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Contribution to the assessment of the pollution intensity by trace metals in surface sediments of the Sidi Chahed dam (NE Meknes, Morocco)

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Abstract
The purpose of the present work and evaluation of the impact of pollution on the water quality of the Sidi Chahed dam (Meknes, Morocco) : it focuses on the analysis and evaluation of metal contamination of sediment by using an index of contamination which is the ratio of the metal content of the reference content (geochemical background), spatiotemporal variations in grade sediment Fe, Pb, Cd, As, Cu, Cr, Mn and Zn reveals the presence of significant contamination of the elements Pb, Cd, Cu, Mn and As. However, contamination indices (content metal / reference content) and indices means of contamination (Icm <2) registered for the eight trace elements analyzed Cd, Cu, As, Mn, Fe, Zn, Pb and Cr show a state of unpolluted to moderately polluted. The sources of contamination are probably related to runoff, erosion of agricultural land, discharges of domestic sewage and traffic.

1. Introduction
Heavy metal pollution is a topical issue, which is of concern to all communities concerned about maintaining their water heritage to a certain degree of quality. L'étude des métaux lourds dans les sédiments est une contribution à la détermination, la compréhension et la prédiction de la pollution métallique. This contribution is all the more important as this compartment, depending on its nature and its surrounding conditions, can also act as a reservoir in the event of a massive contribution, as well as a polluting source if the release conditions are favorable.
The purpose of this work is to evaluate the impact of pollution on the water quality of the dam reservoir Sidi Chahed (Meknes, Morocco). It focuses on the analysis and evaluation of metal contamination of sediments by using a contamination factor, which corresponds to the ratio of the metal content to the reference level (geochemical background) [1, 2, 3, 4].

2. Geographical and geological framework
The Sidi Chahed dam is built on Oued Mikkes, a tributary of Oued Sebou, about 30 km North West of Fez city and 30 km North Est of Meknes city, on the main road n° 3 linking Fez and Sidi Kacem (Figure 1). It was built on Miocene and Triassic soft formations in the transition zone between the South Rif corridor and the Prerif (Figures 1 and 2). It was mainly intended for the supply of drinking water and irrigation to the city of Meknès [5]. However, since its introduction in February 1997, the water quality of the reservoir has been unsuitable for consumption because of its relatively high salinity [6].
The Oued Mikkès watershed is drained by four tributaries: Oued N'ja and Oued Atchane on the right bank and Oued Tizguit and Oued Akkous on the left bank. The first two drain the plain of Sais and the last two drain the plateau of Meknes and the causse of El Hajeb-Ifrane.
Going from the south to the north of the watershed, the altitude decreases in parallel with precipitation as the temperatures become higher. The maximum rainfall is recorded at the level of the cause and precisely at the station of Ifrane (Altitude 1600 m), while the minimum of rain is observed downstream of the basin at the station of Sidi Chahed 190 m). The determination of the interannual mean rainfall in the Oued Mikkès

catchment area during the period 1968-2005 is very approximate given the small number of measurement stations and the variations of the relief. The mean depth of runoff calculated by the isohyetes method is of the order of 484 mm [7]. The aridity index I of the region, of 18 mm / °C (De Martonne 1942), corresponds to a semi-arid climate with 10 <I <20 [8].

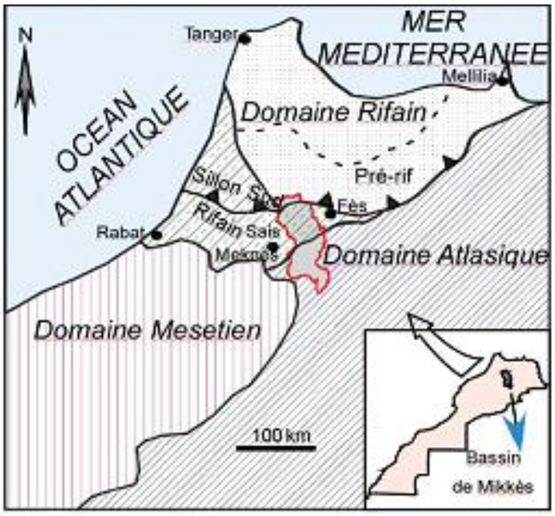

Figure 1: Location of the Wadi Mikkes watershed in relation to the map of Morocco and in relation to the structural domains (Rif, Atlas and Meseta occidentale).

