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# Impact of cesspools sanitation system on the physicochemical and bacteriological groundwater quality of El Kolea's locality (Agadir Region, South Morocco)

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**Abstract**
The aim of this work is to study the impact of cesspools on groundwater quality, used as sanitation system in El Kolea's municipality in the Agadir region-south of Morocco. Waters of three boreholes used for population drinking have undergone physicochemical and bacteriological analysis. The physicochemical analysis was performed by measuring the following parameters: temperature (T), pH, nitrite ($NO_2^-$), nitrates ($NO_3^-$), ammonium ($NH_4^+$), electrical conductivity (EC) and turbidity (Tur). The bacteriological analysis of Fecal Indicators Bacteria (FIB) parameters i.e. total coliforms (TC), fecal coliforms (FC) and fecal streptococci (FS) have been carried out. The results showed that physicochemical parameters analyzed are within the Moroccan standards. However, water from these boreholes exceeds the standards of the bacteriological quality. The high presence of fecal bacteria represents a significant risk to the health of populations consuming these waters. Thus, the used cesspools do not respect hygiene rules and the generated wastewater contaminates the groundwater.

## 1. Introduction

Universal and equitable access to safe and affordable drinking water for all populations and also protecting the quality of natural drinking water sources against contamination by fecal pathogens are among the targets of United Nation [1]. Percentages of 29 % and 61 % of the global population of the world are respectively lacked safely managed drinking water at home and safely managed sanitation [2].

El Kolea is one of many areas without sanitation system in the region. The domestic wastewater is evacuating in different cesspools. The majority of these cesspools are near to the drinking water well sources. The degradation of groundwater quality is caused by the predominantly calcareous nature of the soil, which makes it easy to infiltrate wastewater from cesspools. The volume of this

wastewater is increasing with the demographic development of this locality and presents a real threat of drinking water boreholes. Indeed, the use of cesspools has been banned for more than a century in European countries because they do not correspond to the hygienic conditions or standards required [3]. The contamination of natural groundwater by the dumping of wastewater over the last two decades has been the subject of several researches [4-6]. Many studies reveled that the majority of boreholes inspected are polluted by physicochemical contamination such as nitrates $NO_3^-$, nitrites $NO_2^-$, ammonium ion $NH_4^+$, phosphate $PO_4^{3-}$, chloride $Cl^-$, and sulfate $SO_4^{2-}$. These boreholes are also infected by bacteriological contamination such as total aerobic mesophilic flora, total coliforms, fecal coliforms (E. coli), fecal Streptococci, Clostridium sulfito-reducers, Staphylococcus aureus, Klebsiella pneumoniae, Salmonella spp., Shigella spp., Pseudomonas aeruginosa, and Candida albicans [7-11]. The origin of these high levels of nitrogen and microorganisms is attributed to the presence of manure, septic tanks, defective septic systems and pit latrines near neighboring boreholes. Thus, the use of water from these boreholes could be an important health risk for the majority of the inhabitants.

The choice of fecal coliform and enterococcus bacteria to assess fecal contamination of water is done according recommendations of Moroccan standards NM 03.7.001[12] and according of three organizations: US Environment Protection Agency, European Environment Agency and World Health Organization [13,14]. The aim of this research is to examine the impact of domestic wastewater discharges into cesspools on the groundwater quality in the El kolea's municipality. Physicochemical and bacteriological analysis were carried out on the three main sources (one well and two boreholes) that are serving for domestic use including drinking, cooking and washing in this locality. The aims of this present work are based on 1) the quantification of physicochemical parameters and 2) the quantification of FIB parameters in the groundwater of three sites in the municipality of El kolea.

