International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 11, November - 2013

Contamination by Heavy Metals of Mining Dams, Steam Sediments and Pit Lake Waters in Zeida Abandoned Mine (High Moulouya, Morocco)

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Abstract

In Zeida abandoned mine, huge amount of mining dams were left without any adjustment and remediation. Their exposition leads to mass erosion and transport over large distance in the watershed. Chemical analysis of these wastes show high contamination by heavy metals especially in fine grain size fraction. The leachate of wastes leads to the contamination of pit lake waters, the low content of Pb and Zn in the most sampled lakes is related to their low mobility in alkaline solution and their adsorption by clay and iron hydroxides. While high values recorded in As are attributed to its methylation by organic matter. Stream sediments show high contamination due to their location downstream the mining districts.

Keywords:
Chemical analysis, Pit lakes, Stream sediments, Wastes mining, Watershed, Zeida mine.

1. Introduction

The abandoned mine of Zeida (Pb, Zn) was one of the main Lead and Zinc mines of Morocco by a production of 640,000 tons of concentrated Lead among 14 years of activity [8]. This Mine is located in the eastern part of the mining district Aouli-Mibladen-Zeida, 30 km in the North of Midelt city. On the banks of Moulouya river, the mining dams (10Mt) were deposited without adjustment (Fig. 1). In this area, the pit lakes originated from the Pb ore exploitation are currently used for irrigation and livestock watering (Fig.1). These dams are spread over tens of hectares in conical flat surface and composed of a residue highly charged by heavy metals. The exposition of the mining dams to the meteoric agents, Lead to release and dispersion of heavy metals in ecosystems (water, sediments and soil) over large distance. The chemical study of mining dams, stream sediment and waters had been conducted to estimate the degree of their contamination by heavy metals.