The simplified geological map shows the predominance of Miocene marly lands that are highly vulnerable to water erosion and landslides, especially in the presence of rugged mountainous terrain [9].

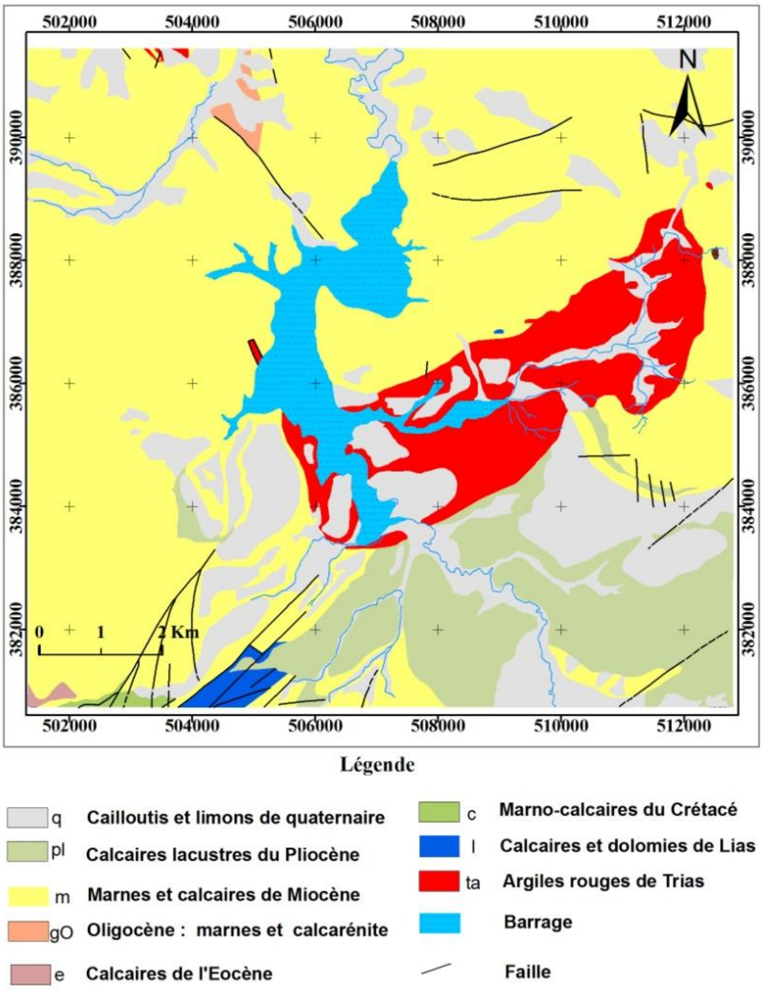

Figure 2: Simplified geological map of Sidi Chahed dam watershed [9].

In the eastern part along the Wadi Lmaleh, Triassic formations predominate. The latter threaten the dam reservoir by the impact of saline contributions in addition to the phenomenon of siltation by clays. Towards the south are mainly the lacustrine limestones of Saïss (Figure 2).

3. Materials and methods

This work deals with the evaluation of metallic contamination, contained in the sediments of the Sidi Chahed dam reservoir (NE of Meknès, Morocco). The choice of sediment lies in the fact that it constitutes an environment conducive to accumulation, reduces pollution in surface waters by trapping [10], reflects the pollution of the aquatic environment and gives a history of the evolution Of pollutants, both qualitatively and quantitatively, in time and space.
So, 88 superficial sediment samples were collected during the 2010-2011 crop year, in winter 2010, spring, summer and fall 2011 respectively, at 22 stations spread over the entire dam reservoir (Figure 3). Other samples were taken from the catchment area at sites far from any anthropogenic activity (4 reference stations) [1] in order to make the comparisons and detect the origin of the pollution (Figure 4). The sediments were taken aboard a boat using an Eck man hopper to collect samples at various depths at the water-sediment interface (surface sediments of 0 to 5 cm). The 22 sampling stations were positioned using a Magellan eXplorist 100 portable GPS.

