The quality of surface waters of the dam reservoir Mexa, Northeast of Algeria

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Abstract

In this work, we have conducted a physicochemical study that assesses the impact of agricultural activities and urban domestic wastewater on the surface water quality of the dam reservoir Mexa in the area of El-Taref, which is located in the eastern coastal basin of Constantine. 36 samplings have been conducted for three years (2010, 2011 and 2012), at the rate of one sampling per month on the dam reservoir water; 36 samples have been analysed. The samples taken have been subjected to an in situ measurement of physicochemical parameters (temperature, hydrogen potential, electric conductivity and dissolved oxygen) and laboratory analysis (anions, cations, biological oxygen demand, chemical oxygen demand, organic matter, phosphate, nitrate, nitrite and ammonium).

Concentrations of various organic and inorganic pollutants varied from one month to another and from one year to another. From a temporal point of view, the contamination of water of the dam reservoir Mexa varies according to climatic conditions, being generally low during the winter period and high during the low-flow periods. The results obtained reveal that water of the dam reservoir Mexa is fairly contaminated. It is certain that the dam reservoir is subject to pollution of agricultural and urban origin.

Key words: *dam reservoir Mexa, organic compounds, pollution, water quality*

INTRODUCTION

Water resource protection is one of the most essential concerns of any environmental policy [ATTOUI *et al.* 2016]; water becomes a global strategic issue whose management must essentially integrate into a sustainable development policy perspective [ALLAL-GUA *et al.* 2014]. In fact, some assert that it will be a war issue, in the third millennium, as it is the case for oil in the past and today [GARCIA 2006]. The competition between agriculture, industry and drinking water supply for access to limited existing water requires development efforts of many countries [REMINI 2010].

Dams provide many benefits for our society such as the supply of drinking and irrigation water [DERDOUS *et al.* 2015]. The dam Mexa is one of the structures for the mobilization of surface water. It was constructed to ensure the protection of downstream areas from flooding and to supply drinking water to the provinces of El-Taref and Annaba. This dam reservoir receives, among others, the surface water from certain wadis that include urban effluents. The main problem of the dam reservoir water is contamination by organic compounds from domestic wastewater from agglomerations, engendering the degradation of the water quality. They may contain significant quantities of natural organic matter such as humic substances, as well as organic compounds derived from various pollutants or intensive agricultural practices [ACHOUR 2001].

Given the demographic growth of the city of El-Taref and the deterioration of the quality of these

waters, this dam could alleviate this problem of water [ABHCSM 2005]. In order to meet the needs of the population, a study of characterization and assessment of the dam reservoir water quality is necessary. As current knowledge suggests, work has been carried out on the dam reservoir water quality by Agency Hydrographic Basin (Fr. Agence de Bassin Hydrographique) [ABHCSM 2005; HARRAT, ACHOUR 2010] on the physicochemical quality of surface waters by the determination of mineral and organic parameters, and the present work, which aims to characterize the waters of this dam for the period from January 2010 to December 2012, comes within this framework.

PRESENTATION OF THE STUDY AREA

Dam Mexa is located at the extreme Northeast of Algeria (Fig. 1), on the eastern Wadi Kebir, 20 km south of the town of El Kala, and has been put into service in 1998. This dam reservoir has initially covered a basin of an area of 560 km^2, reduced to 393 km^2 after the construction of a dam on Wadi Barbara in Tunisia and reduced to 158 km^2 after the construction of the dam Bougous. This work regularizes an annual volume of 30 hm^3 for the supply of drinking water to the corridor of El Kala – Annaba [Ministère des Ressources en Eau 2009]. The study area is subject to a temperate climate characterized by two seasons, the first is wet from September to May, and the second is dry from May to September [BAHROUN et al. 2016].

From a geological point of view, the study area is part of the geological domain of the Algerian north-eastern Tell [VILLA 1980]. This domain extends from the region of Constantine to the Algerian-Tunisian border. The basin of Mafragh (Bounamoussa and eastern Kebir) includes the following units:
– Triassic located south of the study area (Triassic diapirs, vermicular limestone, set of pelitic sandstones);
– the sedimentary terrains of Oligocene to lower Burdigalian; these are sandstones, clays and marls;

– some deposits of Quaternary are of marine origin (alluvial deposits, beach sandstone), and others are part of continental sedimentation (sandstone, red soil, dunes, screes, and alluvia) [DERRADJI et al. 2007].

