly samples of irrigation water (wastewater mixed with the waters of Medjerda wadi) have been taken from the three wastewaters discharges sites, for a cycle from March to August 2019, in order to cover the seasonal variation. Water samples were collected in glass bottles of 1000 ml for the physico-chemical analysis, and in sterile glass bottles of 500 ml and stored at 4 °C in according to the protocol of Rodier [13], then sent to the laboratory within a maximum of 24 hours, for parasitological analysis [13].

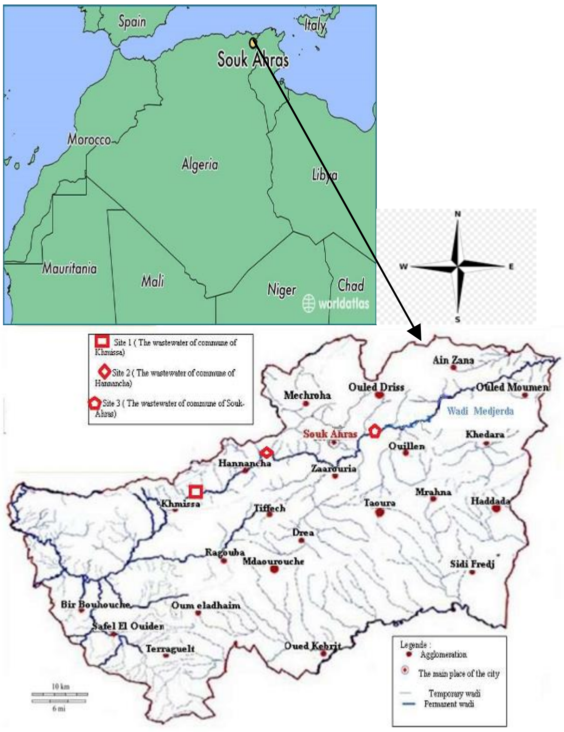


Figure1. Location of studied sites [12]

TEST METHODS

Determination of physico-chemical indicators

The physico-chemical indicators (Temperature, pH, electrical conductivity, redox potential, turbidity, suspended matters (TSS), ammonium (NH_4^+), orthophosphate (PO_4^{3-}), biochemical oxygen demand for 5 days (BOD_5), chemical oxygen demand (COD), cobalt and cadmium) were determined following various analytical methods, as indicated in Table 1.

Determination of parasitological indicators

The parasitological analyses of wastewaters include, principally the research for helminth eggs. Here, we have performed the centrifugal flotation technique of Faust et al. [14]. Briefly, direct dilution of the pallet resulted from centrifugation in solution of zinc sulfate (33% & density 1.18) at 1500 rpm for 1 to 2 minutes [15]. We have afterwards collected by pipette the superficial layer of the supernatant, in which the found parasites were spread on a Malassez chamber for the identification and then the counting [16]. The total number of helminth eggs per litter (N) of the wastewater samples is determined according to the following formula:

$$N = X/P * V/S \quad (1)$$

where N is the number of total eggs per litter, X is the number of counted eggs, P is the volume of suspension involved in cell counting in ml, V is the total volume of the suspension in ml, and S is the volume of the wastewater sample.

TABLE 1. Methods of analysis of physico-chemical indicators

Parameters	Determination Methods	References
pH Electrical Conductivity Redox potentiel	Multi parameter probe	HQ40d multi /NACH
Turbidity	Turbidity meter	NF EN ISO 7027
TSS	Spectrometric (HACH : DR5000)	NF, T 90-105
BOD_5	Manometric method	NF, T90-103
COD	Oxydation of potassium dichromate	NF, T90-101
NH_4^+	Spectrometric method	ISO 7150/1-1984
PO_4^{3-}	Spectrometric method	ISO 6878/1-1998
Cobalt	Spectrometric method	FD T 90-112
Cadmium	Spectrometric method	NF EN ISO 5961

Statistical analysis

The data were processed and analyzed using statistical software: Statistica ® 8.0 (Statsoft: www.statsoft.com) where a statistical description was given for each variable studied (physico-chemical and parasitological).

The statistical study is also based on two-factor ANOVA analysis (site, time) and Principal Component Analysis (PCA); in order to establish a relationship between the different physico-chemical and parasitological parameters and to better assess the effect of human activities on water quality; this method is commonly used to interpret hydro-chemical data [17]. XLSTAT version 2014.5.03 was used for this analysis.

RESULTS AND DISCUSSION

Physico-chemical characteristics of the water in the three sites

The results obtained are presented in the Figures 2 to 11. The water temperature is an important ecological factor, which causes significant ecological repercussions [18]. The water temperatures vary slightly between the different sites; with extreme values ranging from 18.1 to 25.2°C in site 1, 18.6 to 24.5°C in site 2, and 17.6 to 24.7°C in site 3 (Figure 2), These temperatures still less than 30°C, considered as limit value, for direct discharges into the environment [19] and also an indicative limit value for the wastewater used in the irrigation [20]. These temperature variations follow those of the climate of the region; which confirms the previous studies of Bougherira et al. [2]. The difference in mean equalities between the sites is not significant (p =0.913).