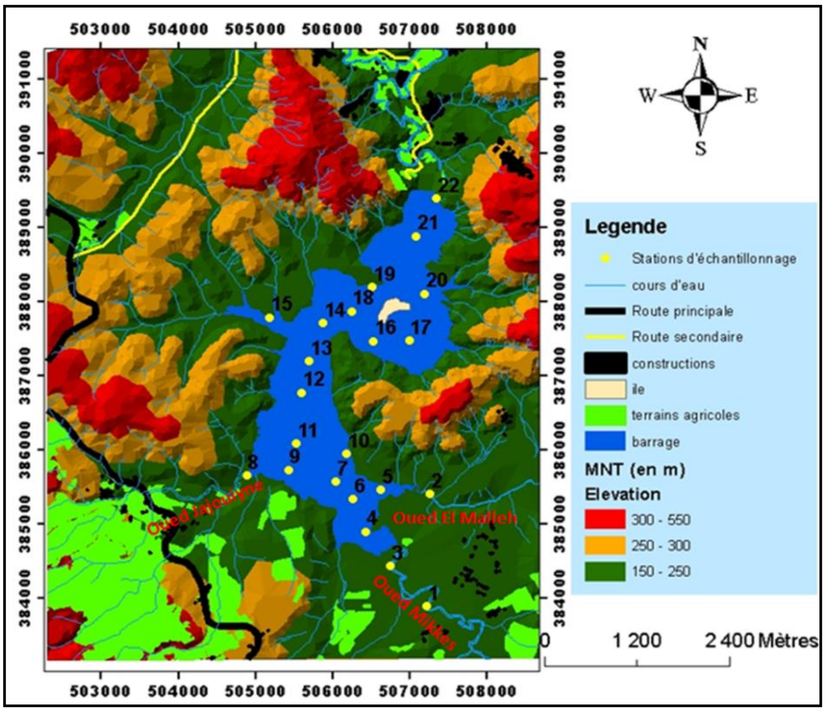

Figure 3: Digital Elevation Model (DEM) of the study area and position of sampling stations in Sidi Chahed dam reservoir.

The samples were transported in plastic bags and conditioned at 4 °C until the laboratory [11, 12, 13]. They were then stirred until a homogeneous mixture was obtained, dried in an oven for 48 hours at 80 °C and sieved in a sieve with a mesh size of less than 200 µm, in order to extract the fraction of less than 200 µm.
A quantity of 1 g of sediment (<200 µm) is mineralized at 120 ° C. for 4 hours in the presence of aqua regia (mixture of HNO_3, Supra pure 63% and HCl, Supra pure 37%) in proportions 1/3 (1V / 3V). The mineralized body is taken up by successive rinsing with ultrapure water and then filtered over a 0.45 µm membrane and supplemented to a volume of 50 ml [2, 14, 15]. Concentrations of Fe, Mn, Zn, Cu, Pb, Cr, As and Cd were analyzed using ICP-AES (Inductively Coupled Plasma Atomic Emission Spectrometry) at the National Center for Scientific and Technical Research (CNRST)-Morocco.

4. Results and discussion

The results of analyzes of the trace metallic elements observed in the sediments make it possible to classify them in order of increasing contents. The highest concentrations are those of iron (21.56 to 118.73mg / g), followed by manganese (116.73 to 732.70µg /g), zinc (10.72 to 103.88µg /g), Chromium (10.89 to 86.99µg /g), Lead (4.87 to 24.57µg /g), copper (2.90 to 45.61µg/g), arsenic 9.73µg/g) and cadmium (0.50 to 5.39µg/g). The high Fe content is related to the ferromagnesian nature of the soils and the geology of the region (Red Trias clays).

