Journal of Materials and Environmental Sciences
ISSN : 2028-2508
CODEN : JMESCN

J. Mater. Environ. Sci., 2018, Volume 9, Issue 2, Page 631-640

http://www.jmaterenvironsci.com

Moroccan reservoirs water quality: A review

W. Belokda[1, 2,3*], K. Khalil[1], M. Loudiki[2], K. Elkalay[1]

1. Laboratoire des sciences appliquées à l'environnement et au developpement durable, Ecole supérieure de technologie. Université Cadi Ayyad. Essaouira Al Jadida, Route d'Agadir, BP 383, Essaouira, Maroc.
2. Laboratoire d'algologie et d'hydrophyte. Faculté des Sciences Semlalia . Université Cadi Ayyad. Bd. Prince Mlly Abdellah, B.P. 511. Marrakech, Maroc
3. Laboratoire de Biotechnologie Végétale, Ecologie et Valorisation des Écosystèmes, Faculté des sciences El Jadida, Université Chouiab Doukkali, B.P. 20, El Jadida, 24000, Maroc.

Received 05 Sep 2017,
Revised 05 Feb 2018,
Accepted 14 Feb 2018

Keywords

- Moroccan reservoirs;
- state of research;
- research areas;
- water quality;
- hydrobiology

W. Belokda
wafaebelokda@gmail.com
+212663391330

Abstract
A review of the existing Moroccan reservoirs studies (number and fields studies) was done to help reveal the strategy used in accordance with the actual challenges. Three major scientific search tool (Scopus, Science Direct and ResearchGate) were used with keywords in English and French (e. g. "Moroccan reservoir", "nutrients", "freshwater", "water quality). A documentation of 49 articles and 30 theses was collected. Morocco have 139 reservoirs. Only 20 of them have been subject to scientific studies that took place between 1987 and 2016. The total number of field studies includes 19 in ecology, 17 in toxicology, 12 in hydrobiology, 11 in sedimentology, 10 in hydrogeochemistry, and 8 in biology. Spatial comparison of physical, chemical and biological key variables was done. The comparison of observations values obtained was made between the reservoirs existing in the same basin (e.g. Oum Rbia basin). The water column has usually the same phytoplankton species with a difference in their appearances and /or their disappearance time. This review prove the urgent needfor future research, monitoring and evaluation of Moroccan water reservoirs.

1. Introduction
Morocco has always considered water as one of the priorities of the socio-economic development priority. To this end, he provided a long-term strategy based on water engineering wich leed to reservoirs construction [1]. Those reservoirs give the drink water supply, water for industry and irrigation sectors. Morocco has more than 139 large reservoirs with total capacity of more than 17.6 billion m^3, 13 water projects and water transfer over a hundred small dams and hill reservoirs [2]. The preservation of those reservoirs remains a need in the choice of water management system and the comprehensive planning for economic development not only for the preservation of biodiversity, but also for the maintenance of goods and services they provide to the society. Numerous observational studies have taken place in some Moroccan reservoirs [2-3-4-5-6]. However still not enough, a review of the studies (number and fields studies) will help reveal the strategy used in accordance with the actual challenges.
A correct and well-defined identification of the key variables of the water (physical, chemical, nutritional, organic ...) remains an essential link in the process of adopting this review. This diagnosis calls for reflection and a multidisciplinary strategy aimed at improving management protocols appropriated to the characteristics of each type of reservoir (small or large, short or long residencetime, etc.), and thus anticipating their evolutions. The purpose of this study is to review and synthesize conclusions on available research works on Moroccan reservoirs.

2. Materials and Method
To achieve this study, three major scientific search tool (Scopus, Science Direct and Research Gate) were used with keywords in English and French. Examples include "Moroccan dam", "Moroccan lake", "Moroccan reservoir", "nutrients", "freshwater", "water quality", "phytoplankton", and "ecology" and the process yielded 79 results.After that, the focus is on presenting the spatial and temporal distribution of the studies per data availability and compare between studies fields. The subsequent time highlights the spatial variation of physical, chemical and biological parameters (water temperature, pH, dissolved oxygen, turbidity, nutrients, algae / chlorophyll-a, zooplankton, fish). The paragraph summarizes and integrates the results of the studies, using a quantitative framework to find common themes and processes that lead to specific results of water quality.

3. Results and discussion

3.1. Reservoirs sudies number

This comparative study between different Moroccan reservoirs (Figure 1) is based essentially on a documentation of 49 articles and 30 theses. The majority of the articles were published in the revue des sciences de l'eau. A minor part of them has been featured in other journals such "Hydroecology Application", "Research of Reservoir Management", or "International Journal of Limnology".

