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Assessment of Potential Ecological Risks of Cr, Cd, Pb, and As in Coastal Sediments †

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Abstract: Coastal sediments are a powerful tool for analyzing pollution levels and reconstructing history. The Oualidia lagoon plays an essential role as it provides several ecosystem services, including aquaculture, fisheries, and coastal tourism, among others. Therefore, the conservation and protection of this natural system requires the continuous monitoring of its environmental quality. The present study evaluates the potential ecological risks of Cr, Cd, Pb, and As in coastal sediment cores collected from the Oualidia lagoon. These sediment cores were also dated using lead-210 to study the temporal variations in the studied metals. The potential ecological risk values of the metals show a moderate ecological risk to the lagoon since the 1950s, while the toxic units indicate low toxicity. The Adverse Effect Index (AEI) values indicate a probable effect on biota due to the concentrations of Cr, As, and Cd, mainly in the surface layers. This suggests that the development of human activities in the last two decades has contributed to increased heavy metal concentrations, leading to potential ecological risks to the lagoon. Activities such as agriculture can be potential sources of Cd. Excessive use of fertilizers and pesticides may contribute to the increase in this heavy metal in the lagoon. This finding highlights the need for the careful monitoring and remediation of Cd levels in this aquatic system, as Cd presents a high ecological risk value among the selected heavy metals.

Keywords: sediment; heavy metals; ecological risk; Oualidia lagoon

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1. Introduction

Lagoon ecosystems provide multiple ecosystem services and contribute to human well-being [1]. Various activities are practiced in coastal lagoons and play an essential role in socio-economic growth at local and national levels. Coastal tourism, fishing, and aquaculture are the main activities practiced in such ecosystems [2–4]. The uncontrolled development of these activities can lead to the depletion of natural resources due to increased pollution, overfishing, and overtourism [5].

The Oualidia lagoon is Morocco's oyster capital and is well known for its oyster farming activities. National and international tourists visit Oualidia to taste its exceptional oysters. However, the increase in human activities around this lagoon could reduce its environmental quality and threaten its ecological functions.

The sustainability of Oualidia lagoon's natural resources, including fisheries and oysters, mainly depends on various ecological factors. For example, oyster growth is affected by salinity, temperature, and natural food availability [6]. In addition, the chemicals in the lagoon water could affect oysters' growth rate and quality.

Due to the importance of such a natural ecosystem, its conservation and protection require continuous monitoring of its environmental quality. In this sense, we evaluate the potential ecological risks of chromium (Cr), cadmium (Cd), lead (Pb), zinc (Zn), cobalt (Co), nickel (Ni), and arsenic (As) in coastal sediment cores collected from the Oualidia lagoon using environmental assessment indexes. In addition, the chronological changes in metal content and their potential ecological risks over the years are also major objectives of this study.

Coastal sediments are a powerful tool for analyzing pollution levels and reconstructing history, so the results of the present study would allow a better understanding of the environmental quality of this coastal lagoon.

2. Materials and Methods

Sampling and Analytical Techniques

Two sediment cores were retrieved from the Oualidia lagoon in 2014 using UWITEC corer. The sediment cores have undergone physical preparation (sectioned into 2 cm slices, dried, powdered, homogenized, and stored in plastic bags for further analysis) and radiometric and chemical analyses using gamma spectrometry and ICP-MS, respectively (see [4,7]) (Figure 1).