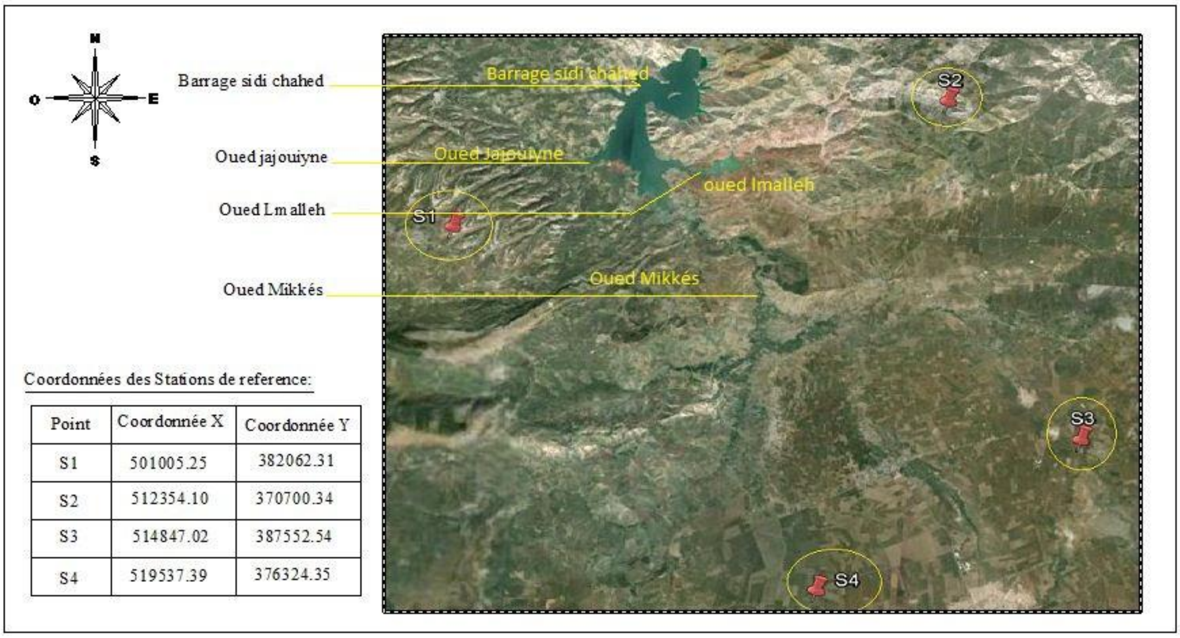

Figure 4: Location and coordinates of reference stations in the catchment area of the Sidi Chahed dam reservoir.

Comparison of these results with sediment pollution thresholds [16] and with Moroccan sediment pollution standards [17, 18, 19] shows that these standards are exceeded for chromium, cadmium and arsenic (Table 1).

Table 1: Metal trace elements content of Sidi Chahed dam sediment compared to Moroccan pollution standards [16, 17, 18, 19].

Eléments métalliques	Barrage Sidi Chahed	Stations de références	Normes marocaines	Normes mondiales [14]	Nature de la pollution
Mn (µg/g)	116,73-732,70	265,73	400 [2]	--	Pas de pollution
Zn (µg/g)	10,72-103,88	49,17	88 [2]	315	
Cu (µg/g)	2,90-45,61	16,19	26 [2]	35	
Pb (µg/g)	4,87-24,57	11,79	22 [2] 34,5 – 66,7 [15]	91,3	
Fer (mg/g)	21,56-118,73	61,58	3,12-6,68 [15]	--	Pollution : agricole, domestique, contexte géologique riche en ferro-magnésiens (altération des argiles rouges du Trias)
Cd (µg/g)	0,50-5,39	1,44	0,6 [16]	0,6	
As (µg/g)	2,36-9,73	4,37	5 µg/g moyenne mondiales des sédiments de rivières [16]	5,9	
Cr (µg/g)	10,89-86,99	42,40	45 [16]	37,7	

5. Evaluation of contamination degree

The evaluation of the contamination intensity by means of the sole determination of the trace metallic elements observed in the sediment samples is insufficient. To do this, some authors introduce the notion of contamination

index (Ic), which makes it possible to better distinguish the contribution of anthropogenic and natural sources that may be present in the study area. The calculation of this index, which highlights the levels of geochemical background noise, is an approach that deserves to be completed. Thus, [1], [2], [3] et [4] express metal contamination using contamination index Ic (metal content / reference content) and mean contamination index Im, : Im = ΣIc / n; With n, the number of chemical elements analyzed.
Analysis of the results obtained shows that elements such as Zn, Pb, Cd, Cu, Mn, As and Cr have contamination indices well above 1 (Ic> 1) (Fig. 5, 6, 7, 8, 9, 11, 12) during the winter and spring season; However, Fe has contamination rates greater than 1 (Figure 10) during the summer and fall season, which highlights the presence of moderate metallic anthropogenic pollution by these elements. The contamination indices recorded in the study area remain much lower than those obtained in the Oued Moulouya sediments near a mining site varying from 5 to 25 [20].