The pH is used to quantify the concentration of H^+ ions in the water, which gives it its acidic or basic character. This measure provides information on the water quality [21]; the pH of the irrigation water in the studied sites ranges from 7.22 to 7.9 for site 1, from 7.48 to 7.89 for the site 2, and from 7.46 to 7.72 for site 3, so the pH is slightly alkaline. A slight reduction in pH has been recorded for the site 1 and 3 in March, which can be expressed by the dilution of water (Figure 3). These values meet the Algerian standards for the quality of wastewater used for the irrigation [20] and are also in the interval recommended by the Food and Agriculture Organization (FAO) (6.5-8.4) [22]. These findings are in concordance with those reported by Tfeila et al. [23]. The difference in means equalities is not significant (p = 0.231) from one site to another.

The electrical conductivity reflects the rate of global mineralization and provides information on the salinity [17]. The values of the electrical conductivity revealed fluctuations in the studied sites (Figure 4), ranging from 1100 to 1668 $\mu S \cdot cm^{-1}$, for the site 1 with a mean of 1410.67 ± 98. 1 μScm^{-1}, from 1040 to 1311 $\mu S \cdot cm^{-1}$for site 2, with a mean of 1199.2 ± 73.36 $\mu S \cdot cm^{-1}$, and 1239 to 1500 $\mu S \cdot cm^{-1}$for site 3, with a mean of 1385.68 ± 94.65 $\mu S \cdot cm^{-1}$. The water is then saline and strongly mineralized; according to Rodier [13] (conductivity of 1000 to 3000 $\mu S \cdot cm^{-1}$: saline water). The high salinity of the irrigation water induces undesirable effects on both physical properties of the soil and the crop yields [21]. These results are in agreement with those reported by Guerraiche [24]. The difference in means equalities is significant (p = 0.015) between the sites.

The turbidity in our study recorded values ranging from 63 to 115 NTU, for site 1, with a mean of 97.28 ± 18.12 NTU, from 91 to 122 NTU for site 2 with a mean of 109. 5 ± 7.86 NTU, and 100 to 121 NTU for site 3, with a mean of 111.57 ± 13.11 NTU (Figure 5).The average value in the sites exceed the threshold of 50 NTU, which the standard for discharges into the receiving environment prescribed by the Algerian

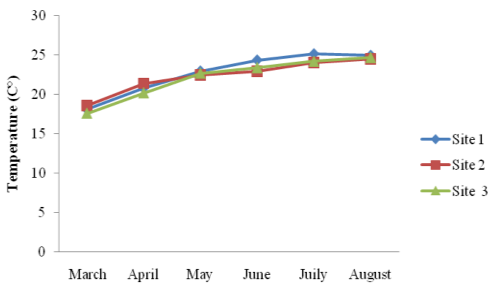


Figure 2. Spatio-temporal variation of the temperature at the three study sites

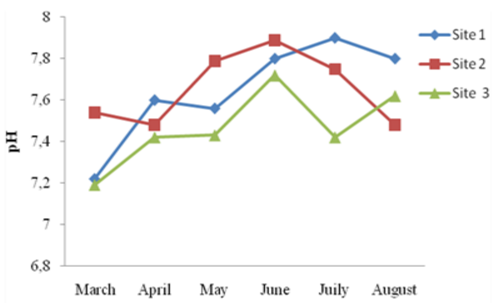


Figure 3. Spatio-temporal variation of pH at the three study sites

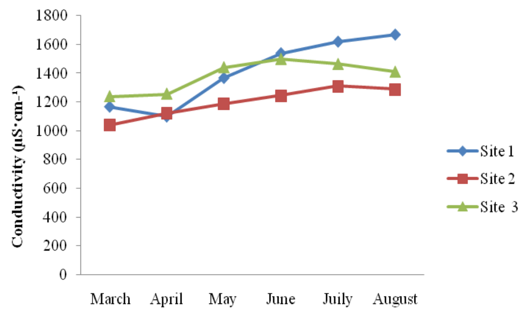


Figure 4. Spatio-temporal variation of the conductivity at the three study sites

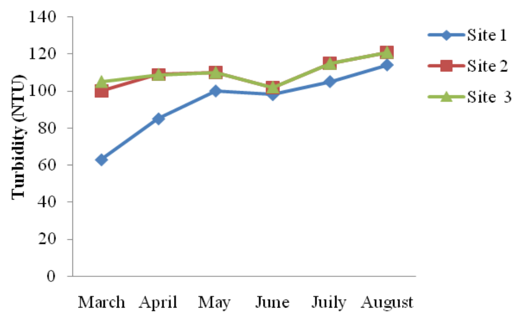


Figure 5. Spatio-temporal variation of the tubidity at the three study sites

standard [19]. This high turbidity could be a vector of pesticide residues, traces of heavy metals and organochlorines found in water intended for irritation [25]. According to Thayer et al. [26], if the turbidity values are quite high, this means that the water reused for irrigation is unsuitable from the human consumption point of view should therefore be treated before their release into the environment. The most important health-related effect that characterizes turbidity is probably its ability to protect bacteria and viruses from disinfection. These values are more or less comparable to those published Tfeila et al. [23], and are inferior to those obtained by Gnagne et al. [27]. The difference in means equalities is not significant (p = 0.168) between the sites.