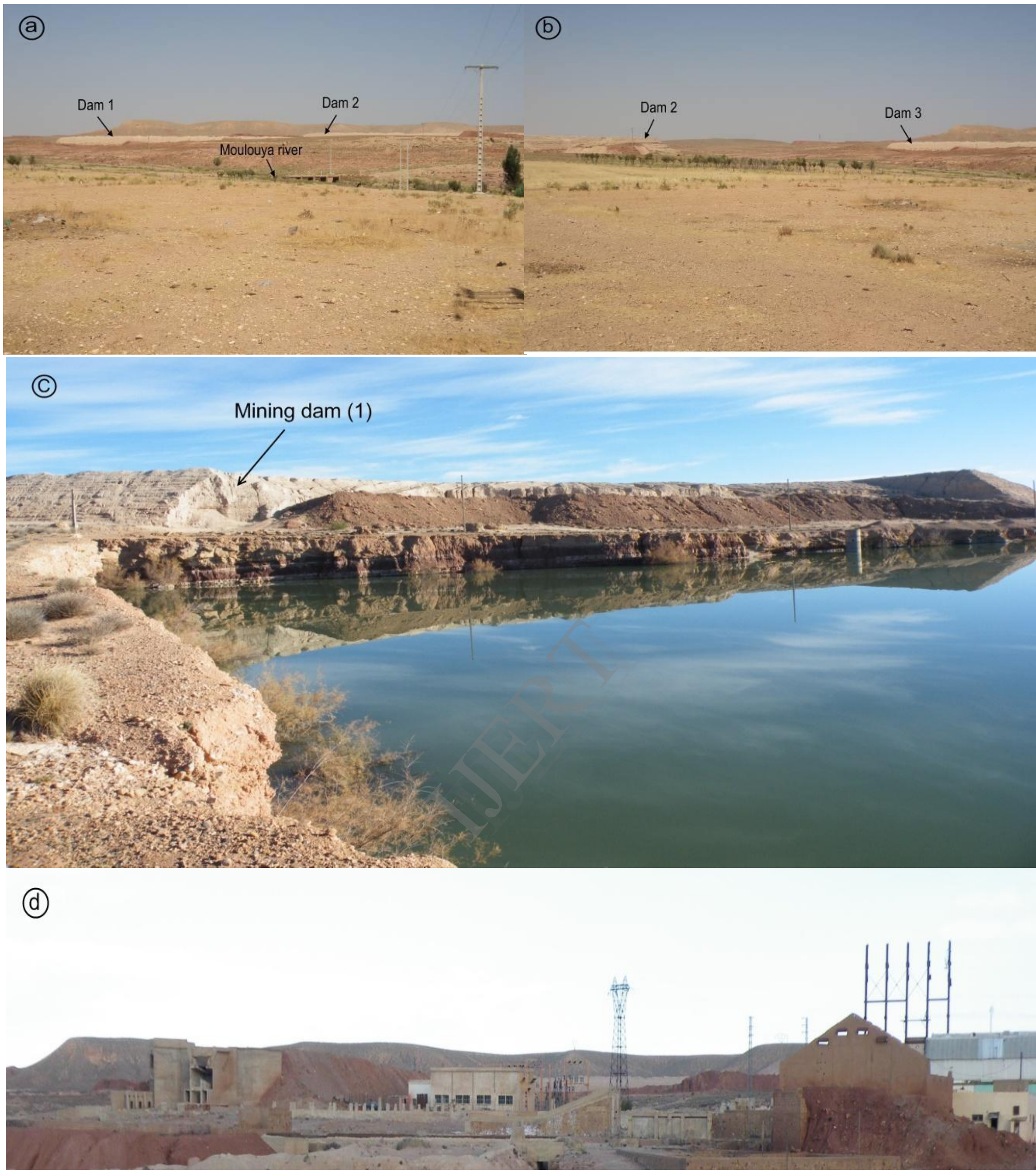


Figure 1. a,b : mining dams; c: pit lake ; d: mine infrastructure

2. Study area

The abandoned mine of Zeida is situated 2 km approximately in the North of Zeida, in the centre of high Moulouya basin (Fig. 2). The basin is naturally surrounded by Atlasic range followed in the east by the middle Moulouya plain. The area of this basin is spread over 4500 km2, which 85% is plains average altitude of 1600 m, and 15% mountains, the summit of the High Atlas is the highest point of the high Moulouya watershed [8].

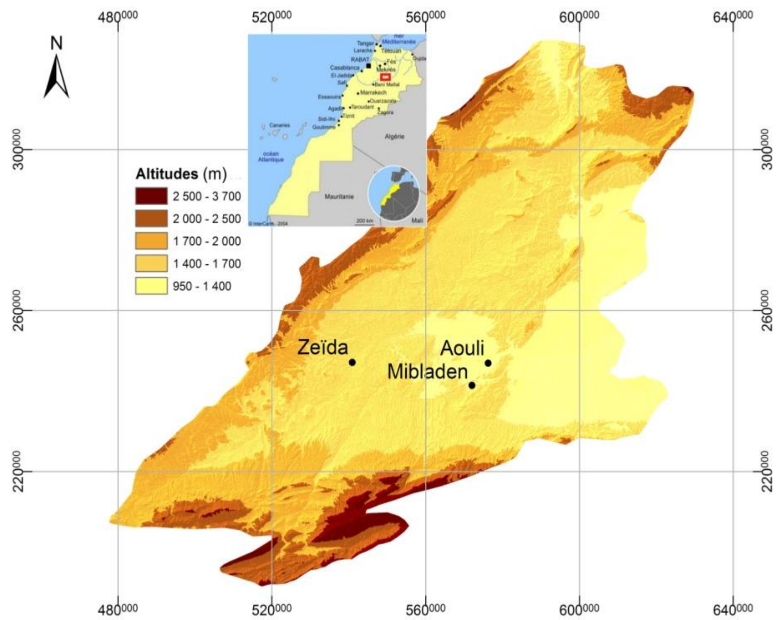


Figure 2. Geographical situation of high Moulouya watershed with location of mining areas

3. Geology

The Paleozoic basement is formed by a granitic rocks attributed to Cambro-Ordovician [10]. These granites are affected by a late hercynian and alpine fracturing. The granite of high Moulouya include several facies arranged one above the other and characterized by increasing acidity toward upper part [9]. These granitic massifs have been raised by the faulting in the western crystallophyllian series from Aouli to Zeida and Boumia Kerrouchene (Fig. 3). These hercynian granites are crossed by a network of veins which the petrography is diversified, they include several facies : diorite, granodiorite, granite amphibole porphyritic monzonite granite, aplitic granite, muscovite granite [7].

Trias is deposited by angular discordance on granite [7]. This cover fills the areas of paleolandscape [5]. The Triassic series is covered by marls and liasic limestones [4]. On the totality of this detrital cover the thicknesses are reduced, especially near the granite, influenced by the erosion [9].