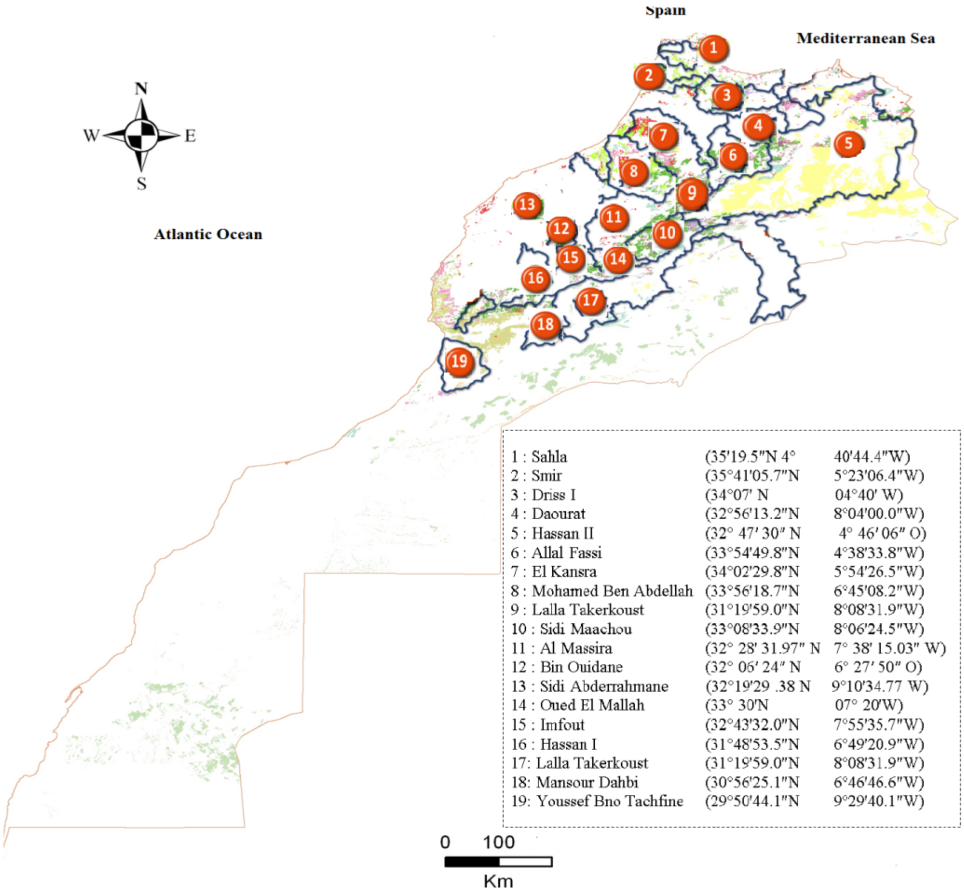

Figure 1: Map of the water reservoirs studied.

A comparison between the number of existing reservoirs per basin and the number of reservoirs studied was done (Table 1). The analysis shows a clear heterogeneity between the number of reservoirs existed and those targeted for study. The Oum Rbia basin have the highest reservoirs number in Morocco (18 reservoirs). In fact, only 7 of them were targeted by 25 studies according to the available literature. The same remark was recorded for Sebou basin with 5 reservoirs which 4 of them were studied (12 studies). Bouregrag basin contains 6 reservoirs and 2 have been studied (8 studies). Sus-Massa-Deraa basin reported the same finding (7 reservoirs installed, 2 reservoirsstudied, and 8 studies). Starting water quality studies efforts involved with a consistent factors. including the availability of surface water resources, climate regime (climate, average precipitation per year), and geological characteristic of each basin [7]. In fact, a basin formed of highly permeable materials with continuous vegetation cover (e.g.Moulouya basin) will generally have a low drainage density ensuring better infiltration of surface water. On the other hand, a basin formed of impermeable but erodible and movable rocks, such as marls or clays, with medium vegetation, often has a high drainage density (Oum Rbia, Tensift and Sebou).

3.2. Spatial distribution for reservoir studies

The reservoirs water capacity and studies number was shown in Figure 2. Al Massira [5], Bin El Ouidane [8], Driss I, and Mohamed Ben Abdellah [9] are the largest reservoirs with a capacity between 10000 Mm3 and 28000 Mm3. Others with a capacity between 200 Mm3 and 600 Mm3 like El Kansra, Hassan I, and Youssef ben Tachfine. The smaller reservoirs have a water capacity fluctuating between 2 Mm3 and 100 Mm3 (Daourat[4], Sidi Maachou[4], Imfout [4], Sidi Abderrahmane [10]). Al Massira and Manssour Dahbi reservoirs were the most representing with 11 and 9 studies respectively. Yaakoub Manssour (7 studies), Oued El Mellah (8 studies), El Kansra (7 studies), and Takerkoust (7 studies) rank second. Other reservoirs studies number fluctuate between 1 and 5. To our knowledge, spatial distribution of studies number is heterogeneous. Many factors affect this distribution. The reservoirs capacity is one of many reasonable factors to find studies for Al Massira and Bin Ouidane reservoirs. However, increasing nutrients concentrations with distance is one of the most reasons for more studies, as is noted for Imfout (3studies), Daourat (4 studies) and Sidi Maachou (4 studies). These reservoirs are in the downstream part of the Oum Rbia basin, and they can be affected by natural processes , or anthropogenic impacts [11] such as man-induced pollution.. The climate and the observed ecological phenomena (e.g. algae bloom, eutrophication) are also among the major factors for finding spatial distribution reservoir studies [15].

Table 1: Number of Moroccan reservoirs studied per basin area.

