Desalination and Water Treatment
www.deswater.com
doi: 10.1080/19443994.2014.982192

57 (2016) 2766–2774
February

Taylor & Francis
Taylor & Francis Group

Study of Beni Haroun dam pollution (Algeria)

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Received 2 February 2014; Accepted 10 October 2014

ABSTRACT

The aim of this work is to study pollution parameters evolution in Kebir-Rhumel basin over 10 years, considering data from four hydrometric stations, and analyze physicochemical and bacteriological characteristics of Beni-Haroun dam streamwater over 5 years. Some analyzed parameters are in relation with water natural structure such as (pH), conductivity, turbidity, chloride ions, sulfate ions…etc. and undesirable substances as nitrates (NO_3^-) and phosphates (PO_4^{3-}) excessive concentrations, which are the main factors responsible for algae proliferation and eutrophication phenomenon acceleration. Thus, pollution indicator parameters as chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), dissolved, and saturated oxygen were also studied. The elaborated work had shown increasing turbidity and suspended matter (SM) in Beni-Haroun dam and Kebir-Rhumel basin, where sulfate concentrations (SO_4^{2-}) are noticeable in different samples. BOD_5, COD, dissolved, and saturated oxygen values indicate organic, chemical, and microbiological water contamination in both dam streamwater and basin catchment.

Keywords: Pollution; Water surface; Beni-Haroun dam; Kebir-Rhumel catchment basin

1. Introduction

Algeria is characterized by water resources scarcity as all arid and semi-arid areas. Population and industrial activities growth polluted domestic and industrial effluents, deteriorated water resources quality, and compromised receiving environment disequilibrium [1–3], Many elaborated works on surface water pollution have shown high phosphorus and nitrates concentrations in rivers [4–6], particularly during storm events. In [7], the author deduced that 85% of phosphorus quantity rejected on studied basin drainage surface is produced in plains because of sewage discharges and intensive agricultural land losses (agricultural land erosion) [8].

Streamwater nutritive enrichment has led to watery plants excessive growth, biotic structure changes, and dissolved oxygen reductions [9–11], This eutrophication phenomenon is a growing problem particularly in rural area [4,12]. The work of Kelly and Wilson in [13] presents dominated eutrophic conditions in all Stour River at Ashford, which cause watery life death (ex fish) [14,15].

Other work [16] indicates that pollution is excessive in downstream river. However, at upstream, sediments consist of materials with low total phosphorus content, weak potential biodisponibility and strong fixing capacity. All these elements suggest an origin related to banks erosion rather than soils. During flood, these sediments are transferred downstream and then mixed with materials resulting from agricultural land erosion

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and gradually with phosphorus, especially during low flows, particularly when facing wastewater [16].

Basin morphological characteristics allowed largest dam achievement in Algeria (Beni Haroun, 960 million m $year^{-1}$), it mobilizes waters main region surface water resource (Kebir-Rhumel river) and it is intended to supply potable water for over than two million inhabitants in 2030 and irrigate four perimeters about 102,000 acres (Teleghma, Remila, Ouled Fadel, and Batna).

Majority of domestic and industrial region discharges are rejected in Kebir Rhumel basin [4] which contributed to water enrichment by nutrient elements, phosphorus and azotes, particularly correlative to aquatic vegetable production; thus, increasing planctonics or fixed algae that deteriorate physical and chemical water properties [9,10].

Several studies on lakes were related to phosphorus available quantity, water-level typology, and plankton algae biomass. These results accredited the idea that could limit algae developments by reducing phosphorus contributions [9,10,17] therefore, it is necessary to react quickly to protect streamwater recycling and polluted discharges recovering on rivers, to avoid any water dam's contamination.

2. Materials and methods

2.1. Study area description

Kébir Rhumel basin covers about 2,174,500 acres stretching from Constantine region boundaries; it expands from high septrional plain margins and Sebkhas at south and Mediterranean Sea at north. It is drained by two main streamwater, oued Rhumel at south and Oued Enndja at west, their confluence downstream Grarem gives oued Kebir which joins the Mediterranean Sea.

