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The role of artificial water bodies in limiting nutrient transfers in the hydrosystem. case study in the Oued d'Houss watershed (Bouira- Algeria).

Hamdani Aziz[1], Khettab Nour El Houda[2]
[1] Research laboratory in Management and valorization of biological resources and quality control. University of Bouira., Algeria
[2] Master. Faculty of Natural and Life Sciences University of Bouira., Algeria

Abstract

In a context of climatic vulnerability and scarcity of water resources, the quality of water and environment is strongly threatened by organic and inorganic pollution caused by human practices, such as industrial and agricultural activities but also domestic practices. Pollution and degradation of water can be translated through the change of its physicochemical and biological properties in the natural and artificial hydraulic structures. In the present paper we have conducted a measurement campaign of the water quality of one dam and three hillside reservoirs of the Oued D'houss watershed to show the impact of these artificial water bodies in the transfer regulation of pollutants from upstream to downstream watershed. The results obtained show that a large part of the pollution is trapped upstream of the watershed in three hillside reservoirs and the Oued Lekhal dam which greatly reduces the pollution of the Tilesdit dam located downstream of the watershed (not far from the city of Bouira). The decrease of the pollution rate from upstream to downstream contribute to the reduction of the cost treatment in the downstream but also consequently prevents the spread of pollutants throughout the hydrographic and hydrogeological networks in the watershed.

Key Words*:* Water bodies, environment, dams, hillside reservoirs, pollution, watershed, human population,

Le rôle des plans d'eau artificiels dans la limitation des transferts des nutriments dans l'hydrosystème. Étude de cas dans le bassin versant de l'Oued d'Houss (Bouira-Algérie)

Résumé

Dans un contexte de vulnérabilité climatique et de raréfaction des ressources hydriques, la qualité des eaux et l'environnement en général est dangereusement menacée par la pollution organique et inorganique issue des pratiques humaines surtout industrielles et agricoles mais aussi domestiques. les barrages et les retenues collinaires sont les ouvrages où peut s'exprimer la pollution et la dégradation des eaux à travers le changement de ses propriétés physicochimiques et biologiques. Dans la présente étude nous avons mené une compagne de mesures de la qualité des eaux d'un barrage, trois retenues collinaires et un point à l'exutoire du bassin versant d'oued d'houss et ceci dans l'objectif de savoir l'impact de ces ouvrages dans le transfert des polluants de l'amont vers l'aval du bassin versant. les résultats obtenus montrent qu'une grande partie de la pollution est piégée à l'amont du bassin versant dans les trois retenues collinaire et le barrage de oued lekhal ce qui réduit grandement la pollution du barrage de tilsdit situé à l'aval du bassin versant (non loin de la ville de bouira) , ce même barrage qui est destiné à l'alimentation de la population. L'estompage du taux de pollution de l'amont vers l'aval aura comme conséquence la réduction du coût de traitement à l'aval mais aussi empêche conséquemment la diffusion des polluants à l'échelle du réseaux hydrographique et hydrogéologique du bassin versant.

Mots Clés : eaux, environnement, barrages, retenues, pollution, bassin versant, population humaine

[1] Corresponding author: hamdani.aziz@gmail.com

INTRODUCTION

The growing need for water for consumption, agriculture and industry has led the authorities to adopt an approach aimed at ensuring the satisfaction of the increasing demand which is in line with demographic growth and new consumption patterns imposed by socio-economic changes and the new lifestyle adopted by human populations (Butler ; Memon , 2005).
The construction of dams and hillside reservoirs is one of the state's priorities for guaranteeing water security in a vulnerable and unstable climatic context reflected in the scarcity of water resources. In this context, the health of the environment and the quality of water are heavily threatened by organic and inorganic pollution resulting from human practices, especially industrial and agricultural practices. This situation can weaken and even render useless any measure of governance of water resources (Vörösmarty et al, 2010).
In this paper, we have studied the impacts of artificial water structural (dams and hillside reservoirs) on the transfer of organic pollution, from upstream to downstream, through the hydrographic network of the Oued D'Hous watershed in Bouira which constitutes the upper part of the large Soummam watershed.
Two objectives are aimed across the present study, a specific objective and an overall objective. The first is to know the impact of artificial water bodies on the quality of the natural environment as a whole. secondly we purpose to know the role can played by an artificial water body located upstream of a catchment to defining the quality of water stored in water body located downstream, especially if the work is intended for drinking water supply.

PRINCIPLES AND METHODOLOGY FOLLOWED IN THE STUDY:

The present study was carried out in two distinct stages:
The first stage was devoted to gathering all the general information related to the studied catchment area such cartographic documents, information on morphometry, topography and geology, geomorphology, climate as well as everything related to demography and socio-economic character included in the catchment area. This information was combined with the results of the analyses obtained for interpretation purposes. In this step we identified the existing artificial water bodies and their location, at the same time we have contacted with administrative manager of water bodies. These managers showed an interest in this study by providing us with technical information about the structures.
The second stage was purely practical, consisting of sampling, analysis and interpretation. The sampling has been unrolled from 05/07th/2017 to 05/21th/2017
Sampling and analysis were carried out according to conventional methods and normative protocols.

