Sediments and Water Interactions

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Preface

The first symposium on sediment/freshwater interactions was held in Amsterdam, in 1976, and the second was held at Kingston, Ontario, Canada, in 1981. The third symposium was held at the University of Geneva, in 1984, and also included a number of contributions dealing with sediment/saltwater interactions. It is expected that future symposia of this series will retain this approach, and that the revised symposium title will remain the same for later proceedings of these meetings.

Because of the large number of submissions in 1984, many were given as poster presentations. Extended abstracts of all contributions to the Geneva symposium appear in *Interactions Between Sediments and Water* (C.E.P. Consultants Ltd., 26 Albany St., Edinburgh, EH1 3QH, U.K., 1984). Full-length papers appear only in the proceedings. The format of the third symposium was similar to its predecessors. The location provided a particularly good opportunity for attendance by European scientists, who represented about 81% of the participants. About 16% came from North America and 3% were from Southeast Asia and Australia. It is unfortunate that there were no contributors from either Africa or South America, or other parts of Asia. In all, 16 countries were represented at this symposium. In a continuing attempt to provide equal opportunities for attendance by scientists from other parts of the world, it is planned to hold the next symposium in Australia in 1987. Further information about the symposia series can be obtained from Dr. E. D. Ongley (Secretary/Treasurer, International Association for Sediment Water Science [IASWS], Environment Canada, National Water Research Institute, CCIW, P.O. Box 5050, Burlington, Ontario, Canada, L7R 4A6).

In both previous proceedings (Golterman et al., 1977; Sly, 1982), the introductory section has been used to summarize the content of contributions and to highlight scientific advances and the significance of particular contributions. Similar comments are provided, again, in these proceedings.

Although not all of the symposium contributions are included in this publication, it is generally representative of the content of the meeting. The presentations clearly show that interest remains firmly rooted in the mechanisms that control nutrient cycling and the distribution, speciation, and availability of heavy metals. It is also clear, however, that little of the current work relating to the role of organic contaminants is represented. This may reflect the pressure of applied research, which directs attention to toxic substances as a discrete topic, rather than to the processes at the sediment-water interface with which contaminants interact. It is particularly unfortunate that the separation of these related interests continues. There is much to be gained from a closer integration of research presentations describing the effects of environmental processes on both natural and man-made contaminants at this interface. In the following sections, the chapter numbers are those contributions, as listed in the Contents.

Sediment Dynamics, Transport and Deposition, and Distribution

Contributions in this section characterize several different case studies in which interest is strongly focused on relationships between texture and geochemistry. Chapter 1 emphasizes the importance of seasonal water level cycles as a means of incorporating organic loads in tropical "blackwater" rivers. The authors of Chapter 2 use statistical techniques to establish sediment provenance, and to characterize the influence of cultural impacts in the Tyrrhenian Sea. The rapid drop in bacterial counts, away from shore, is clearly evident. Chapter 3 demonstrates that high levels of U in the upper Rhône River and Lake Geneva are related to the natural occurrence of U in the watershed. The author of Chapter 4 describes an approach to improving coastal zone planning by means of a new classification of coastal types derived from sediment type, hydrodynamic data, and morphometric data. It is hoped to use this information to provide an early indication of possible problems associated with watershed, shoreline, and near-shore development proposals. In Chapter 5, the authors demonstrate, again, the significance of stratification and anoxia as a primary control on seasonal P release from bottom sediments. Chapter 6 uses hydraulic criteria as the basis for predicting the behavior of contaminated fine sediments in rivers.

While these contributions cover a very wide spectrum of sediment studies, the Swedish Coastal Zone Project is particularly thought provoking and should stimulate the use of empiric studies in the near-shore zone, where data for deterministic studies are dominated by a lack of temporal and spatial consistency.

Land Use and Loadings Regulation Effects

The authors of Chapter 7 provide a good example of the importance of wetlands as a means of decreasing high flow conditions and reducing downstream sediment loads. Chapter 8 provides a particularly interesting assessment of the effects of large-scale P regulation in Ontario. Concentrations of P in stream tributaries to the Great Lakes have greatly reduced since regulation. Unexpectedly, however, the decrease has been noticeable in streams which are characteristic of both point source loadings and diffuse source loadings. The authors of Chapter 9 report on a rural watershed of Lake Geneva that is dominated by agricultural inputs. Weekly cycles in the concentration of soluble P are related to domestic use of detergents. The highest total P levels occur when storm events flush out particulate P that has accumulated during prolonged storage periods.

