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RESEARCH ARTICLE

EVOLUTION OF WATER QUALITY OF A MOROCCAN DAM AFTER ITS SETUP.

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Abstract

This study was conducted to monitor, and to assess the water quality of the dam "Yaacoub Al Mansour" recently filled. The monitoring program concerned the evolution of physico-chemical parameters, bacteria indicating fecal contamination, trophic status and cyanobacteria biomass with their associated toxins. This reservoir is located at 65 km southeast of the city of Marrakech and was filled in May 2008. The main role of the dam is to supply Marrakech city with drinking water.

The early occurrence of *Microcystis aeruginosa* bloom and the high microcystin concentrations measured just only two years after the set up of the reservoir Yaacoub Al Mansour show the importance to consider the control of microcystins concentrations in the surveillance. So, the bacteriological control cannot be the only indicator of water quality of reservoirs which are intended for the supply of drinking water and it is necessary to consider others parameters. Indeed, management programs of drinking water should take into account the toxicity of cyanobacterial blooms from the setup of the reservoirs to protect effectively the health of humans and animals.

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Introduction:-

Water resources are becoming increasingly scarce due to the progression of incessant demands of the people.

In order to satisfy the increasing requirements for water, a strategy of establishing a large number of dams was adopted in Morocco.

However, after the construction of a dam, stream regimes are suddenly transformed into stagnant or lake aquatic systems. Species adapted to running water will disappear or readjust to lake conditions and will establish with the newly emerging species, a complex ecosystem in terms of relationships and interactions (Dauta, 1978; Landner and Wahlagreen, 1986). Moreover, after the filling of dams, several changes of physico-chemical, biological and microbiological water quality are induced. These changes require controls of several parameters to assess water quality and to establish a management system that will help to ensure water supply.

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Therefore, we conducted a water quality study of the dam «Yaacoub Al Mansour» recently filled and which will be intended to supply drinking water for Marrakech city.

We performed a bimonthly sampling from February 2009 to December 2010, to study temporal variations of abiotic parameters, bacteriological parameters, cyanobacteria biomass and microcystins concentration since the filling of the dam.

Materials and Methods:-

Study site and sampling:-

Yaacoub Al Mansour lake ($31^{\circ} 11'$ North $8^{\circ} 05'$ West) is located at 65 km south-east of Marrakech city and 20 km upstream of the reservoir of Lalla Takerkoust (Fig. 1). The dam was built on Oued N'Fis (High Atlas stream) and filled in 2008. This reservoir is characterized by a total water volume of 70 Mm^3 and a maximal depth of 70 m. The main role of the reservoir is to supply Marrakech city with drinking water.