## 2. Experimental details

### *2.1.Study area*

El Kolea's municipality is located in the plain of Souss, 25 km south-east of the Agadir's city on the regional road N° 105 linking Aït Melloul city to Biougra city. Its area is 98 $km^2$ and its population increased from 17921 in 1994 (3492 households) to 83235 in 2014 (18127 households) [17]. The climate in this region is arid with an average annual rainfall of 216.7 mm [17]. The mean annual minimum temperature is 13.4 °C, while the mean annual maximum temperature is 26.1 °C [17]. It contains as water resources a river (undefined flow), a damaged artesian source having dried up in the late 90s, and a groundwater with a flow rate of 9 L/s that is currently being reduced [17]. The geological formations encountered extend from the Precambrian to the Quaternary [18]. The geology of this region is part of the recent Quaternary and the Villafranchien since it is located between the Chtouka's plain and Agadir's city. The Souss plain contains two types of aquifers; the first one is superficial and the second is deep. The surface aquifer consists of a superficial underground water that circulates in sedimentary layers composed of sandy marls and sandstone in the Agadir region, and on the other hand, by conglomerates, marls limestones, sandstones and silts in the whole plain [18]. The general water flow in the Souss's plain is from the east to the west and it is heterogeneous and sometimes limits the lateral dispersion from the Souss river towards the southern part of the plain. This flow plays an important role in the drinking water's supply and irrigation in the region [18].

Since 1994, the drinking water sector in El Kolea's municipality has been managed by twelve water associations and one private company. These stakeholders take charge of the boreholes digging, water pumping, chlorination treatment and distribution to the population, and Moroccan Ministry of Health monitored the water quality. The Water and Electricity National Office (WENO) water branch, began in 2013, the distribution of drinking water on 5614 members to

reach 7983 members in 2016 [17]. Collective sanitation is currently non-existent, but work is being carried out by the WENO water branch. The type of sewage network is separative and work has started to implement a sewage treatment station with a flow rate of 3000 $m^3$/day and which is based on the activated sludge process [19]. Individual sanitation is based on cesspools, geometrically characterized by depths ranging from 3 to 5 m, composed of three different diameters sections and having a volume ranging from 4 to 5 $m^3$ (Fig. 1 A). The majority of the cesspools follow the same sizing mentioned, but there are abandoned wells transformed into cesspools directly receiving these untreated sewages.

This system of cesspools causes several genes such as olfactory nuisances resulting from cesspools emptying, superficial drainage of wastewater in the streets and accumulation of solid waste around wastewater (Fig. 1 B). The cesspools, saturated every 7 to 10 days, are emptied by private providers in charge of this task. There are 40 of providers equipped with tractors and tanks with pumps to aspirate the wastewater. All providers encountered do not use safety equipment such as gloves and masks. In addition, during pump failures, the cesspools are emptied manually. Then, these waters are spread in a random space of wastewater of about 300 m located in the Argan tree forest where the animals graze and sometimes drink (Fig. 1 C and D).

