Study on uptake kinetics of Ba-133 and heavy metals (Co, Cr, Cd and Pb) in the Gibraltar Strait marine waters

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1.Introduction

Various anthropogenic sources contribute to enhance the levels of many radionuclides and metals in the marine environment.

Quantitative information on the adsorption/desorption of radionuclides and metals by suspended loads is important in the study of their environmental behaviour.

In this work, laboratory experiments were directed at studying the kinetic transfer of Cd, Cr, Co, Pb and Ra in marine aqueous suspensions. The samples were collected from the Strait of Gibraltar (North of Morocco).

The quantification of these transfer processes is carried out by determining the distribution coefficients; Kd; and the kinetic transfer coefficients, Kij. These are obtained by adopting the appropriate compartment model able to describe the observed behaviour (A. Laissaoui & al, 2008).

2. Objective

This work has several objectives:

- the study of uptake kinetic of metals: Cd, Cr, Co, Pb.
- the study of effect of direct and indirect spiking on the adsorption (with Cd).
- the study of uptake kinetic of Ra (using an environmental analog 133Ba-133).

3.Materiel and Method

- The experimental procedure followed consists of adding a known amount of the tracer in dissolved form to water samples. Aliquots were extracted at controlled time intervals. Solids were removed by centrifugation and the aqueous phases were analysed by appropriate equipments: Gamma spectrometer for Ba-133 and Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) for heavy metals (fig1).

-To highlight the effect of direct and indirect spiking on the adsorption, two experiments were carried out. In the first one (Experiment Cd1), the unfiltered seawater had direct spiking. While in the second one (experiment Cd2), the sea water followed all the preparation steps shown in the figure 2.

- In the case of Ba-133, two experiments were carried out. The experiment A was carried out only with natural sea water containing 7.8 ppm of suspended particle matter (SPM). The experiment B was performed by suspending (101.2 mg) of sediment in 1L of sea water.

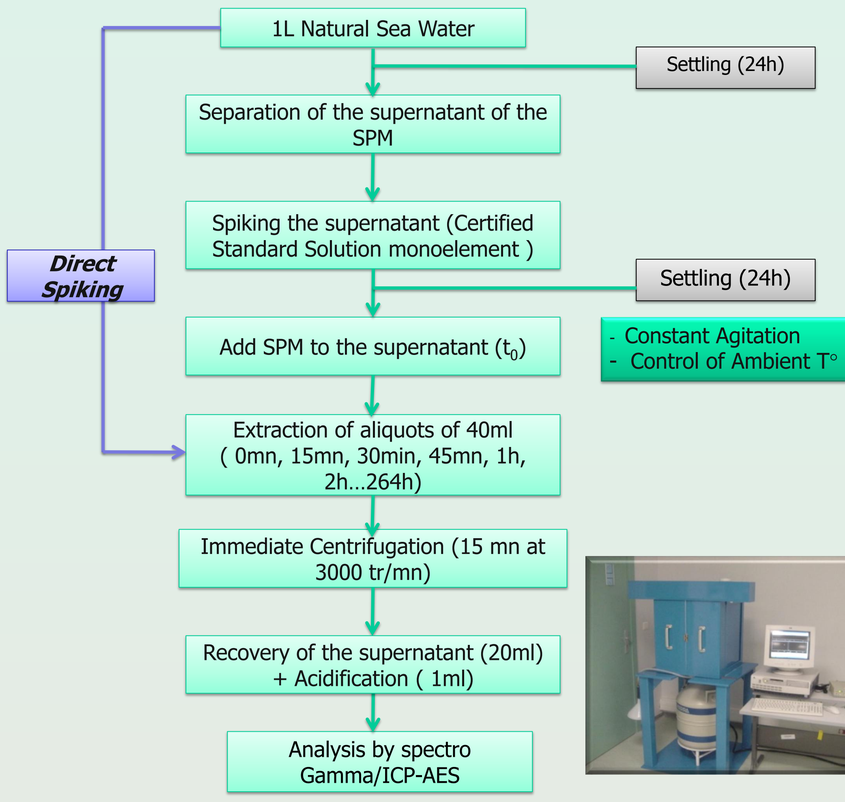


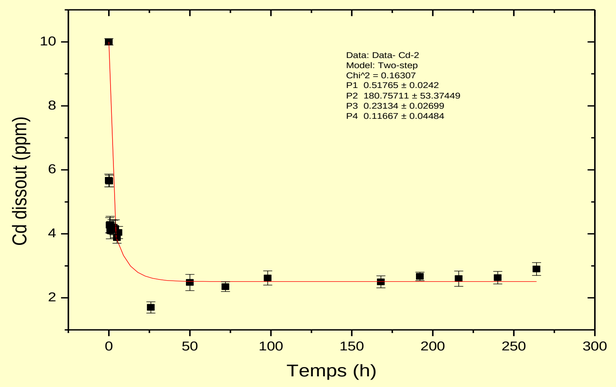
Fig.1: Flow program of the experimental sorption study