Available statistics announce 373 183 inhabitants for the whole basin, estimate 2011, according to Census 2008. This population is highly concentrated in the most important areas such as, El-Taref and El Kala whose rate of urbanization recorded in different localities has showed a slide of the dispersed and rural population toward important groups located on road axes [BRAHAMIA, SEMOUK 2010]. The region has undoubtedly an agricultural vocation. Farming sector provides most of permanent and seasonal jobs [OUELMOUHOUB 2005]; it is characterized by a very wide variety of cultures (citrus fruits, pear trees, pomegranate trees, medlar trees, quince trees, sorghum, melon, watermelon, and other vegetable growing [SADOUNE 2012]. Industry, in the proper sense of the term, is almost nonexistent in the basin, as well as in the whole province [SAADALI et al. 2015]. It is mainly characterized by a few agri-food industry as a tomato canning factory, a lemonade factory and a bricks plant [BAHROUN 2016]. This wealth in the first two areas is currently a major concern, because these latter represent the most significant sources of pollution, namely: urban pollution represented by urban discharges in the study area, which are thrown up, without prior treatment, into the wadis. Domestic sewage contains mineral particles, faecal bacteria, organic matter, toxic products, significant quantities of nitrogen and phosphorus, as well as other products [GAUJOUS 1995]. Agricultural pollution is mainly related to the existence of several farms, practicing various types of cultures, the intensive use of fertilizers and pesticides rich in nitrate, phosphate and sulphate. These generate nitrogen-rich leachate (organic or ammoniacal nitrogen), which is conveyed by the runoff after spreading and joins surface waters by hypodermic flow [CANN 2000; RECOUS et al. 1995].
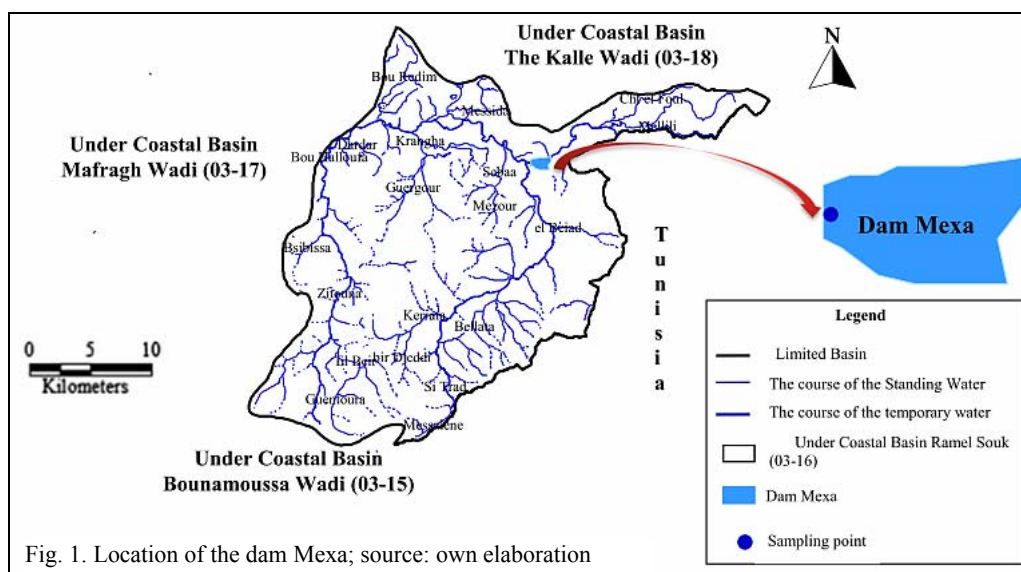

Fig. 1. Location of the dam Mexa; source: own elaboration

MATERIALS AND METHODS

The sampling of waters of the dam reservoir Mexa have been carried out for a period of three years (2010, 2011 and 2012), one sample per month. The sample has been taken on the raw water of the dam reservoir itself. In total, 36 water samples have been collected at the reservoir of the dam Mexa. The samples of surface water have been collected directly with polyethylene bottles. All sampling bottles have previously been washed with an alkaline solution and rinsed several times with distilled water.

