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A MODEL OF THE DISPERSION OF WASTEWATER CONSTITUENTS

In the past, we have developed several simulation models to assist in understanding processes in the marine environment and to estimate how changes in treatment and disposal methods may be reflected by changes in this environment. A basic shortcoming in each of these models is the inadequate information available regarding the properties of ocean cur-rents in the study area. As a result of our recent current measurements (described in the previous article), we now have a better, although still incomplete, understanding of water flow past the outfall pipes, and we have attempted to use this new information to develop an improved model of dispersion.

The principal change in the model is the attempt to incorporate information on the persistence, or duration, of the currents to flow in one direction. To illustrate the importance of this aspect, consider the following hypothetical example: Assume that the only currents present in an out-fall area have a maximum velocity of 7 cm/sec and are due to a semidiurnal tide of a 12-hour period. Furthermore, assume that particulates discharged from this outfall require 12 hours to settle to the bottom. It can then be shown that, in the absence of eddy diffusion, the maximum distance a particle will move away from the outfall will be about 1 km.

Compare this distance with the predictions of commonly used models that do not consider persistence. One such model assumes the average distance traveled will be given by the average speed. In this case, the particles will settle at a distance of slightly less than 2 km from the outfall. Another model, which uses the average velocity and the variance of the velocities about this average, predicts that more than 80 percent of the particulates will settle outside the l~km boundary. Laboratory simulations of particulate settling, using 1973 Whites Point effluent (Myers 1974), indicate that most particles will take longer than 24 hours to settle: Hence, the discrepancy between model predictions and the real situation becomes even greater. Furthermore, as the settling times lengthen, the persistence of the currents that flow in one direction for times greater than 6.2 hours (or periodicities greater than 12 hours) becomes increasingly important.

Our new approach to this problem assumes that the along-shore component of the water movement in the outfall area can be adequately approximated by the alongshore component of a progressive vector diagram, or PVD. The latter is created by representing each velocity measurement by an arrow; the length of the arrow is proportional to the speed, and its orientation is determined by the direction of flow. These arrows are then joined end to end sequentially.

A continuous discharge from an outfall can be approximated by a sequence of individual discharges, or "patches," each with an alongshore position given by the PVD hypothesis. If the spread of each of these patches as the result of eddy diffusion is then estimated, the distributions from each patch can be combined into a single distribution approximating that produced by the continuous release. In many cases, however, the distribution observed in the field may actually represent the average of many such distributions produced over a long period of time. The buildup of sediments represents one such case. The average distribution could, in principle, be obtained from a very long sequence, or series of sequences, of current measurements using the model just outlined. We have attempted to see if a reasonable approximation can be made using a much more limited current measurement program and much less tedious and expensive computations.

To do this, it is necessary to make some assumptions about the general properties of the currents. We have assumed that the amplitudes of the components of the cur-rents (distinguished by differing persistences or periodicities) are representative of "typical" currents in the area, and furthermore, that the current components with different periodicities are unrelated to one another. Using these assumptions, it is possible to generate a collection (or ensemble) of potential PVD's; from this ensemble, we can calculate the conditional probability, $P(x|t)$ (i.e., the probability that a particle discharged at an earlier time, t, is now at a given position, x). This probability distribution function can then be used to estimate the dispersion of constituents with properties that change with time, such as bacteria (which die) or particulates (which settle).

To test this model, we used current measurements made in the Whites Point outfall area, combined with particulate settling velocity data for that effluent (Myers 1974). The results—a prediction of longitudinal (alongshore) distribution of sediments in that area—are shown by the solid line in Figure 1. It should be noted that since the onshore/offshore dispersion has not been included, the organic carbon buildup indicated in the figure is the amount contained in 1-cm wide strips that extend from the coast to a distance well offshore, rather than the amount contained in 1 sq cm of sediment area. For comparison, the values estimated from the actual field measurements of Myers (1974) are shown by the dots on Figure 1. The agreement is certainly encouraging. Note that because some of the released organic material decays, only a portion of the deposited material will remain. We have assumed that this remaining fraction is 53 percent of the deposited material.

From these results, it is estimated that approximately 10 to 12 percent of the discharged solids are deposited within the area bounded by onshore/offshore lines 12 km to the northwest and 4.5 km to the southeast of the outfall, and that approximately 5 to 6 percent of the released organic material remains within these boundaries after decay.

At the present time, we cannot confidently estimate the distribution of materials in the onshore/offshore direction. The results of a limited series of drogue measurements, and the distribution of actual sediments, suggest that lateral dispersion is less than would be predicted by current meter measurements or "typical" estimates of eddy diffusion rates. Additional studies that will provide further information are currently being conducted.

In spite of this present limitation, we hoped to predict the properties of the sediments and their buildup given estimates of onshore/offshore distributions. The ability to predict the fraction of organic material in the sediments is particularly important as field studies of the properties of outfall sediments indicated that the concentrations of many trace metals are correlated with this parameter. To do this, we adopted the mass balance approach, which considers the input of organic and inorganic material from both natural and effluent-related sources. Both the fraction of organic material and the buildup of organic material are parametrically related to the ratio of effluent and natural sedimentation rates, and hence to each other. It was found that the observed relationship between the organic fraction and the buildup of organic material could not be reproduced by the model unless significant agglomeration between natural and effluent particulates takes place, and that the accumulation rate of natural sediments is increased by the presence of outfall-related sediments (see Figure 2).

