THE FATES OF TRACE METALS AND PARTICULATES

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The concentrations of trace metals on effluent particulates are frequently one to two orders of magnitude higher than the concentrations associated with the natural sediments; hence, it is not surprising that the sediments around the Whites Point outfalls have enhanced metals levels. An examination of the trace metal distributions within this area, however, raised some questions regarding the processes affecting trace metals in a marine environment. Why, for example, did it appear that only about 10 percent of the discharged metals were retained in the nearby sediments even though about 90 percent of these metals are associated with effluent particulates? Moreover, why were the concentrations of some trace metals, such as zinc or chromium, in the sediments close to the diffuser less than the concentrations on the effluent particulates, while the concentration of cadmium in these sediments was comparable, or perhaps even higher, than on the effluent particulates.

In the past year, we initiated several experimental and theoretical studies to answer some of these questions. The experimental studies are described in the following article; here, we discuss a simulation model developed by the Project to determine if various hypothetical processes or chemical reactions could account for the observed properties of the sediments. A complete description of the original version of this model has been published by the Project as Technical Memorandum 208, and an updated and refined version will be submitted for publication in a scientific journal. Only a brief description will be given here.

The simulation consists of two parts first, a model that estimates the deposition rates of effluent particulates in the outfall area, and second, a model of hypothetical chemical processes that may alter the concentrations of the trace metals on the particulates.

To estimate the rates and distribution of sedimentation in the Whites Point area, the deposition model uses a set of current measurements made in the Whites Point outfall area during the period 1960 to 1964 and a distribution of settling velocities determined for digested sludge from the Hyperion Treatment Plant. We were somewhat surprised to find that the rates predicted by the model were comparable with those inferred from the vertical profiles of the trace metal concentrations in these sediments because we expected the settling velocities for Whites Point effluent (which were unavailable at the time) to be significantly lower than those for digested sludge. Subsequent work by people outside of the Project has confirmed this expectation; hence there is some substantial question about the validity of laboratory simulations of effluent particulate settling in the marine environment.

The model predicts that the sedimentation rate of effluent particulates at a distance of about 3 km from the outfall is about 10 to 15 times the natural rate (a similar value can be obtained from the metals profiles) and that approximately 20 to 50 percent of the discharged particulates will settle within 10 km of the outfall.

As we noted earlier, the concentrations of some trace metals in the sediments near the outfall can be essentially the same as those on the effluent particulates; for other metals, sediment concentrations can be significantly less than effluent values. Since physical mixing of the effluent particulates with natural particulates (during sedimentation, or by burrowing benthic biota) should produce the same dilution for each trace metal, this difference suggested that other processes must also be occurring. We felt that one of the most likely candidates was mobilization (release) of the metals from the particulates into the water. This mobilization could take place in the water column and in the sediments. Earlier data, combined with the recent experimental work on mobilization described in the following article, indicated that water column mobilization alone would not produce the observed differences in the trace metal concentrations; hence, we decided to see if mobilization in the sediments could account for these differences.

In contrast to the water column, which is an aerobic environment, the bottom sediments may be either aerobic or anaerobic, depending on the oxygen demand of the decaying sediments and the ability of the water near the sediments to supply this demand. It was found that the observed trace metal distributions could be reproduced by the simulation model (a combination of the sedimentation and chemical models) if an anaerobic region of sediments extended out about 3 kilometers from the outfall (see Figure 1).

We wished to determine if an anaerobic sediment region does in fact exist, since this would give some evidence of the validity of the model. Unfortunately, such a measurement is difficult to make since the layers of sediments could be quite thin. Some direct measurements may be possible in a planned study of the properties of the interstitial water in the sediments, but for the time being, we had to rely on rather subjective observations.

The first of these involved the appearance and odor of the sediments, and gave encouraging results (see Figure 2). In a second comparison, we looked for the changes that may occur in benthic invertebrate communities as the sediments become anaerobic. A cluster analysis (described in Part I) was used to group sites in the outfall area, combining similar sites until essentially only two groups remained in the area at a depth comparable to that of the outfall. It was gratifying to discover that the boundary between these two site groups (Figure 3) coincided quite well with the predicted boundary of the region of anaerobic sediments.

In view of these encouraging results, we feel that it may be possible to develop a predictive model of the fates of trace metals and particulates in outfall areas. At the same time, we recognize that a number of potentially important processes have not been incorporated in the model, or have been included in a very approximate manner. We have been improving some of the theoretical aspects of the model and will use the improved model with new experimental data (such as the recent current measurements described later in Part III). Even in its present stage of development, however, the model has been useful in identifying areas where sufficient information is lacking, and in demonstrating the potential importance of various processes and their relationship to changes in the marine environment.