From upstream to downstream, appears two contrasted aspects; flat and bare reliefs and hydrographic scalp fairly loose of high plains, low hills succeed Tellian, the deep valleys, which extend to the north by the massive mountainous affected by a high density of drainage [18] (Fig. 1).

2.2. Data and sample selections

This work is carried under various pollution indicator parameters in four gauging stations on Kébir Rhumel basin (Ain Smara, H. Grouz, Grarem and Menia) from 1984 to 2005 realized by National Agency of Hydraulic Resources and daily analysis of physico-chemical and bacteriological parameters at Beni Haroun's dam has been developed during 2007–2011.

Sample flasks are treated during 24 h with nitric acid (HNO_{3^-}) diluted with the one-twentieth, drained, then rinsed with distilled water, the second washing is also treated with nitric acid to the one-third, rinsed with distilled water until end of any acidity thru sunflower paper. A final rinsing with cold distilled water is carried [19,20].

(1) For analysis purposes, flasks are rinsed three (3) times with water, filled to edge. The cal is set to avoid any air or bubble and not to be displaced during transportation [20].
(2) Bacteriological analysis samples were done in glass bottles braised at 220˚C, transported at low temperature (4˚C) from site to laboratory. pH, dissolved oxygen, electric conductivity, and temperature were measured *in situ*.

3. Results and discussion

3.1. Pollution parameters indicator

Pollution indicator parameters analysis was elaborated by N.A.H.R on measured data in Ain Smara, Grarem, Menia, and Hammam Grouze hydrometric stations from 1984 to 2005.

3.1.1. NH_4^+ parameter study

Parameter NH_4^+ annual variations during 1984–2005 are shown on Fig. 2 which variegate between 4.5 and 27 mg L^{-1}, while highest concentrations were observed in Ain Smara and Menia stations.

These concentrations come primarily from domestic and chemical industry rejections, especially from Constantine fertilization industry [14,21–23]. At chlorine presence, high NH_4^+ concentrations can form chloramines which are very toxic and affect treated water quality [23]. While low concentrations were obtained in Grarem and Hamam Grouze stations (<2 mg L^{-1}).

3.1.2. NO_2^- parameter variation

Maximum concentrations NO_2^- are obtained in Grarem, Menia, and Ain Smara stations (Fig. 3) with concentrations exceeding largely standards (1 mg L^{-1}). These high concentrations which come essentially from fertilizer misuses, industrial, and domestic wastes [14,24] can be mortal, since they prevent binding oxygen to hemoglobin [19,25].

3.1.3. NO_3^- parameter variation

Results had shown a nitric pollution in Grarem station with concentrations reaching 35 mg L^{-1}. All