The suspended matter represents all the mineral and organic particles in the water. It depends on the nature of the lands crossed, the season, the rainfall, the flowregime, the nature of the effluents, etc. [28]. The values of suspended matter range between 363.4 to 422.2 mg.L^{-1} with a mean of 397.33 ± 20.6 mg.L^{-1} for the site1, between 332 to 367 mg.L^{-1} with a mean of 351.6 ± 15.52 mg.L^{-1} for the site 2, and between 361 to 400 mg.L^{-1} with a mean of 380.8 ± 13.43 mg.L^{-1} for the site 3. The highest rates have been recorded during the low-flow season; for the three sites (Figure 6); this result is often related to the important load of organic and mineral matter. The presence of suspended matter, in quantities exceeding the standard recommended by the World Health Organization (WHO) (30 mg.L^{-1}) may result in soil clogging, with damaging effects on the agriculture [29]. These findings are in concordance with those reported by Sultana et al. [30]. The difference in means equalities is highly significant (p = 0.003) from one site to another.

The redox potential is a measurement quantity to quantify the presence of oxidant in a fluid under certain conditions. When it is positive it translates a weak electronic activity, thus an ability to take electrons (oxidizing power), conversely when the values of redox potential are negative (they absorb electrons), it hears an important capacity to take the electrons [31]. The potential redox in our study recorded values ranging from -69.2 to 84.6 mV for site 1 with a mean of 7.65 ± 1.32 mV from -69.4 to

-25. 9mv for site 2 with a mean of -11.97 mV and -69. 6 to -20.9 mV with a mean -39.1 ± 10.4 mV for site 3 (Figure 7).

Based on the results obtained, the wastewater of site 1 and 2 has a negative redox potential which indicates a significant reductive power [31], that the positive values recorded in the 3 indicate an oxidizing power important [32]. These results

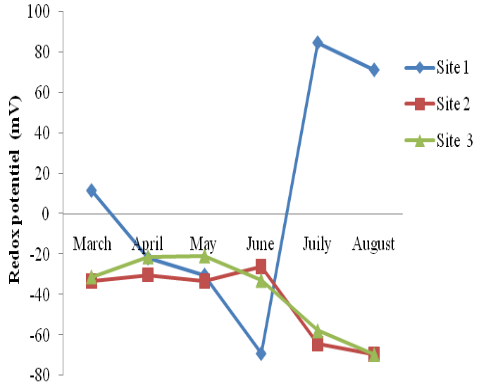


Figure 7. Spatio-temporal variation of redox potential at the three study sites

are consistent similar with those found by Idrissi et al. [31]. The difference in means equalities is highly significant (p = 0.001) from one site to another.

The ammonium is the product of the final reduction of nitrogenous organic substances and inorganic matter, in water and soil. It also comes from the excretion of living organisms and the reduction and biodegradation of the dung, without neglecting the inputs from domestic, industrial and agricultural sources [33]. The concentrations in ammonium ion range from 7.22 to 11.25 mg.L^{-1} in the site1 with a mean of 9.32 ± 1.58 mg.L^{-1}, from 6.48 to 11.14 mg.L^{-1} in the site 2, with a mean of 8.51 ±1.94 mg.L^{-1}, and from 8.19 to 16.36 mg.L^{-1}, with a mean of 11.19 ± 3.18 mg.L^{-1} recorded in the site 3 (Figure 8). The average values in three sites are superior to the standard of irrigation water recommended by the FAO [22]; WHO [34] requiring rates <2 mg.L^{-1}. The transformation ammonium into nitrite and nitrate is done by oxidation, this reaction is rapid in the presence of oxygen. The high CO_2 content and the low oxygen content increase the ammonium concentration in the water [35]. Our results are superior to those reported by Youbi et al. [4]. The difference in means equalities is not significant (p = 0.170) between the sites.

The monthly evolution of orthophosphate concentrations in the three sites showed that site 3 is more concentrated with an average value of 5.29± 1.78 mg.L^{-1} and extreme values of 2.88 to 7.35 mg.L^{-1}. The average orthophosphate content is 4.81 ± 1.24 mg.L^{-1} with extreme values of 3.22 to 6.85 mg.L^{-1} for the site 1 and an average value of 3.69 ± 1.40 mg.L^{-1} with extreme values of 2.10 to 5.58 mg.L^{-1} recorded in the site 2 (Figure 9).