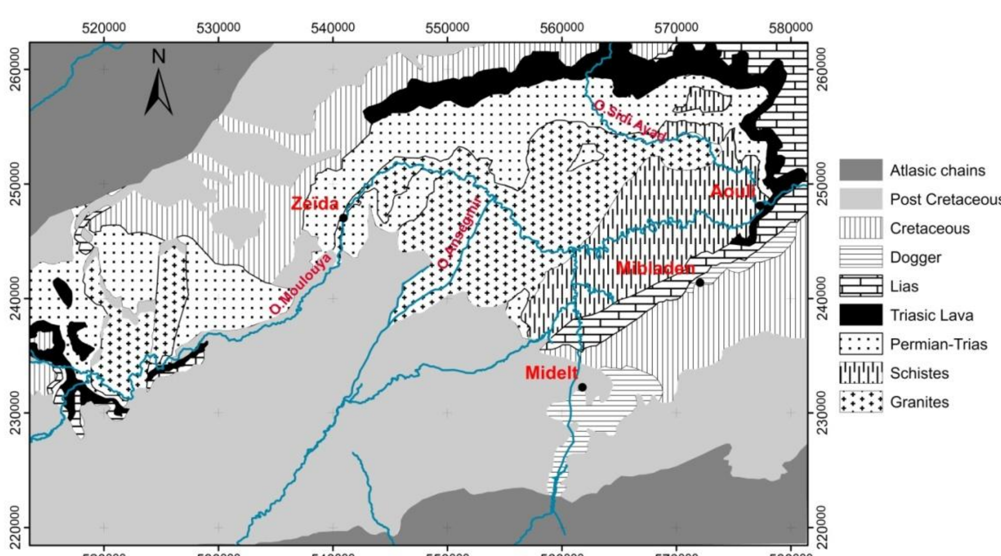


Figure 3. Geological setting of the studied area

4. Ore deposit

In zeida, the ore deposit is located under a cover of sterile from 5 to 50 m and they are distributed in panels spread over tens of thousands m^2 in the arkoses (5 to 7 m) [17] and in the sandstones (2 to 4 m) exploited as open cast. These mineralized formations are of Permo-Triassic [7], [1], [9]; this ore has an important economical value. The contents mineralized of Lead higher than 3 %, are of the cerusite 70% and the galena 30 %, associated with abundant pink barite, and the other inorganic oxides of lead [14].

The laundry of Zeida has a capacity of 1.4 Mt/year, treats the ore by mechanical and chemical processes of crushing (250 mm), grinding (0.3 mm), flotation and filtration. The chemical phase is based on the use of sulfydrate sodium amylxanthate, the sodium silicate and the oil of pine tree.

5. Wind

The valley of Moulouya is influenced by two types of winds, Chergui from the East and the Sirocco of the South; these two winds are mobilizing following direction NE-SW [2].

They so cause thunderstorms and storm which transports sedimentary particles towards the depressions favorable to deposition of these particles. The daily increase in temperature generates an expansion of the air which moves toward altitude. The clouds in low height take a higher level and by consequence the currents coming from Jbel Ayachi weakens. In the North of high Moulouya the original masses air of Middle Atlas go down towards the plain causing vertical movements [15].

The violence of the wind in this region is intense in the summer but it is stronger in spring. The Chargui has the power to cross Atlasic chains and even to happen to the Atlantic Ocean [13].

The Chergui is a desert wind, hot and dry and persists for a long period during the year. It crossed the immensity of the Atlas towards to Atlantic ocean [13].

6. Material and Methods

6.1. Sampling

In the three huge white mining dams, samples were taken at different depth. Downstream the mining district stream sediments were collected from Moulouya, Sidi Ayad streams and their intersection. The pit lakes waters have been collected also at the surface.

6.2. Analytical techniques

The samples taken at different depths of mining dams were subject to granulometrical and geochemical analyzes.