Contaminant Accumulation, Mineralogy, and Speciation

In Chapter 10, the authors note the importance of organic matter, water content, and sedimentation rates as factors influencing associations and diagenesis of mobile heavy metals. Off the coast of Aquitaine, Cu, Pb, and Zn are culturally enriched in the surface sediments. The study by the authors of Chapter 11 shows that although redistribution of materials may obscure the origin of point source loadings, good correlations can be retained between quantifications that characterize both point and diffuse source inputs in lakes. Chapter 12 shows that differences in interstitial ion concentrations (Ca, Fe, Mn, and P) reflect differences in P retention in sediment cores; P release could be predicted under different environmental conditions. The authors of Chapter 13 used P fractionation to demonstrate the significant differences between sediments of eutrophic, oligotrophic, acidified, and limed lakes. Speciation of P, in interstitial waters of sediment cores from Lake Geneva, is reported in Chapter 16. These authors show that orthophosphate was dominant in the upper sediments, but that more condensed forms of P occurred at depth. Chapters 14 and 15 describe the extent of heavy metal contamination in selected Italian lakes and, in particular, the historical record of pollution in Lake Orta.

The P-related studies demonstrate clear geochemical differences in the sediments from various lake types and the likelihood of predicting P release. This is also explored in later contributions to these proceedings. The heavy metal-related studies add further attention to the widespread nature of environmental contamination and point to the possibility of ranking concerns associated with these materials.

Modelling

Although modelling is a part of many contributions in these proceedings, it is the principal focus of contributions included in this section. The authors of Chapter 17 show that sorption kinetics largely control the rate of radionuclide removal from the water column to particulates. They point to the significance of this in near-shore marine ecosystems, where particle residence times are shorter than sorption reaction times. This point also underlies Chapters 19 and 20, which address radionuclide transport between water and sediments in lakes and the calculation of dose commitment. Chapters 21–23 describe an oxygen model, the output of which has been compared with a laboratory study and field data from Hamilton Harbour. The model uses biofilm concepts to describe sediment-water fluxes. It considers: (1) diffusion between layers, nitrification, and organic carbon oxidation in the aerobic zone; (2) nitrate consumption and ammonia production in the anoxic zone; and (3) organic carbon methane and carbon dioxide production in the anaerobic zone. The causes of disparity between predicted and measured values are discussed. The CHARON-BLOOM II model, presented in Chapter 18, couples a chemical model (which calculates composition of a natural aquatic system as a result of chemical and biochemical processes and loadings) and a phytoplankton model. It is applied to predict the response of Lake Heenvliet to sludge disposal. The model addresses nutrient, heavy metal and organic contaminants, and other water quality parameters. The SED-MOD model is described in Chapter 24, and is designed to predict nutrient fluxes across the sediment-water interface. It is based on four sediment layer components. Initial comparisons of measured and predicted interstitial water profiles show that this approach has considerable promise.

The advance in modelling, during recent years, is very substantial. Although many of the models described in these proceedings are still under development, it is clear that several are rapidly approaching the point of more general application. More specific field and laboratory data, however, are required to improve spatial and temporal resolutions, and to explain the departures between predicted and measured values in model hypotheses. The linking of submodels, which address separate components, offers valuable flexibility in structuring later variants for application either to different types of aquatic environments or to partially related systems.

Material Cycling

In Chapter 25, the authors demonstrate that the diffusive loss of gases represents a major pathway for the export of sediment C and N, and that methane and dissolved organic carbon are positively correlated in Lake Erie. This relationship does not hold in Hamilton Harbour, due probably to different forms of organic substrate. The authors of Chapter 27 developed a sediment C budget for an area of the southwest Baltic Sea, but could not accurately assess fluxes for the shallow macrophyte zone. Horizontal transport to deeper water was assumed. In Chapter 34, bioavailable P in lake sediments was assessed by using derivative spectroscopy to measure algal growth. Available P was highly correlated with orthophosphate in interstitial and overlying waters; uptake increased with pH. Phosphorus associated with organic matter was least available. Laboratory studies in Chapter 33 show a good correlation between nitrate concentrations and the rate of transfer from particulate to soluble forms of P. This is thought to indicate the influence of nitrate-reducing bacteria that utilize Fe as an electron acceptor after exhaustion of nitrate; this causes both Fe and P to dissolve. In Chapter 39, the sorption effects on P supply to Cayuga Lake were studied. The amount of soluble-reactive P adsorbed was found to be related largely to the input of particulates. Thus, following storm events when turbid streamwaters covered much of the lake, more than 20% of the total P was removed from the entire water column. Studies in Lake Balaton, described in Chapter 37, indicate that lime precipitation and plankton settlement provide the most important fluxes of P to the sediment. Because there is such a low return flux to the water, eutrophication is not likely to be controlled unless the input of P to the lake is much reduced. Experiments on the interactions of Fe and humic acid during the formation of colloidal P, reported in Chapter 40, suggest that increasing amounts of humic acid decrease the polynuclear nature of colloidal Fe and, coincidently, change the number of sites for the adsorption of P.