Basin name	Mean rainfall (mm/an)	reservoirs numbers per basin	reservoirs studied per basin	Studies reservoirs name
Oum Rbia	550	18	7	Almassira Bin Ouidane Hassan I Imfout Daourat Sidi Maachou Sidi Abderrahmane
Bouregragand coastal basin of Casablanca-Rabat	443[28]	6	2	Oued Mellah Mohammed Ben Abdellah
Sebou	600[7]	5	5	Sahla Driss I El Kansra Allal Fassi
Tensift	300[7]	5	2	Lalla Takerkoust Yaakoub Manssour
Moulouya	600[7]	6	1	Hassan II
Souss-Massa-Draa	200[7]	7	2	Manssour Dahbi Youssef bno Tachfine
Somme	-	47	19	

3.3. Spatial distribution for reservoir studies

The reservoirs water capacity and studies number was shown in Figure 2. Al Massira [5], Bin El Ouidane [8], Driss I, and Mohamed Ben Abdellah [9] are the largest reservoirs with a capacity between 10000 Mm3 and 28000 Mm3. Others with a capacity between 200 Mm3 and 600 Mm3 like El Kansra, Hassan I, and Youssef ben Tachfine. The smaller reservoirs have a water capacity fluctuating between 2 Mm3 and 100 Mm3 (Daourat[4], Sidi Maachou[4], Imfout [4], Sidi Abderrahmane [10]). Al Massira and Manssour Dahbi reservoirs were the most representing with 11 and 9 studies respectively. Yaakoub Manssour (7 studies), Oued El Mellah (8 studies), El Kansra (7 studies), and Takerkoust (7 studies) rank second. Other reservoirs studies number fluctuate between 1 and 5. To our knowledge, spatial distribution of studies number is heterogeneous. Many factors affect this distribution. The reservoirs capacity is one of many reasonable factors to find studies for Al Massira and Bin Ouidane reservoirs. However, increasing nutrients concentrations with distance is one of the most reasons for more studies, as is noted for Imfout (3studies), Daourat (4 studies) and Sidi Maachou (4 studies). These reservoirs are in the downstream part of the Oum Rbia basin, and they can be affected by natural processes , or anthropogenic impacts [11] such as man-induced pollution.. The climate and the observed ecological phenomena (e.g. algae bloom, eutrophication) are also among the major factors for finding spatial distribution reservoir studies [15].

3.3. Temporal distribution for reservoir studies

The most worldwide water quality monitoring programs started in the 1960s [16]. Studies appeared sparse in the scientific literature until the 1970s, and then a substantial increase occurred between 1990 and 2010 [16]. In Morocco, to our knowledge, the first monitoring studies on water quality started in 1987 [9] (Figure 3), and focused their efforts to classify the water bodies status or groups of water bodies [4-13-14] (studies per basin). The challenge was to understand and to explaine the causes and consequences of sporadic phenomena (bloom, fish toxicity, etc.).

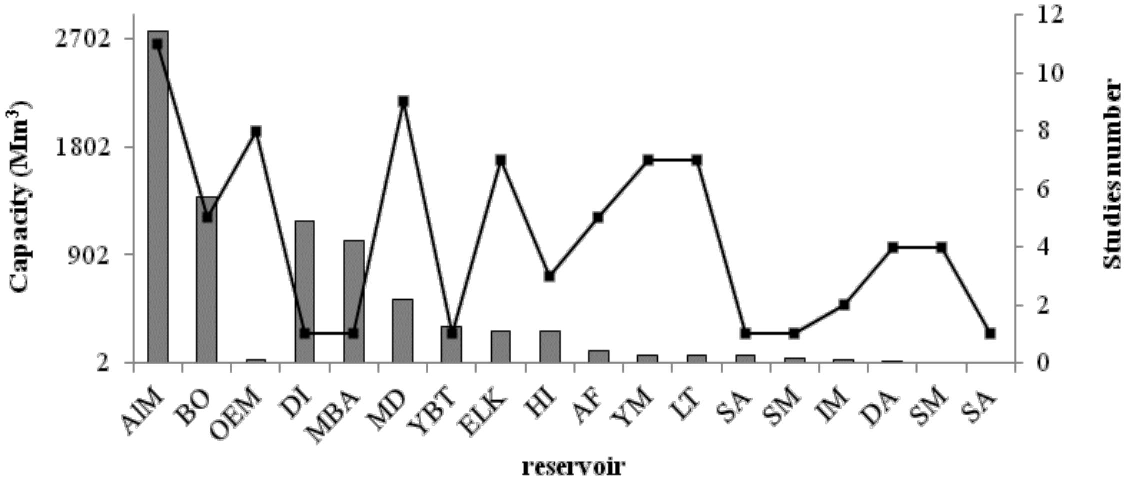

Figure 2: Moroccan reservoirs water capacity and studies number (1987-2016):

AlM (Al Massira); BO (Bin Ouidane); **OEM** (Oued El Mallah); **DI** (Driss I); **MBA** (Mohamed BenAbdellah); **MD** (Mansour Dahbi); **YBT** (Youssef Bno Tachfine); **ELK** (El Kansra); **HI** (Hassan I); **AF** (Allal Fassi); **YM** (Yaakoub Manssour); **LT** (Lalla Takerkoust); **SA** (Sahla); **SM** (Smir); **IM** (Imfout); **DA** (Daourat); **SM** (Sidi Maachou), **SA** (Sidi Abderrahmane).