Criteria for selecting study sites

In the present study the choice of artificial water bodies to be analyzed is imposed by the following reasons

- To have a regular and homogeneous geographical distribution of water bodies at the scale of the catchment area
- According to the nature and importance of the socio-economic activities located within the radius of influence of the water body
- According to the importance of the urban phenomenon located within the radius of influence of the water body
- According to the importance of the agricultural activities dependent on the studied water bodies.

Sampling principles

The sampling approach applied is the targeted sampling. Two samples were taken from each water body studied, one at the upstream end of the water body. Sampling was carried out according to the conventional rules of representativeness, spot selection, bottle decontamination, labelling, storage and transport. The storage temperature of the samples was < 4° C (Morin-Crini et al, 2017).

Physicochemical and microbial parameters analyzed

The list of parameters to be analyzed was established on the basis of the objectives of the study previously set, namely to know the qualitative character of the water stored in the artificial water bodies and to determine the

presence or absence of pollution (organic and/or mineral). In addition, the bacteriological parameters are analyzed in order to determine whether any faecal germs from the waste water are passing through the water bodies. The physicochemical analysis parameters consisted of PH, Turbidity, conductivity, Suspended solids (SS), Nitrite, Nitrates, PO4- and BOD5. The microbial analysis analyses consisted of the search for total and faecal coliforms, sulphite-reducing Clostridium and total germs.

TOOLS AND PROTOCOLS APPLIED

The analyses of the samples taken for the five (05) sites were carried out at two establishments according to the availability of equipment, materials, reagents and techniques. This is the wastewater treatment plats of Sour El Ghozlane attached to the wilaya of Bouira, this purification station is located immediately downstream of the city Sour El Ghozlane whose function is the purification of water coming from the city and its surroundings. Other analyses were carried out at the laboratory of the Faculty of Natural and Life Sciences of the University of Bouira.
The following table 1 summarizes the methods, equipment and protocols applied in the analysis of each of the physicochemical and bacteriological parameters.

Tab 1 : parameters analyzed, techniques and methods applied

Analytical parameter	Device	Method	Protocol	Laboratory
pH	portable multi-parameter	/	NF T90-008	STEP SEG
CE (µs/cm)	portable multi-parameter	/	NF EN 27888	STEP SEG
Turbidity (NTU)	portable multi-parameter	/	NF EN ISO 7027	STEP SEG
SM (mg/l)	fibre filter method	filtration at 0.45µm of a known volume of water	NF EN 872	STEP SEG
BOD_5 (mg/l)	manometric BOD meter types OXITOP IS6		NF EN 1899-1	STEP SEG
NO_3^+ (mg/l	Spectrophotomtry	Rodier 2009	/	STEP SEG
NO_2 (mg/l	Spectrophotometry	Rodier 2009	/	STEP SEG
PO_4 (mg/l)	Spectrophotometry	Rodier 2009	/	STEP SEG
Total coliforms	Microbiological	Rodier 2009	ISO 9308	Fsnv-Univ Bouira
Fecal coliforms	Microbiological	Rodier 2009	ISO 9308	Fsnv-Univ Bouira
Total germs	Microbiological	Rodier 2009	ISO 6222	Fsnv-Univ Bouira
Sulphite-reducing Clostridium	Microbiological	Guiraud et Galzy	ISO 6461-1	Fsnv-Univ Bouira

- STEP SEG: Sour El Ghozlane wastewater treatment plant (Bouira)
- Fsnv-Univ Bouira: Faculty of Natural and Life Sciences and Earth Sciences University of Bouira.

Presentation of the study area (catchment area)

The watershed of Oued D'Houss is an integral part of the Great Soummam watershed in its upper part, it is fully integrated in the wilaya of Bouira as illustrated in Fig. 1, Oued D' Houss drains an area of 892 km2 of the watershed in elongated form having a perimeter of 264 km. The prevailing bioclimatic character is that of semi-arid in the South and sub-humid in the vicinity of the Djurdjura mountain range in the North. The average rainfall is 540 according to the values recorded by (ONM 2008). The average monthly temperatures vary between 27.8°C and 27.7°C in the summer, and the minimum temperatures vary between 8.7°C and 9.2°C in the winter.

The watershed is sparsely populated with vegetation, particularly in the south, with some forest formations in the north at the edge of the Djurdjura chain.
The lithological nature of the land is predominantly quaternary, with alluvial and red clay fillings (Ficheur. 1911).