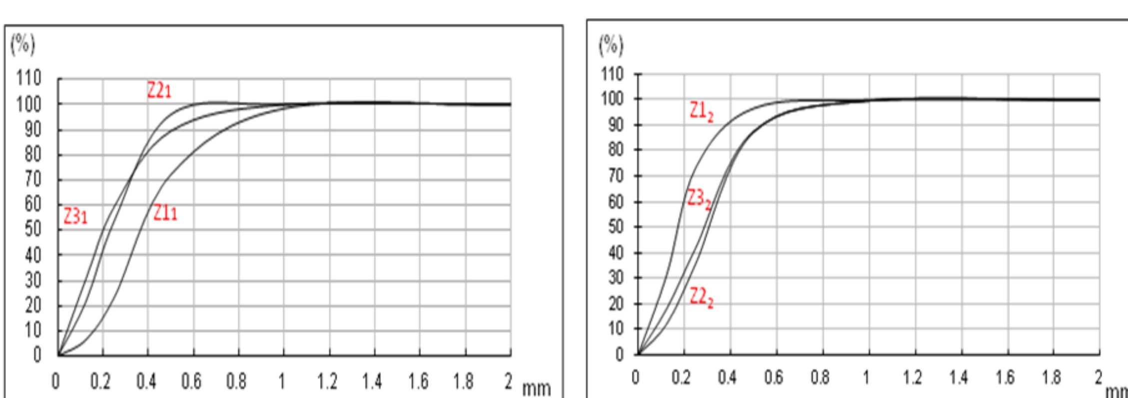
The granulometrical analysis of sediment was made according to AFNOR 933-1 series of 16 sieves, whose the diameters are between 63µm-2mm. A quantity of 100 g of sediment was dried at 50 °C for 12 hours and then placed in a series of sieves. The cumulative curves are plotted against the cumulative percentage of refusals of each class and the corresponding diameters of the grains.

For chemical analysis, water was filtered in the field through 0.22 µm Millipore membranes, acidified to pH 1 with HNO_3 Merck Suprapur (14.5 M) and stored at 4 °C in acid-cleaned polyethylene bottles until analysis. Another 10 ml subsample for the analysis of major ions was filtrated, stored at 4°C and analyzed within one week of collection. The chemical analyzes of sediments and waters were made by ICP-AES technique in UATRS-CNRS lab and in hydrosciences laboratory of Montpellier, France.

7. Results

7.1. Mining dams grain size distribution

Samples taken at different depth, in the mining dams show very similar grain size curves (S shape). The raw material is represented by very fine grain sand with particle diameter between 0.2 and 0.6 (Fig. 4).



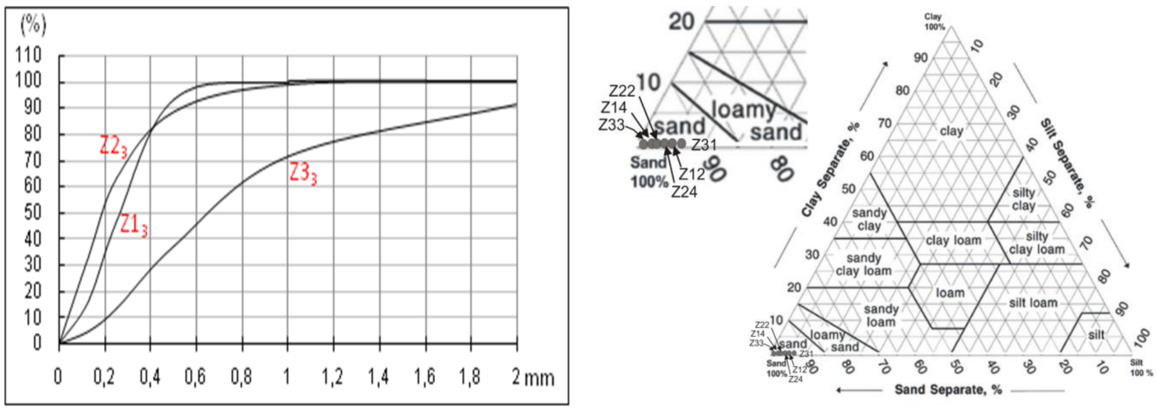


Figure 4. Grain size distribution and texture of mining dam wastes

The different proportions of sieved materials (% sand, % silt and % clay) were plotted in the diagram of texture. All studied samples have sandy composition.

7.2. Heavy metals in mining dams

The metallurgical processing of exploited and associated ores (cerusite, galena and barite, chalcosite, malachite and chalcopyrite) provide huge amounts of mining waste containing high content of heavy metals which will have harmful impact on ecosystems.

The chemical analyzes of mining dams show variable concentrations in heavy metals (As, Cd, Cr, Cu, Pb, Zn), some concentrations are much higher in comparison to Clark, while others samples show lower contents than standards.