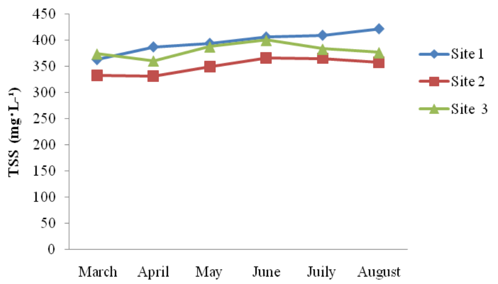


Figure 6. Spatio-temporal variation of the matter in suspension at the three study sites

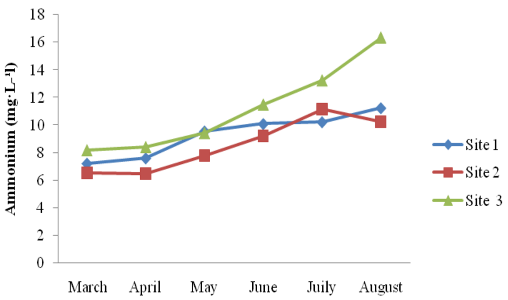


Figure 8. Spatio-temporal variation of ammonium at the three study sites

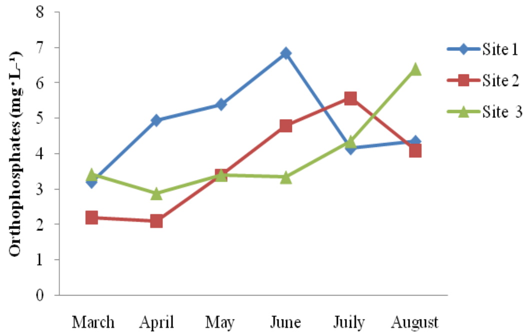


Figure 9. Spatio-temporal variation of orthophosphate at the three study sites

These values exceed the threshold of 2 mg·L^{-1}, which the standard for discharges into the receiving environment prescribed by the Algerian standard [19] and are notably superior to those recommended by the FAO for irrigation water [22]. The variability of orthophosphate rates can be explained spatially by the additional discharges of neighboring agglomerations and industrial units and by the leaching of agricultural soils, treated with fertilizers. The concentrations of orthophosphates are inferior to those obtained by Messai et al. [36], but they are higher than those found in the southeast of Côte d'Ivoire [37]. The difference in means equalities is not significant ($p = 0.170$) from one site to another.

The parameters BOD_5 and COD allow evaluating the quantity of organic matter present in water [4]. The BOD_5 values in the three sites studied ranged from 115 to 205 mg·L^{-1} of O_2 in site1 with a mean of 170.25 ± 32.34 mg·L^{-1} of O_2, from 90 to 189.25 mg·L^{-1} of O_2 in site 2, with a mean of 142.38 ± 38.42 mg·L^{-1} of O_2 and from 74 to 187 mg·L^{-1} of O_2, with an mean of 120.62 ± 43.17 mg·L^{-1} of O_2 in site 3 (Figure 10 a). The average values recorded in three sites are superior to 30 mg·L^{-1} of O_2 considered as limit value, recommended by the Algerian standard [20]. These values are lower than those recorded in Ouagadougou [38] and superior to those found by Derradji et al. [39] in city Annaba (Algeria) for urban wastewater. The difference in means equalities is significant ($p = 0.015$) between the sites.

The monthly evolution of the COD, in the three sites discharged varies between 256 to 390 mg·L^{-1} of O_2, in site1, with a mean of 286.73 ± 39.65 mg·L^{-1} of O_2, between 289.6 to 403.2 mg·L^{-1} of O_2 in site 2 with a mean of 358.9 ± 32.81 mg·L^{-1} of O_2, and between 289.6 of O_2 to 387 mg·L^{-1} of O_2, with mean of de 333.85 ± 42.12 mg·L^{-1} of O_2 in site 3 (Figure10 b). These sites are characterized by a high excessive pollution in COD, exceeding the standard for irrigation water (90 mg·L^{-1} of O_2) [20]. Our findings are superior to those found in the wastewater effluent in Uttarakhand [40]. The difference in means equalities is very highly significant ($p = 0.00$) between the sites.

For a better appreciation of the origin of the studied wastewater, the calculation of the ratios COD/BOD_5, BOD_5/COD and the estimation of the oxidizable material (OM) are highly important (Table 2) in order to recommend an appropriate treatment. The ratio COD/BOD_5 ranging from 1.35 to 2.17 confirms that the water of the wadi studied

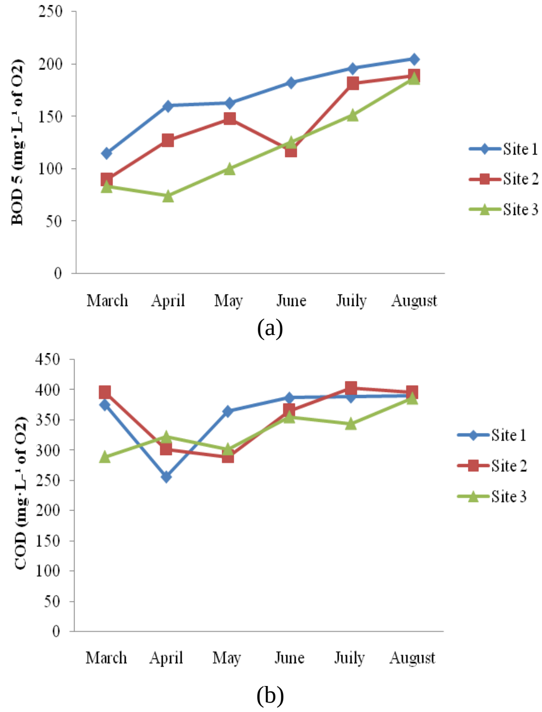


Figure 10. Spatio-temporal variation of BOD_5 (a) and COD (b) at the three study sites

receive domestic wastewater with COD/BOD_5 ratio less than 3 [13], hence the wastewater from these urban discharges have a high organic load and they are easily biodegradable. To characterize an industrial pollution, the BOD_5/COD ratio gives very important indications on the origin of water pollution and its treatment options. The tributaries studied have a high BOD_5/COD ratio, superior to 0.3, which confirms that this water is highly loaded with organic matter. This result is confirmed by the estimation of oxidizable material. The ratios obtained are similar to those reported by Youbi et al. [4] for irrigation water, Gnagne et al. [27] for wastewater in of the city of Abidjan, where the ratio of COD/BOD_5 is less than 3.