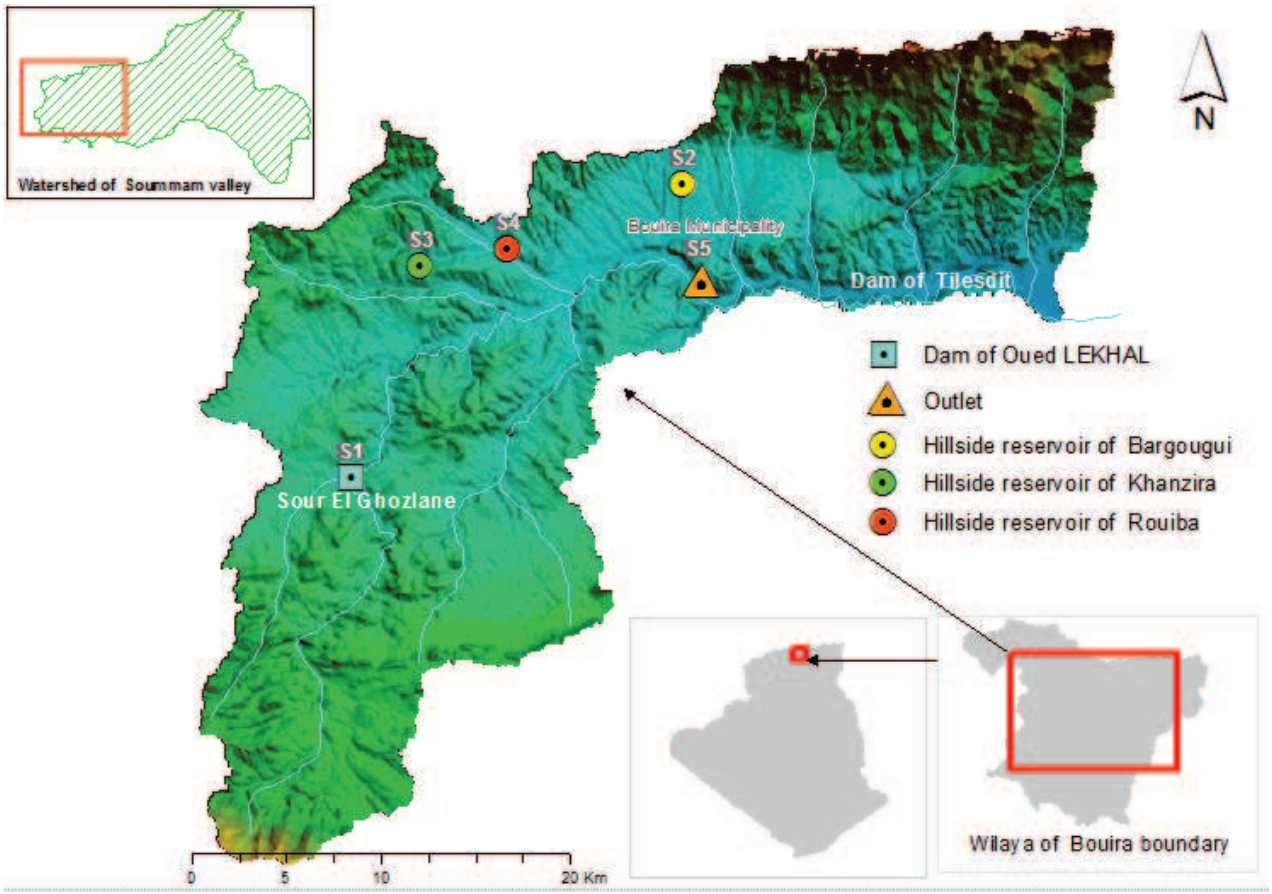

Fig. 1: catchment boundary and study sites location (obtained by GIS in original shapefile)

Presentation of the sampling sites

The location of the sampling sites is represented in Fig. 1, in the table below (Table 1) some characteristics of each site are indicated, three hill dams, an artificial hydraulic dam in earth with a clay core, and a point at the outlet at the level of the wastewater treatment plant of the city of Bouira. To simplify the reading of the results, the letter codified the name of each site S followed by a numbering from 1 to 5 in the following order.
S1: Oued Lekhal dam; S2: Chabet Bergougui hillside reservoir; S3: Khenzira hillside reservoir; S4: Gares Rouiba hillside reservoir; S5: watershed outlet (Bouira STEP).

Tab 2 : some characteristics of the sites studied

Designations	Type of use	X-UTM	Y-UTM	ELEVATION	Type of structure	Capacity (m3)
S1- Weir O.LEKHAL	Industrial -irrigation - domestic	564139 .37	4013003.84	698.5m	Artificial	2millions
S2- Hillside reservoir – Chaabet Bargougui	Irrigation	581670.46	4028438.76	540.5 m	Artificial	240000
S3- Hillside reservoir - Khanzira	Irrigation	567881.74	4024192.7	681.9 m	Artificial	120000
S4- Hillside reservoir - Oued Gares Rouiba	Irrigation	572412.67	4025034.19	567.2 m	Artificial	300000
S5- Point- STEP- outlet of watershed	----	582482.11	4023392.691	489.178 m	--------	-----

All the sites studied are illustrated by a satellite image associated with a photograph taken during the visit.