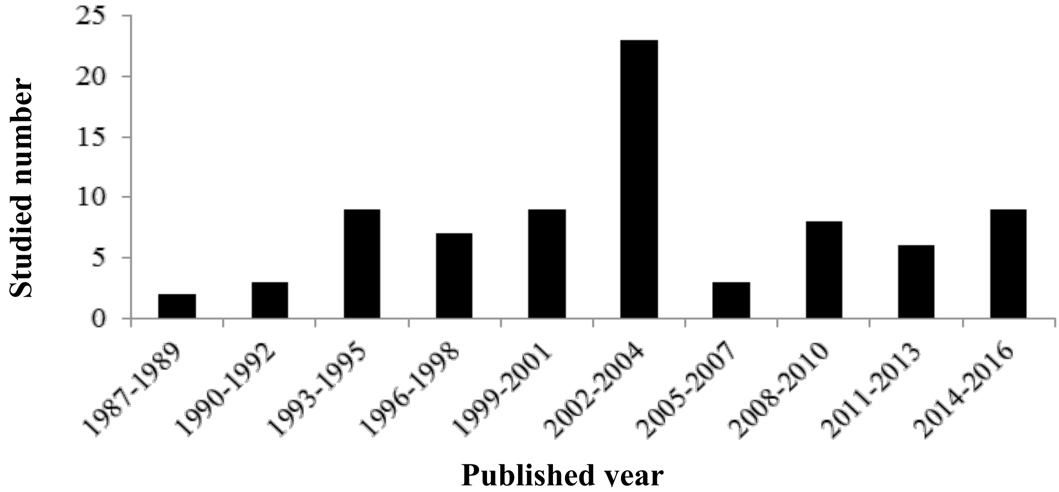

Figure 3: Moroccan reservoirs studies number during 1987-2016 period.

3.4. Reservoirs studies fieldes

The studies focused on ecology field with 17 studies [6], toxicology [8-17] (17 studies), hydrobiology [4] (11 studies), sedimentology [4] (10 studies), hydro geochemistry (9 studies), and biology[18] (5 studies), and only two studies in modeling by developing a thermal regime model of Al Massira reservoirs, and ecological modeling in Sidi Abderrahmane [10] (Figure 4).

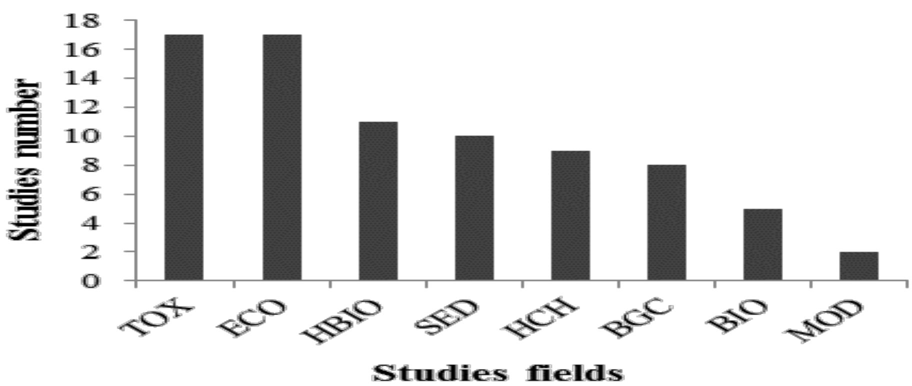

Figure 4: Number of field studies in Moroccan reservoirs (1987-2016): **SED** (Sedimentology); ECO (Ecology); **BIO** (Biology); **HBIO** (Hydrobiology); **MOD** (Modeling); **TOX** (Toxicology); **HCH** (Hydrochemistry); **BGC** (Biogeochemistry).

3.5. Water quality variables in Moroccan reservoirs studies

Basic variables commonly included in a water monitoring effort at Moroccan reservoirs are listed in Table 2. Mosley [16] showed that water quality monitoring refers to the acquisition of quantitative and representative information on the physical (e.g. water temperature, and turbidity), chemical (e.g. pH, dissolved oxygen,), nutrients (Orthophosphorus, ammonium, nitrate, nitrite, total phosphorus), and biological (chlorophyll-a, phytoplankton, zooplankton, and fish) indicators' properties and their response variables over time and space [20-21-22]. These response variables are related to both the trophic states of the reservoirs' catchment processes [23], and therefore, may be used as response variables of the reservoir's ecosystem health [24], ecology [25], and the changes by anthropogenic activities [26]. Dai [19] conclued that in recent years, the design of water quality monitoring networks has evolved to more focused topics, such as eutrophication, salinization, acidification, microbial, and heavy metals contamination. It was probably the consequence of cost-effective and designed targeted monitoring programs. Indeed, published literature shows that monitoring studies shed light on the same key determinant parameters.