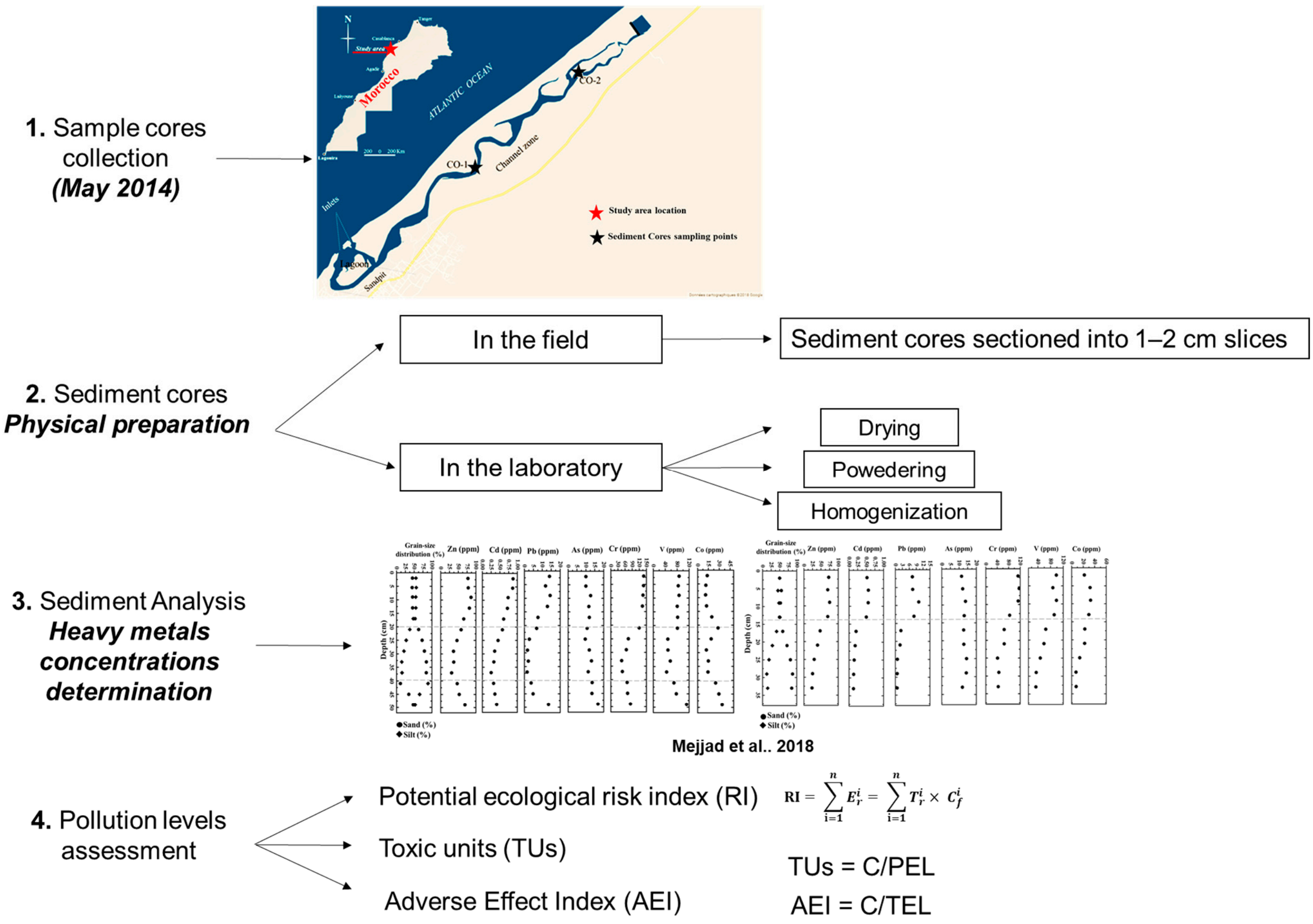

Figure 1. The study flowchart.

These sediment cores were also dated using lead-210 and Ceasium-137 in order to study the temporal variations in the studied metals [7].

Three indexes were used to assess the potential ecological risks of heavy metals in sediments. Ecological risk estimation is performed using the potential ecological risk index (RI) [8]. The Adverse Effect Index (AEI) is used to assess the biological effects of metals in sediments [9]. Toxic units (TUs) are used to evaluate toxicity [10].

The potential ecological risk index (RI) is calculated using the following equation:

$$RI = \sum_{i=1}^{n} E_r^i = \sum_{i=1}^{n} T_r^i \times C_f^i \quad (1)$$

where

E_r^i—ecological risk of heavy metal;

T_r^i—toxic-response factor (Zn = 1; Cr = 2; Ni = 5; Cu = 5; Pb = 5; As = 10; Cd = 30);

C_f^i—contamination factor.

