Editorials

New and Recent Developments in Soil and Sediment Management, Policy and Science

Do We Need a Journal of Soils AND Sediments?

Sabine E Apitz[1,2]*

[1] SEA Environmental Decisions, Ltd, 1 South Cottage, The Ford, Little Hadham, Hertfordshire, SG11 2AT, UK
[2] Institute of Water & Environment, Cranfield University, Silsoe, Bedfordshire, MK45 4DT, UK

* To whom correspondence should be addressed: dresea@cvrl.org; +44 (0)1279 771890

DOI: http://dx.doi.org/10.1065/jss2005.08.001

Introduction

As the reader of this editorial will know, the title of this journal is the 'Journal of Soils ***and*** Sediments'. However, whilst for reasons discussed below, a journal addressing these topics together is logical and necessary, a review of the literature, conference proceedings and academic department affiliations of soil and sediment scientists and managers reveals that there is much less collaboration between these fields than their close relationship might warrant.

Soil can be defined as "…the top layer of the earth's crust. It is formed by mineral particles, organic matter, water, air and living organisms. Soil is an extremely complex, variable and living medium" (http://europa.eu.int/comm/environment/soil/). Sediment, on the other hand, has been defined by SedNet as "suspended or deposited solids, acting as a main component of a matrix which has been or is susceptible to being transported by water" (Brils 2003). The first thing one notices when comparing these definitions is that the above definition of soil does not specifically exclude sediments. A further examination of the SedNet sediment definition reveals that all soils, during the weathering and transport process, have been sediments, and also suggests that they will be sediments again during their lifetime. Clearly, both soils and sediments often have a common origin – the weathering products of rocks and organic material. Generally, if they are deposited (or formed) in a terrestrial setting, they are considered soils, while if deposited in an aquatic setting they are considered sediments. The greatest distinguishing factors are water and time. Although these differences will result in different biogeochemical, ecological and other behavior in soils vs sediments, in many cases, the distinction between these two materials will be subtle, transitory and, arguably, unnecessary.

1 The Development of Soil and Sediment Science

Why, then, do we have two separate groups of scientists addressing such similar materials? It can be argued that the difference is entirely a social reality, and not a matter of methods or physical and chemical facts. Soil science developed in support of agricultural chemistry, when people started to look at soil as a production medium for biomass in agriculture and forestry. Thus, the field of soil science evolved for and was funded by organisations that were interested in enhancing and protecting agricultural production. Soil science departments, journals and conferences were thus closely linked with their agricultural audience. Sediment science and management has, on the other hand, evolved in support of entirely separate goals – closely linked with hydrology, navigation, stratigraphic and geological studies, linked to the enhancement, management and understanding of aquatic systems. Thus, sediment scientists and managers were in institutions or departments with little direct involvement with agriculture. Many analytical and modelling methods have transferred from one field to the other. In other cases, however, the separation of departments, meetings and journals have resulted in practitioners in both fields having to 'reinvent the wheel' as they addressed similar issues at different times, sometimes benefiting from scientists who crossed the divide or worked at the interface, but at other times completely unaware of similar work.

2 Similarities and Differences

As urbanisation and industrialisation resulted in the release of contaminants into the environment, both soil and sediment science evolved to assess and manage the impact of these releases on the ecosystem. In terms of the management of contaminated soils and sediments, there are many commonalities, as they behave similarly: both are accumulators (and long-term donators) of persistent pollutants such as heavy metals and lipophilic organic compounds. In both, the speciation chemistry and the biogeochemistry are of key importance to the behaviour, transport, risk and management of these materials. Ecotoxicological problems occur in both. Although there is also some similarity of analytical and physical methods, there tend to be many differences between soil and water/sediment testing methods. The degradation/metabolism of substances, sorption and leaching processes, the availability for organisms and how they are tested in laboratory and simulation systems (e.g. lysimeters, micro- and mesocosms) often differ in soil and sediment studies. Some of these differences are based upon differing contaminant behaviour and pathways of exposure in terrestrial and aquatic systems, while some differences are most likely based upon differing development in the field and expertise of practitioners.

However, contaminated sediment investigations have features that make them more complex than water evaluations and, to a lesser degree, soil or terrestrial investigations (NRC

2001, Apitz et al. 2005a). The simple fact that sediments lie under water implies that measurement, observation, and mapping of contaminant and ecosystem characteristics are technically challenging and expensive. Sediments integrate contaminant input from multiple sources within a watershed or coastal region, creating difficulties in tracking the potential sources of contamination. This can lead to ubiquitous, regional 'background' levels of anthropogenic contaminants that are difficult to separate from site specific sources (Crommentuijn et al. 2000). For the same reasons, sediments are, more often than soils, contaminated with multiple chemicals (Long et al. 1995), making risk assessment and management decision-making difficult and complex. The hydrodynamics and geochemistry of aquatic ecosystems are also quite different from those of terrestrial ecosystems. While soils and groundwater can often be isolated from receptors during remediation, similar isolation or removal approaches for contaminated sediments are more difficult to implement successfully; sensitive aquatic biota are more likely, and at times unavoidably, directly affected during the implementation of the remedy (USEPA 2002). Because the benthic community in direct contact with sediments is often near the base of the aquatic food chain, ecologically-based quality criteria can be orders of magnitude lower than those at most contaminated land sites. Together, these and other factors often push the limits of equivalent assessment methods and cleanup technologies for sediment and can at times increase costs significantly over what may be needed to address similar contaminant conditions in soils. On the other hand, some disposal and containment approaches, when available, compare favourably with soil cleanup technologies and some groundwater cleanups can be prohibitively expensive, so it is difficult to make sweeping statements about costs, which are always driven by site-specific conditions. While the benefits of ownership and cleanup of contaminated land, which can subsequently be sold or developed (or both) to offset the costs of remediation, are clear, such benefits are less obvious in aquatic ecosystems. Furthermore, although contaminated soils can often be left in place untreated (assuming there are no immediate ecological risks), the economic need for sediment dredging, whether for navigational or construction purposes, often requires that large volumes of sediments must be removed and managed even when there is no easily available or cost-effective disposal site or remedial technology. However, the management of sediments cannot be completely separated from that of soil and water, as these systems are interrelated and linked, hydrodynamically, even though not always in regulatory terms (Apitz and White 2003, Apitz et al. 2005a).