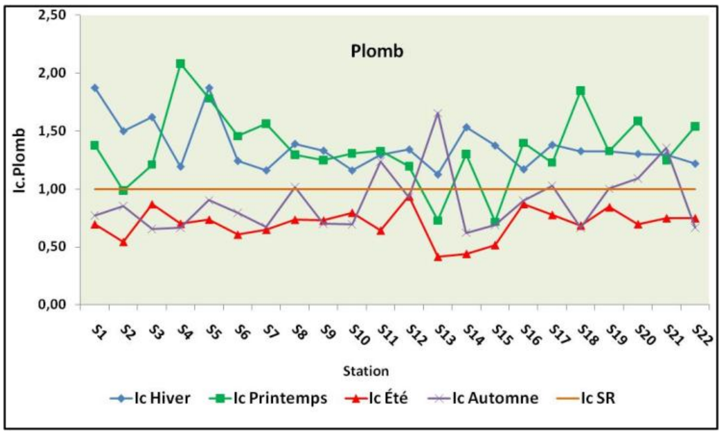

Figure 5: Seasonal variation in the Pb contamination index (Ic.Lead) in the surface sediments of the dam reservoir compared to the reference stations contamination index (IcSR).

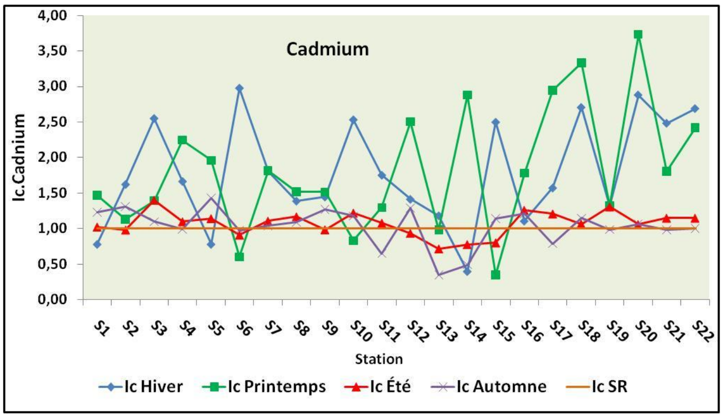

Figure 6: Seasonal variation in the Cd contamination index (Ic.Cadnium) in the surface sediments of the dam reservoir compared to the reference stations contamination index (IcSR).

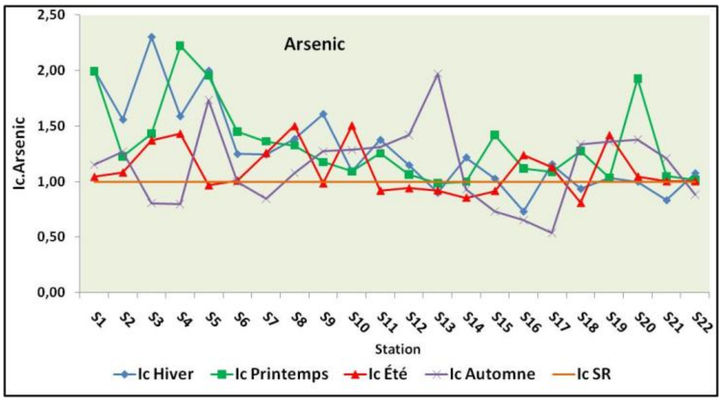

Figure 7: Seasonal variation in the As contamination index (Ic.Arsenic) in the surface sediments of the dam reservoir compared to the reference stations contamination index (IcSR).

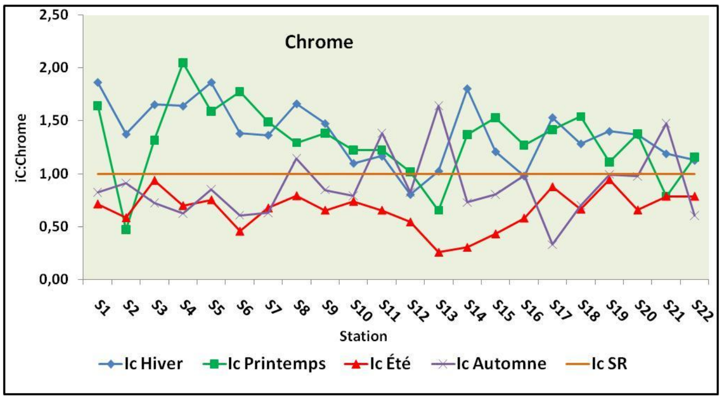

Figure 8: Seasonal variation in the Cr contamination index (Ic.Chromium) in the surface sediments of the dam reservoir compared to the reference stations contamination index (IcSR).

