

MODELING THE TRANSPORT OF CHROMIUM AND FINE SEDIMENTS WITH A MESHLESS METHOD

* Alfredo E. Trento¹ and Ana M.T. Alvarez¹

¹ Universidad Nacional del Litoral, Santa Fe, Argentina
CC 217- Santa Fe 3000 - Argentina
atrento@fich.unl.edu.ar

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ABSTRACT

Point sources in water quality problems are difficult to represent in the so-called Eulerian methods, and the particle method represents a good alternative for solving this kind of transport problems. In this method the mass transport is a consequence of the aleatory movement of a great number of discrete particles. From the practical point of view, they are free from both oscillations and numerical diffusion [1], and also, from negative concentrations and mass loss. These properties are very significant when the contamination source produces a high environment concentration. A particle model, which represents transport processes of fine sediments and chromium in fluvial courses and their interactions with bed sediments, is presented here. The particle model implemented for this work is detailed in Trento [2]. Because of their high specific surface and capacity to adsorb other substances, fine sediments, limes and clays, from both the bottom and in suspension, are of extreme importance in the transport processes of chromium [3]. Several international environment organizations consider sediment contamination as a major risk in aquatic environments, because chromium remain in the medium as micropollutant of high toxicity.

The conceptual-model main hypothesis lies in the assumption that the transport processes of metals and sediments are relatively slow compared to the kinetics of metal sorption. Thus, the assumption of instantaneous equilibrium could be adopted [4]. A fundamental aspect considered was the depth of active bed layer d , or layer of interchange with the water column chromium.

Pioneer work regarding an exhaustive analysis of mathematical models for the transport and fate of toxic metals and sediments in surface courses was reported by Thomann and Mueller [5] and Chapra [6], among others. In rivers and streams, the problem of pollutant transport can be simplified as a 2D problem, as far as the time scale of the processes in the longitudinal and transversal flow directions are significantly higher than the time scale of the processes of vertical mixture. The number of differential equations in partial derivatives is three, one for the chromium total concentration in the water column, $C_{T,w}$, another for the amount of chromium adsorbed per mass of bed dry sediment, r , and the third one for suspended sediment concentration, S_w .

A simplified scenario is considered in the model. Chromium discharge was represented

by a vertical line source, which flows at a constant rate, located in the main fluvial course. The model was implemented for a rectangular domain 5200 m long, 80 m wide and 1.50 m deep, with axes x and y in the longitudinal and transversal directions, respectively. A unidirectional flow of $6 \text{ m}^3\text{s}^{-1}$, with a uniform velocity of $U = 0.05 \text{ ms}^{-1}$ and a Manning coefficient $n = 0.045$, were adopted. These steady flow conditions are similar to those observed during a marked low water level of the Salado river in November, 1999. Also, longitudinal and transversal coefficients of diffusion, of 0.059 and $0.010 \text{ m}^2\text{s}^{-1}$, were respectively set, differential advection not being considered since the flow was uniform. A vertical line source placed in the centre of the course ($y = 40$ m) and 400 m downstream of the entrance source was simulated, this source having a continuous flow of $0.080 \text{ m}^3\text{s}^{-1}$, with $S_w = 0.280 \text{ kgm}^{-3}$ and $C_{T,w} = 4570 \text{ mg}_C\text{m}^{-3}$. An initial amount of chromium adsorbed per mass of dry bed sediment, $r_0 = 10 \text{ mg}_C\text{kg}^{-1}$ was adopted. The partition coefficient parameter was calculated from Gallo et al. [7]. Active bed depth of 1, 3 and 5 cm were considered. Upstream boundary conditions for $C_{T,w}$ and S_w were considered and they were simulated with four vertical sources close to that boundary. The time interval, $\Delta t = 120$ s, and the number of particles entering every Δt was of 70 and 40 particles, for the source and the upstream conditions, respectively.

The time scale for $C_{T,w}$ was 2 days, independently from the active layer bed. In the case of bed chromium concentrations, about 5 days are needed for $d = 1$ cm, 15 days for $d = 3$ cm and 20 days for $d = 5$ cm. The concentrations S_w reached the equilibrium for a temporary scale similar to that set for the travel time, about 15 hours. For the conditions under study, the source, on total concentration of chromium in both the water column and sediment, has a local influence which is in the order of the model geometric scale. Initial conditions and the thickness of the active bed are relevant, mainly for computed chromium accumulation in bed.

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