Table 1. Heavy metal contents in studied mining dams

Samples	As(g/t)	Cd (g/t)	Cr (g/t)	Cu (g/t)	Pb (g/t)	Zn (g/t)
Z14	45.422	3.627	7.426	25.733	3246.874	151.463
Z12a (fine grain sand)	62.261	3.652	11.478	44.174	3426.108	139.131
Z12b (medium grain sand)	53.007	3.127	7.147	42.584	3890.637	122.243
Z12c (coarse grain sand)	43.300	3.355	7.669	30.677	3077.336	123.030
Z11	50.666	4.136	7.652	54.595	9570.749	131.319
Z24	50.780	3.508	13.530	27.060	2488.872	89.031
Z21	41.419	2.791	7.050	42.741	3560.245	93.412
Z31	44.585	2.858	6.716	38.869	2563.644	62.591
Clark en (g/t)	5	0.15	100	62.5	16	101

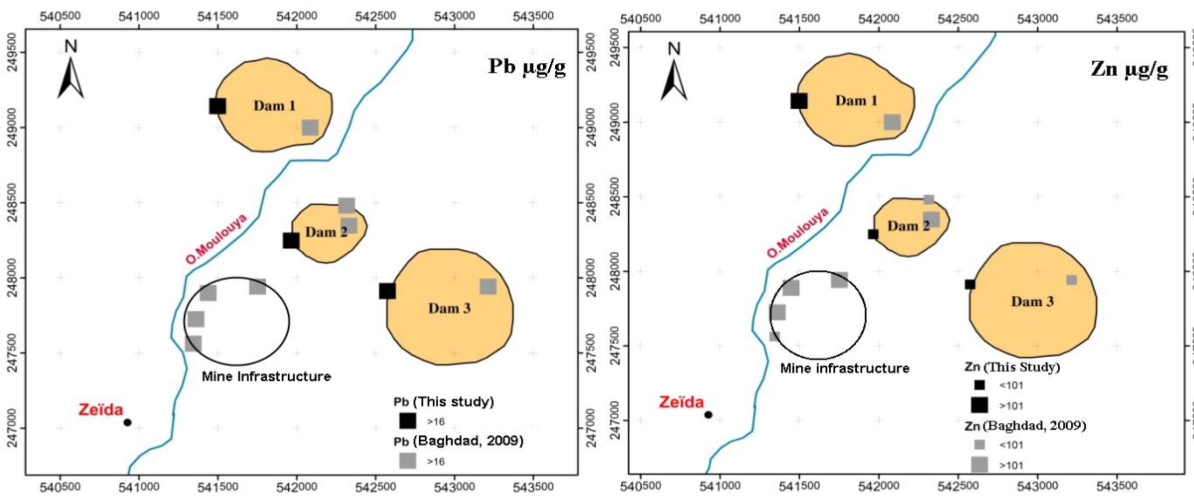


Figure 5. Comparative maps of the spatial distribution of heavy metals (Pb,Zn) in the mine area and mining dams

In all studied mining dams, the chemical compositions of heavy metals exceed the Clark standards except for Cr and Cu.

In dam (1) samples show the higher values of heavy metals in comparison to the other samples collected from dams (2) and (3). This difference is related probably to a good extraction of these metals. The Cd is naturally associated with Zn in small quantities in ores deposit like blend (ZnS) and smithsonite ($ZnCO_3$) [8].

In dam (1), all chemical elements show higher values in the bottom of the dams except for Zn. This difference can be explained by the lixiviation of elements in the upper part and their concentration in bottom of the dam [12]. In order to know which granulometric fraction of dams raw material in which heavy metal are concentrated, one sample of dam (1) was separated in three grain size fractions : fine grain fraction **a** :*63µm<∅<250µm*, middle grain fraction **b**: *250µm<∅<1.25mm*, coarse grain fraction **c** : *1.25mm<∅<2mm*. The chemical compositions of different fractions show in general that heavy metals are concentrated preferentially in fraction a (Table 1) except Pb which occurs in the three fractions.

In the dam (2) the concentrations of heavy metals (Table 1) remain higher than Clark except for Cu and Cr. From the bottom to the upper part of the mining dam, concentrations of chemical elements increase. This can be explained by the perfect extraction of the ore.

For the dam (3), the concentrations of heavy metals exceed the Clark but show chemical compositions remaining much lower compared to the dams (1) and dam (2) (Table 1). This dam is the latest one in Zeida mining district. The low values of metals recorded in this dam testify of the improvement of the extraction operations of metals over time (Fig. 5).