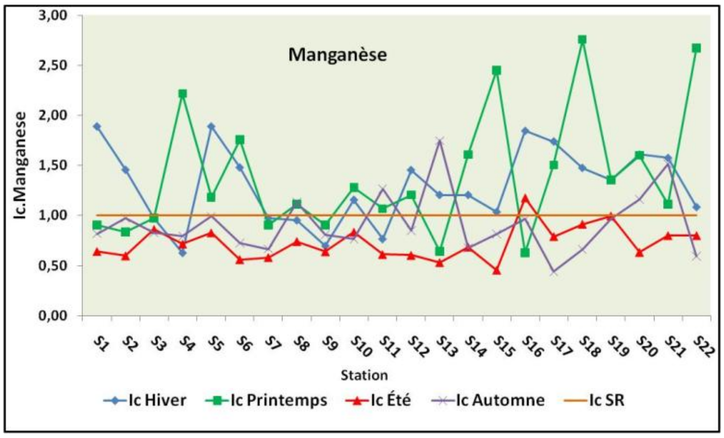

Figure 9: Seasonal variation in the Mn contamination index (Ic.Manganese) in the surface sediments of the dam reservoir compared to the reference stations contamination index (IcSR).

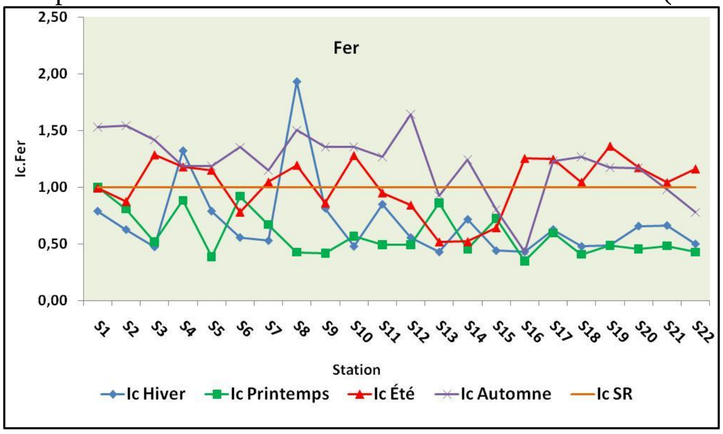

Figure 10: Seasonal variation in the Fe contamination index (Ic.Iron) in the surface sediments of the dam reservoir compared to the reference stations contamination index (IcSR).

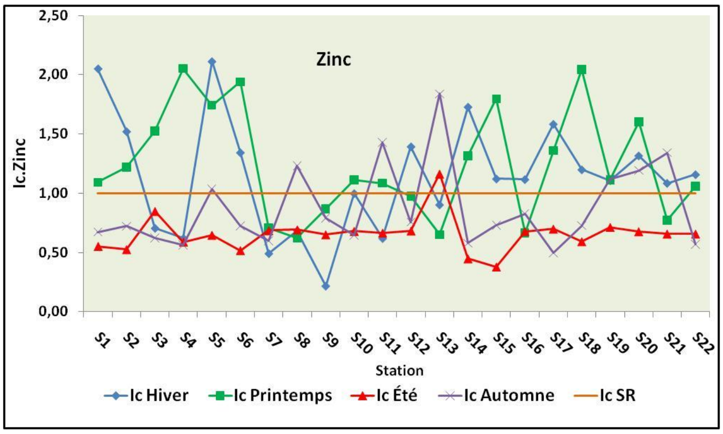

Figure 11: Seasonal variation in the Zn contamination index (Ic.Zinc) in the surface sediments of the dam reservoir compared to the reference stations contamination index (IcSR).