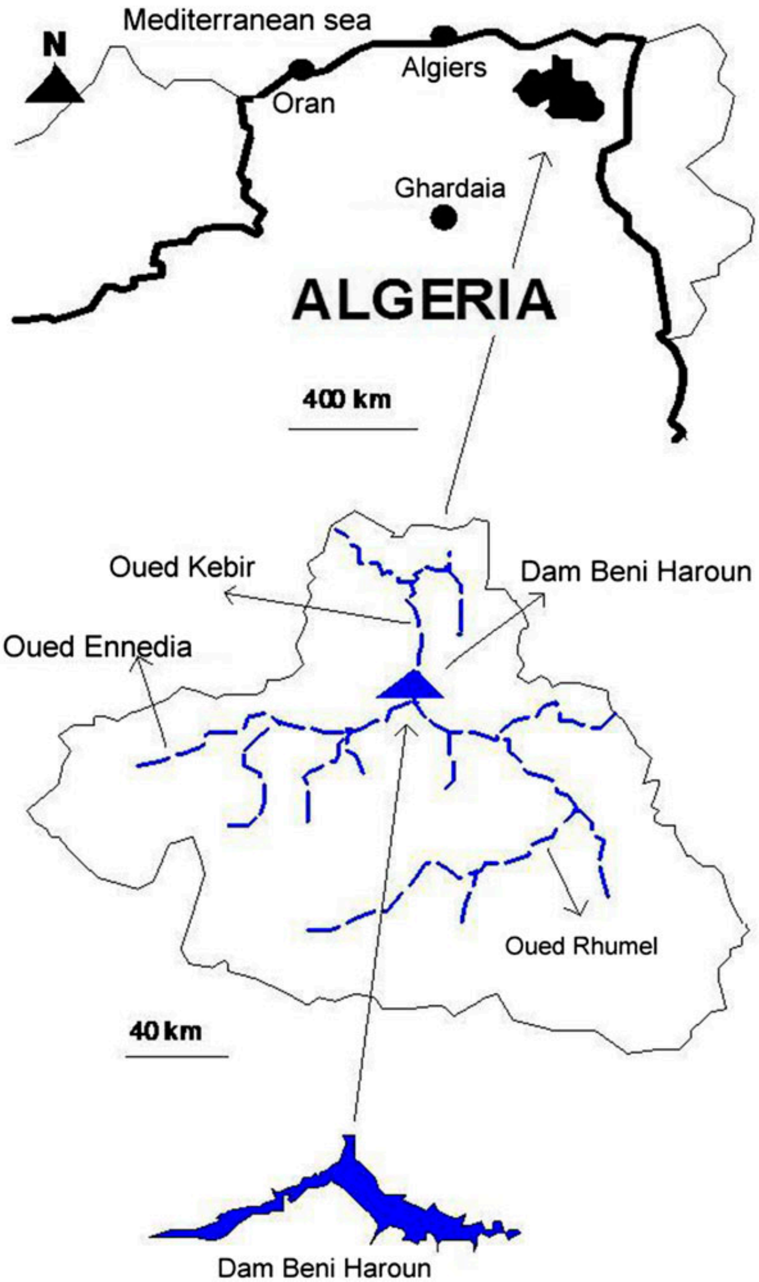

Fig. 1. Location of the dam (Source: NAWR, as amended by the authors).

observed concentrations are acceptable as shown in Fig. 4 and are of primarily agricultural and domestic origins [21,22,25].

3.1.4. Dissolved O_2^- parameter variation

Oxygen is an essential factor in watery life, particularly for organism, it ensures river self-purification, good indicator for pollution, and self-purification tracking. Majority of dissolved oxygen results obtained in Ain Smara and Menia stations. Fig. 5 presents sub-norm concentration (70% O_2), which vary between 21% O_2 and 57% O_2.

Dissolved oxygen concentration decreasing is mainly due to their consumption by micro-organisms which oxidize organic or mineral matters [12]. Only the observed values in Grarem and H. Grouze stations had shown acceptable water quality.

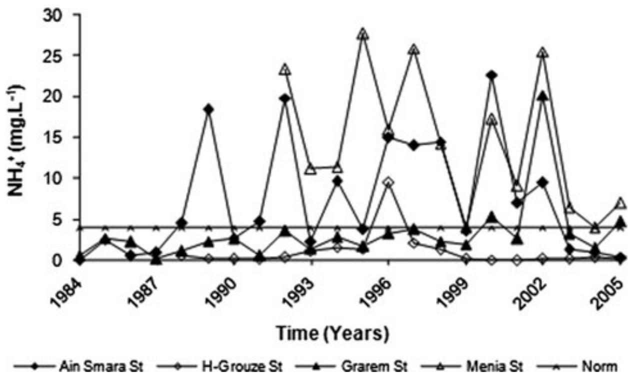

Fig. 2. Annual variation of NH_4^+ parameter during period (1984–2005).

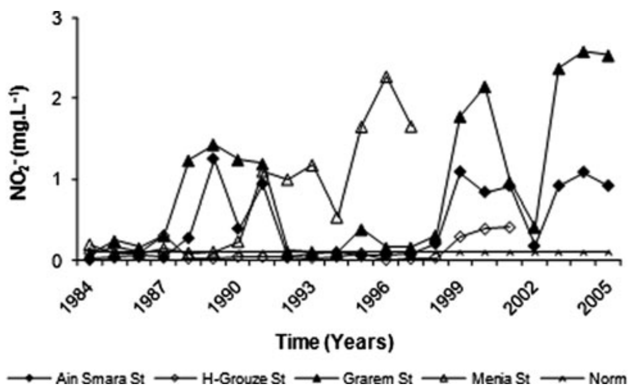

Fig. 3. Annual variation of NO_2^- parameter during period (1984–2005).