7.3. Heavy metals distribution in stream sediment and waters

7.3.1. Distribution maps of the contamination by Pb, Zn and As

7.3.1.1. in stream sediments

Stream sediments collected downstream of the mining district sites (Zeida, Mibladen, Aouli) show contamination by heavy metals. Close to Zeida mining area, the recorded Zn contents are below the standards, while at the intersection of Moulaouya and Sidi Ayad streams, the composition of Zn, Pb and As exceed Clark (Fig. 6). The increase of contamination at this point is due to release of heavy metals from other mining areas like Aouli and Mibladen (Fig. 6).

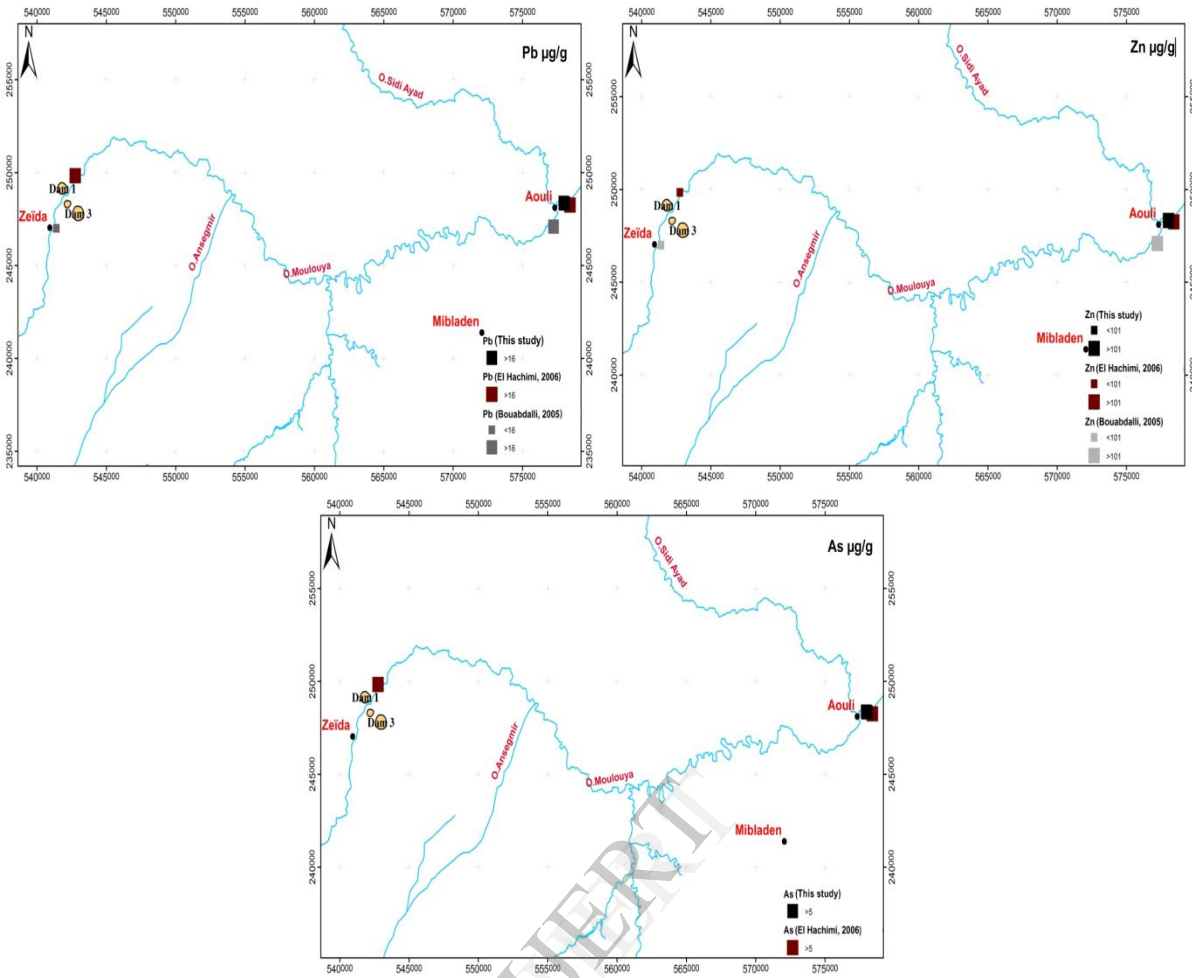


Figure 6. Spatial maps of contamination of Stream sediments by heavy metals (Pb, Zn, As)

7.3.1.2. in pit lake and stream waters

The hydrochemical analysis of pit lakes and stream waters showed many As, Pb anomalies (Fig.7). The small amounts of Zn reported in these waters are probably due to strong sorption capacity of these elements by clay minerals and iron oxides present in this area. The high concentration of As and Pb recorded in some pit lakes are probably related to their high mobility in suitable physical and chemical conditions (presence of bacteria).

