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Environmental Impacts of Open-dumping Landfill to Lagoon Sediments - A Case Study in Bizerte Lagoon, Northern Tunisia

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I. Introduction

Populated cities and/or industrial zones in northern Tunisia have been mostly developed along Mediterranean coastal lagoons, e.g. Tunis and Bizerte. It is also very common in Tunisia that lagoon basins and streams ("Wad") flowing into the lagoons or ocean coasts have been used as uncontrolled open-dumping solid waste disposal sites. Thus, an important problem in these lagoons is environmental contamination and pollution caused by human activities such as industrial effluents, wastewater, and solid waste disposals. The lagoon bottom sediments are, in this context, a sink of pollutants. The Bizerte lagoon is one of such lagoons located near the industrial and urban zones, where industrial zones of Menzel Bourguiba, Bizerte, and Menzel Jmil have been developed as urban as well as industrial zones, and three open-dumping type municipal/industrial solid waste landfills have been operated near the Bizerte, Menzel Bourguiba, Menzel Abderahmen, and Menzel Jmil. In addition to these land uses, the eastern side of the Bizerte lagoon is a widely opened as an agricultural zone where potential pollutants like fertilizer and agro-chemicals (pesticides and insecticides) are applying. In this paper, we report the results of potentially toxic elements (PTEs) analysis of lagoon bottom sediments sampled by the 'JICA Research Promotion Programme, Study on Environmental Pollution of Mediterranean Coastal Lagoons' RPP-SEPMCL leg Bizerte2002, and interpret the environmental impacts of landfill activities through the spatial distribution of PTEs contamination.

II. Samples and Analysis

A total of 180 samples were collected from lagoon bottom sediments of 100 sites using a grab sampler. According to the on-site observation with naked eyes, the collected sediments, which were more or less maintained the original texture, were mostly divided into two layers, the upper thin (thickness < 1 cm) unconsolidated layer ('Upper Layer') and the lower semi-consolidated sediments ('Lower Layer'). The former is normally light brown color indicating oxidizing conditions but the later is dark gray to black in anoxic conditions. We collected separately for the chemical analysis, named 'U' samples and 'L' samples.

The dredged sediment samples were disintegrated and dried under 105°C, and powdered by a ceramic mill. Then the powder samples were sieved by a 68 micron, and the finer fraction was used for the analysis. A 15.0 gm sample split was digested in 90 mL aqua regia (HCl-HNO_3-H_2O) at 95°C for one hour. The solution is diluted to 300 mL with distilled water. Analysis was made by an Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES) and Mass Spectrometry (ICP-MS). Total 37 elements were measured: B, Na, Mg, Al, P, S, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, As, Se, Sr, Mo, Ag, Cd, Sb, Te, Ba, La, W, Au, Hg, Tl, Pb, Bi, Th, and U. The aqua regia digestion of sediment extracts only a fraction of the major elements (pseudo-total analysis) because silicates are not completely dissolved with this method. Owing to this limitation, results are total to near total for trace and base metals and possibly partial for rock-forming elements such as Na, Mg, Al, K, Ca, Mn, and Fe. However, environmentally concerned components like heavy metals or PTEs not bound to silicates are efficiently dissolved, which is indicative for the assessment of toxicity.

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III. Results - Spatial Variation of PTEs in the Lagoon Basin

Spatial variation of 20 PTEs; Al, Sb, As, Ba, Cd, Cr, Co, Cu, Fe, Pb, Mn, Mo, Hg, Ni, Se, Ag, Tl, U, V, and Zn, which are typical elements that have been monitored for assessing soil/sediment contamination. The spatial data are statistically averaged using a Distance Weighted Least Squares algorism of which result was expressed by a curved surface. The criteria defined by NOAA SQuiRT are applied for our screening of the data obtained.