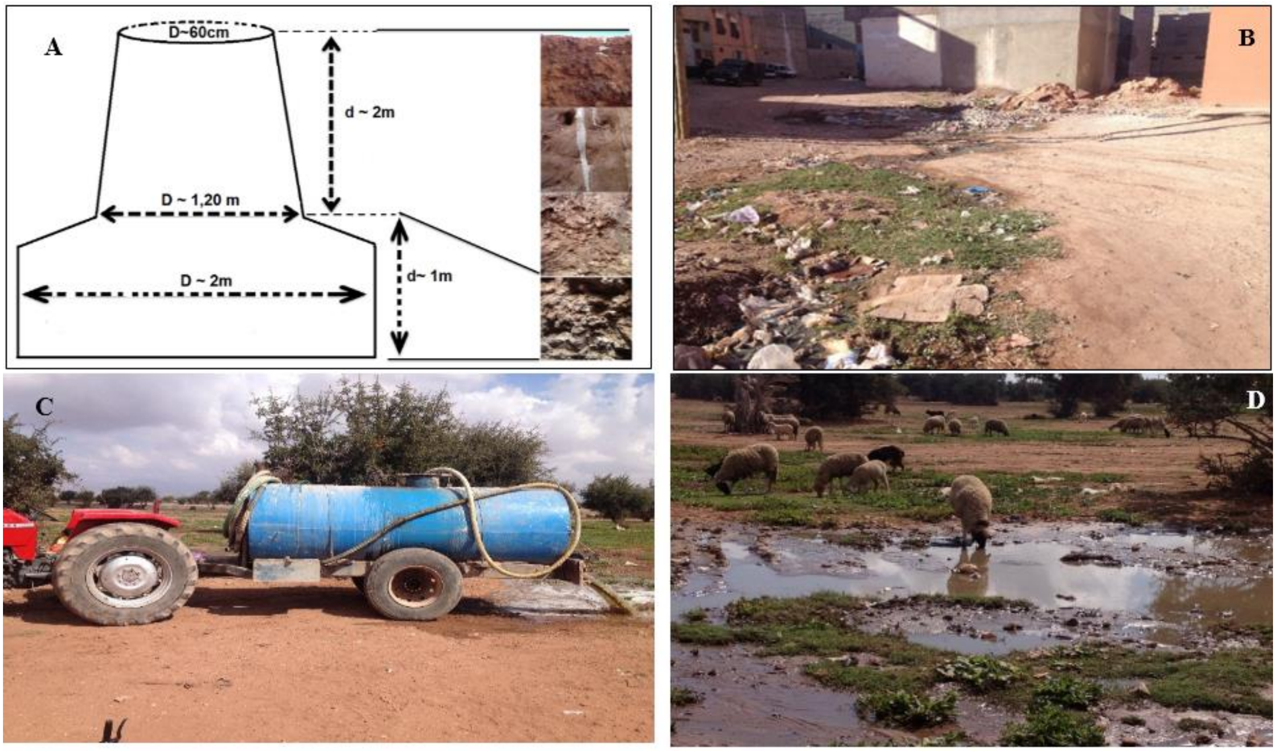


**Fig.1.** Photos taken by Y. El Mourabit in Mai 2016. A: Diagram of a cesspool sizing; B: Drainage of wastewater; C: Spread of wastewaterin a random space; D: Drinking of wastewater by animals

### *2.2.Sampling procedure*

To assess the degree of contamination of underground water in the El kolea's municipality by wastewater from cesspools, three representative boreholes are selected. The choice of these boreholes is fixed according to the number of adherents, the frequency of emptying of the cesspools and the distance between source of pollution (cesspools) and domestic drinking water boreholes. These boreholes are used for drinking purposes and other domestically or agricultural activities and likely to pose a risk to the health of their users. Two sampling campaigns were performed at the three boreholes during May 2016 and June 2016. Microbiological analysis was carried out on water samples collected manually in 500 ml sterile bottles containing sodium

thiosulfate (to remove the Chlorine introduced into water treatment) [20]. These samples were collected in triplicate from each sampling site. Water samples for physicochemical analysis were stored in the 500 ml polyethylene vials filled to the brim and closed properly after three rinses by the distilled water. Then, the samples were stored in an ice box at a temperature of 4°C in obscurity and transported to the laboratory for analysis within 24 hours after sampling [20]. Sample description and GPS geographical coordinates of sampling sites are presented in Table 1 and Fig.2 show Geographical position of three studied sites.

**Table1:** Description of sampling sites and GPS location

| Sampling site names | Comments | GPS coordination's |
|---|---|---|
| Taddart's well (TW) | Located south-west of El Kolea at 12 km in the Taddart region and it is far from the agglomerations and located near the farms. | 30°16'25.7"N 9°27'50.5"W |
| Chorafa Lkhmaïss's well (CLW) | It is near the center of El Kolea in the most populous area of Lkhmaïss. | 30°17'27.9"N 9°28'32.2"W |
| Widadiat Lkhir's well (WLW) | It is located northwest of El Kolea in the region of Laazibe moderately populated. | 30°19'07.2"N 9°28'47.6"W |