Illustration of site S 1 (Oued Lekhal Dam)

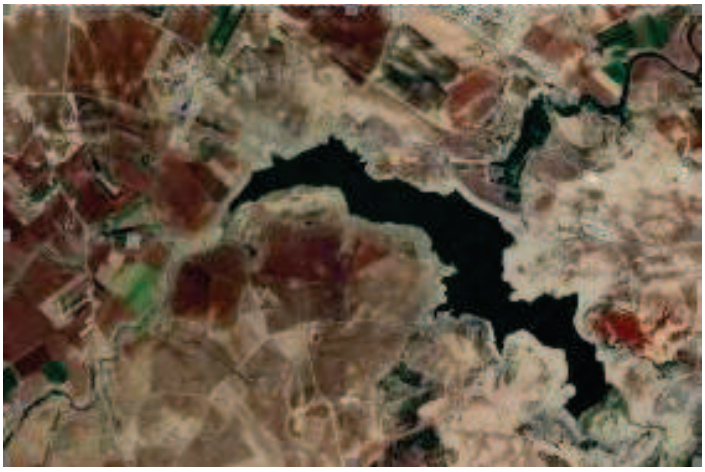

Fig. 2 : Satellite image of Oued Lakhal Dam

Fig. 3: Photo of Oued Lakhal Dam (2017).

Illustration of site S 2 (Chabet Bergougui hillside reservoir)

Fig. 4: Satellite image of the Chabet Bergougi hillside reservoir

Fig. 5: Photo of the Chabet Bergougi hillside reservoir (2017).

Illustration of site S 3 (Khenzira hillside reservoir)

Fig. 6 Satellite image showing the Khenzira hillside reservoir

Fig. 7: Photo of Khenzira hillside reservoir (2017).

Illustration of site S4 (Gares Rouiba hillside reservoir)

Fig. 8: Satellite image showing the Gares Rouiba hillside reservoir

Fig. 9: Photo of the Gares Rouiba hillside reservoir. (2017).

RESULTS

The physicochemical and microbial analysis results obtained are reported in the tables below (tab 3 and 4), to simplify the visual reading of the numerical values we have represented them graphically in the form of histograms where each analysis parameter has been represented on the same graphical column to facilitate the comparison between the five analyzed sites.

Tab 3: Physicochemical analysis results

Parameters / Sites	pH	EC (µs/cm)	Turbidy (NTU)	SS (mg/l)	BOD_5 (mg/l)	NO_3^+ (mg/l)	NO_2^- (mg/l)	PO_4 (mg/l)
S1	8.12	700	130	8	95	9.9	0.172	0.85
S2	6.19	2100	140	76	09	13.04	0.26	0.96
S3	7.02	629	196	150	05	7.20	0.14	0.92
S4	7.10	1600	175	135	10	11.30	0.34	1.24
S5	6.9	1004	29	4	24	4.4	0.069	0.12