Table 3: Common water quality variables of the Moroccan Reservoirs

Common variables	***References***
Hydrological variables	
Residence time	[29-30]
Flow ratio	[29-31]
Size and depth	[19-29]
Water discharge /level	[29-32]
Chemical and physical variables	
Temperature	[19-33-34]
pH	[19-33-34]
Dissolved oxygen	[19-33-34]
Electrical conductivity	[32-33-34]
Transparency	[19-33-18]
Nutrients	
Orthophosphorus	[19-33-34]
Total phosphorus, dissolved	[32-35-36]
Total phosphorus, particulate	[36-37]
Nitrate	[33-35]
Nitrite	[19]
Ammonium	[30-33-36]
Silica	[14-29-36]
Dissolved salts	
Sulfate	[19-37]
Organic matter	
Chlorophyll-*a*	[29-38-39]
Phytoplankton	[38-39]
Zooplankton	[5-29-40]

3.6. Monitoring objectives in relationshep with sampling location and samplig frequency

The basic monitoring objective generally determines the level of detail and the necessary approach to explore water quality [28]. However, the need to identify the optimal water informations should be the most reason to specified sampling location and frequency sampling. In this comparative study, the network designs subdivide the sampling locations into two groups. Many studies suggested locating sampling stations at critical quality points, such as outfalls, infalls, and the deepest stations. In others studies, the pollution sources [27] or the number of tributaries were used to identify sampling locations. Sanders Consider the placement of a permanent and representative sampling station probably the most critical design factor in a water quality monitoring network design [28].Nonetheless, in the literature found, sampling frequency varied between twice a month, once a month, or only once per season (Table 4). Sampling frequency depends on the objective of the water quality monitoring network, on the relative importance of the sampling station location, and the expected variability of the water quality data at each sampling station [7].

Table 4: Sampling location and samling frequency in Moroccan studies reservoirs

Sampling location	*References*	*Sampling frequency*	*References*
Infall and outfall	[8-17-18-34-64]	once a month	[2-3-4-8-17-27-33-39-64]
Deepest	[2-3-4 -27-33-39]	twice a month	[17-39]
Tributarie	[34]	once per season	-

3.7. Spacial variation of physical, chemical and biological variables

3.7.1. Water temperature

The comparison of observations values recolted from studies was made between the reservoirs in the same basin. Table 5 shows the mean values of water quality variables of the moroccan reservoirs. The average value of water temperature fluctuated between 18.89 °C (Bin Ouidane) and 20.66°C (Al Massira). The studies indicate a seasonal differences between 1.7 and4.8 °C depending to the reservoirs, strongly influenced by the geographic characteristics [41], and the prevailing climate [16]. Thermal stratifications wereexpressed in the selected large sizes and deepest reservoirs such Al Massira [4] and Bin Ouidane [11] reservoirs. Thermal stratification increase with the long residence time (ex: 42 months at Al Massira) especially in summer [2] while they are not presented in small reservoirs like (Sidi Maachou, Daourat) in which the water was renewed rapidly (2-25 days) [4].

3.7.2. pH

No acidified reservoirs were observed (pH < 5). All reservoirs were presented alkaline waters, influenced by the lithological nature of the soil dominated by carbonates and limestone[4-5-29]. The average values of the pH in surface waters fluctuate between 7.55 (Allal al-Fassi) [35]and 8.32 [33](Yacoub Al Mansour). The difference between the alkalinity of the surface and the bottom is low and does not exceed a 1 pH unit, remained unchanged despite large alkalinity and productivity changes.

3.7.3. Dissolved Oxygen

Dissolved oxygen concentrations ranged between 1.89 mg. L^{-1} [33](Yaakoub Manssour) and 10.00 mg. L^{-1} [4](Sidi Maachou and Daourat). Some studies have reported that reduced concentrations of dissolved oxygen couldbe passed to anoxia during the summer (Yaakoub Manssour, Al Massira). This finding is related to the high depth, the high residence time and low wind speed. Declines in dissolved oxygen have been recorded in some studies where water temperatures have been noted to increase [43-44]. Nonetheless, changes keep occurring at these levels, particularly from the surface to the bottom; and increase with a thermal stratification. This is the case of the values recorded at Al Massira, Yaakoub Mansour, and Hassan I [5]. As for the other reservoirs (Sidi Maachou, Imfout, and Daourat) where depths do not exceed 19 m and the residence times are very low, no chemical stratification was detected.

3.7.4.Turbidity

Increased turbidity has been observed in many reservoirs. This has been attributed to algal blooms occured [6-8-45-46], during droughts [47], or when a significant portion of the suspended load is derived from sediments [4-30-48].

3.7.5. Nutrients

Within the same basin, nutrients analysis concentrations revealed a growing upstream-downstream gradient. These increased levels result from excessive use of fertilizers and pesticides in agricultural soils, sediment release, and urban discharges [4-45]. Some works showed that reservoirs in high latitudes had lower nitrogen and phosphorus concentrations [30-58]. Whereas low-latitude reservoirs have shown higher concentrations, the cumulative appearance of reservoirs in series (reservoirs in the same basin) has appeared. On the vertical within the same reservoir, the nutrient concentrations trace an increasing gradient from the surface to the bottom. The release by microbial decomposition of organic matter in deep water is the main factor for this gradient [47].

7.6. Plankton

In the same basin, the reservoirs have the same plankton species with a difference in their appearances and /or their disappearance. The main species belong to Cyanobacteria, Bacillariophyceae, Dinophyceae, and Chlorophyceae whereas Cladocerans, Rotiferans, and Copepods dominate the zooplankton population. Some reservoirs have known toxic cyanobacteria blooms like Bin El Ouidane and Al Massira, and Ouel Mallah. This has been attributed to more favorable hydrodynamic conditions for algal growth [33-51-52-49], at the proper temperature [16-38-49], and changes in nutrient dynamics [37-50]. Temperature and nutrient conditions in the low flows were conducive to sustaining the algal bloom (microcystins) as it was transported downstream over several weeks [16]. Other reservoirs have never known algal blooms or have never been detected and followed by any previous study.