3.1.5. SO_4^{2-} *parameter variation*

SO_4 values in Grarem, Ain Smara, and Menia stations exceed 280 mg L^{-1} as shown in Fig. 6 but are acceptable according to norms. Maximum concentrations obtained in these stations reach successively (347, 357, and 473 mg L^{-1}), however, these high concentrations are not dangerous but can cause diarrheal

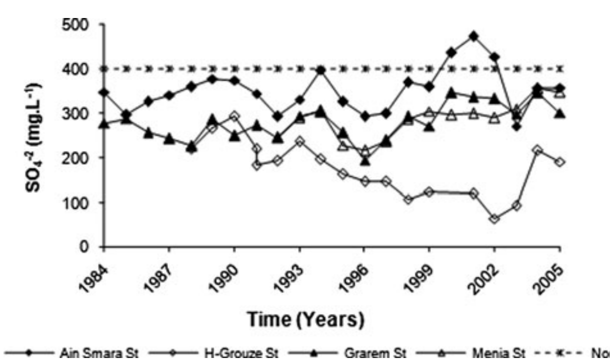

Fig. 6. Annual variation of SO_4^{2-}parameter during period (1984–2005).

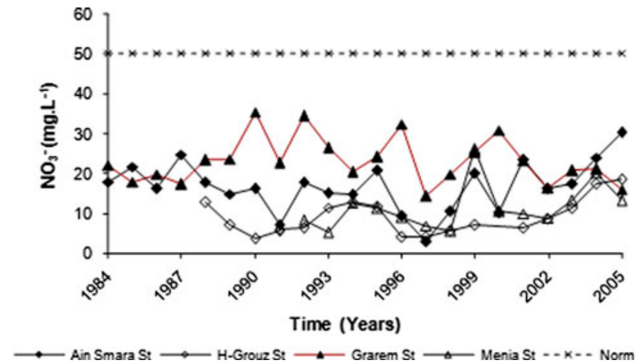

Fig. 4. Annual variation of NO_3^- parameter during period (1984–2005).

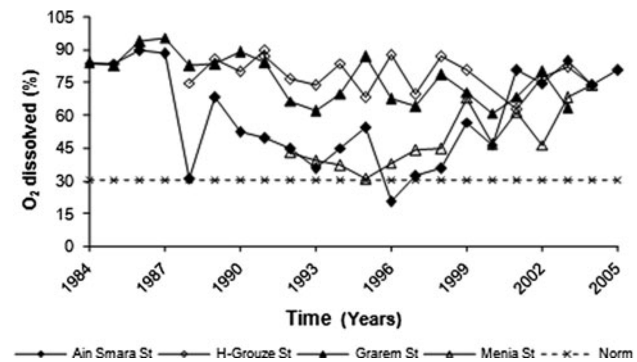

Fig. 5. Annual variation of dissolved O_2 parameter during period (1984–2005).

disorder risks, especially for children [9]. In Menia station, sulfate presence can be related to industrial wastes and traversed soil nature [24,26].

3.1.6. *Turbidity variation*

Turbidity measurement results largely exceed 2 FTU and high concentrations obtained in these stations exceed 50 FTU as shown in Fig. 7. This turbidity increasing is mainly due to an important presence of suspended matter in water caused by watershed soil erosion and streamwater bank instability. These SM have an adsorption capacity which constitutes a bacteria support to [9,12]. This parameter presents a sanitary risk, since it can reduce disinfection treatment effectiveness (turbidity increases chlorine consumption) and generate microbiological risks.