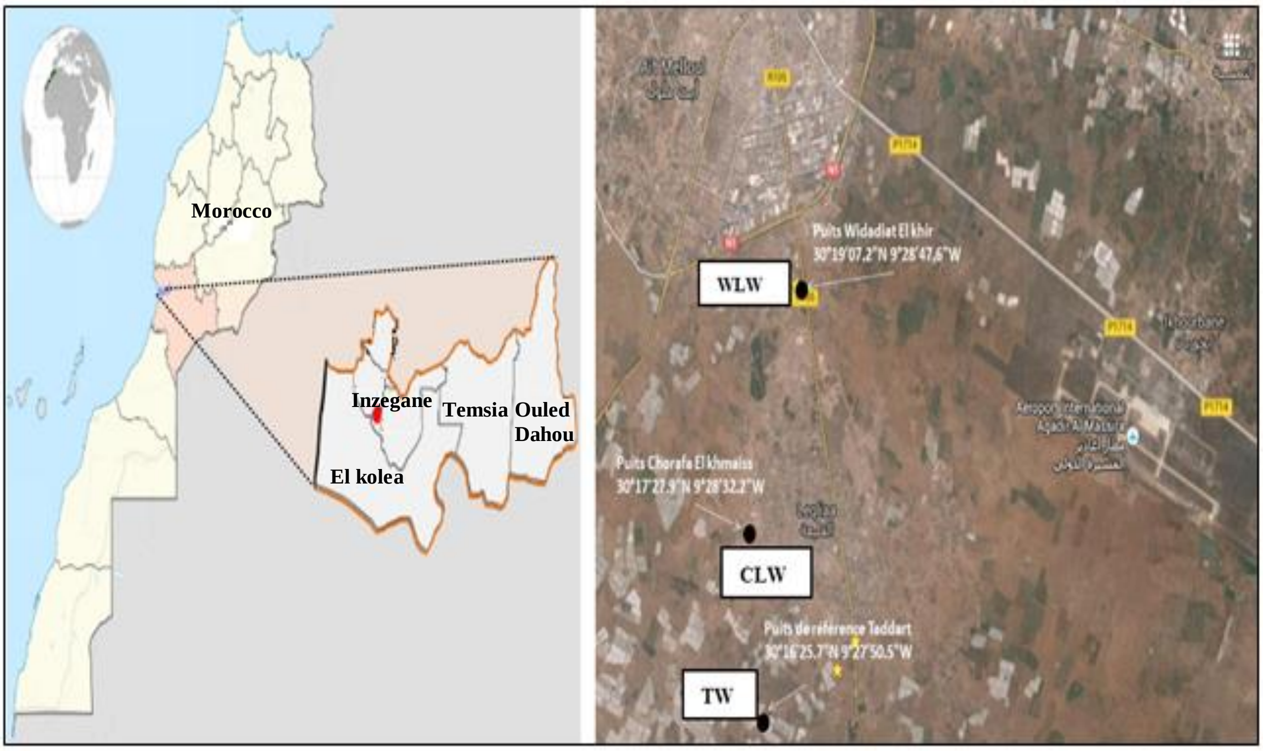


**Fig.2.** Map of study area: a) Geographical position of locality of El Kolea, b) Sites of studied water sources.

## *2.3. Physicochemical analysis of water*

Physicochemical parameters including temperature (T), pH, electrical conductivity (EC), nitrite ($NO_2^-$), nitrate ($NO_3^-$), ammonium ($NH_4^+$) and turbidity were measured according to the analysis methods advocated by the Moroccan standard recommendations [12,20]. Table 2 presents specific limit values of drinking water in Morocco.

**Table 2:** Physicochemical analysis methods and specific limit values of drinking water.

| Measured parameters | Analysis methods references | Specific limit values [12] |
|---|---|---|
| Temperature (T) (°C) | NM 03.7.008, 1989 | 25-30 |
| pH | NM 03.7.009, 2001 | 6.5< pH < 8.5 |

| | | |
|---|---|---|
| Electrical conductivity(µS/cm) | NM 03.7.011, 2001 | 2700 |
| Nitrite ($NO_2^-$) (mg/l) | Rodier et al.2009 [20] | 0.5 |
| Nitrate ($NO_3^-$) (mg/l) | Rodier et al. 2009 [20] | 50 |
| Ammonium ($NH_4^+$) (mg/l) | Rodier et al. 2009 [20] | 0.5 |
| Turbidity (NTU) | Rodier et al. 2009 [20] | 5 |

### *2.4.Fecal indicator bacteria analysis in drinking water*

The fecal indicator bacteria were quantified in water samples using the most probable number method [20].Triplicate for each water samples were analyzed and placed on selective culture media. The petri dish inoculated by SF was incubated at 37°C for 24-48h, TC and FC bacteria's petri dish was incubated at 44.5°C for 24-48h.The results were expressed as colony forming units per 100 ml of water (CFU 100 $ml^{-1}$).