Many human activities are responsible for the metallic pollution of the water. The concentrations in cobalt (Co) range from 0.04 to 0.54 mg·L^{-1}in the site1 with a mean of 0.14 ± 0.01 mg·L^{-1}, from 0.07 to 0.5 mg·L^{-1} in the site 2, with a mean of 0.21 ± 0.02 mg·L^{-1}, and from 0.05 to 0.52 mg·L^{-1}, with a mean of 0.21 ± 0.16 mg·L^{-1}recorded in the site 3 (Table 3). These values exceed the threshold of 0.05 mg·L^{-1}, which the standard of irrigation water recommended by WHO [42]; this metallic element translates the chemical pollution of the water

TABLE 2. Ratios of the pollution global parameters of wastewaters

Sites	Parametrs		
	BOD_5/COD	**COD/BOD_5**	**Oxidizable matter (OM)* (mg/l)**
Site 1	0.58	1.73	397.34
Site 2	0.73	1.35	308
Site 3	0.45	2.17	343.16

* OM=COD + 2(BOD_5) /3 [41]

TABLE 3. Variation of heavy metals in the three sites

Parametrs	Sites Mean ± SD (Min-Max)		
	Site 1	Site 2	Site 3
Co ($mg{\cdot}L^{-1}$)	0.14 ± 0.01 (0.04-0.54)	0.21 ± 0.02 (0.07-0.5)	0.21 ± 0,.16 (0.05-0.52)
Cd ($mg{\cdot}L^{-1}$)	0.002 ± 0.001 (0.001-0.005)	0.002 ± 0.001 (0.0002-0,004)	0.006 ± 0.003 (0.004 -0.009)

SD: Standard deviation; Min: minimum; Max: maximum

of Medjerda wadi. Several authors have announced that wastewater are responsible for the metallic pollution of the surface water [43, 44, 45]; During the entire irrigation period, which could pose enormous health risks among consumers [45]. In the field of public health, the metallic trace elements absorbed by the plants enter the food chain and cause a phenomenon of bio-concentration at each passage in the upper trophic level [46]. These results are in agreement with those reported by Sharma et al. [44].The difference in means equalities is not significant ($p = 0.545$) between the sites. Regarding the concentrations cadmium we noted low concentrations in three sites, with still less than 0.01 $mg{\cdot}L^{-1}$, considered as limit value, for wastewater used in the irrigation [42]. The rate of cadmium showed notable fluctuations in the site 3, which can be explained by the industrial discharges into the wadi. These results are consistent with those found by Khaled-Khodja et al. [47]. The presence of these metals in water, even with low concentrations induces adverse ecological and health effects [48]. The difference in means equalities is not significant ($p = 0.391$) from one site to another.

Parasitological characteristics of the wastewater in the three sites

The results of parasitologique analyzes of the wastewater of the three sites rejected in the Medjerda wadi are presented in Table 4. In all samples for three sites, we found significant concentrations of helminth eggs parasites, the results obtained revealed in the form of helminth eggs belonging to two classes: the nematodes and the cestodes. Among the nematodes found, we found eggs of *Ascaris sp*, *Enterobius vermicularis* and *Oxyure sp*. In the class of Cestodes, we have found eggs of *Hymenolepis sp*. The spatio-temporal variation of helminth eggs of cestodes and nematodes showed fluctuations, during the study period.

TABLE 4. Parasitological analyzes in the three sites

Helminthe		Mean ± SD (Min-Max)		
		Site 1	Site 2	Site 3
Nematodes	*Ascaris sp* (egg·L^{-1})	18.9 ± 7.1 (10-25)	19.7± 7.9 (10-30)	31.9 ±7.16 (20-38)
	Enterobius vermicularis (egg·L^{-1})	11.1 ± 4.23 (1.2-23)	14.41± 2.8 (6.7-21.6)	10.1 ±5.29 (0-23.1)
	Oxyure sp (egg·L^{-1})	2.81±0.68 (1.2-5)	1. 2±0.11 (1-2.5)	2.95 ±1.56 (1.60-5.9)
Cestodes	*Hymenolepis sp* (egg·L^{-1})	2.4 ± 0.45 (0-3.3)	1.64±0.23 (0-2.20)	1.24 ±0.45 (1.2-3.30)

SD: Standard deviation; Min: minimum ; Max: maximum

For nematodes the average *Ascaris sp.* is 18.9 ± 7.1 egg·L^{-1} in site 1, 19.7 ± 7.9 egg·L^{-1} in site 2 and 31.9 ± 7.16 egg·L^{-1} in site 3. The microbial charges are higher in July and August, The presence of this parasite in the water indicates faecal pollution [49]. The difference in means equalities is significant ($p= 0.022$) from one site to another.