Table 5: Mean Values of Water Quality Variables of the Moroccan Reservoirs: **AIM** (Al Massira); **BO** (Bin Ouidane); **OEM** (Oued El Mallah); **DI** (Driss I); **MBA** (Mohamed Ben Abdellah); **MD** (Mansour Dahbi); **YBT** (Youssef Bno Tachfine); **ELK** (El Kansra); **HI** (Hassan I); **AF** (Allal Fassi); **YM** (Yaakoub Manssour); **LT** (Lalla Takerkoust); **SA** (Sahla); **IM** (Imfout); **DA** (Daourat); **SM** (Sidi Maachou), **SA** (Sidi Abderrahmane).

	ALM	**BO**	**OEM**	**DI**	**MBA**	**MD**	**YBT**	**EIK**	**HI**	**AF**	**LT**	**SA**	**IM**	**DA**	**SM**	**HII**	**SA**
Basin	Oum Rbia	Oum Rbia	Bouregrag	Sebou	Bouregrag	Sous-Massa	Sous-Massa	Sebou	Oum Rbia	Sebou	Tensift	Sebou	Oum Rbia	Oum Rbia	Oum Rbia	Moulouya	Oum Rbia
Capacity (Mm^3)	2760	1384	33	1186	1025	529	303	266	262	110	69	62	27	9	2	16.81	3.2
Climat	Arid	Arid	Arid	Arid	Arid	Arid	Arid	Arid	Semi-Arid	Arid	Arid	Arid	Semi-Arid	Semi-Arid	Semi-Arid	Arid	Semi-Arid
Temperature (°C)	20.66[5]	18.89[8]	21[8]	17.88[56]	21[9]	23.31[47]	22[56]	22.34[45]	22[57]	22.2[35]	21[8]	-	22.83[4]	22.41[4]	25[4]	-	21.67[39]
pH	8.5[36]	7.7[8]	7.5[8]	7[40]	7.7[9]	7.8[47]	-	8.1[45]	8[57]	7.9[35]	8[8]	-	8.8[4]	8.7[4]	7.9[4]	8[64]	7.29[39]
Dissolved Oxygen ($mg.L^{-1}$)	9.2[5]	7.1[8]	7.25[8]	6.2[55]	7.22[9]	-	-	-	8.5[59]	8.2[60]	7.4[8]	-	7.4[4]	9.2[58]	18[4]	-	10.94[39]
Orthophosphorus ($mg.L^{-1}$)	1.3[54]	5[8]	0.3[8]	0.06[35]	0.12[9]	0.03[33]	0.14[56]	0.05[45]	0.21[54]	0.15[60]	0.01[8]	2.74[60]	5.25[58]	0.05[58]	0.1[4]	0.15[64]	0.61[39]
Ammonium ($mg.L^{-1}$)	2.5[54]	1.3[8]	4[8]	0.15[35]	0.1[9]	0.2[33]	0.04[56]	0.12[31]	0.75[54]	0.04[60]	0.1[8]	1.41[60]	1.8[62]	10.2[4]	0.09[4]	0.13[64]	1.22[39]
Nitrate ($mg.L^{-1}$)	5.1[54]	0.16[8]	0.02[8]	1.52[35]	0.12[9]	0.22[33]	0.02[56]	9[31]	6.2[54]	-	0.1[8]	1.99[60]	1.2[4]	2.1[4]	3.1[4]	-	1.22[39]
Chlorophyll-*a* ($\mu g.L^{-1}$)	1.85[54]	1.98[8]	71.83[8]	2.15[55]	2.3[9]	17.23[33]	-	12[31]	1.81[54]	4.1[60]	15[29]	-	-	-	-	-	1.36[39]

3.7.7. Fish

In addition to native fish species, three fish species (*Gibbosus eupomotis, Tinca tinca, Cyprinus carpio*) were introduced by managers in Moroccan reservoirs as part of the biological control. Many studies [8-9-29-50-53] have revealed of 94% of a planktonic algae composition in the fish food spectrum. The greater part was allocated to cyanobacteria and diatom phytoplankton.

Conclusion

The aim of this paper was to collect the studies on the Moroccan reservoirs during the last three decades. Subsequently, we grouped the research results by studies number of related to reservoirs, basins areas and fields. The synthesis summarizes and integrates the results of the studies, using a quantitative and qualitative framework, in the interest of collecting common processes between the reservoirs, and which then lead to specific conclusions. The available literature reveals a clear heterogeneity between the number of implanted reservoirs and the number of reservoirs studied. Morocco have 139 reservoirs, only 15.11 % of them were subject at least to one scientific study (between 1987 and 2016). The Oum Rbia basin has the biggest number of reservoirs with 18. In fact, only 7 of them were targeted by 25 studies. Nevertheless, some basins have not reported any studies as was the case for the North-west and Ziz-Rhéris-Guir. The reservoirs capacity (socio-economic importance), geographic location, prevailing climate, and observed ecological phenomena were among the main factors for planning studies. Much of documentation collected was limited in many scientific fields mainly to ecology (19 studies), toxicology (17 studies), hydrobiology (12 studies), sedimentology (11 studies), and hydrogeochemistry (10 studies). The limit of studies for some fields may refer to budget constraints and on the availability of technological means. The emergence of new scientific fields (e.i. modeling) must be incorporated in monitoring network design. In fact, there is a need to better develop a specific and particle search procedures for each type of reservoirs (deep, shallow, large, and small). Given the predictions of reservoirs freshwater systems evolution, it was considered beneficial to undertake a review and synthesis of the relevant literature on this topic.