**Table 3:**Bacteriological analysis methods and specific limit values

| Counted germs [12] | Refernces of the analysis method | Specific limit values [12] |
|---|---|---|
| **Total coliforms (TC)** | Rodier et al. 2009 [20] | 0 CFU /100 ml |
| **Fecal coliforms (FC)** | Rodier et al. 2009[20] | 0 CFU /100 ml |
| **Fecal enterococci (FS)** | Rodier et al. 2009[20] | 0 CFU /100 ml |

### *2.5.Data analysis*

Three sites were monitored during two months. Triplicate for each set of conditions were conducted in all analyses. Data are expressed as mean ± standard deviation (SD) of seven independent physicochemical experiments and three bacteriological parameters.

## 3. Results and discussion

### *3.1.Results of the survey*

23 boreholes (12 exploited boreholes and 11 abandoned boreholes) were the subject of this survey. The results of the field survey (Table 4) show first that the drinking water sector is managed in a random manner with regard to the condition of the boreholes in the drinking water supply, the lack of respect of chlorine doses and the spaced frequency of water analysis. All of the cesspools are only pits for infiltrating the wastewater directly into the ground or even into the groundwater, which will alter their microbiological quality.

**Table 4:** Overall results of the field survey

| Subject of the question | Answers | Comments |
|---|---|---|
| Number of exploited boreholes<br>Number of abandoned boreholes<br>Piezometric level | 12<br>11<br>110 m – 150 m | 50% of the boreholes are abandoned because the level of the water has decreased. It can be said that 150 m represents the dynamic level of the groundwater. |
| Height of the water tower<br>Volume of the water tower<br>Volume of flow rate | 10 m to 15 m<br>10 $m^3$ to 23 $m^3$<br>60 to 120 $m^3$/day | There is a high consumption of water, which will affect the volume of the water table. |
| Number of households connected to water from associations<br>Number of active associations<br>Number of non-active associations | 10377<br>9<br>4 | The number of members connected to water from associations decreases as the drinking water sector of the WENO begins to supply households. |
| Distance between cesspool and drinking water boreholes | 2 m to 100 m | The distance between cesspools and boreholes of drinking water are very close which alters the quality of groundwater. |
| Frequency of drinking water analysis | 1 time in 3 to 6 months | The periods of analysis are spaced in addition to |

| | | |
|---|---|---|
| | | non-adequate chlorination treatment |
| Number of evacuation of cesspools per day | 5 to10 cesspools per day | The soil of the cesspools is blocked by oils and greases, the wastewater infiltration will be weak and the overflowing of the cesspools is frequent. |
| Overflowing frequency of cesspools | 1 week to 1 month | |
| Hygiene of staff evacuating cesspools | Nothingness | Lack of personal hygiene can cause illness. |