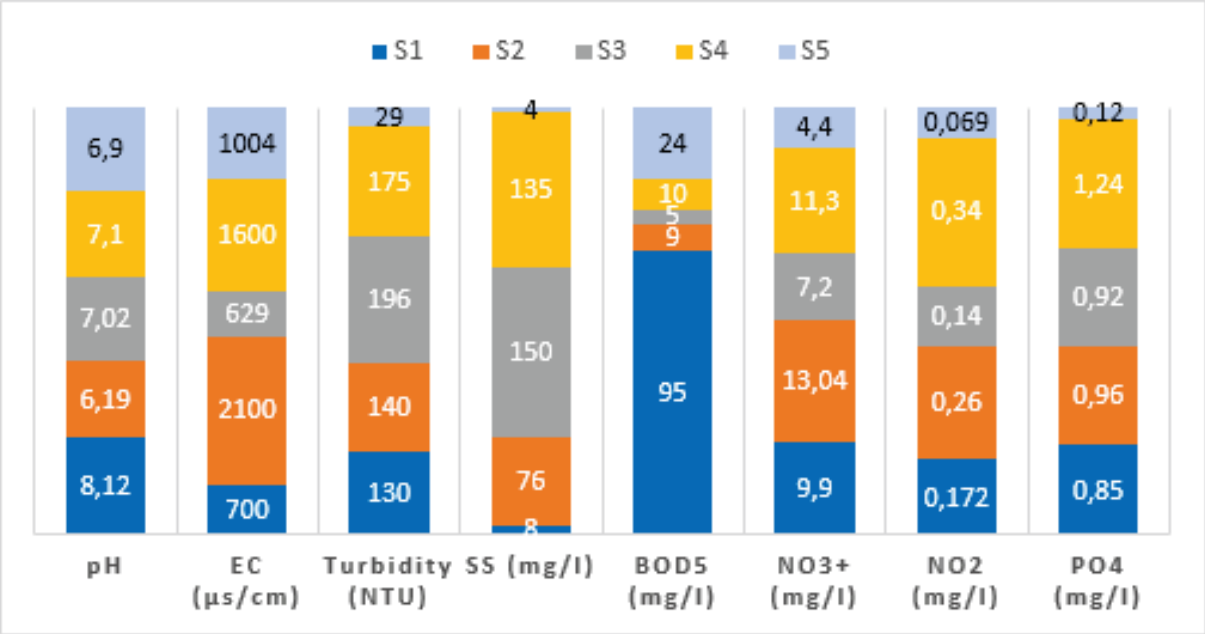

Fig. 10: graphic representation of the physicochemical results obtained

Microbial analysis results: the results of the microbial analysis are grouped in table 4 below.

Tab 4: microbial analysis results

Parameters / Sites	S1	S2	S3	S4	S5
GT	331	226	190	458	125
CT	333	332	287	333	268
CF	425	350	194	347	245
CLOST	available	available	available	available	available

GT: Total germs; TC: Total coliforms; FC: Faecal coliforms; CLOST: Clostridium sulphite-reducers

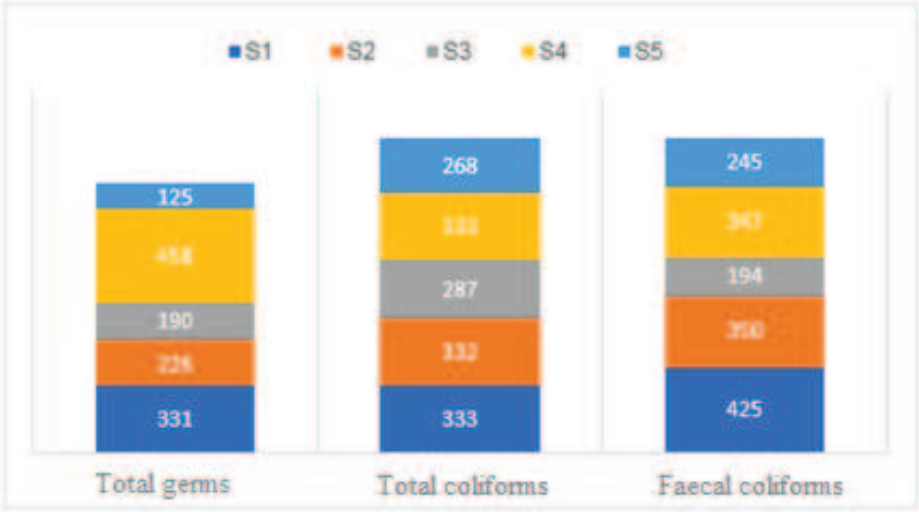

Fig 11 : graphic representation of the microbial analysis results obtained

DISCUSSION

The interpretation of the results obtained is carried out according to an integrated spatial reading approach of the natural, socio-economic and anthropic environment of the studied sites.
Although the analyzed samples belong to the same catchment area, which is the physical unit of analysis, it is clear that there is an intrinsic heterogeneity in the distribution of values within the same analyzed water feature and a spatial heterogeneity of distribution between analyzed sites. This heterogeneity should be related to the surrounding conditions that characterize each site, these conditions are those related to the physical environment (morphometry, geology, geomorphology...etc.) (Stallard; Edmond ,1983), to the socio-economic environment (activities practiced and land use) (Li, S et al, 2008), and to the approach practiced in the environmental management of each site (each site belongs to a different communal territory).
The spatial geographic analysis shows that the surface areas drained by each site are different. it can be noted that the Oued Lekhal dam site (S1) has a much larger drained surface area (impluvium) than the other sites. the map below (Fig. 12) shows graphically surface areas drained by each site , which implies that the quantities of dissolved and dry substances retained in Oued Lekhal dam are much higher than in the other sites studied.