Acknowledgments-The authors wish to sincerely express their gratitude to Ed-Dali Rachid and Rhomad Hanane for providing language improvement and for data analysis.

References

1. A. Kabbaj, M. Combe. *Notes et Mém. Sev. Géol*. 3 (1977) 231.
2. M. Alaoui Mhamdi, L. Aleya, S. Rachiq, J. Devaux, *Rev. Sci. Eau.,* 7-2 (1994) 115-130.
3. A. Abdellaoui, M. Derraz, M. Benabdellah, S. Lek, *Rev. Sci. Eau.,* 1 (1998) 101-116.
4. F. Benzha, A. Hilalia, F. Zidane, *Enviro. Tech.,* 30 (2009) 969-983.
5. M. Moncef, M. Malki, A. Fahde, J. Deveau, *Rev. Sci. Eau.,*7 (1994) 3-22.
6. H. Chergui, E. Pattee,K. Essafi,M. Alaoui Mhamdi, *Limno. Devel.Countries,*2 (1999) 235-330.
7. L.W. Canter, *Lewis Publishers*, Chelsea (1985).
8. B. Sabour, M. Loudiki, B. Oudra, S. Oubraim, B. Fawzi, S. Fadlaoui, M. Chlaida, *Rev. Sci. Eau.,*15 (2002) 327-342.
9. C. Abouzaid, L. Bourchich, *Actes Journ. Nat.*, *Kenitra Maroc*, 7 (1987).
10. H. Rhomad, Mémoire de Master. *Fac. Sci. Semlalia Marrakech Maroc*, (2017).
11. Z.E. Taranu, I. Gregory-Eaves, *Ecosystems,* 11 (2008) 715-725.
12. D.E. Chapman, *A Guide to the Use of Biota, Sediments and Water in Environmental Monitoring*,London, (1996).
13. D.S. Rawson,*Am. Assoc. Adv. Sci. Publ.,* 10 (1939) 9-26.
14. W.Z. Liu, Q.F. Zhang, G.H. Liu, *Hydrobiol. J.,* 644 (2010) 289-299.
15. L. Brown, F. Edwards, A. Milner, G. Woodward, M. Ledger, *J. Anim. Ecol.,* 80 (2011) 884-895.
16. L.M. Mosley, *Earth-Sci. Rev.,*140 (2015) 203-214.
17. D. Fqih Berrada, R. Berrada, A. Benzekri, E. Jabry, *Hydroecol. Appl.,* 12, 1-2 (2000) 207-231.
18. B. Sabour, M. Loudiki, B. Oudra, S. Oubraim, B. Fawzi, S. Fadlaoui, M. Chlaida, *Rev. Sci. Eau.,*15 (2002) 327-342.
19. A. Dai, *Nat. Clim. Chang.,* 3 (2013) 52-58.
20. T.G. Sanders, R.C. Ward, J.C. Loftis, T.D. Steele, D.D. Adrian, V.W. Yevjevich*, Water. Resour. Pub.,* (1983).
21. World Meteorological Organization. *Guide to Hydrological Practice* Geneva, 168 (1994).
22. K. Dörnhöfer, N. Oppelt, *Ecol. Indic.,* (2016) 105-122.