The RI values can be defined as follows [8]: when RI < 150, it indicates a low ecological risk; if RI ranges between 150 and 300 and between 300 and 600, this indicates a moderate ecological risk and a considerable ecological risk, respectively. An RI > 600 means a very high ecological risk.

The Adverse Effect Index (AEI) was used in the present study to analyze if these metals can induce negative biological effects on this lagoonal ecosystem. The following equation was thus used to calculate the AEI:

$$AEI = C/TEL \quad (2)$$

C is the content of a metal in sediment samples, and TEL is the threshold effect level (As = 7.24; Cd = 0.68; Cr = 52.3; Cu = 18.7; Ni = 15.9; Pb = 30.24; Zn = 124) [10].

Based on Koukina and Lobus [10], these metals are not sufficient to induce a negative biological effect (or moderate impact is suspected) if their present values are <1. In contrast, adverse effects on biota are probable when the AEI values are higher than 1.

Toxic units (TUs) for metal content measured in sediment samples were calculated using Equation (3):

$$\text{TUs} = \text{C}/\text{PEL} \quad (3)$$

C is the metal content in the analyzed samples, while PEL is the probable effect level (As = 41.6; Cd = 4.21; Cr = 160; Cu = 108; Ni = 42.8; Pb = 112; Zn = 271).

According to Yan et al. [10], if ΣTUs < 4, this indicates low toxicity to an ecosystem. In contrast, if ΣTUs > 4, this means moderate toxicity to an ecosystem.

3. Results and Discussions

3.1. Potential Ecological Risks and Toxic Units

The present study evaluates the potential ecological risks of Cr, Cd, Pb, and As in coastal sediment cores collected from the Oualidia lagoon. These sediment cores were also dated using lead-210 in order to study the temporal variations in the studied metals [4].

The investigated metals' potential ecological risk (RI) values show moderate ecological risk in the first 21 cm and 15 cm of sediment cores CO-1 and CO-2, respectively (Figure 2). The increasing trend of RI values over time is almost correlated to the growth in human activities in Oualidia. The Oualidia lagoon has been known for its development of oyster culture since the 1950s, when the first oyster farming station was installed in the lagoon. Throughout the 1970s, human activities developed around the lagoon, mainly agricultural activities, which contributed to the lagoon's contamination by metals resulting from the excessive use of pesticides and fertilizers [2–4]. TUs calculated for heavy metals are higher for chromium, arsenic, nickel, and zinc. However, toxic unit values are lesser than 4, indicating low toxicity to the lagoon ecosystem (Figure 3).