In Chapter 32, the authors describe ion exchange experiments on clay minerals. Kaolinite, illite, and montmorillonite were exposed to solutions of Cd, Mn, Ni, and Zn. The results further define the different modes by which these trace metals can be incorporated into fine-grain sediments. The authors of Chapter 28 studied the influence of quartz and flint on dissolved Si in chalk rivers and groundwater. Quartz can influence the characteristics of slow-moving groundwater, but unlike flint, it had little effect on the quality of surface water flow at the test site.

Chapter 29 describes a comparative study of natural and man-made estuarine marshes. The most significant mobilization of elements occurred during and immediately after dredging and fill. Manganese and Ca, however, were depleted at depth in the natural marsh, but not in the man-made marsh. The behavior of heavy metals entering the Rhône River delta is described in Chapter 30. Only about half of the input is retained near the rivermouth; soluble forms are transported offshore. Cadmium and Cu are best retained as sulfides and carbonates in reduced sediments; Fe and Mn are best retained as oxides/hydroxides in oxic sediments. Lead and Zn are held as coprecipitates with Fe/Mn. Sequential extraction techniques, in Chapter 31, are used to demonstrate that land disposal of dredged material (from Hamburg and Rotterdam harbors and the Neckar River) presents particular problems of heavy metal mobility and bioavailability under the influence of reduced pH and changing redox conditions; riverine disposal is also influenced by the formation of organic complexes. The effect of salinity is particularly significant on Cd-rich fine sediments disposed of in the marine environment. A study on urban snowmelt runoff, in Chapter 35, shows that Cd, Cu, Pb, and Zn exceed threshold toxicity levels, and that metal speciation is related to surface area adsorption and ionic strength. Bioavailable Cu and Zn are strongly associated with particulate organic carbon, and bioavailable Cd and Pb are related to dissolved chloride levels. In Chapter 26, the authors use bioassay techniques to show that heavy metals uptake by algae from suspended matter is related to the adsorbed/exchangeable phase, and not to bulk sediment geochemistry. In marine algae, the relationships were found to be modified by the salinity levels. The use of algal fractionation bioassays, as a means of assessing simulated dredging experiments, is presented in Chapter 36. The immediate impact of sediment mixing caused a drastic reduction of ^{14}C assimilation and electron transport activity. Subsequent mixing had comparatively less inhibitory effect. Production per biomass quotients were based on the use of constant light intensity in this study.

Chapter 38 presents an overview of the use of radionuclides as tracers of sedimentary processes and biological/geochemical cycles in lakes and oceans. The author advocates the use of multiple tracers, with different decay times in the field, to be complemented by the use of tracers having different chemical properties in experimental systems.

Although many of the contributions in this section are most properly considered to be case histories, they significantly expand the basis for our understanding of materials cycling. Their value is enhanced where the data can be incorporated into the evaluation of systems modelling, and where innovative thinking has been applied. It is particularly interesting to note that techniques using bioassay as a means of assessing the impact of sediment contamination are reaching a point where they can be evaluated both at a theoretical and practical level. However, they are not yet at the stage where they can be incorporated into test protocols.

Manipulation and Disposal Techniques

Chapter 41 is unusual in the context of a scientific proceeding. The author describes a very large-scale research program, designed to evaluate dredged material disposal in both aquatic and subaerial environments. Because the data derived from this work will be of very wide interest to all research on sediment-water interactions, this presentation is included to provide a unique source of information. The contribution refers to both the data that is/will be available and to the study activities.

Sedimentation Rates, Fluxes, and Dating

In Chapter 42, the authors describe studies on the net loss of particulate P from the hypolimnion to the sediments of Lake Zug. The mean sinking velocity is used instead of net P sedimentation. This was derived by comparing particle flux (sedimentation trap measurements) with the particle concentration in the water column (above the traps). The authors of Chapter 43 tested the hypothesis that ^{210}Pb can be used to establish sediment chronologies in acidified lakes. By comparing lakes in acidified and nonacidified areas, whole lake ^{210}Pb fluxes were found to be much lower in the acidified lakes. The authors suggest that acidification leads to less retention of both stable Pb and ^{210}Pb. In Chapter 44, the authors describe a study to quantify ^{210}Pb sources to Lake Kinneret and its residence time in lake waters. ^{210}Pb is also used to trace the flux and spatial distribution of allochthonous sediments.

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