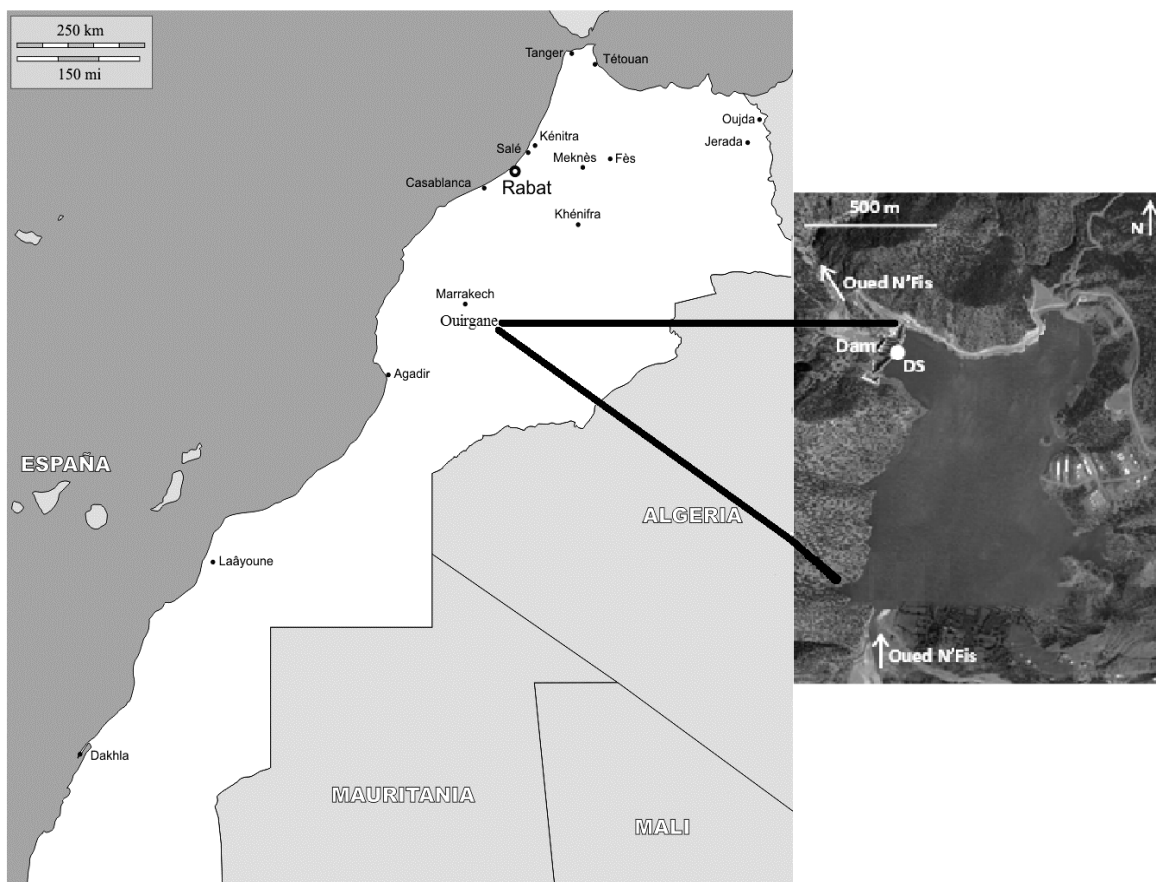


Figure 1:- Geographical location of “Yaacoub Al Mansour” reservoir.

From February 2009 to December 2010, water samples were performed using a Van Dorn bottle (2 L), monthly in winter and spring and bimonthly in summer and autumn, at the surface of the deep station (DS) located near the bridge.

Analysis of Abiotic parameters:-

Water samples were collected in 1.5L bottles to measure abiotic parameters.

Temperature and conductivity were measured using the conductivity-type WTW LF 318. pH and dissolved oxygen were measured using pH meter type WTW PH 330i and oxygen probe HANNA HI 9142 successively. Transparency was measured by Secchi disk.

Total phosphorus, total nitrogen, ammonium and chlorides were analyzed using standard methods (AFNOR, 1994).

Nitrates, sulfates and oxidisability were analyzed according to standard methods of Rodier (1984). Chlorophyll a was determined using spectrophotometric method (ISO, 1992). Total Suspended Solids is obtained by filtration on Millipore filter (0,45µm).

Fecal indicator bacteria:-

From water samples (1 liter) stored in sterile glass bottles, enumeration of Total Coliform (TC), Fecal Coliform (FC), and Fecal Streptococcus (FS), was performed according to techniques described in AFNOR (1994).

Cyanobacteria abundances:-

Cyanobacteria cells count were estimated after the fixation of 250 mL of water with 10% of Lugol's solution.

The abundance of *Microcystis aeruginosa* cells was estimated after the fixation of 10mL of water with 10% of Lugol's solution. The samples were sonicated (50 KHz during 5 seconds) to disrupt *Microcystis aeruginosa* colonies and not alter the cellular integrity (Latour *et al.* 2004). Cells were counted in a Malassez cell with an optical microscope (objective x40). The results were expressed as number of cells per liter of water.