Regarding the *Enterobius vermicularis*, the mean values are 11.1 ± 4.23 egg·L^{-1} in site 1, 14.41 ± 2.80 egg·L^{-1}in site 2 and 10.1 ± 5.29 egg·L^{-1} in site 3. The use of wastewater for irrigation can cause contamination of vegetables, and presents a real risk for the human health [50]. The difference in means equalities is not significant ($p = 0.06$) between the sites.

For *Oxyure sp*, the average values reached 2.81± 0.68 egg·L^{-1} in site 1, 1. 2 ± 0.11 egg·L^{-1} in site 2 and 2.95 ± 1.56 egg·L^{-1} in site 3. The microbial charges are higher in July and August. This water is inappropriate to be used in the agriculture [13]. The difference in means equalities is not significant ($p = 0.283$) between the sites. In the class cestodes, the presence is not significant ($p = 0.283$) between the sites.

In the class cestodes, the presence of *Hymenolepis sp* reach respectively 2.4 ± 0.45 egg·L^{-1}in site 1, 1.64 ± 0.23 egg·L^{-1}in site 2 and 1.24 ± 0.45 egg·L^{-1} in site 3. The difference in means is not significant ($p = 0. 118$) between the sites. Eggs from nematodes and especially *Ascaris sp* are relatively more common in all sites than eggs from cestodes. However, it is clear that the kinds of parasites present in the wastewater studied depend on local conditions (presence of slaughterhouses, population infestation rate, etc.). However, our results are consistent with observations made in India [51], as well as in Morocco [15] it is the eggs of nematodes that predominate. These rates for three sites for wastewater for irrigation are higher than WHO guidelines [52]. Who requires an egg concentration of less than or equal to 1 egg L^{-1}. The presence of parasitic helminth eggs in reusable wastewater for irrigation is considered a major health risk [51].

Explanatory analysis

The Principal Component Analysis (PCA) allows creating and summarizing a dataset, thus to study the linear links between the variables (correlations). A raw data matrix with 12 physico-chemical and 4 parasitological variables has been used for the three sites. The results obtained are presented in Figure 11. The correlation circle (Figure 11 a) revealed that the F1 axis has a variance of 66. 79% expressed to its positive pole by temperature (T), electrical conductivity (EC), pH, suspended matter (TSS), turbidity and COD, contrary to ammoniums (NH_4^+), orthophosphates (PO_4^{3-}) and redox potential are negatively correlated to this axis. This axis provides information on most of the parameters that determine the degree of mineral and organic pollution of water. This pollution can increase the turbidity of the water and create an eutrophication phenomenon with a decrease in the quantity of dissolved oxygen [25]. These environmental changes have profound consequences on the populations of an environment (disappearance of species, proliferation of other species) [53].

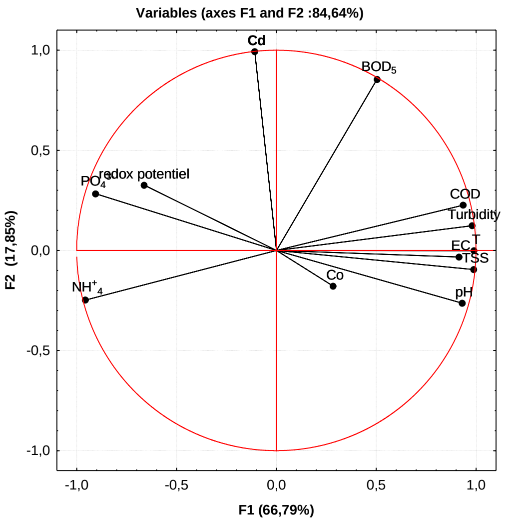
The second contributory component of 17.85% of the total variance is positively correlated with cadium (Cd) and BOD_5. These variables depend primarily on anthropogenic activity, especially human activity [54]. The projection of the parasitological variables on the factorial plane F1-F2 (Figure 11 b) showed that *Ascaris sp.*, *Enterobius vermicularis* and *Hymenolepis sp.* are positively correlated to the axis F1 which cumulates 61.93% of inertia. The second component, with the captured variability of 30.49%, indicated that *Oxyure sp.* contribute negatively to the expression of this axis.

In the correlation circle (Figure 12 a) the first component (F1), contributing with 63% of inertia is opposed ammoniums (NH_4^+), redox potential and COD to temperature (T), EC, turbidity, suspended matter (TSS), BOD_5, cobalt (Co) and cadmium (Cd). This component highlights the organic and mineral inputs that can be related to industrial, agricultural, and domestic activities. The second contributing component for 18.1% of the total variance is positively correlated with pH and orthophosphates (PO_4^{3-}). These variables are mainly dependent on anthropic activity, particularly human activity [54].