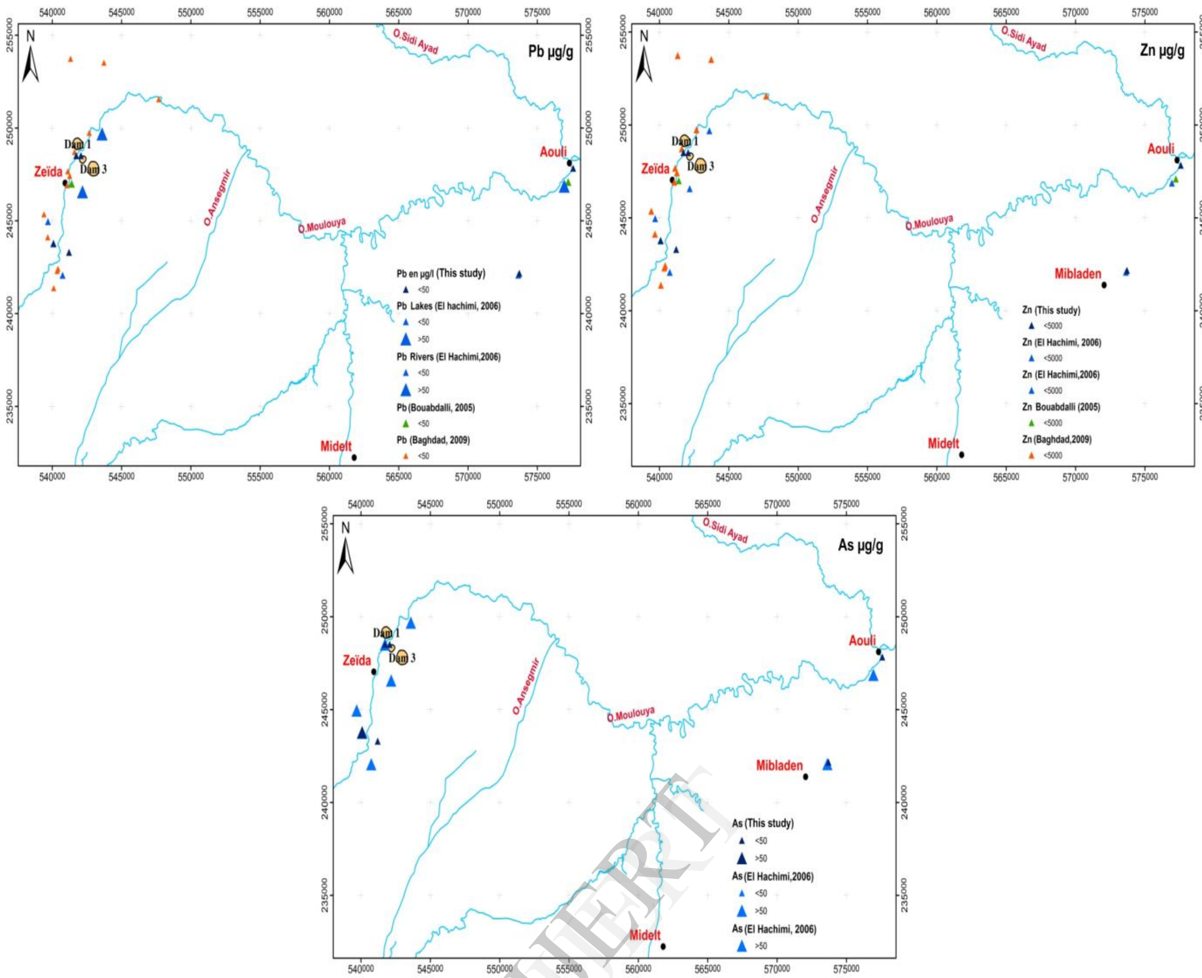


Figure 7. Spatial maps of contamination of pit lake and stream waters by heavy metals (Pb, Zn, As)

8. Conclusion

In Zeida abandoned mine huge amount of mine waste were left in situ without any adjustment and remediation. These mine waste are deposited close to river and are subject to mass erosion and discharged leading to their dispersion over a great distance in the watershed. The chemical characterization of these mine wastes confirm their high contents by heavy metals. The grain size distribution of wastes exhibit their sandy texture with the concentration of heavy metals especially in fine grain size fraction.