However, the counting of other cyanobacteria species was performed according to the classical method of Uthermohl (Uthermohl, 1958).

Analyses of microcystins:-

After filtration of 1 L of water on Whatman filter Grade GF/C, the microcystins (intracellular) were extracted twice by sonication (two sets of 5 baths during 15 min) of the filter in 2 ml of 75% methanol. The lysate was centrifuged at 14 000 rpm during 15 min to remove cellular debris then the supernatant was evaporated with a concentrator (Concentrator 5301, Eppendorf, Hamburg, Germany). The extract obtained was dissolved in 200 µl of methanol 20% and stored at -20°C until analysis.

The microcystin measurements were achieved by high-pressure liquid chromatography coupled with photodiode array detection (HPLC-DAD, Agilent Technologies Waghäusel-Wiesental, Germany). The sample was pushed by a mobile phase consisting of water (A) and acetonitrile (B) (each containing 0.1% formic acid). Separation was performed with a C18(2) column (250 of 4.6mm, 5Mm particle size; Phenomenex Luna) with the following gradient: 0-2 min, 98% A; 2-12 min, 98-2% A(linear); 12-13 min, 2-98% A. Quality control samples (MC-LR) and blank runs were interspersed between the samples under investigation.

Results and Discussions:-

Study of physicochemical and bacteriological quality:-

For nitrogen compounds; total nitrogen, nitrates, and ammonium successively vary between 76 and 820,9 (µg/L), 35,9 and 568 (µg/L) and 15,2 and 351 (µg/L) (table 2).

During the two years of study, temperatures of reservoir waters of Yaacoub Al Mansour vary generally between 12 and 33,2 (°C) (table 2). The pH was alkaline throughout the study period and varies between 7,08 and 9 (Table 2). Concerning conductivity, values are between 165 and 420 (µg/cm). Concentrations of total phosphorus were included between 30,9 and 312,68 (g/L) (Table 2). For nitrogen compounds; total nitrogen, nitrates, and ammonium successively vary between 76 and 820,9 (µg/L), 35,9 and 568 (µg/L) and 15,2 and 351 (µg/L) (table 2).

Chlorides and sulfates are extremely low and successively vary between 14 and 77 (mg/L) and 0,1 and 2,8 (mg/L) (Table 2). However, values of suspended matter were relatively high (between 0,01 and 2,6 mg/L) (Table 2). The oxidisability varies between 0,1 and 3,8 (mg/L) (Table 2). Moreover, dissolved oxygen values were included between 2,15 and 11 (mg/L) showing then the oxygenation of reservoir waters (Table 2).

The comparison of values of the whole physico-chemical parameters measured with Moroccan standards for raw water intended to drinking water supply (Moroccan Standards, 2008), shows that the dam Yaacoub Al Mansour has a bad water quality and this water require an intensive physical and chemical treatment.

However, the number of bacteria colonies indicating water pollution (table 2) does not exceed Moroccan standards (Moroccan Standards, 2008). In this case, water requires just a simple physical treatment to be drinkable.

The bacteriological study has shown that the raw waters of the dam Yaacoub Al Mansour are good for production of drinking water and require only a simple treatment by disinfection. Nevertheless, physicochemical analysis has shown that water requires extensive treatment because some parameters exceed the Moroccan standard for raw water intended for drinking water. This treatment includes several stages: screening, sieving, desabling, settling and pre-oxidation.

Table 2:- Minimum and maximum value for each physico-chemical and bacteriological parameters studied.