The concentration of aluminum (Al) varies widely but generally the sites of central to central western part of the lagoon basin show very high concentration around the threshold value (1.8 %). The concentration decreases towards the shoreline, which suggests us the granulometry is a controlling factor of the variation. Antimony (Sb) concentration is rather homogeneous in the lagoon basin except abnormally high values near Menzel Bourguiba landfill which indicates a strong impact of human activity such as landfilling. However the concentration does not exceed the threshold values for toxicity (<9.3 ppm). Arsenic (As) contents is relatively homogeneous but toward Menzel Bourguiba and Bizerte city, the concentration tends to increase, which is more significant in the Lower Layer. The concentration level is rather high in comparing with the threshold value (35 ppm) and it exceeds in the sites near the Menzel Bourguiba. The concentration of Barium (Ba) is also relatively homogeneous in the lagoon basin but it tends to increase toward Menzel Bourguiba, which is more significant in the Lower Layer. The level of concentration is generally high above and around the threshold value (48 ppm). Cadmium (Cd) also exhibit similar trend in the cases of Sb, As, and Ba, while even the highest concentration near Menzel Bourguiba does not exceed the threshold value (3 ppm). Chromium (Cr) concentration is generally high around west central part of the basin to Menzel Bourguiba, and it suddenly decreases eastward and Mediterranean side, which indicates the polluter(s) is possibly found around Menzel Bourguiba – Tinja, and the Cr is migrating central-eastward. It should take note that the concentration level in the west central part (the zone of higher values) does not exceed the threshold value (62 ppm), but very closed to the threshold value. The spatial variation of the concentration of cobalt (Co) is quite similar to that of Cr, which also suggest the polluter is around Menzel Bourguiba –Tinja. The concentration level is also around the threshold values (10 ppm). Copper (Cu) content does not vary in the major part of the lagoon basin where it is low around background level (10-25 ppm). However only the sites close to the Menzel Bourguiba landfill show several times higher value as a peak. The concentration of iron (Fe) is generally high in central to western area of the basin and around Menzel Bourguiba, but the concentration level is lower than the threshold value (22 %). The concentration of lead (Pb) is again showing Cu-type pattern of variation, and the peak values above the threshold value (400 ppm) can be found in the Lower Layer near the Menzel Bourguiba landfill. Manganese (Mn) content in the basin is rather high in comparing the threshold values (260 ppm), where the concentration increases toward Menzel Bourguiba. Central and western parts of the basin exhibit a plateau of high concentration above the threshold value, which is more significant in the Upper Layer. The concentration of molybdenum (Mo) is generally low and monotonous, but near the Menzel Bourguiba it suddenly increases several times. The concentration in the Lower Layer also depicts some peaks in the western margin of the lagoon basin. However they do not exceed the threshold value (40 ppm). The concentration of mercury (Hg) is generally low in the lagoon center, but surrounding areas such as Bizerte, Menzel Bourguiba, and southeastern shore zone show higher values around the threshold value (0.41 ppm). Particularly in the Lower Layer sediments, the concentration suddenly increases near the southeastern part where agricultural area is widely developed. The variation of nickel (Ni) concentration is again similar to the Cr and Co type behavior, where the central western part toward Menzel Bourguiba shows a plateau of relative high concentration. However the concentration level is low in comparing with the threshold value (110 ppm) even in the sites showing relative higher values (‘plateau’). The concentration of selenium (Se) in the Upper Layer sediments is generally low in the major part of the lagoon basin (<1 ppm) while it suddenly increases nearby the Menzel Boulguiba landfill as a peak that exceeds the threshold value (1 ppm). The concentration of Se of the Lower Layer sediments shows an increase not only nearby Menzel Bourguiba landfill but towards Menzel Jmil, which suggests us there are two pollution sources. The concentration of silver (Ag) is also very low in the major part of the lagoon

basin. It only shows a peak value near the Menzel Bourguiba landfill, but it is still less than the threshold value (3.1 ppm). The concentration of thallium (Tl) little varies in the major part of the lagoon basin but marks peak values only nearby the Menzel Bourguiba landfill (1 ppm). Industrial uses of Tl are varied, but all are, at present, small scale, such as using as a catalyst, semiconductor, and in electric engineering. However, its major use was a pesticide and rodenticide. The variation of uranium (U) concentration does not vary so much while it increases near Menzel Bourguiba and Bizerte port. There is no reliable criterion for evaluating sediment contamination by U, while the concentration obtained by present study is background level previously reported in other areas. The variation of vanadium (V) concentration is similar to the Cr and Co type 'plateau' behavior, where the central western part toward Menzel Bourguiba shows a plateau of relative high concentration. The higher concentrations in 'plateau' around Benzel Bourguiba are above the threshold vale (57 ppm). The concentration of zinc (Zn) is rather monotonous in the major part of the lagoon basin. It shows peak values near the Menzel Bourguiba landfill, which marks abnormally high vales above the criteria (410 ppm).

IV. Concluding Remarks

Thus the spatial pattern of PTEs distribution in the lagoon bottom sediments is basically classified into three types, (i) peak type, (ii) plateau type, and (iii) the others:

(i) In the *peak type* distribution, abnormally high concentration sites limitedly appears nearby the landfill of Menzel Bourguiba. The other sites show relatively homogeneous distribution with low concentration values. This variation pattern implies that the contamination source is at the Menzel Bourguiba landfill, and the contamination has not widely spread toward the lagoon basin. Twelve elements are found in this type: Sb, As, Ba, Cd, Cu, Pb, Mo, Se, Ag, Tl, U, and Zn. Three heavy metals, Ba, Pb, and Zn, and two metalloids, As and Se, show toxic level of values above the criteria.

(ii) In the *pleateau type* distribution, very high concentration zone is present from southwestern part (Menzel Bourguiba, Tinja, and its north) to the west central part of the lagoon basin. The concentration significantly decreases eastward, southward, and northward. This 'Plateau' type pattern implies that the pollution source is the southwestern side (Menzel Bourguiba, Tinja, and its north) of the lagoon, and the contamination migrates towards the central of the lagoon. Seven elements are found in this pattern: Al, Cr, Co, Fe, Mn, Ni, and V. The concentration of five metals, Al, Cr, Co, Mn, and V, indicates above or around the threshold value in the 'plateau' zone. The 'plateau' zone corresponds to the area of clay and organic matters distribution zone that shows high cation exchange capacity. It means these metal elements have been adsorbed by the clay mineral and/or complexed with organic matters.

(iii) The other distribution pattern can be observed the variation of Hg concentration basically shows 'peak' pattern but it also enhances near the southeastern part of the lagoon basin. The peak values exceed the threshold value. One of the pollution sources can attribute to the Menzel Bourguiba landfill, but the other is probably due to a non-point pollution of Hg contained agro-medicals such as pesticides in the eastward-southward agricultural zone.

Consequently, sediment contamination by 11 PTEs, Ba, Pb, Zn, As, Se, Al, Cr, Co, Mn, V, and Hg, can be recognized in the Bizerte lagoon, of which concentrations indicate toxic level according to NOAA SQuiRT criteria. Occurrence of those PTEs contamination is closely related with the open-dumping landfill of Menzel Bourguiba industrial zone, which means environmental impact of uncontrolled open-dumping landfill is hazardous particularly if it is located in adjacent to lagoons.

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