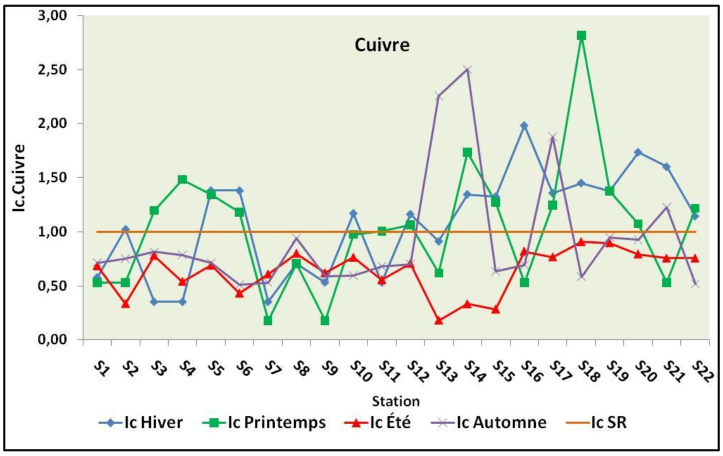

Figure 12: Seasonal variation in the Cu contamination index (Ic.Copper) in the surface sediments of the dam reservoir compared to the reference stations contamination index (IcSR).

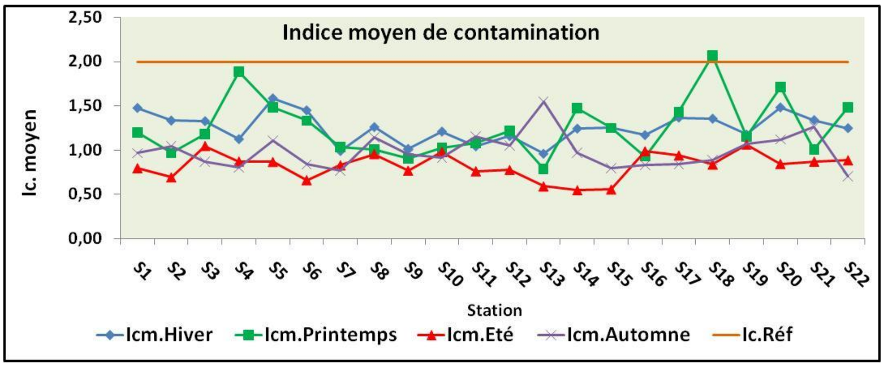

Figure 13: Seasonal variation in average contamination index (mean Ic) relative to mean reference contamination index (Icm <2).

Many authors [1, 2, 3 and 4] suggest that there is an initial contamination for an average contamination index Icm> 2. Moreover, the detailed analysis of the results shows that the average contamination indexes recorded for the majority of the prospected stations for the eight elements analyzed Cd, Cu, As, Mn, Fe, Zn, Pb and Cr have indices Icm <2 (Fig. 13), with the exception of the stations S4 situated at the mouth of the wadi Mikkés and S18 downstream near the banks and which have indices which vary respectively from 1.88 to 2.07 during the spring season.

These values lower than 2 reveal a state of unpolluted to moderately polluted by these elements for all stations studied. Indices recorded in the surface sediments of the reservoir of the Sidi Chahed dam are similar to those obtained in soils irrigated by the waters of the Sébou hydraulic basin at the level of the town of Kénitra [21]. Hawever, these indices are still much lower To those obtained in Lake Fouarat sediments ranging from 3 to 5.5

[22], in soils of Zaida mining area reaching a value of 14 [23] and in mining sites soils of eastern Morocco (Touissit and Boubker and the Oued El Heimer foundry) varying from 0.43 to 47.69 [24].

6. Conclusion

The analysis of the results obtained in this work shows that the majority of the surface sediment stations surveyed during the 4 sampling campaigns have traces of metallic trace elements superior to those of the geochemical background of control stations. The chromium and cadmium levels recorded in the reservoir sediments exceed the tolerance threshold in relation to the Canadian standard. The calculation of the contamination index Ic confirms these results by values greater than 1; This reflects a metallic contamination probably linked to anthropogenic activity (agricultural amendment).

The results obtained show the presence of metallic pollution moderated by these elements in the reservoir of the Sidi Chahed dam. The average contamination index reaches values which remain below 2 for the majority of stations but close 2 for S4 and S18 stations during the spring season, which reflects anthropogenic inputs (agricultural amendment), without excluding the contributions of Industrial and urban activities.

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