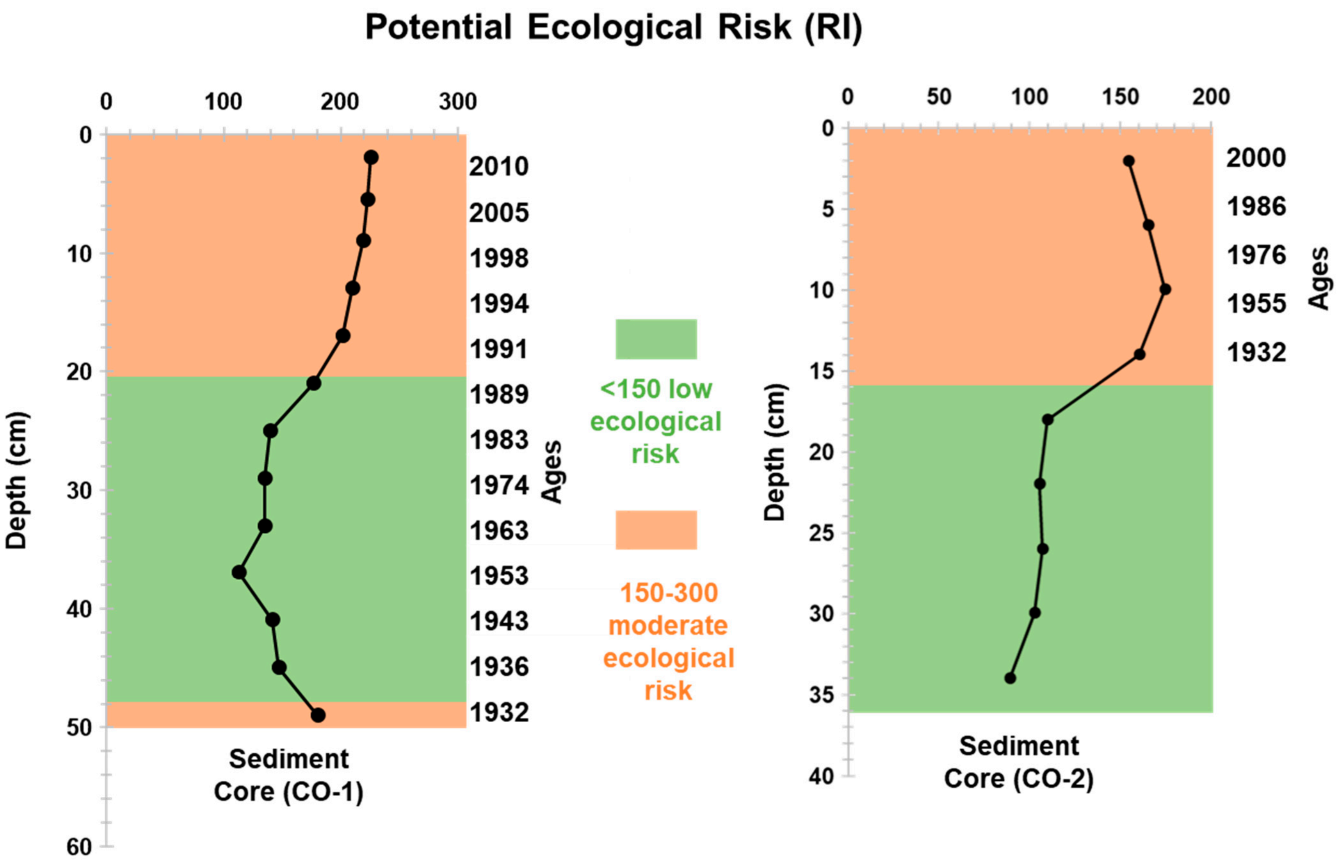

Figure 2. The potential ecological risk calculated for the total analyzed heavy metals.