The sampling can be performed in several ways according to the accessibility of the site, in our case, the ideal is to collect samples at outlet of the dam reservoir and at the middle; in the morning at 15 to 30 cm depth, and in a way to avoid the edge effects (oxygenation, too close to the surface, suspension of solid material too near the bottom), by facing water streams. This is what is called spot sampling [Agence de l'eau Loire 2003; Aqua-Ref 2011].

The samples were stored at a temperature of 4°C. The measurements of temperature, electrical conductivity, dissolved oxygen and pH have been carried out in the field using specific probes of a multi-parameter device. The chemical analyses have been conducted in the laboratory. The analyses of major elements have been performed on the previously filtered samples. Chlorides have been dosed by the method of Mohr, gravimetric sulphates and bicarbonates by the volumetric method. Sodium, potassium, calcium and magnesium ions have been dosed by means of flame spectrometer.

Nitrates, nitrites, phosphates and ammonium have been dosed by flame spectrophotometer [Rodier 2009]. The parameter of biological oxygen demand has been measured using an OxiTop IS12. In addition, the characterization of geochemical facies of surface water has been conducted using Piper diagram.

RESULTS AND DISCUSSION

TEMPERATURE

The temperature of water taken from the dam reservoir Mexa during the period of (2010–2012) varies between 10°C recorded in January 2012 and 30°C in August 2012, with an annual mean temperature of 19.05°C. This state of temperature remains lower than that reported by Mehanned *et al.* [2014] at the dam Sidi Chahed (Morocco). These variations are directly related to the temperature of air and seasons. The dam reservoir water has a normal temperature (<25°C).

HYDROGEN POTENTIAL

The pH of water of the dam reservoir Mexa recorded on samples is rather alkaline and varies between 7.1 recorded in November 2011 and 8.4 in September 2010, with an average of around 7.67 reflect-

ing a normal quality. These results are consistent with those found by Harrat [2007] at the dam Mexa.

ELECTRICAL CONDUCTIVITY

The electrical conductivity of water of the dam reservoir Mexa measured during the period of (2010–2012) varies between 340 and 710 $\mu S \cdot cm^{-1}$. The highest value is recorded in June 2011 and the lowest in March 2012, the average is of the order of 518.89 $\mu S \cdot cm^{-1}$ 90% of the values of electrical conductivity measured at the dam reservoir water exceed the maximum permissible standard of water for human consumption, referenced to the standard of 400 $\mu S \cdot cm^{-1}$. This increase indicates contamination of water and makes it unsuitable for human consumption. It should also be noted that the highest values have been recorded during the low-water period while in the high-water period a phenomenon of dilution appears. As compared to other works, the conductivity is lower than that reported by Ismail *et al.* [2010] at the dam Bir M'chergua (Tunisia).

TURBIDITY

According to the results of the series of analyses of water of the dam reservoir Mexa, we have noted that the water sample of May 2011 is the most turbid (it has a turbidity of 100 NTU). This is explained by the presence of colloidal particles in suspension of clay and various organic matter (as a result of urban discharges). The lowest is of the order of 1.4 NTU recorded during January 2011. In general, the mean turbidity is of 15.65 NTU reflecting from good to fair quality. The results are comparable to those obtained by Harrat [2007] at the dam Mexa.

DISSOLVED OXYGEN

The values obtained for dissolved oxygen ranging from 5.7 $mg \cdot dm^{-3}$ in January 2012 to 11.2 $mg \cdot dm^{-3}$ in February and December 2011. The mean is of 8.62 $mg \cdot dm^{-3}$ reflecting normal quality. The results are comparable to those obtained by Ismail *et al.* [2010] at the dam Bir M'chergua (Tunisia).

MAJOR ELEMENTS

The results of analyses of major elements (sulphate, chloride, calcium, magnesium, sodium, potassium and bicarbonate) corresponding to water of the dam reservoir Mexa are presented as follows.

Sulphates. The concentrations observed in water of the dam reservoir basin indicate that the mean contents of sulphate do not exceed the standard. The maximum value is of 120 $mg \cdot dm^{-3}$ recorded in January 2010 while the lowest is 80 $mg \cdot dm^{-3}$ recorded during December 2012. The mean is of 80.89 $mg \cdot dm^{-3}$. The concentrations of our waters are still higher than those reported by Chahboune *et al.* [2013] at

the dam reservoir Hassan II (Morocco). The origin of water sulphates is Pliocene-Quaternary alluvia [HANDOUZI 2011].