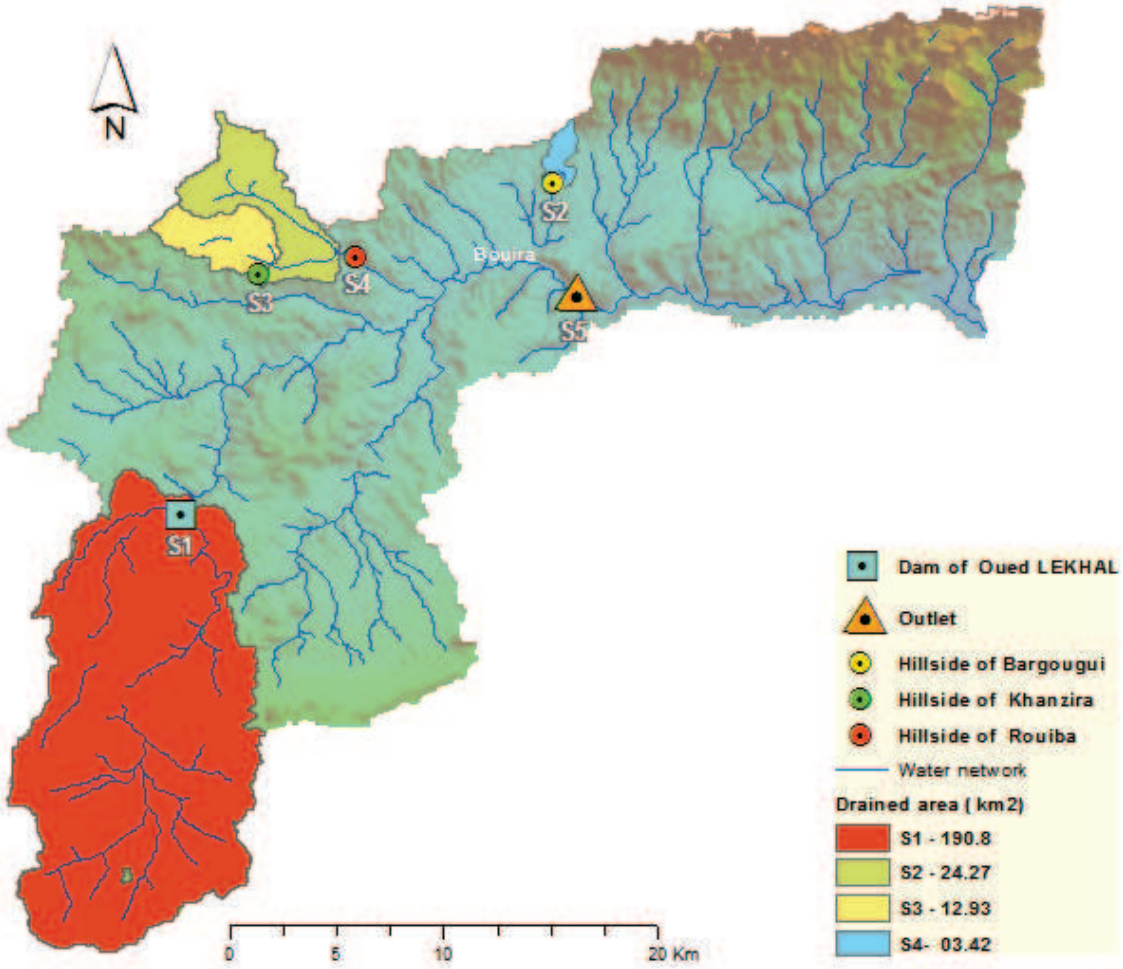

Fig.12: impluvium areas of the studied sites (obtained by GIS in original shapefile)

Therefore, the first lesson that can be drawn is that the storage capacity of the water bodies located upstream of the catchment area will strongly reduce the quantities of substances conveyed to the catchment area outlet, as highlighted by the results obtained for site S5 (outlet).
The spatial variability of the values obtained for each parameter analyzed in each site can be explained by the heterogeneity of the control variables of the physical, natural and anthropogenic environment as outlined above. The intrinsic and extrinsic control variables that characterize each impluvium of the analyzed site are responsible for the quantities and categories (nature) of substances transiting in the hydro system of the impluviums of each site.

PH values interpretation: The recorded PH values are around 7 for site S3, S4 and S5, which translates into a neutrality linked to the nature of the geological soils through which the runoff water flows (Krumbein; Garrels, 1952). As for the two other sites S1 and S2, the value of 8.12 indicate alkalinity, this should be in relation with the predominance of calcareous soils (geological bedrock sheet of Aumale) with contributions in HCO 3 - . the site S2 displays a value of 6.1 presenting a slight acidity due to the biochemical activity related to the decomposition of organic matter resulting from anthropic practices especially (Li, S et al, 2008), this interpretation agrees with the values of nitrates, nitrites and PO4 recorded in the same site.

Conductivity values interpretation: The conductivity values recorded at the sites can be described as ranging from high to very high depending on (Rodier et al, 2009). Site S4 shows the highest value with 2100 (µs/cm) followed by S4 with 1600 (µs/cm) and S1 with 1004 (µs/cm). These high values may be due to the mineralization of nitrogen and phosphate compounds (Koull; Halilat, 2016), which can be seen from the nitrite and nitrate values, which are consistent with the conductivity values, indicating a sort of correlation. The spatial analysis of the environment of the studied sites suggests that a domestic origin in mineral load is behind the very high mineralization of the waters. The presence of very high concentrations of settlements in the immediate vicinity of sites S4 and S2 (Fig. 13 and 14) reinforces our assumption that a source of mineralization is mainly related to effluents from the surrounding settlements, especially since the sewage system is not connected to a wastewater treatment plant. The same situation is observed for the S2 hillside reservoir site.