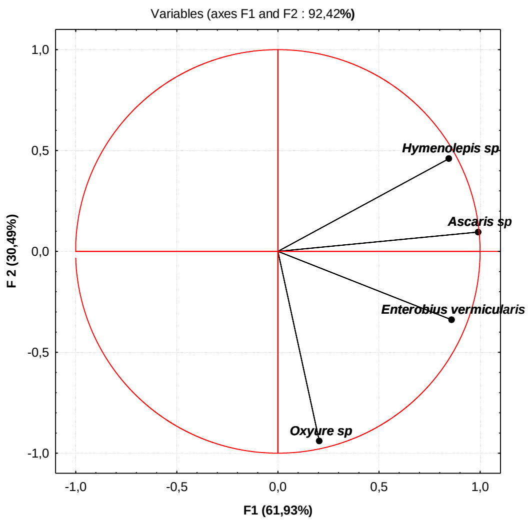
The space of parasite variables of the factorial plane F1-F2 (Figure 12 b) shows that this plane expresses 92.56% of the variance expressed. The first contributing component for 63.46% of the total variance is positively correlated with *Ascaris sp.*, *Enterobius vermicularis* and *Hymenolepis sp.*

The second contributing component for 29.1% of the total variance is positively correlated with Oxyure sp. The presence of these parasites of oeuf helminthes in the water of the Medjerda wadi used in the irrigation prove that they are subject to an anthropogenic influence.

In the correlation circle (Figure 13 b) the first component (F1), contributing with 56.68 % of inertia is opposed by ammoniums (NH_4^+), cadmium (Cd) and redox potential to temperature (T), pH, EC, suspended matter (TSS), BOD_5, COD and cobalt (Co). This component highlights the organic and mineral inputs that can be related to industrial, agricultural, and domestic activities. The turbidity and orthophosphates (PO_4^{-3}) contribute negatively to the second component F2, which accumulates only 19.22 % of the variability captured. These different variables are indicators of pollution which consists of a turbid water rich in phosphorus compounds coming from urban and agricultural

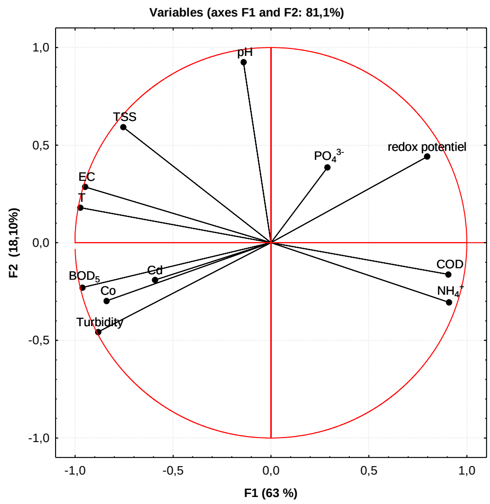


(a)

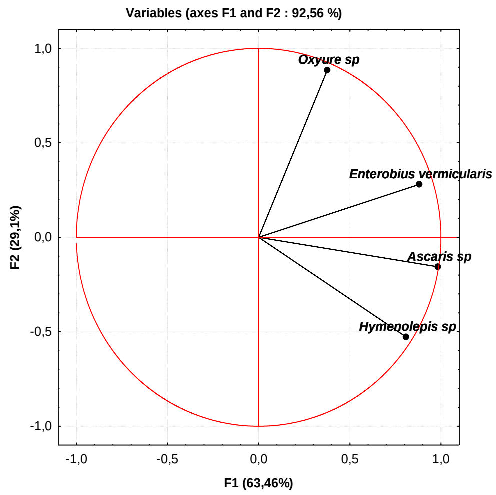


(b)

Figure 11. Results of PCA for Site 1. (a). Projection of physicochemical variables (Site 1) on the factorial plane F1-F2 of the PCA; (b). Projection of parasitological variables (Site 1) on the factorial F1-F2 of the PCA



(a)



(b)

Figure 12. Results of PCA for Site 2. (a). Projection of physico-chemical variables (Site 2) on the factorial plane F1-F2 of the PCA; (b). Projection of parasitological variables (Site 2) on the factorial F1-F2 of the PCA

pollution [25]. The Figure 13 b summarizes 81.14% of the information, the axis F1 has a variance equal to 50.28 % expressed to its pole positive by Ascaris sp contrary to Enterobius vermicularis and Oxyure sp. are negatively correlated to this axis. The second contributing component for 30.86% of the total variance is positively correlated with Hymenolepis sp. These differences variables are indicators of faecal pollution and are largely of human origin [55].