Studied Parameters	Minimum and maximum value
Temperature	12-33,2 (°C)
pH	7,08-9
Conductivity	165-420 (µg/cm)
Total phosphorus	30,9-312,68 (µg/L)
Total nitrogen	76-820,9 (µg/L)
Nitrates	35,9-568 (µg/L)
Ammonium	15,2-351 (µg/L)
Chlorides	14-77 (mg/L)
Sulfates	0,1-2,8 (mg/L)
Oxidisability	0,1-3,8 (mg/L)
Dissolved oxygen	2,15-11 (mg/L)
Suspended matter	0,01-2,6 (mg/L)
Total Coliform	0 (UFC/100mL)
Fecal Coliform	0 (UFC/100mL)
Fecal Streptococcus	0-20 (UFC/100mL)

Temporal evolution of cyanobacteria and microcystins:-

The autumn of the year 2009 was characterized by a significant development of cyanobacteria and a manifestation of *Microcystis aeruginosa* bloom (Maximum: $46 \cdot 10^6$ cells/L) (Fig. 2).

This bloom appeared early just at the second year after the filling of the dam. However, the year 2010 has recorded a low development of cyanobacteria in summer (maximum: $18 \cdot 10^4$ cells/L) (Fig. 2).

According to the World Health Organization, the presence of cyanobacteria blooms in water constitutes a high health risk and it should forbid any contact with these blooms (OMS, 2003).

Concerning concentrations of intracellular Microcystins LR (MCLR), they were very high in autumn of 2009 which corresponds to the bloom period (max: $7,5 \mu\text{g/L}$). However, concentrations decreased in 2010 (max: $1,12 \mu\text{g/L}$) (Fig. 2).

In all cases, maximum concentrations of MCLR for the two years exceed the standard ($1 \mu\text{g/L}$) established by the World Health Organization for microcystin-LR in drinking water (OMS, 2004).

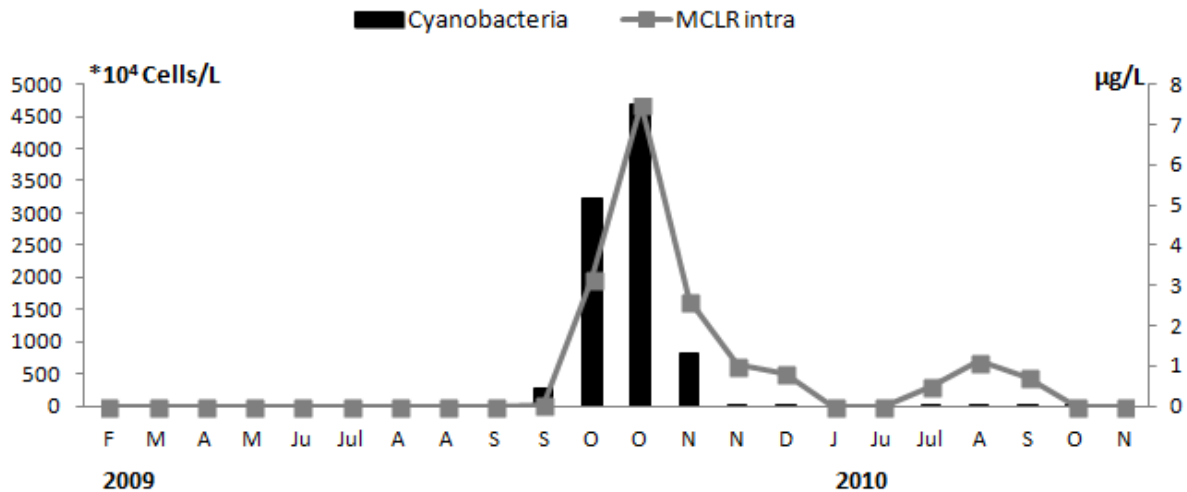


Figure 2:- Temporal evolution of cyanobacteria and microcystin LR at the surface of the reservoir

Evolution of trophic Status:-

Several authors determine the trophic status of lakes based on qualitative and quantitative characteristics of the phytoplankton population. Others were based on phosphorus, nitrogen, chlorophyll a and transparency (Galvez-Cloutier and Michelle Sanchez, 2007; Vollenweider, 1968; OECD, 1982).