3.1.7. PO_4^{3-} *parameter variation*

Observed PO_4^- concentrations increase suddenly and largely exceed (1 mg L^{-1}). Ain Smara, Menia, and

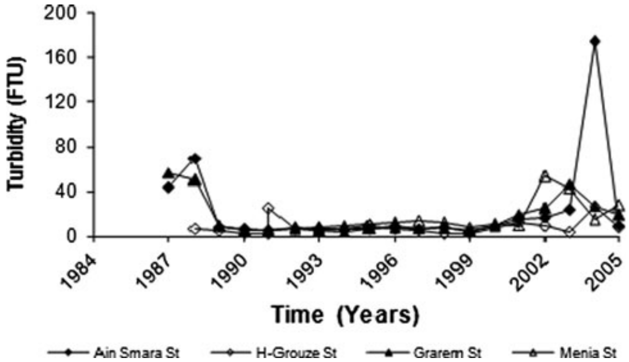

Fig. 7. Annual variation of turbidity during period (1984–2005).

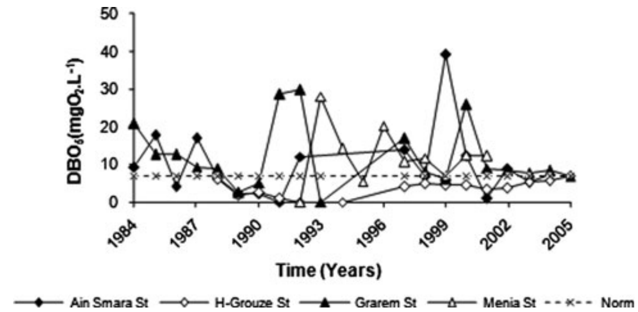

Fig. 9. Annual variation of COD during period (1984–2005).

Garem stations are mostly affected by high PO_4^{3-} content, maximum values reach (9.5, 9, and 5 mg L^{-1}), respectively. These results indicate effective bad water quality in the basin (Fig. 8).

Increased PO_4^{3-} concentrations come mainly from industrial and domestic discharges, essentially due to phosphatic detergents use, showing significant algae development (algae plankton proliferation that gives green or brown color to water) which characterizes eutrophication phenomenon [9,26].

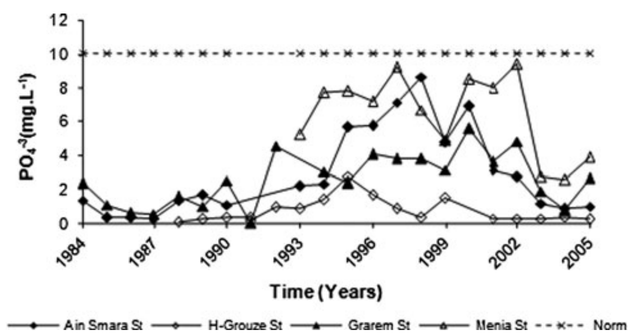

Fig. 8. Annual variation of PO_4^{3-} parameter during period (1984–2005).

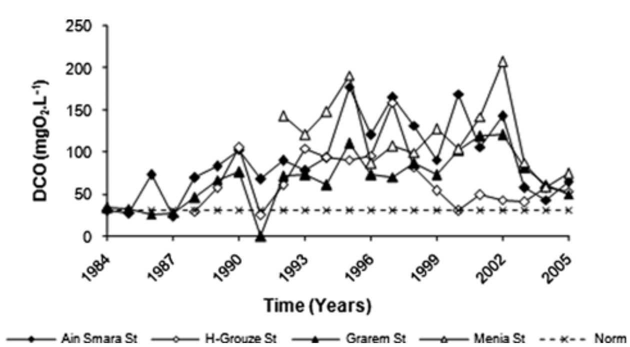

Fig. 10. Annual variation of biological oxygen demand (BOD_5) during period (1984–2005).

3.1.8. BOD_5 parameter variation

High BOD_5 concentration was observed in various stations during several periods as shown in Fig. 9, which largely exceeds norms (7 mg L^{-1}). Consequently, there is potential oxygen consumption through biological ways (all biodegradable organic matter pollution will involve oxygen consumption).

3.1.9. COD parameter variation

Majority of COD values in four hydrometric stations as shown in Fig. 10 largely exceed (30 mg L^{-1}). We note a sudden increase in COD parameter starting from 1993. This may due to urban growth and industrial development, especially during drought years.

This COD increasing indicates high oxygen consumption in basin streamwater, showing natural degradation of water organic matter (aquatic micro-organisms development, which also characterizes eutrophication phenomenon). These micro-organisms are not dangerous but involve a sanitary risk.