The chemical analysis of stream sediments collected far from the contamination source shows their high contamination due to their location downstream of the three mining districts (Zeida, Mibladen and Aouli).

The exposition of mine wastes and their leachate Lead to the contamination of surrounding pit lake waters and soils. In general, chemical analysis of pits lakes show low contamination by heavy metals except for As. This is explained by the low mobility of these elements in alkaline solutions and their sorption by clay minerals and iron hydroxides. The high concentration of As is due to its great mobility and its methylation by organic matter [3].

9. References

[1] Amade, E., (1965). Les gisements de plombe de Zaida et de Bou Mia. *Not et mém*. Serv géol, Maroc, 181, 175-184.

[2] Ahamrouni, J., (1996). Erosion hydrique dans le bassin versant de la Moulouya (Maroc oriental). Recherche des zones sources d'envasement de la retenue du barrage Mohamed V. Thèse de troisième cycle en géologie appliquée, Université Cheikh Anta Diop.

[3] Benyassine, E.M.; Dekayir, A.; Héry, M.; Delpoux, S.; Desoeuvre, A.; Bruneel, O.; Benhassou, H.; Rouai, M.; Casiot C., (2013).Contrasted arsenic speciation in two alkaline pit lakes from the abandoned Pb mining area of Zeida (Moulouya, Morocco). International Symposium On Emerging Pollutants in Irrigation Waters: Origins, Fate, Risks, and Mitigation. 25-28 November. Tunisia : Hammamet.

[4] Dagallier, G., (1977). Une série carbonatée littorale : le Lias moyen à Pb-Ba de Mibladen (Maroc). *Science de la ter*, 21 (1), 53-101.

[5] Derrar, N., (1996). Synthèse géologique et hydrologique de la haute et la Moyen Moulouya (Maroc). Mémoire de fin d'étude, Ecole Nationale de l'Industrie Minérale, Rabat, Maroc.
[6] Eisler, R., (1988). Lead hazards to fish, wildlife, end invcrtebrates: a synoptic review. U.S. Fish Wild. *Serv Biol Rep*,. 85 (1), 130-142.
[7] Emberger, A., (1965). Carte polygénétique des minéralisations plombifères de la Haute Moulouya (gisements d'Aouli, Mibladen et Zeïda), Maroc. *C. R. Acad. Sci*. Paris, 160. 3433-3436.
[8] El Hachimi, M.L.; EL Founti, L.; Bouabdli, A.; Saidi, N.; Fekhaoui, M.; Tassé, N., (2006). Pb et As dans des eaux alcalines minières : Contamination et risques (mine abandonnée de Zeida, Maroc). *Revue des sci de l'eau*, 19.
[9] El Jaouani, L., (2001). Etude géologique et gitologique des gisements plombifères de la boutonnière d'Aouli (Aouli, Zeida, Mibladen) Haute Moulouya (MAROC). Thèse en géologie appliquée. Université Mohammed V Rabat.
[10] Hoepffner, C., (1987). La tectonique hercynienne dans l'est du Maroc. Thèse ès Sciences, Université de Strasbourg.
[11] Jayaraj, K.A., (2008). Response of infaunal macrobenthos to the sediment granulometry in a tropical continental marginesouthwest coast of India. *Estuarine, Coastal and Shelf Science.*, 77, 743-754.
[12] Juste, C.; Chassin, P.; Gomez, A.; Lineres, M.; Mocquot, B.; Feix, I.; Wiart, J., (1995). Les micropolluants métalliques dans les boues résiduaires de stations d'épuration urbaines. Convention ADEM-INRA.1-209.
[13] Leroux, M., (2001-2002) - Les climats subtropicaux dits "méditerranéens" et les climats de la Méditerranée. *L'information géographique*., 65 (4), 304-320 et 66 (1), 34-52.
[14] Nasloubi, M., (1993). Genèse et modélisation des minéralisations plombifère de la haute Moulouya (Maroc). Mémoire de maitrise. Université du Québec à Montréal.
[15] Rhanem, M., (2009). L'alfa (Stipa tenacissima L.) dans la plaine de Midelt (haut bassin versant de la Moulouya, Maroc) – Éléments de climatologie. *Physio-Géo.*, 3, 1-20.