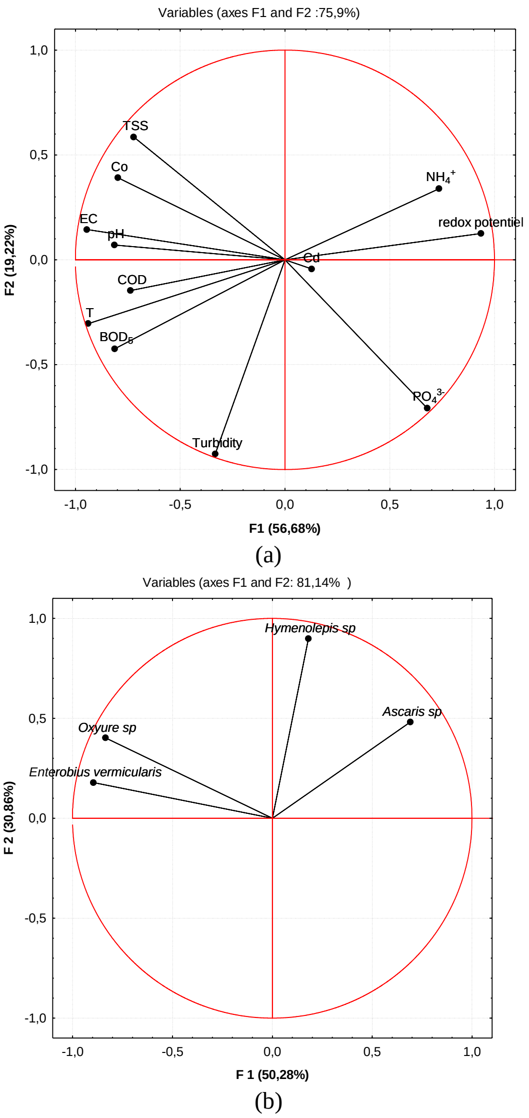


Figure 13. Results of PCA for Site 3. (a). Projection of physicochemical variables (Site 3) on the factorial plane F1-F2 of the PCA (b). Projection of parasitological variables (Site 3) on the factorial F1-F2 of the PCA

CONCLUSION

The urban wastewater of the Khmissa, Hannancha and Souk Ahras communes of Souk-Ahras city (North-East Algeria) used to irrigate the crops of the perimeter of the Medjerda wadi constitute an environmental risk for the surface waters of the Medjerda wadi. Similarly, these effluents pose a health risk for farmers in these areas and for consumers of agricultural products irrigated by these waters. These wastewaters are characterized by redox potential negative and high levels of turbidity, TSS, BOD_5, COD, ammonium, orthophosphates and the presence of some toxic heavy metals (cobalt and cadmium) as well as a significant presence of eggs of helminths: *Ascaris sp.*, *Enterobius vermicularis*, *Oxyure sp* and *Hymenolepis sp*.

The COD/BOD_5 ratio indicates that the water of the studied wadi receive the urban wastewater and are easily biodegradable, the high BOD_5/COD ratio confirms that these waters have a high organic load. It is evident that the majority of parameters analyzed do not comply with national and international standards, for the irrigation water. The statistical application of the PCA to sixteen of the variables studied revealed that Medjerda wadi (Souk Ahras, North-East Algeria) receives raw wastewater of a domestic nature and should not be reused directly in irrigation, before being subjected to pre-treatment, in order to improve its quality by meeting the required standards.

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Persian Abstract

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چکیده

در استفاده مجدد از فاضلاب شهرداری‌های شهری خداما (سایت ۱)، هانانچا (سایت ۲) و سوک احراس (سایت ۳) رد شده در وادی Medjerda منطقه سوک احراس (الجزایر شمال شرقی) برای اهداف کشاورزی در شمال شرقی دور الجزایر با خطرات بهداشتی و محیطی همراه است، که ارزیابی آن مستلزم توصیفات فیزیکی و شیمیایی و انگلی است. نمونه‌های دو هفته از مارس تا آگوست سال ۲۰۱۹ در سه دبی فاضلاب محل مورد مطالعه گرفته شد. نتایج نشان داد که آب‌های مورد بررسی از نظر میزان نمک زیاد، پتانسیل ردوکسید منفی و میزان بالای کدورت (۹۷/۲۸±۱۸/۱۲ تا ۱۱۱/۵۷±۱۳/۱۱ NTU)، ماده معلق (TSS) (۱۵/۵۲ ± ۳۵۱/۶ تا ۲۰/۶ ±۳۹۷/۳۳ میلی‌گرم در لیتر)، آمونیوم (۱/۹۴ ±۸/۵۱ تا ۳/۱۸ ±۱۱/۱۹ میلی‌گرم در لیتر) و ارتو فسفات (۱/۴۰ ±۳/۶۹ تا ۱/۷۸ ± ۵/۲۹ میلی‌گرم در لیتر)، مقادیر زیادی در BOD_5 (۴۳/۱۷ ± ۱۲۰/۶۲ تا ۳۲/۳۴ ±۱۷۰/۲۵ میلی‌گرم بر لیتر O_2)، و COD (تا ۳۹/۶۵ ± ۲۸۶/۷۳ تا ۳۲/۸۱ ± ۳۵۸/۹ میلی‌گرم در لیتر O_2) و همچنین وجود برخی از عناصر کمیاب فلزی مانند کبالت (Co) و کادمیوم (Cd). تجزیه و تحلیل پارازیتولوژیک، آلودگی بالای این آب‌های آبیاری توسط تخم‌های حلزونی را نشان می‌دهد که از استانداردهای استفاده از پساب در کشاورزی فراتر می‌رود. استفاده از تجزیه و تحلیل مؤلفه‌های اصلی (PCA) به این نتیجه رسید که آب‌های Medjerda wadi پساب شهری را از مناطق اطراف دریافت می‌کنند و نباید قبل از اینکه در معرض فرآوری قرار گیرند، مستقیماً در کشاورزی مورد استفاده قرار گیرند تا کیفیت آن‌ها با رعایت استانداردهای لازم بهبود یابد.