4. Results & Discussions

Experiments with Metals

Time evolutions of metal concentrations in the dissolved phases are shown in Figures 2 and 3. Adsorption of metals was described by a two consecutive and parallel reactions (CPR) having different characteristic times; a fast adsorption in the first moment followed by an extremely low reaction. By fitting the experimental data (points) to the theoretical function, kinetic transfer and distribution coefficients were obtained (Table 1).

Consecutive and Reversible Reactions Model



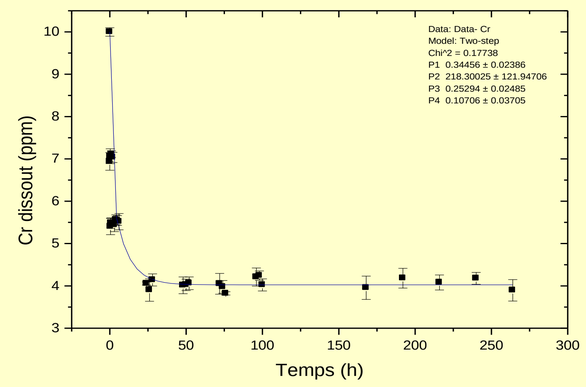
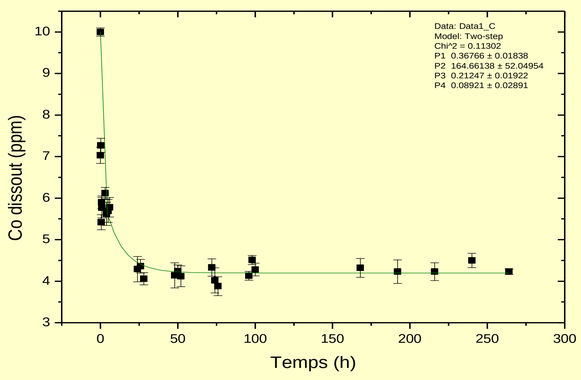


Fig. 2: Time evolutions of Cd and Cr concentrations in the dissolved phases. The lines are the best fits to the theoretical function.



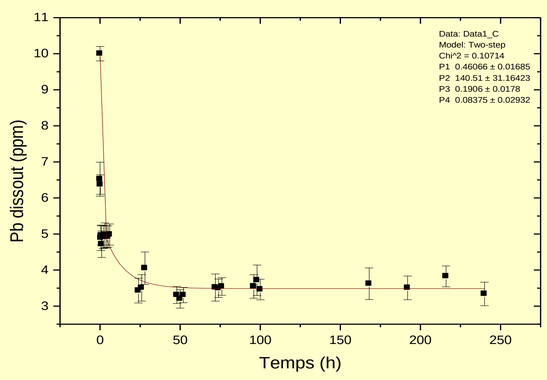


Fig. 3: Time evolutions of Co and Pb concentrations in the dissolved phases. The lines are the best fits to the theoretical function.

Effect of direct and indirect spiking

the adsorption of Cd by particulate matter is both rapid and significant in the case of experiment 2. This means that the Cd is relatively less available to the particles when complexed with ions from the seawater.

By fitting the experimental data (points) to the theoretical function, kinetic transfer and distribution coefficients were obtained (Table 1).

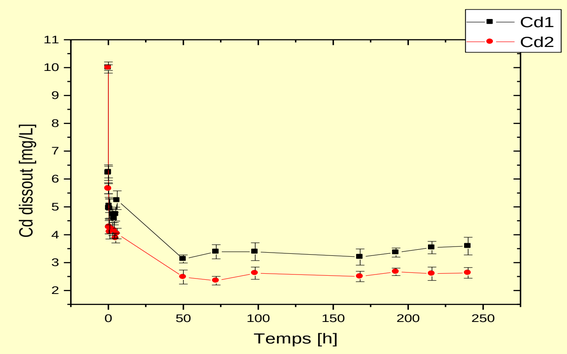


Fig.4: Time evolutions of Cd1 and Cd2 concentrations in the dissolved phases.