### *3.2.Physicochemical parameters*

The multiple anthropogenic activities cause changes on the physicochemical parameters of natural waters and affect their quality [21]. Results of physicochemical parameters at three studied sites are shown in Fig.3. Temperature values of the groundwater samples measured in the three boreholes varies between a minimum value (24°C) and maximum value (29°C) with an average of 26.59°C. This temperature variation could be assigned to the climatic conditions of the region [22]. Levels of pH reflect the concentration of $H^+$ ion containing in the water. The pH values range from a minimum value 7.37 to a maximum value 7.52 with an average of 7.45. This fluctuation of pH between the sites can be explained by the pollution of groundwater due to the disposal of domestic wastewater [23,24]. The WLW borehole shows a low pH comparing to others because it is too concentrated in organic matter [25] from livestock breeding. Electrical conductivity is the ability of the water to let the electrical loads move freely and conduct an electrical current. Thus, the increase of dissolved salt concentration in the water increases the Electrical conductivity [26]. For the conductivity of groundwater, it varies between a minimum value (744.67 µS/cm) and a maximum value (863 µS/cm) with an average of 814 µS/cm. Moreover, only the CLW borehole has a low conductivity because it is far from houses, from sources of pollution and far from saline intrusions. Measurement of nitrite concentrations in the studied sites are ranged between minimum value 0.011 mg/L and maximum value 0.027 mg/L with an average of 0.018 mg/L. Soluble form of nitrogen in the soil is nitrate and its presence in the waters indicates their contamination by the fertilizers of chemical or organic nature [27-29]. Measured nitrate concentrations showed that it ranged from minimum value 7.17 mg/L to maximum value 27.30 mg/L with an average of 13.07 mg/L. The main cause of water pollution in these boreholes is linked to the presence of human activities such as agricultural fertilization, manure use, poultry and livestock breeding, etc which are experiencing a boom in the region. Nitrates and nitrites are carried to groundwater by the infiltration of rainwater. The groundwater contains less nitrite concentrations than the nitrate concentrations. This may be related to the bacterial oxidation of ammonium to nitrite and afterward to nitrate [30]. Nitrogen is more representative in the soil by ammonium form that comes from anaerobiose reactions of ecosystems [26, 28, 31]. It is noted that the ammonium ion concentrations oscillate between 0 mg/L and 0.016 mg/L with an average of 0.005 mg/l.Turbidity is the measurement of clarity of a liquid. So, the turbidity of the water reflects the presence of colloidal materials in organic or mineral suspension [20]. The turbidity values range from 0.3 NTU to 1.013 NTU with an average of 0.54 NTU.This physicochemical analysis showed that all studied parameters can be considered eligible and do not affect the quality of the El Kolea’s municipality drinking water. As well, these average values are compatible with the supply of Moroccan standards of water [12]. These results are in agreement with those obtained by Chippaux et al. [32] which studied the water tables of Niamey in the Niger and those obtained by Bricha and al which studied the groundwater quality of M’nasra (Morocco) [7].