Chlorides. It is noted that chloride levels in water of the dam reservoir Mexa do not exceed the World Health Organization standard (250 mg·dm^{-3}). The maximum concentration is of 70 mg·dm^{-3} recorded in August 2011 while the lowest value is of 30 mg·dm^{-3} recorded in April 2010; the mean value of chlorides in water of the dam reservoir is about 51.11 mg·dm^{-3}. These results are consistent with those found by CHAHBOUNE *et al.* [2013] at the dam reservoir Hassan II (Morocco). Water chlorides are from Numidian clays, and marls and clayey marls are from Lutetian [BAHROUN 2016].

Calcium. Water of the dam Mexa has calcium levels between a minimum value of 40.6 mg·dm^{-3} observed on May 2012 and a maximum value of 86.3 mg·dm^{-3} recorded in June 2011, with a mean of 62.27 mg·dm^{-3}. Calcium content in water of the dam reservoir is consistent with the maximum permissible standard of water intended for human consumption (classified as good quality). As compared to other works, the concentrations are lower than those reported by ISMAIL *et al.* [2010] at the dam reservoir Bir M'chergua (Tunisia).

Magnesium. The highest levels are observed on September 2010, with a maximum value of 23 mg·dm^{-3}. The lowest value is recorded in December 2012. The dam reservoir water reaches a magnesium mean value of about 12.22 mg·dm^{-3}. The comparison of concentrations with the permissible standard for potability shows that the levels are below the limit. These results are not consistent with those found by ISMAIL *et al.* [2010] at the dam Bir M'chergua (Tunisia), because they are less high.

Sodium. Sodium values fluctuate between 10 mg·dm^{-3} in June 2012 and 39 mg·dm^{-3} in December 2011; the mean is of the order of 27.92 mg·dm^{-3}, lower than the permissible European standard (100 mg·dm^{-3}), and does not reach the Algerian standard of 200 mg·dm^{-3}. The results are comparable to those obtained by HARRAT [2007] at the dam Mexa, Cheffia and Beni Zid (Algeria).

Potassium. The highest potassium values are of the order of 3 mg·dm^{-3}, and the lower values are of the order of 1 mg·dm^{-3} observed during the three years. The mean is of the order of 1.78 mg·dm^{-3}, lower than the potability standard of the World Health Organization (12 mg·dm^{-3}) and the Algerian standard (20 mg·dm^{-3}). The results are comparable to those obtained by HARRAT [2007] at the dam Mexa, Cheffia and Beni Zid (Algeria).

Bicarbonates. The maximum concentrations of bicarbonates in water of the dam reservoir basin are of the order of 201.3 mg·dm^{-3} recorded in June 2011, and the minimum is of the order of 85.5 mg·dm^{-3} recorded in March 2010. The concentrations show significant variations around the mean value of 134.78 mg·dm^{-3}, indicating heterogeneity of bicarbonate ori-

gins. Our bicarbonate contents remain lower than those reported by ISMAIL *et al.* [2010] at the dam Bir M'chergua (Tunisia).

GEOCHEMICAL FACIES OF WATER

Classification according to Piper diagram. The results of the chemical analyses of the dam reservoir water for the three years and during all the sampling months (from January to December) are shown in Piper diagram below (Fig. 2). This figure shows that the dominance of bicarbonate ions is clear on sulphates and chlorides.
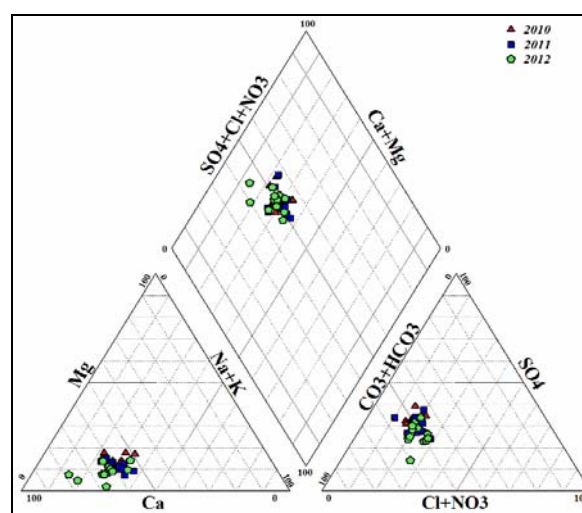

Fig. 2. Piper diagram of water chemistry in Mexa dam reservoir for the period 2010–2012; source: own study

The interpretation of diagram (Fig. 2) has allowed us to highlight a clear concentration of points cloud located on the upper and left parts. It therefore shows an enrichment of bicarbonate and calcium, a dominant facies grouping bicarbonate-calcium family. It has to be noted that calcium cations characterize the totality of the points represented on cations triangle, giving indications on the origin of water. Bicarbonate anions characterise all the points represented on anions triangle, giving indications on the origin of water.