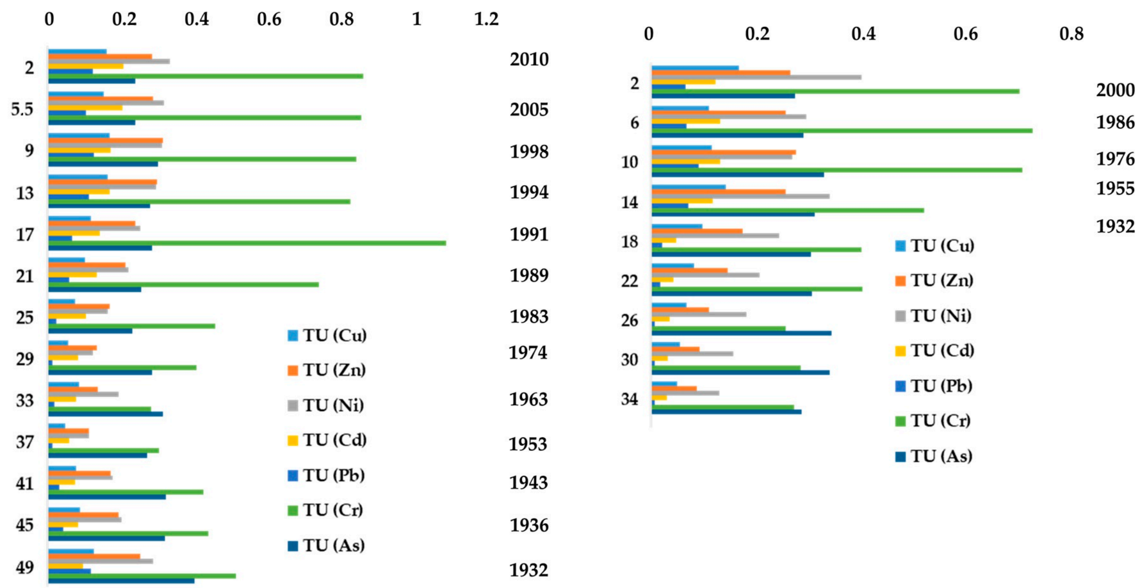

Figure 3. Toxic units (TUs) calculated for the total analyzed heavy metals.

3.2. Adverse Effect Index (AEI)

Adverse Effect Index (AEI) values indicate a probable effect on biota due to the concentrations of Cr, As, and Cd, mainly in the surface layers (Table 1). The vertical distribution of AEI values reflects changes in factors contributing to the accumulation of heavy metals, and there are new sources feeding the lagoon with pollutants, which is in good accordance with the previous results reported by Zourarah et al. [11], Maanan et al. [2], and Mejjad et al. [4]. It is to be noted that, even if the other heavy metal concentrations are not sufficient to induce a negative biological effect, the continuous monitoring of heavy metal levels in the lagoon is required as AEI values are close to 1, mainly in surface layers.

Table 1. Adverse Effect Index (AEI) calculated for the total analyzed heavy metals.

(green) **< 1** not sufficient enough to induce a negative biological effect (or moderte impact is suspected).
(orange) **> 1** adverse effects on biota are probable.

CO-1

Depth	AEI (Cu)	AEI (Zn)	AEI (Ni)	AEI (Cd)	AEI (Pb)	AEI (Cr)	AEI (As)
2	0.16	0.62	0.90	1.29	0.46	2.65	1.38
5.5	0.16	0.63	0.86	1.27	0.39	2.63	1.38
9	0.17	0.69	0.84	1.08	0.48	2.59	1.75
13	0.16	0.66	0.80	1.05	0.43	2.54	1.61
17	0.12	0.53	0.68	0.89	0.25	3.34	1.65
21	0.10	0.47	0.60	0.84	0.23	2.28	1.48
25	0.08	0.37	0.45	0.66	0.09	1.41	1.33
29	0.06	0.29	0.34	0.51	0.06	1.25	1.65
33	0.09	0.30	0.52	0.48	0.07	0.87	1.81
37	0.05	0.25	0.31	0.37	0.05	0.93	1.56
41	0.08	0.38	0.48	0.47	0.12	1.31	1.87
45	0.09	0.42	0.54	0.52	0.16	1.35	1.85
49	0.13	0.55	0.78	0.60	0.45	1.58	2.32

CO-2

Depth	AEI (Cu)	AEI (Zn)	AEI (Ni)	AEI (Cd)	AEI (Pb)	AEI (Cr)	AEI (As)
2	0.17	0.58	1.08	0.76	0.24	2.15	1.58
6	0.11	0.56	0.80	0.82	0.25	2.22	1.67
10	0.12	0.60	0.72	0.81	0.33	2.16	1.89
14	0.14	0.56	0.91	0.73	0.27	1.59	1.79
18	0.10	0.38	0.66	0.30	0.08	1.23	1.75
22	0.08	0.32	0.56	0.26	0.07	1.23	1.76
26	0.07	0.24	0.49	0.22	0.03	0.78	1.98
30	0.05	0.20	0.42	0.19	0.02	0.87	1.96

4. Conclusions

The moderate potential ecological risks and AEI values of the sediments recorded in the surface layers suggest that the development of human activities in the last two decades has contributed to high metal concentrations in this ecosystem. Activities such as agriculture can be potential sources of Cd. Excessive use of fertilizers and pesticides may contribute to the increase in this heavy metal in the lagoon. This finding highlights the need for the careful monitoring and remediation of Cd and As levels in this aquatic system, as Cd and As present high ecological risk values among the selected heavy metals.

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