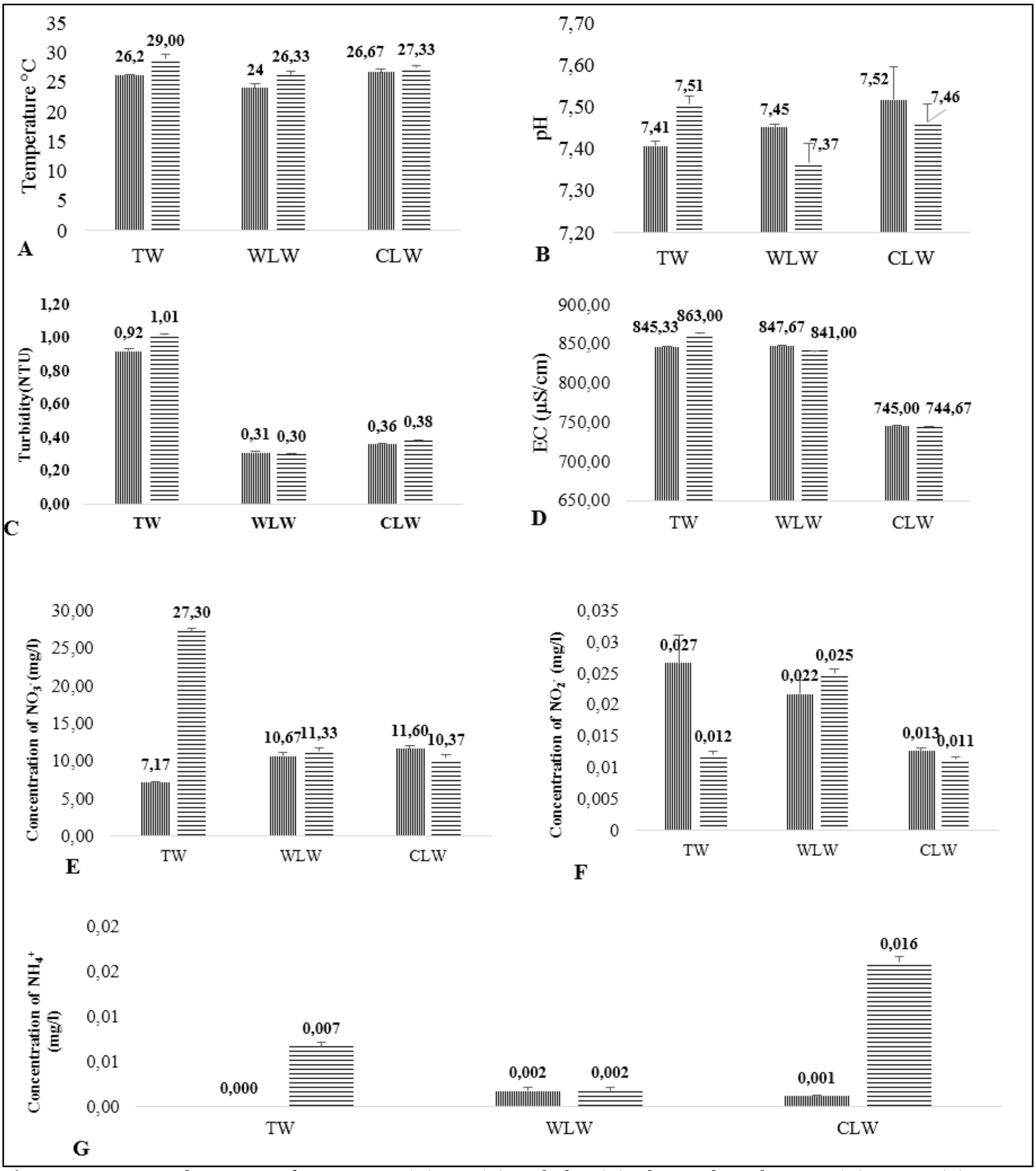


**Fig.3.** Spatiotemporal variation of temperature(A), pH (B), turbidity (C), electrical conductivity (D), nitrate (E), nitrite (F), ammonium (G). May 2016: (▥), June 2016: (▤). Vlaues are expressed as the Mean ± SD.

### *3.3.Microbiological parameters*

Microbiological analyzes carried out on the waters of the three boreholes are represented in the Fig.4. The microbial analysis of investigated boreholes revealed a high contamination of water by fecal material. The TC values ranged from 0.95 $\log_{10}$ CFU 100 mL$^{-1}$ and 3.05 $\log_{10}$ CFU 100 mL$^{-1}$ with an average of 2.87 $\log_{10}$ CFU 100 mL$^{-1}$. The FC values ranged from 0.95 $\log_{10}$ CFU 100 mL$^{-1}$ and 3.05 $\log_{10}$ CFU 100 mL$^{-1}$ with an average of 2.94 $\log_{10}$ CFU 100 mL$^{-1}$. FS values fluctuate between 0.87 $\log_{10}$ CFU 100 mL$^{-1}$ and 3.02 $\log_{10}$ CFU 100 mL$^{-1}$ with an average of 2.58 $\log_{10}$CFU 100 mL$^{-1}$.

The analyzed waters exceed the maximum permissible values of Moroccan standards [12]. The high bacterial load of these waters in TC and FC shows the presence of fecal contamination [12]. Such increasing contamination by fecal bacteria may results from the infiltration and overflow of traditional sanitation systems (e.g. septic tanks and pit latrines) into drinking water boreholes. The presence of enteropathogenic microorganisms such as Salmonella and Norwalk virus may be indicated by the presence of FC in water [33,34]. These microorganisms are responsible for water related diseases such as typhoid, cholera, gastro-intestinal illnesses and diarrheal diseases [35-37]. While the existence of fecal streptococci in all waters of boreholes confirms that the origin of fecal pollution from the water samples analyzed of El Kolea municipality can be attributed to several potential sources including natural of infiltrating soil, inadequate sanitation, the presence of pit latrines located in the proximity of boreholes and lack of wastewater treatment. These results are in agreement with those obtained by Kayembe and al. [37] how studied fecal contamination in drinking water and sanitation, in the sub-rural neighborhoods of Kinshasa, Democratic Republic of the Congo. The high contamination by these fecal indicators is in the same level than those found by Boutin and Dias [38] for the Marrakech water table in Morocco and by Belghiti et al. [39] on the groundwater of the Meknes region.