Annual COD/BOD_5 average ratio varies between 10 and 20 mg L^{-1} in different measurement stations and provides an indication about lowly biodegradable organic pollution origin. Highest values were reported from Ain Smara and Menia stations and reach 139.09 and 40.67 mg L^{-1}, respectively.

Obtained results had shown strong water pollution by organic matters which are more important in dry season.

3.2. Kebir-Rhumel basin streamwater quality (2004–2005)

Water in basin catchment area presents acceptable nitrate (NO_3^-) concentrations, while nitrite (NO_2^-) at Garem and Menia stations presents high content

Table 1
Physicochemical characteristics of Beni Haroun dam (2007–2011)

Parameters	pH	Cl^- (mg L^{-1})	Na^+ (mg L^{-1})	Ca^{2+} (mg L^{-1})	Mg^{2-} (mg L^{-1})	Conductivity (S cm^{-1} μ)	HCO_4^- (mg L^{-1})	K^+ (mg L^{-1})	T (mg $L^{-1})^1$	Rs_{105} (mg L^{-1})
Concentration	7–8.2	70–180	52.4–115.5	74–152.3	18–48	1,000–13,000	103.7–225.7	1–9	2.7–30	104.8–878
Parameters	SO_4^{2-} (mg L^{-1})	SM (mg L^{-1})	Turbidity (mg L^{-1})	O_2 dis (mg L^{-1})	$NH_4^+NH_4^+$ (mg L^{-1})	NO_3^- (mg L^{-1})	NO_2^- (mg L^{-1})	PO_4^{3-} (mg L^{-1})	DBO_5 (mg L^{-1})	DCO (mg L^{-1})
Concentration	174–734	12–180	0.3–24	6–16.21	0–0.35	0–22	0–18.3	0–25	0.2–15	4.4–105.6

(excessive pollution). Turbidity and phosphates show bad water quality in the majority of studied stations. Sulfate (SO_4^{2-}) concentrations are very salient. Pollution indicator parameters as dissolved oxygen, BOD_5 and COD demonstrate poor water quality in Kebir-Rhumel basin, particularly from Ain Smara and Menia stations.

3.3. Water reservoir dam physicochemical results

Physicochemical water analysis of Beni-Haroun dam reservoir results is shown in Table 1.

The analyzed water is alkali or basic, pH varies from 7 to 8.2 and alkalinity from 7.28 to 10.40. Conductivity and salinity can reach peak values of 1,300 μs cm^{-1} and do not exceed regulation recommended concentrations (2,800 μs cm^{-1}) [19,25]. These results are proportional to dissolved salts which reflect strong water mineralization of studied region. These values are probably related to mechanical erosion and industrial waste contribution [27]. Hardness also presents an average concentration exceeding 19 mg L^{-1}. Chlorides reached an average value of 141 mg L^{-1} (<500 mg L^{-1}), and have not show any toxic threat for human being, but elevated concentrations can damage metallic pipelines. This content expresses possible pollution by domestic wastewater or/and industrial product rejections [19]. Turbidity increases proportionally with SM which reaches maximum value of 180 mg L^{-1} at dam edge as shown in Fig. 11(a), while turbidity concentrations reach 24 FTU. Streamwaters enrichment with SM is in relation with basin mechanical erosion and factories waste discharge (as ceramics, marble, and brickyard units situated near the basin), which discharge mineral mater particles as clay and led to significant water hardness.

Concerning phosphates in Fig. 11(b) show that PO_4^{3-} parameter increases progressively during analysis period and presents an important concentrations which reaches maximum value of 25 mg L^{-1}. The huge amount of industrial and domestic pollutants rejected in reservoir can explain the obtained results (agro food industry, surface treatment workshop, launderettes, cultivated soils washing fertilized by phosphate, and treated by pesticides) [21]. Analyzed waters present also average concentrations in sulfates ions (SO_4^{2-}) which reaches 250 mg L^{-1} while maximum value exceeds 700 mg L^{-1} as shown in Fig. 11(c). It means that neighboring lands contain important proportions of reducing sulfate that can form some green vitriol. Presence of sulfates in quality, greater than 300 mg L^{-1}, can also lead, in some conditions, to concrete destruction and iron corrosion acceleration (example: concrete attacks reservoir dam).