	Cd-1	Cd-2	Cr	Co	Pb
k_{11} (s-1)	79.6	93.5	75.2	60.5	64.7
k_{21} (s-1)	94.8	87.2	143.1	104.2	75.8
k_{12} (s-1)	0.0618	0.116	0.063	0.047	0.0549
k_{22} (s-1)	0.0525	0.061	0.065	0.059	0.0541
k_d (l/kg)	$2.56x10^5$	$3.66x10^5$	$1.87x10^5$	$1.75x10^5$	$2.39x10^5$

Table 1. Values of transfer coefficients for the studied metals obtained by processing the time evolutions of concentrations in the dissolved phases.

- The values of table 1 reflect the shapes of the curves in Figures 2, 3 and 4. The coefficients of adsorption, k11, are much higher by two to three orders of magnitude than the transfer coefficients, k12, indicating an excessively rapid adsorption followed by a reaction too slow.

- The desorption coefficients, k21, are as important as the k11, witch shows that metals are weakly bound to the charges distributed on the particle surface part.

Experiments with Ba-133

Adsorption experiments with Ba-133, used as an environmental analogue of Ra-226, in sea water were also conducted. Figure 5 displays the time evolutions of Ba-133 specific activities in the dissolved phases of two aqueous suspensions of different suspended matter concentration (SMC: 7.8 ppm and 101.2 ppm). In this case, the use of a two step model is a sub-parameterization of the observed phenomenon. Therefore, a higher model (three reactions with different characteristic times) should be used to appropriately describe the adsorption curves and to determine kinetic transfer and distribution coefficients.

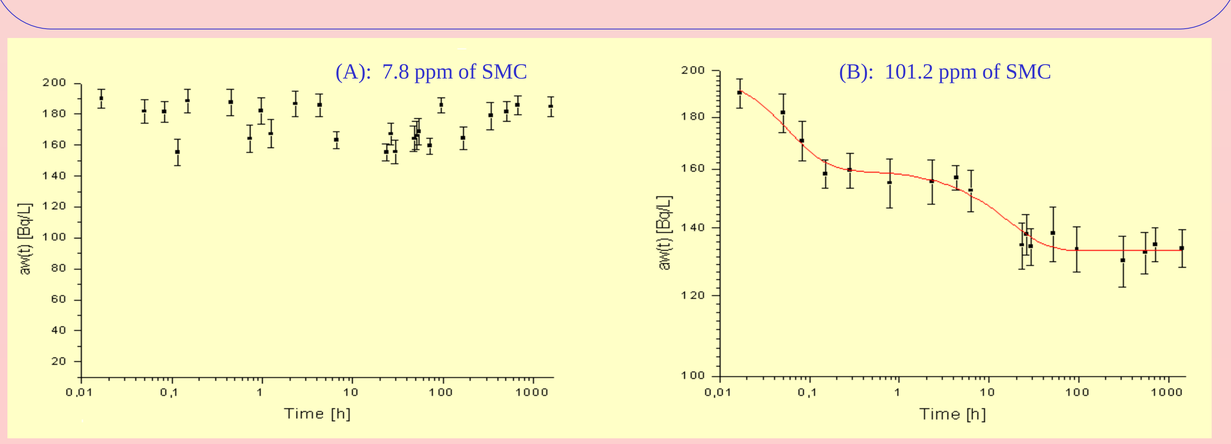


Fig.5: Time evolutions of Ba-133 concentrations in the dissolved phases from two different aqueous suspensions.

5. Conclusions

The experimental procedure followed to explain the environmental behaviour of, Cd, Co, Cr, Pb and Ba 133 , has been successfully developed.

Two steps Model of consecutive and reversible reactions is appropriate to describe the experimental results for all the studied heavy metals, showing the presence of two active sites on the particles.

In the case of Ba-133, the uptake by the SPM doesn't show any kinetic, while that by suspended sediments (101.2 mg) unambiguously shows three-step kinetics. This result underlines the important role of sediments in the dispersion process.

6. Acknowledgements

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7. Reference

- A. Laissaoui & R. El Mrabet. Trends in Modelling of Radionuclides Uptake by Particulate Matter in the Marine Environment Using Box Models Book: Environmental Modelling: New Research. Ed. Paul N. Findley. 101-117.