23. R. Adrian,C.M. O'Reilly, H. Zagarese, S.B. Baines, D.O. Hessen, W. Keller, D.M. Livingstone, R. Sommaruga, D. Straile, E. van Donk, G.A. Weyhenmeyer, M. Winder, *Limnol. Oceanogr*., 54 (2008) 2283.
24. L.L. Zhang, J.L. Liu, Z.F. Yang, Y. Li, Y. Yang, *Ecol. Model.*, 252 (2013) 141-152.
25. S. Poikane, S. Birk, J. Böhmer, L. Carvalho, C. de Hoyos, H. Gassner, S. Hellsten, M. Kelly, A.L. Solheim, M. Olin, K. Pall, G. Phillips, R. Portielje, D. Ritterbusch, L. Sandin, A.K. Schartau, A.G. Solimini, M. van den Berg, G. Wolfram, W. van de Bund, *Ecol. Indic.,* 52 (2015) 533-544.
26. R.O. Strobl, P.D. Robillard, *J. Environ. Manage.,* 87 (2008) 639-648.
27. M. Chahboune, A. Chahlaoui, A. Zaid, A. Ben moussa, *Larhyss J.,* 584 (2013) 239-252.
28. T.G. Sanders, *Proc. Nat. Conv.*, Portland, OR, (1980) 14-18.
29.Y. Bouchelta, A. Azouzi, M. Alaoui Mhamdi, 2001. *Ann. Chim. Sci. Mat.*, 26 (2001),105-110.
30. T. Nõges, 2009. *Hydrobiol. J.,* 633 (2009) 33-43.
31. B. Sabour, M. Loudiki, B. Oudra, S. Oubraim, B. Fawzi, S. Fadlaoui, M. Chlaida, V. Vasconcelos, *Inter. J. Limn.,* 38-1 (2002) 13-22.
32. H. Ait hammou, D. Latour, M. Sabart, S. Samoudi, K. Mouhri, J. Robin, M. Loudiki, *Aquat. Ecol.,* 48-2 (2015) 219-228.
33. L. Damiri, M. Alaoui, *Ann. Chim. Sc. Mat.,*26 (2001) S119 -S123.
34. M. Ouhmidou, A. Chahlaoui, *Larhyss J.,* 22 (2015) 183-196.
35. L. Alaoui, A. Agoumi, M. Moncef, K. Mokhliss, *Hydroecol. Appl.*, 12. 1-2 (2000) 183-206.
36. M. Taoufik, J.E. Dafir, *Rev. Sci. Eau.,* 15-1 (2002) 235-249.
37. I. El Ghazali, S. Saqrane, M. Saker,*Rev. Sci. Eau.,* (2011).
38. D. Fqih Berrada, R. Berrada, A. Benzekri, *Int. J. Limnol.,* 35-3 (1999) 155-166.
39. S. Rachiq, M. Raoui, N. Chadli, C. Amblard, M. Mhamdi Alaoui, J.F. Carrias, T. Sime Ngando,B. Sabour, *Aquat. Ecosys. Heath Manag.*, 8-1 (2005) 95-104.
40. H. Jabari,. *Rev. Sci. Eau.,* 15-1 (1998) 424.
41. J. Ding, J. Cao, Q. Xu, B. Xi, J. Su, R. Gao, S. Huo, H. Liu, *J. Environ. Sci.,* 30 (2015)140-147.
42. M.T.H. van Vliet, J.J.G. Zwolsman*, J. Hydrol.,* 353 (2008) 1-17.
43. I. Ylla, I. Sanpera-Calbet, E. Vazquez, A.M. Romani, I. Munoz, A. Butturini, S. Sabater, *Hydrobiol. J.,* 657 (2010) 217-232.
44. M. W. Lindsey Yasarer, S.M. Belinda Sturm, *Lake and Reservoir Manag.*, 32-1 (2016) 13-26.
45. B. Oudra, M. Loudiki, B. Sabour, B. Sbiyaa, V. Vasconcelos, *Rev. Sci. Eau.,* 15 (2002) 303-313.
46. M. Saadani, N. Ouazzani, L. Mandi, *Rev. Sci. Eau.,* 17 (2004) 69-90.
47. M. Loudiki, B. Oudra, V. Vasconcelos, S. Oubraim, B. Fawzi, *Aquat. Ecosys. Heath Manag.*, 8-1 (2005) 95-104.
48. J. Dafir, S. Kemmou, M. Taoufik*, Water. Qual. Res. J. Can.,* 40-2 (2005) 202-210.
49. P. Nõges, T. Nõges, L. Tuvikene, H. Smal, S. Ligeza, R. Kornijów, *Hydrobiol. J.*, 506–509 (2003) (1–3) 51.
50. B. Oudra, M. Loudiki, M. Sbiyyaa, R. Martins, R. Vasconcelos, N. Namikoshi, *Toxicon*, 39 (2001) 1375-81.
51. B. Oudra, M. Loudiki, B. Sbiyaa, B. Sabour, R. Martins, A. Amorim, V. Vasconcelos, *Lake and Reservoir Manag*., 7 (2002) 35-44.
52. B. Sabour, M. Loudiki, B. Oudra, V. Vasconcelos, R. Martins, S. Oubraim, B. Fawzi, *Aquat. Ecosys. Heath Manag.*, 17 (2002) 24-31.
53. B. Sabour, M. Loudiki, B. Oudra, S. Oubraim, B. Fawzi, S. Fadlaoui, M. Chlaida, V. Vasconcelos V, *Harmful Algae News,*21(2000) 8-9.
54. M. Douma, Y. Ouahid, F.F. del Campo, M. Loudiki, K. Mouhri, B. Oudra, *Environ. Monit. Assess.***,** 160 (2010) 439-450.
55. Y. Bouchelta,M. Alaoui Mhamdi, H. Khattabi, L. Aleya,.*Cah. Techn.I.N.R.A.,*44 (2000) 13-15.
56. A. Hminna, S. Voigt, H. Klein, H. Saber, J.W. Schneider, D. Hmich, *J. African Earth-Sci.,* 80 (2013) 1-7.
57. M. Hassnaoui,*Rev. Sci. Eau.,*9 (1997) 134.
58. J. Bahhou, M. Alaoui Mhamdi, *J. Chim. Phy.,*93-3 (1999) 339-351.
59. L. Ait saleh, *Rev. Sci. Eau.,*10-2 (1997) 144.
60. M. Loudiki, A. Cazaubon, M. Hasnaoui, *Intern. J. Mediterranean Ecol.*,1-2 (1994) 109-120.
61. S.M. Raoui, S. Rachiq, M. Alaoui Mhamdi, N. Chadli, *Rev. Sci. Eau.,* 15-1 (2002) 51-62.
62. D. Sargos, *Rev. Sci. Eau.,* 15-1 (2002) 87-99.
63. A. Gartet, M. El Fengour, J. Gartet, C. Conesa García, *Papeles de Geografía*, 49-50 (2009) 41-54.
64. F. Benzha, M. Taoufik, J.E. Dafir, S. Kemmou, L. Loukili, *Rev. Sci. Eau.,* 18 (2005) 57-74.

(2018) ; http://www.jmaterenvironsci.com