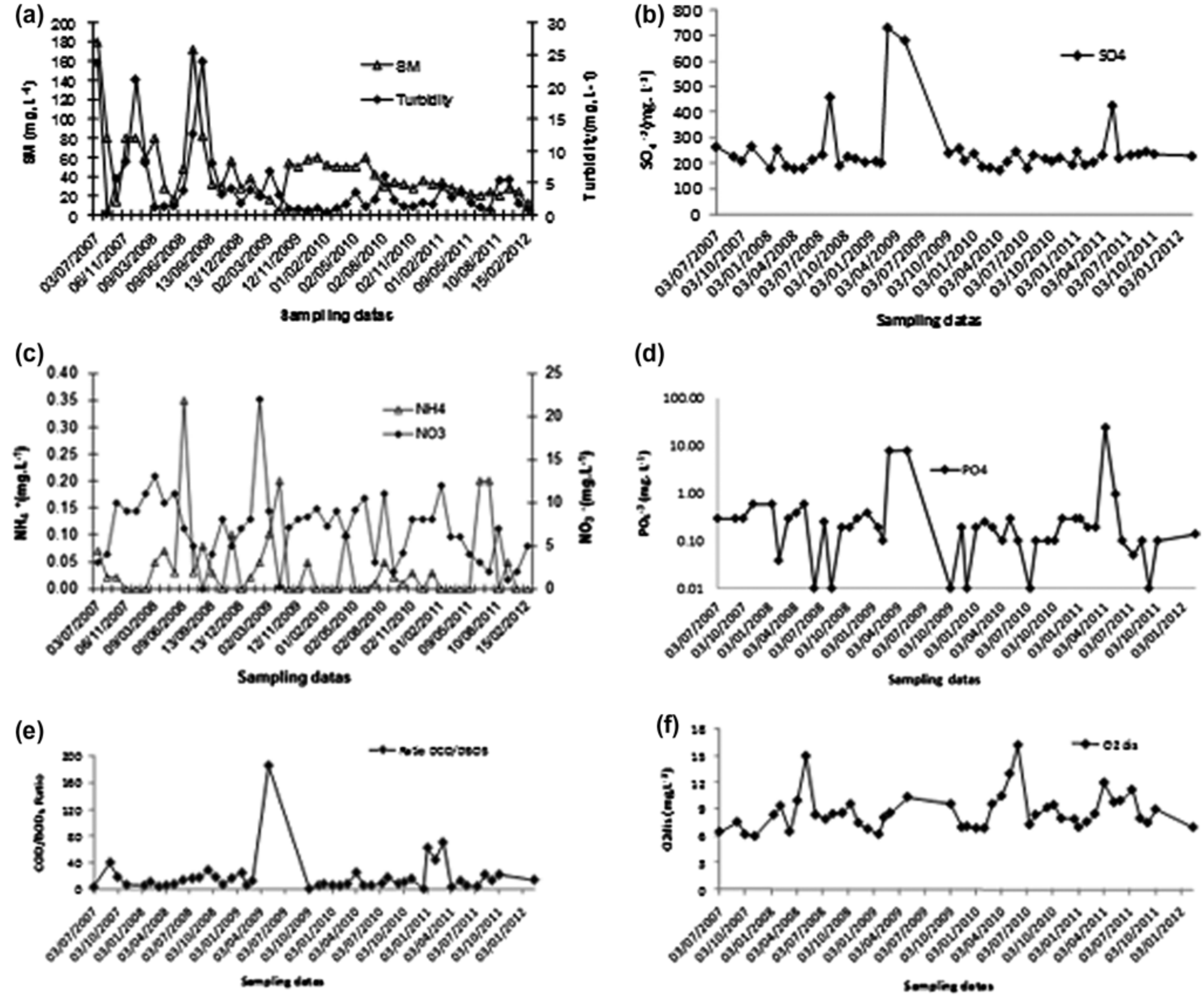

Fig. 11. Different pollution parameters in Ben-Haroun's dam variations (a – SM and TUR; b – PO_4^{2-}; c – SO_4^{2-}; d – NH_4^+ and NO_2^-; e – saturated and dissolved oxygen; f – BOD_5 and COD).