Fig. 13: habitats in the immediate vicinity of the hillside reservoir at sites S4

Fig. 14: habitats in the immediate vicinity of the hillside reservoir at site S2

Turbidity and Suspended Solids values interpretation: The graphical representation reveals a correspondence between TSS load and turbidity, which has been demonstrated in several studies (Rügner et al, 2013; Serajuddin et al, 2019). Depending on the nature and environment of the site, TSS can be the vehicle for organic and inorganic pollutant loads (Grayson, et al 1996; Nasrabadi et al2016). Turbidity could also be related

to the presence of chlorophyll in the microorganism (Ceballos et al 1998). Turbidity and TSS load are intimately linked to the geomorphological and hydrological conditions characterizing the sites (Lenhart, 2008). Thus, anthropogenic practices at the scale of the drained area of the studied sites can have an effect on the nature and content of TSS that transit through the watershed hydro system (Li et al, 2008). In the case of our study, the nuances of turbidity and TSS values recorded in the study sites can be explained by the geomorphological heterogeneity characterizing each drained area where the slopes of the landforms play a key role in the quantities of TSS transported from upstream to downstream. The slope map below (Fig. 14) shows that the slopes range from 1% to over 60%. Except for site S1, all the other sites show values largely exceeding the norms, sites S3 and S4 show alarming values of turbidity and TSS (which can be explained by the nature of the land which is almost uncovered by vegetation and the slopes which range from 10 to 37%. Furthermore, it should be noted that the measurements were made in dry periods, otherwise the values would be as high if the measurements were made in rainy periods.

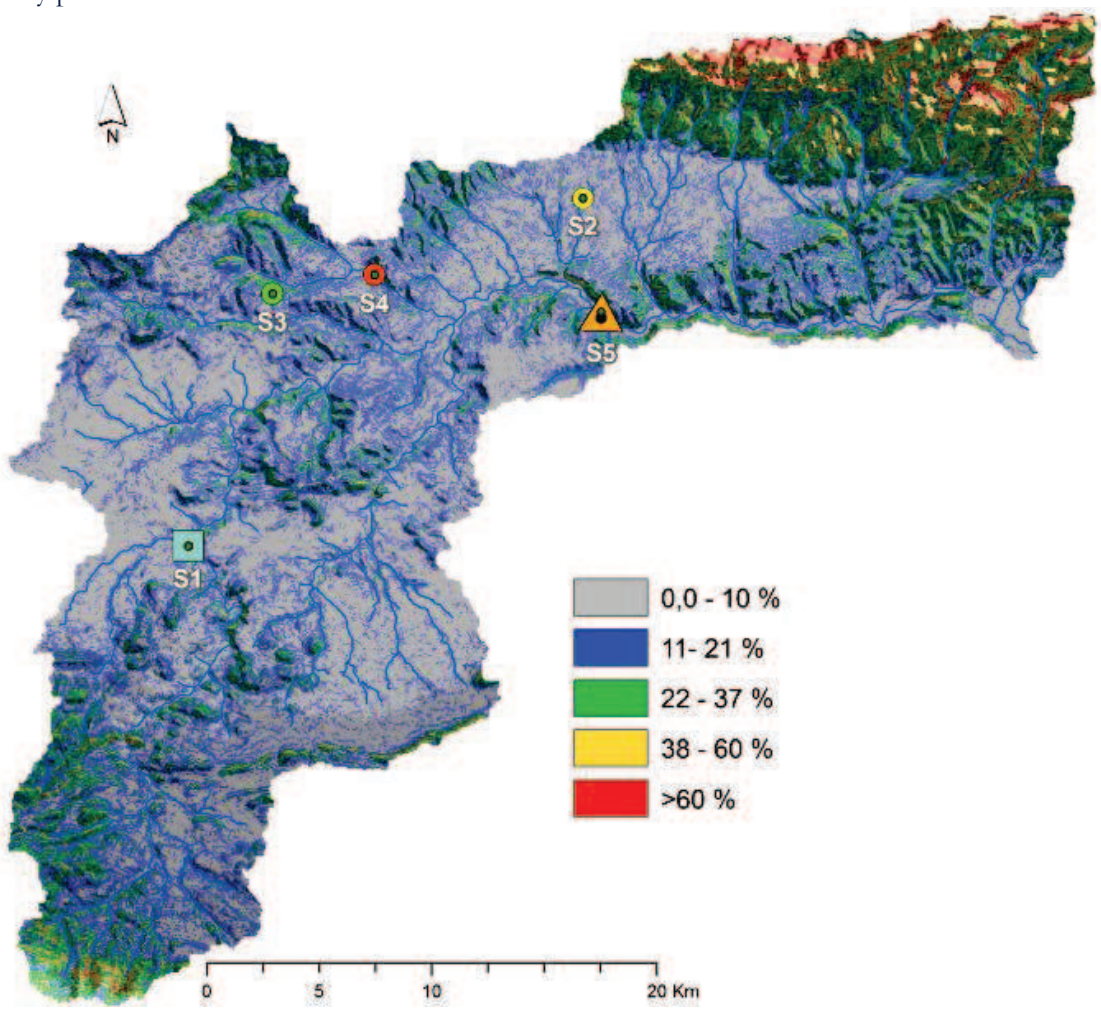

Fig. 14: Terrain slopes of the catchment area (in percent).