FIGURES

Figure 1.
Predicted concentrations of lead and cadmium as a function of the enhanced deposition factors

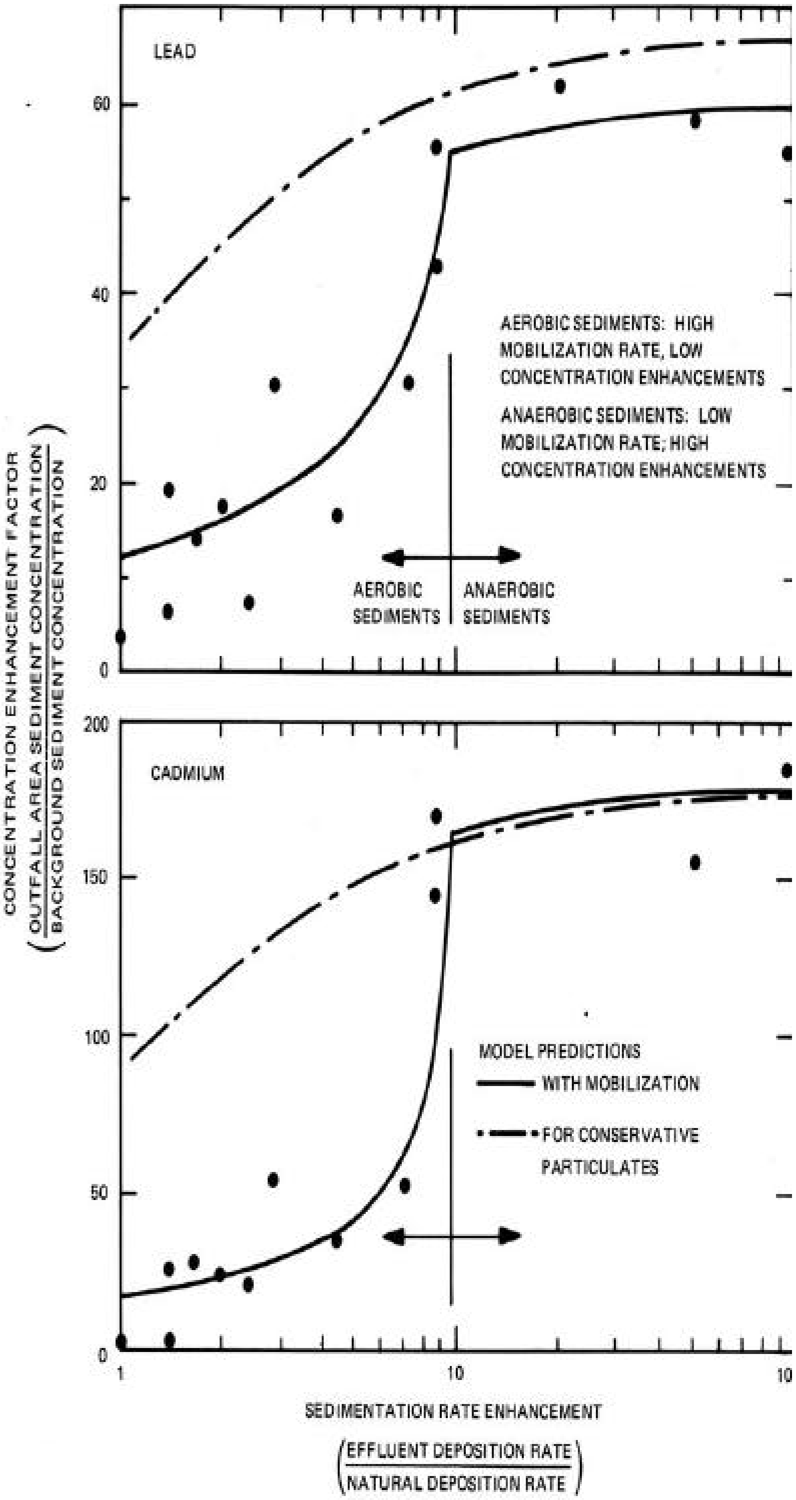

Figure 2.
Comparison of areas observed to have heavy sulfide odor or a highly organic substrate with the model predicted limits of the anaerobic sediments

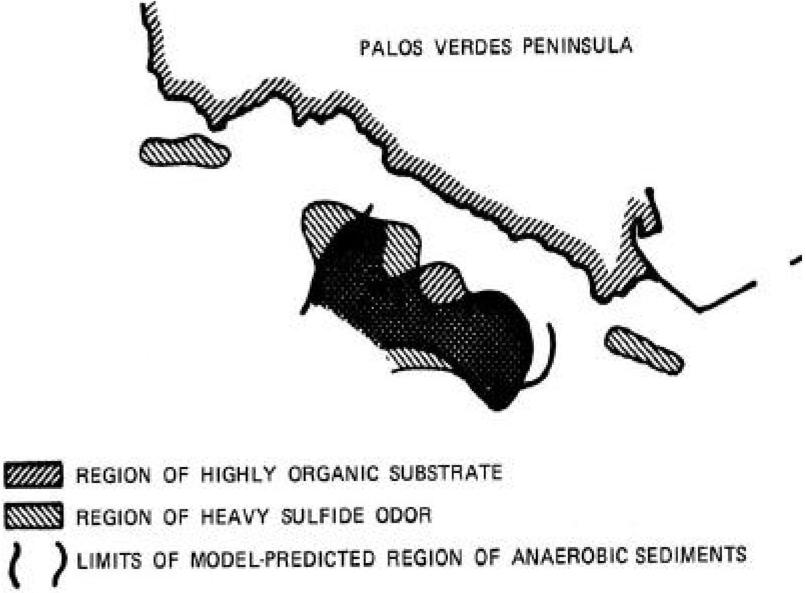

Figure 3.
Comparison of benthic invertebrate site groups with predicted limits of anaerobic sediments