Alteration of water of the dam reservoir Mexa and pollution indicator element. In order to assess the water quality of the studied dam reservoir, we refer to the grid of the overall quality of surface water of dams in Algeria, according to National Agency of Water Resources [ABHCSM 2005] (Tab. 1).

BIOLOGICAL OXYGEN DEMAND

In fact, the time profile of biological oxygen demand (Fig. 3) shows the presence of an organic load during 2011 and 2012. These values can reach 7 mg·dm^{-3}.

During 2010, the percentage of samples displaying an excellent quality is of 41.66%, this percentage increases to 75% in 2011 and decreases to 33.33%

Table 1. Quality grid of the surface waters

Parameter	Quality class				
	excellent	good	fair	poor	excessive pollution
Organic and oxidizable matter					
OM, mg·dm^{-3}	<3	3–5	5–8	8–10	>10
COD, mg·dm^{-3}	<20	20–30	30–40	40–80	>80
BOD$_5$, mg·dm^{-3}	<3	3–6	6–10	10–25	>25
Dissolved oxygen					
O$_2$, %	>90	90–70	70–50	50–30	<30
Nitrogenous matter					
NH$_4^+$, mg·dm^{-3}	<0.1	0.1–0.5	0.5–2	2–5	>5
NO$_2^-$, mg·dm^{-3}	<0.03	0.03–0.1	0.1–0.5	0,5–1	>1
Nitrates					
NO$_3^-$, mg·dm^{-3}	<2	2–10	10–25	25–50	>50
Phosphorus matter					
PO$_4^{-3}$, mg·dm^{-3}	<0.1	0.1–0.5	0,5–1	1–2	>2
Electrical conductivity					
EC, µS·cm^{-1}	<2500	2500–3000	3000–3500	3500–4000	>4000
Turbidity					
Turbidity, NTU	<2	2–35	35–70	70–105	>105

Source: own study.
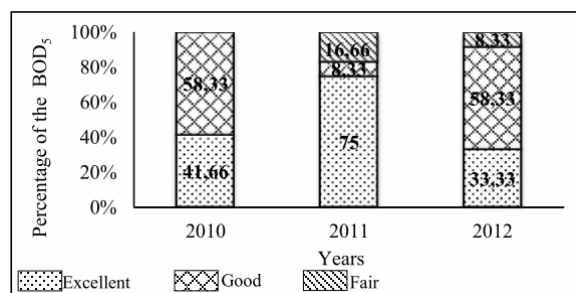
Fig. 3. Temporal variability of the biological oxygen demand; source: own study

during the year 2010, this decrease is due to the existence of an organic load of which 8.33% of the samples display a fair quality. During the year 2010, 58.33% of the samples exhibit a good quality, this percentage decreases to 8.33% during 2011, this is explained by the presence of organic load of which 16.66% of the samples exhibit a fair quality. For the year 2012, the percentage of samples exhibiting a good quality increases to 58.33%. From these histograms, we note that there is a deterioration of water quality during the years 2011 and 2012.

CHEMICAL OXYGEN DEMAND

On the whole, and from the Figure 4, it is observed that the percentage of high-quality samples for chemical oxygen demand decreases from one year to another, with values ranging from 41.66% in 2010 to 0% during 2012. The same observation of samples displaying a good quality; the percentage is of 50% in 2010 and decreases to 16.66% in 2011 to reach 0% in the year 2012.