In summary, our revised dispersion model is able to adequately reproduce the observed alongshore distribution of outfall-related sediments. In addition, an observed relationship between the buildup of organic carbon in the sediments and the percent organic material in the surface sediments can be obtained from a mass balance calculation, but only if agglomeration between natural and effluent-related particulates takes place, and/or the rates of accumulation of natural sediments have changed from their historical values. At the present time, however, we are not able to adequately predict the offshore/onshore distributions of materials. If studies that are currently being conducted to develop this capability are successful, we will have a model that can significantly assist us in many areas, such as in choosing "control station" locations, predicting the distribution and properties of the sediments and associated trace metals, and estimating the "average" distributions of bacteria and other effluent constituents.

REFERENCE

Myers, E.P. 1974. The concentration and isotopic composition of carbon in marine sediments affected by a sewage discharge, Ph.D. dissertation, California Institute of Technology.

Figure 1. Buildup of organic carbon along 1-cm onshore/offshore transects near the Whites Point outfall system.

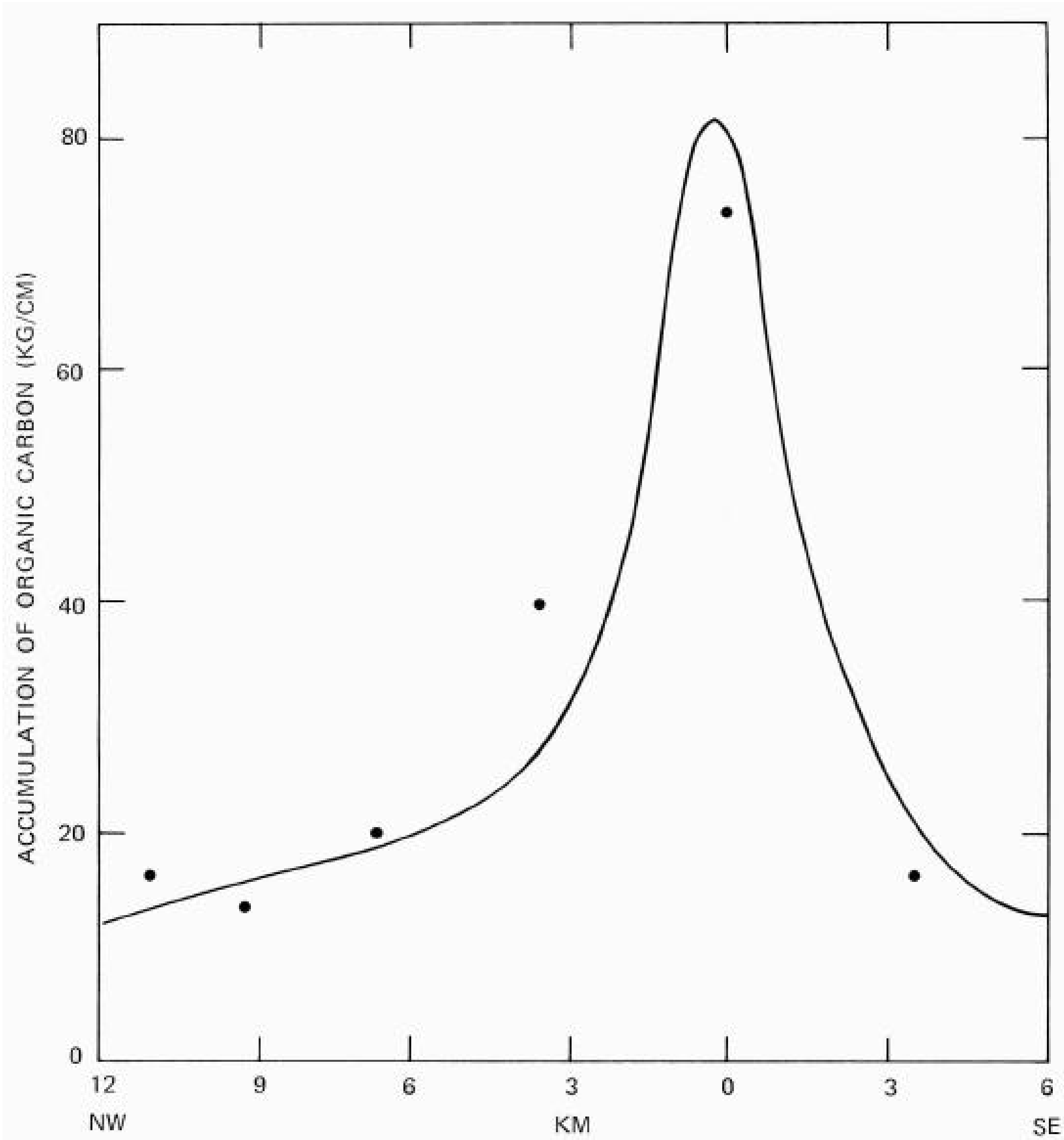

Figure 2. Organic carbon content of the surface sediments as a function of the accumulated organic carbon. Dot-dash line is predicted value with no agglomeration or enhanced natural sedimentation. Solid line is the predicted value with an agglomeration of 1.4 units of natural inorganic material with every unit of effluent related inorganic material, and a natural sedimentation rate enhancement ration of 7.4X. Dashed line represents the field measurements of Myers (1974).