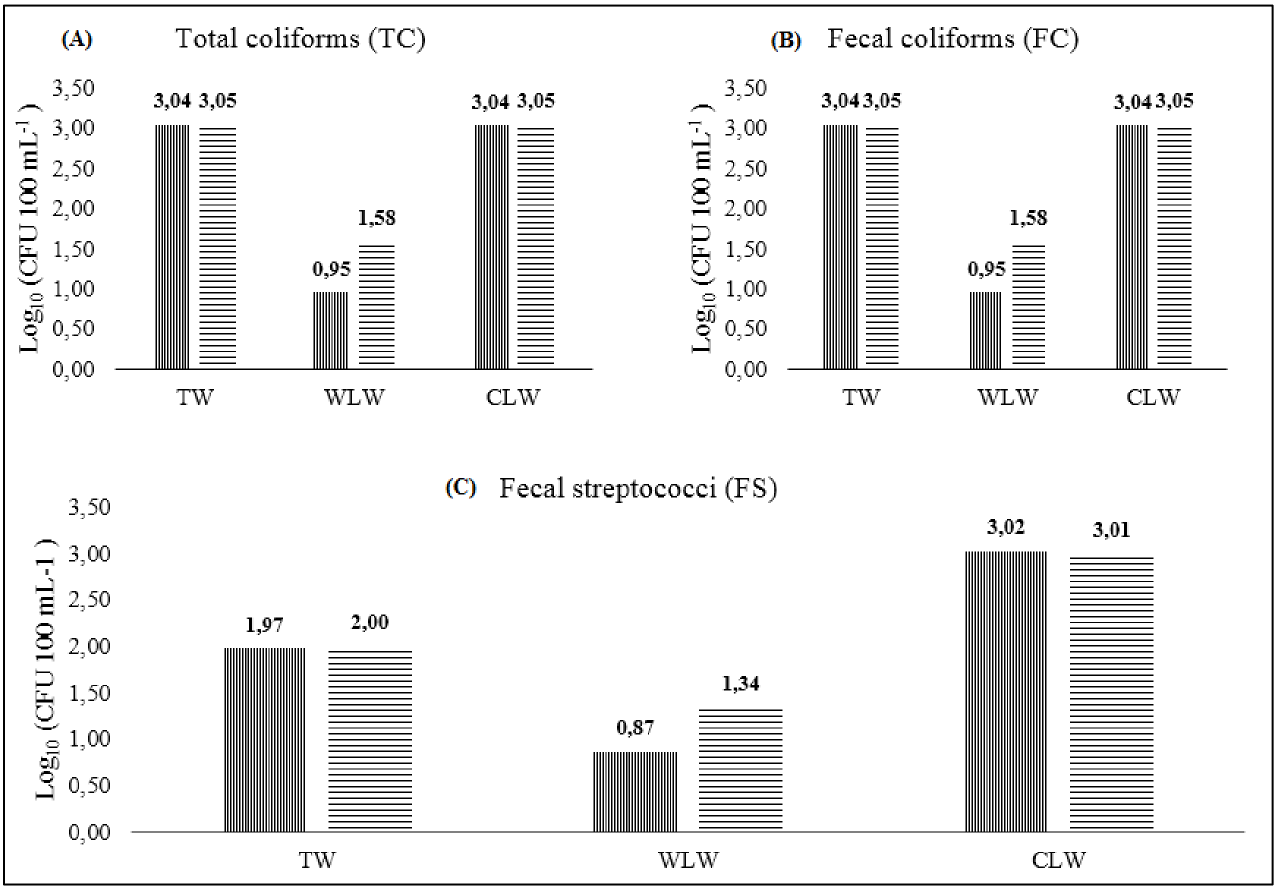


**Fig.4.** Indicators of microbiological pollution in studied boreholes.(A): TC, (B): FC, (C): SF. (▥): May 2016 and (▤): June 2016.

## Conclusion

This work illustrates that the quality of underground water in El kolea's municipality is impacted by the wastewater from the cesspools used as sanitation system. The physicochemical parameters of water samples respect the Moroccan norms but the microbiological parameters exceed the

norms and do not meet the Moroccan norms guideline for drinking and domestic purpose. The pollution of three boreholes by fecal material may be rather explained by several different sources including the presence of cesspools located nearby the boreholes of drinking water. Therefore, these waters cannot be used in domestic use unless they have been effectively treated to irradiate bacterial contaminants. In addition, it is necessary to ban the boreholes of drinking water near the cesspools and accelerate the implementation of the collective sanitation system programmed for this municipality.

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