The percentage of samples of fair quality increases from 8.33% in 2010 to 33.33% in 2011 to reach 58.33% in 2012. The samples of poor quality are of
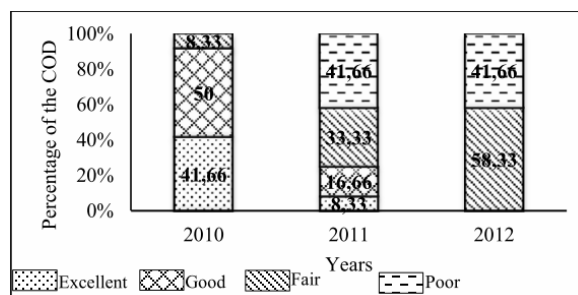
Fig. 4. Temporal variability of chemical oxygen demand; source: own study

the order of 41.66%, this percentage remains stable during the years 2011 and 2012. The histograms show a significant deterioration of the quality of the dam reservoir water during the year 2012.

ORGANIC MATTER

The analysis results show that 16.66% of samples show a good quality of organic matter, this percentage remains stable during the years 2010 and 2011. The percentage of samples of fair quality is of 75% for the year 2010 and decreases to 58.33% for the year 2011, this decrease is due to the degradation of water quality of which 16.66% of samples are of poor quality, and 8.33% show an excessive pollution (Fig. 5).
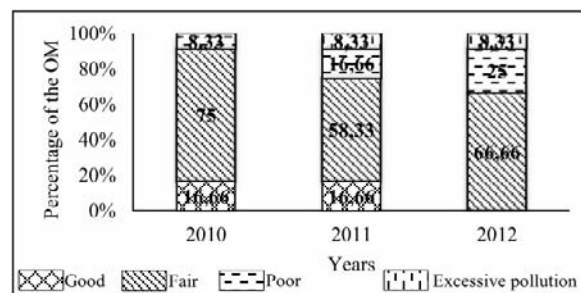
Fig. 5. Temporal variability of organic matter; source: own study

During the year 2012, the deterioration of the quality of water of the reservoir of the dam Mexa becomes more important whose percentage of fair and poor quality increases respectively to 66.66% and 25%. In contrast, the percentage of pollution levels out 8.33%.

NITRITES

The percentage of samples whose water show a natural composition of nitrites is of 33.33% for the year 2010 and 16.66% for the year 2012, and increases to 50% for the year 2011; this is explained by the decrease of samples whose water is degraded significantly to 8.33% (Fig. 6).

As regards the good quality, the percentage levels out, the significantly quality deterioration is of 16.66% in 2010 and decreases to 8.33% in 2011, this deterioration increases to 33.33% in 2012, and this is
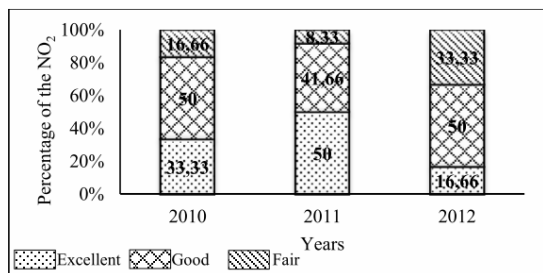
Fig. 6. Temporal variability of nitrites; source: own study

due to the decrease of water percentages showing an excellent quality with respect to the natural state.

NITRATES

The percentage of samples with excellent quality nitrates is of 41.66% in 2010; the percentage decreases to 25% and remains stable during 2011 and 2012. The decrease in 2011 is due to the significant and serious deterioration of water of the dam reservoir Mexa, which is of 8.33% for both levels (Fig. 7).

The good quality of water remains stable at 58.33% during 2010 and 2011 and increases to 75% in 2012. This increase is due to the reduction of samples whose water is of a very good quality.
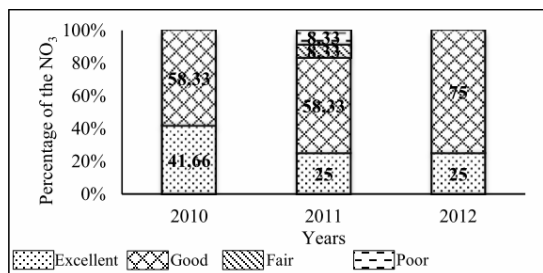
Fig. 7. Temporal variability of nitrates; source: own study