A relation proportionally inversed is shown in Fig. 11(d) between ammonium (NH_4^+) and nitrate (NO_3^-). Majority of measured values are less than 23 mg L^{-1}, NH_4^+ reduction is explained by NH_4^+ transformation in NO_2^- by bacteria [11,17].

In general, dissolved oxygen concentrations are lower compared to Kebir-Rhumel basin streamwater analysis as shown in Fig. 11(e). Average content is roughly equal to 8.71 mg L^{-1}. This oxygen reduction is caused by their main consumption by micro-organisms during oxidization reactions, and in addition to turbidity increasing that disrupts atmospheric oxygen permeability in water. BOD_5 concentrations are upper than 7 mg L^{-1} O_2, and reaches maximum levels about (15 mg L^{-1} O_2). This can explain polluting organic deterioration in these waters under micro-organisms action. Obtained COD concentrations extensively 30 O_2 mg L^{-1} as, with maximum concentrations over 100 O_2 mg L^{-1} (Fig. 11(f)).

3.4. Bacteriological analysis

All bacteriological analyses carried out on several Beni-Haroun reservoir water samples show total and pathogenic germs presence and *Streptococci* and *Escherichia coli* existence, test confirmed. Observed germs contamination average values at dam edge and pumping station are, respectively, (95 c/100 mL, 216 c/100 mL) for total germs and (205 c/100 mL, 250 c/100 mL) for pathogen germs. *Streptococci* and *E. coli* existence were confirmed by a test. These results show recent contamination by wastewater, rich in fecal matters either through direct pouring of human or animal excrements.

For this raison, fecal coliforms and streptococci fecals are considered as germs witnesses of low contamination, their presence in consumed water indicates a recent contamination and consequently presence of certain pathogenic germs. Lawful requirements, indicated in executive decree (N° 11-219 of June 12, 2010), define water quality which is related primarily to pollution indicators.

Fecal coliforms concentration should not exceed 10 c/100 ml; however, coliform total value is of 10 c/100 mL, pathogenic germs requirement, undetectable in 450 mL for chloric vibrio, undetectable in 1 L for salmonella.

5. Conclusion

Our work consists of controlling Kebir basin stream water from 1984 to 2004 and analyzing Beni-Haroun reservoir dam water quality from 2007 to 2011 checking physicochemical, organic, and bacteriological parameters. Some analyzed parameters are in relation with water natural structure, as pH, conductivity, turbidity, chlorides, and sulfates ions. Other parameters concern undesirable substances as nitrates (NO_3^-) and phosphates (PO_4^{3-}) excessive concentrations, which are principal factors responsible for algae proliferation and eutrophication phenomenon acceleration explained by pollution indicator parameters as COD, BOD_5, dissolved, and saturated oxygen.

Through this study; turbidity and suspended matter present high concentrations and indicate water quality deterioration of Beni Haroun reservoir, particularly beside the dam. After several analysis on nitrates and phosphate (NO_3^-, PO_4^{3-}) done in dam reservoir, it appears that water is about average quality, this may be explained by dam periodic filling before starting Beni Haroun great hydraulic transfer which is used to supply water to six Eastern Algerian Wilayas. Observed concentrations in Kébir Rhumel basin streamwater represent a real risk of pollution (triggering the eutrophication phenomenon).

Sulfate concentrations (SO_4^{2-}) are noticeable in different samples, BOD_5, COD, dissolved oxygen, and saturated oxygen indicate streamwaters basin and dam reservoir organic, chemical, and microbiological (*E. coli*, streptococci, pathogenic germs) water contamination, which leads to algae proliferation and accelerates eutrophication phenomenon (water of green color is observed at dam edge and in particular Ain Smara station).

Finally, we can say that a good knowledge of different pollution sources and their influence on aquatic ecosystem is necessary to manage, in a better manner, eutrophication and other pollution types for lakes and reservoirs.

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