Based on the OECD classification (1982) and in particular on chlorophyll a, Yaacoub Al Mansour lake has been transformed from a hypereutrophic state in the first year of its filling in (2009) to a eutrophe state in 2010 (Fig. 3).

The high degree of trophy reached by this reservoir, two years after its filling, is a surprising event especially since there is no clearly visible source of pollution on the watershed. This state would probably represent a transitory state of trophic explosion, which is related to the young and unstable nature of this ecosystem.

This situation is similar to that observed in other lakes of Morocco (Loudiki, 1990; Fqih berrada, 2001). In fact, Loudiki (1990) found that the filling of dam of hassan I has promoted an early eutrophication which is due to the simple cleaning of vegetation.

Moreover, the degradation of organic matter and the geological substrate after the setup of a dam may lead to the nutrient enrichment. Like for the dam "Petit-Saut "in France, its setup resulted a mobilization and a permanent flow of dissolved elements (Richard, 1997). Other secondary contributions of nutrient can thereafter intervene by leaching waters after rainfall (Mama, 2011).

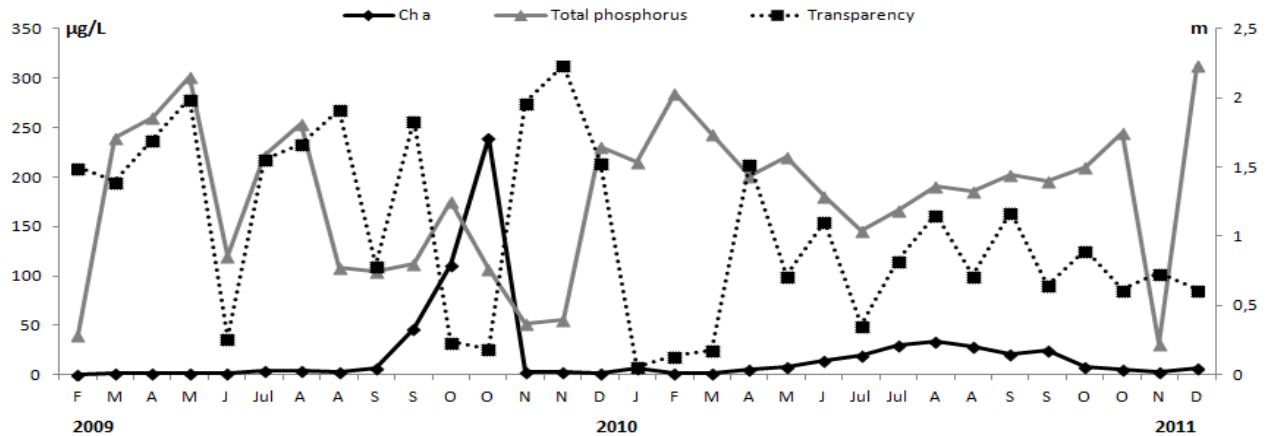


Figure 3:- Temporal evolution of chlorophyll a, total phosphorus and transparency at the surface of the reservoir .

Conclusion:-

The bacteriological study shows that the reservoir Yaacoub Al Mansour has a good water quality which can be consumed just after a simple treatment. However, temporal evolution study of physico-chemical parameters, the biomass of cyanobacteria and microcystin concentrations showed that the reservoir Yaacoub Al Mansour has a bad water quality which can never be used for drinking water supply except after an intensive physical and chemical treatment.

Therefore, only the bacteriological control cannot determine the water quality of reservoirs which are intended for the supply of drinking water and it is strictly necessary to study physicochemical parameters, cyanobacteria biomass and microcystin concentrations.

Finally, the hypertrophic state and the early occurrence of *Microcystis aeruginosa* bloom in the reservoir Yaacoub Al Mansour show the importance to apply surveillance programs immediately after the setup of dam reservoirs to protect the health of humans and animals.

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