PHOSPHATE

The percentage of samples, whose water is of a very high phosphate quality, increases in 2012 to 41.66% instead of 16.66% in 2010 and 2011 (Fig. 8). This is explained for the year 2012 by the increase in the percentage of good water to 75% for the years 2010 and 2011 and by the increase in the percentage of water of good quality while the significant degradation is on the water whose percentage is of 8.33%.
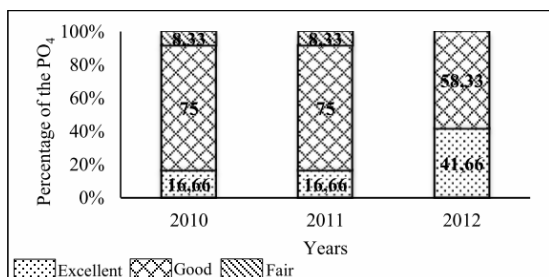
Fig. 8. Temporal variability of phosphate; source: own study

AMMONIUM

According to Figure 9, it is observed that the quality of water of the dam reservoir Mexa has improved for ammonium quality during the period 2010/2012; this is explained by the increase in the percentage of samples with very good quality water. The percentage is 75% in 2010 and passes to 83.33% in 2011 to reach 91.66% in 2012, and concerning the decrease in the percentage of samples whose water shows a good quality, the percentage is of 25% in 2010 and decreases to 16.66% in 2011 to reach 8.33% in 2012.
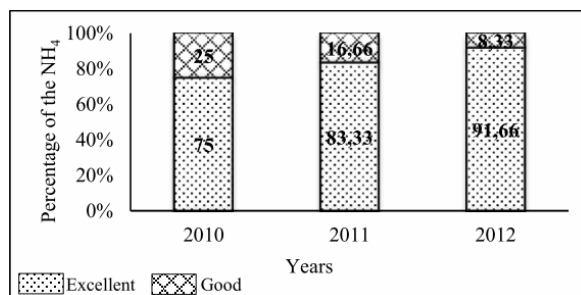
Fig. 9. Temporal variability of ammonium; source: own study

TURBIDITY

The percentage of samples showing a good quality of turbidity is of 100% in 2010 and decreases to 50% in 2011, due to the increase of the percentage of water showing a very good quality on the one hand, and showing significant and substantial degradation of 8.33% of samples on the other hand. In 2012, the quality improves by the increase of the percentage of good quality water to 83.33%, but from the point of view, significant and substantial degradation, the percentage remains stable 8.33% (Fig. 10).
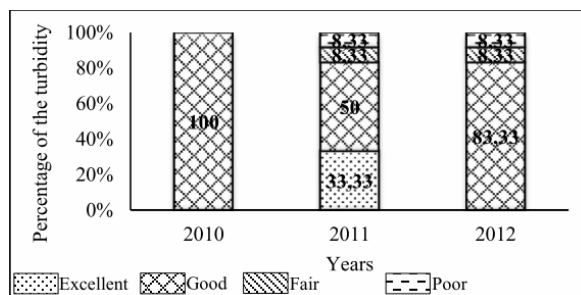
Fig. 10. Temporal variability of turbidity; source: own study

SATURATION

According to the histograms on Figurer 11, we observe that the water quality is very good to good in 2010, with a percentage of 50%. In 2011, the quality improves due to an increase in the percentage of water with excellent quality and a decrease in the percentage of water with good quality.
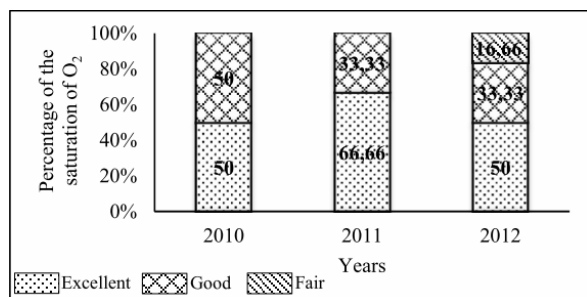
Fig. 11. Temporal variability of the saturation;
source: own study

Fig. 13. Water quality of the dam Mexa during the period
2010/2012; source: own study

In 2012, the quality deteriorates; this is explained by the decrease in the percentage of water showing a very good quality of 50% and the increase in the percentage of water showing a significant degradation of 16.66%.

ELECTRICAL CONDUCTIVITY

The quality of the dam reservoir water is stable for the electrical conductivity during the period 2010–2012 (Fig. 12), all water samples are of a very good quality compared to the natural state, whose percentage of waters of excellent quality is of 100% and remains stable during the years 2010, 2011 and 2012.