Mineral nitrogen compounds (NO^{3+} , NO^{2}) values interpretation: Today, it is known that the origin of organic pollution of surface waters and even groundwater in nitrogen compounds is mainly human activities operated on the natural and physical environment (Carpenter 1998). The values recorded at the sites studied indicate an excessive input of organic elements to the natural environment (Fig. 12). Sites S2 and S4 stand out with significant values. These values would have been greatly multiplied if the analyses had been carried out on the sediments at the bottom of the hillside reservoirs (Dorioz et al, 1989). To corroborate our assumption that the values of nitrogenous elements present in the sediments of the bottom of the reservoirs are very important, we can observe it in the aquatic plant formations growing in the reservoirs (Fig. 4, 5, 6), this vegetation is bio-indicative of a hyper important contribution of nitrogenous nutritive elements.

BOD5 values interpretation: The values of BOD5 show a variability in their distribution in the sites studied, S1 has a value of 95 mg/l followed by S5 located at the outlet which records a value of 24. for S1 the value is consistent with these values of turbidity and TSS, while for S5 the value of BOD could have other origins such as organic matter coming from the wastewater and algal biomass (De Ceballos et al 1998). In addition, it is very likely that the origin of the high BOD values appears in the presence of germ load and faecal coliforms which associated with the chlorophyll a (De Ceballos et al 1998), it should be noted that the coliform load in the sites studied is very high as shown in table 3 and Fig. 11.
The sites S2, S3 and S4 record values lower than the norm and this is not fortuitous as it can be explained by the abundant presence of hydrophilic vegetation (Fig. 5, 7 and 9) where it has been demonstrated that the presence of vegetation significantly reduces the BOD rates by + 75% (Karathanasis et al, 2003)

Phosphorus values interpretation: indicated by the values of PO4, phosphorus by its limiting character is the key element in environmental analyses because it is the nutrient that controls the evolutionary dynamics of algae in the aquatic environment (Tyrrell, 1999; Barroin, 1999). In principle, phosphorus can be of natural, industrial, agricultural or domestic origin. In addition, it should be remembered that the sites where the structures are located are characterized by poultry farming and cereal crops. In abundance, a situation of eutrophication can occur (Carpenter, 1998). The mineralization of phosphorus in an aquatic environment greatly reduces dissolved oxygen. The values recorded at the sites studied show that the environment is highly loaded with phosphorus. The site S4 has a very high value of 1.24 mg/l, which is much higher than the norm of < 0.15. The other sites S2, S3 and S1 have values ranging from 0.85 to 0.92, which are also important, Fig.s 9, 7 and 5 show high levels of PO4 where these values are expressed by the presence of algal biomass for site S4 and hydrophilic vegetation for sites S2, S3 and S1. The values for site S5 (the outfall) are below the norm.

Interpretation of microbial analysis results: The microbial analysis results can be interpreted in the anthropic context so in relation to human installations. The very high values obtained suggest that anthropogenic inputs are in the majority. It should be remembered that the hydraulic structures studied are located in rural areas densely populated by private dwellings not connected to the main sewerage system where all wastewater is discharged into the environment. The poultry farms that characterise the study areas have a share in the load that reaches the facilities (McMurry, et al, 1998). The high values of faecal coliforms could indicate a state of very high dissolved oxygen depletion in the water, which leads to eutrophication (De Ceballos et al 1998).

CONCLUSION

It must be emphasized that the analyses carried out on the water are far from being representative of the real quantities of organic nutrients and inorganic substances retained in the bottoms of the structures studied. Therefore, these values only represent an approximate balance sheet that provides information on the qualitative aspect of the stored water and the quantitative aspect of the contributions of substances transferred through the hydro system of each of the drained area of the studied sites. The quantities of nutrients that can be stored in the sediments at the bottom of the water bodies would be much greater than those recorded in the in the fluid mass (Dorioz et al, 1989). Furthermore, over the years chronic inputs of nutrients can accumulate in the sediments, where chemical reactions lead to the release of nutrients in quantities, that can create eutrophication situations, especially when the water is stagnant (Barroin, 1999). In this case it is highly recommended to reduce sediment and pollutant inputs transferred through the watersheds' hydro systems and to prevent the clogging of hillside reservoirs in order to extend their longevity.

According to this study, It concluded that the pollutant inputs retained in water bodies located upstream have a positive impact on the hydro system of watershed by contributing to significantly reduce the cost and time of worst and drinking water treatment. In addition, water bodies located upstream would allow avoiding diffuse pollution in the hydrological and hydrogeological system of the whole catchment area.

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