Fig. 12. Temporal variability of electrical conductivity;
source: own study

The water quality is a factor and a result at the same time, the first role appears when the physicochemical characteristics of water determine the vulnerability of ecosystems to destructive effects.

According to our analysis and according to the indicator parameters of the quality of raw water of the dam reservoir Mexa, water reveals an excellent conductivity during the years 2010, 2011 and 2012 (Fig. 13). These results are comparable to those obtained by Agency Hydrographic Basin (Fr. Agence de Bassin Hydrographique), 2005 at the dam Mexa and Guenitra (Algeria). For turbidity, low turbidity is observed during 2010, and high turbidity is revealed during the years 2011 and 2012 where the contribution of runoff increases water turbidity. The rainwater carries the particles during their flow and increases this latter. The quality is worse than that obtained by Agency Hydrographic Basin [ABHCSM 2005] at the reservoir dams Mexa and Guenitra (Algeria).

The comparison of the water quality indices of the dam reservoir Mexa during the three years of study (2010, 2011 and 2012) shows a somewhat pessimistic diagnosis. In fact, the results gathered in Figure 13 establish clearly the unfitness of all samples for drinking water supply and require a complete treatment due to significant alteration for almost all the parameters during the years 2011 and 2012.

From this figure, it is observed that water of the dam reservoir Mexa contains more oxidisable and nitrogen organic matter, such as nitrites that clearly indicate a gradual degradation of water quality throughout the years marked by organic pollution. This critical state of water is explained by very high levels of nitrite, phosphate, biological oxygen demand, chemical oxygen demand and organic matter. The quality is comparable to that obtained by Agency Hydrographic Basin, 2005 at the dam Guenitra (Algeria), but worse than that reported by Agency Hydrographic Basin [ABHCSM 2005] at the dam Mexa. The evolution of values shows that this degraded state of water quality of the dam reservoir is due to the discharges of domestic wastewater from agglomerations, as well as to agricultural leaching.

CONCLUSION

At the end of this study, the results obtained for the state of the quality of the waters of the dam reservoir Mexa seem to highlight the direct impact of the overall pollution, generated by the discharge of wastewater of the locality of El-Taref. In fact, this physicochemical quality of water of the dam reservoir reveals that waters are weakly mineralized (*EC* 1000 µS·cm⁻¹) and neutral. In the region, waters exhibit a bicarbonate-calcium facies. The chemical parameters of quality are all below the standard of potability WHO. Significant pollution confirmed by high values of biological oxygen demand, chemical oxygen demand, organic matter, phosphate and nitrite. This pollution could be accentuated by the leaching of salts concentrated at the surface of agricultural soils treated by fertilizers, and also by the domestic discharges from the homes settling throughout the two shores of the wadis. The comparison with earlier work done toward the end of the years 2003 [ABHCSM 2005] has revealed that the dam reservoir waters, which

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Jakość wód powierzchniowych w zbiorniku zaporowym Mexa w północnowschodniej Algierii

STRESZCZENIE

Przeprowadzono badania fizyczne i chemiczne, aby ocenić wpływ rolnictwa i miejskich ścieków bytowych na jakość wody w zbiorniku zaporowym Mexa w regionie El-Taref usytuowanym we wschodniej części basenu Constantine. Próby do analiz pobierano co miesiąc w ciągu trzech lat (2010–2012), łącznie 36 prób. W terenie mierzono temperaturę, pH, przewodnictwo elektrolityczne i stężenie rozpuszczonego tlenu. W laboratorium analizowano aniony, kationy, biochemiczne zapotrzebowanie nas tlen, chemiczne zapotrzebowanie na tlen, stężenie fosforanów, azotanów III i V oraz jonów amonowych.

Stężenie różnych organicznych i nieorganicznych zanieczyszczeń zmieniało się w poszczególnych miesiącach i latach badań. Zanieczyszczenia wód zbiornika zaporowego Mexa zmieniały się w czasie w zależności od czynników klimatycznych. Stężenie zanieczyszczeń było małe w okresie zimowym i duże w okresach niskich przepływów. Uzyskane wyniki dowodzą, że wody zbiornika zaporowego Mexa są w znacznym stopniu zanieczyszczone, a zbiornik podlega zanieczyszczeniom pochodzącym z rolnictwa i ścieków miejskich.

Słowa kluczowe: *jakość wody, zanieczyszczenie, zbiornik zaporowy Mexa, związki organiczne*