In recent years, there is a growing recognition that soils and sediments have important functions beyond the agricultural, transport and hydrological functions described above. In the development of the European Thematic Strategy for Soil Protection, it was recognised that soil has six main functions, three ecological and three technical, industrial and socioeconomic (Blum 2002). Although less explicitly laid out, the important functions of sediment have been pointed out by SedNet (SedNet 2004) and others as well. Upon examination, it becomes clear that the functions of soil do not differ greatly from the functions of sediment, with the proviso that sediments, unlike soils, are intrinsically linked with aquatic systems. One of the ecological functions of soil is as a substrate for the production of biomass, ensuring food, fodder, renewable energy and raw materials. Especially in shallow waters, sediment plays the same, albeit less obvious, role in aquatic systems, although a large part of many aquatic food chains also have primary producers in surface waters. Soils, sediments, and the organisms which live in them play major roles in the biosphere/atmosphere/land and aquatic biogeochemical balance, including filtering, nutrient regeneration, transformation, oxygen balance, buffering, etc. in freshwater and marine systems. Soil and sediments are biological habitats and form the biggest gene reserve on the globe. The major controlling factor of habitat type and health is soil or sediment type, whether the habitat is a healthy benthic community, eelgrass for fish breeding, meadows, desert, forest or farmland.

There are three main technical, industrial and socio-ecological functions of soil (Blum 2002), and these also are similar to the functions of sediments. Soils provide the physical basis for technical, industrial and socio-economic structures and their development, for instance industry, housing, transport, sports, recreation and the dumping of refuse. Sediments provide a similar substrate for most structures and developments in aquatic systems. As will be discussed later, a balanced soil and sediment supply is necessary to protect infrastructure, and, as sea levels rise and climate changes, our management of this cycle will be a primary line of defence. Soils and sediments are sources of raw materials, geogenic energy and water. Lastly, both soils and sediments are the memory of our geogenic and cultural heritage, forming an essential part of the landscape and concealing paleontological, stratigraphic and archaeological treasures.

In spite of these critical functions, both soil and sediment scientists and managers have had difficulty engaging the interest of the regulatory community and the public. The public considers sediments invisible or, in the case of dredged material, a waste, whilst soils are taken for granted while they are eroded, covered, contaminated and destroyed. Extensive discussions were carried out in SedNet meetings about how to engage stakeholders and regulators so that the role of sediments was recognized (see www.sednet.org for workshop reports). Similarly, discussions of the European Soil Strategy grappled with how to make soil more 'sexy' to the same audiences (EEB 2002). Contributors to both the Soil Strategy and SedNet are generating documents and recommendations for the EC to convince them that the protection of soils and sediments are critical in holistic ecosystem management, but they are doing this largely in isolation from one another. Because soils and sediment management are, in reality, interdependent, these efforts should be combined.

Policy changes. It is not, however, just the different historical evolution of soil and sediment science that has hindered better coordination between these fields. Rather, those who work within the web of environmental law and regulation have also recognized that the funnelling of problems within specific programmatic 'stove pipes', defined in terms of a specific medium, (e.g., water, soil, air), system (e.g., rivers, estuaries, marine systems, watersheds), contaminant (e.g., PCBs, pesticides, Hg), or activity (e.g., navigation dredging, waste water discharge, environmental cleanup), has in many cases presented impediments to achieving efficient, integrated solutions to environmental problems (Apitz and Power 2002, Bridges et al. 2005). As our understanding of ecological systems has evolved, it has become increasingly clear that effective and sustainable management strategies must focus on whole catchments and their interconnected media (chemicals, water, soil and sediment), rather than on one site or issue at a time. While conceptual approaches for addressing these disconnects are being developed (Apitz and White 2003, Heise 2005, in press), significant institutional barriers remain. However, the European Union has recently adopted several Directives, Strategies, Recommendations and agreements which will require a move from sectoral-based to more ecosystem-based, holistic environmental management (e.g. Apitz et al. 2005 in press, Borja 2005 in press, Ducroty and Elliott 1997, Elliott et al. 1999, Reader et al. 2001, Apitz et al. 2005b), which should make the integration of soil and sediment science and management (and many other fields) both simpler and more necessary.

The implementation of the Water Framework Directive (COM 2000) is changing the scope of water management from the local scale to basin (watershed or catchment) scale (often trans-boundary). It aims to establish a framework for the protection of ground waters and inland, transitional (i.e. fjords, estuaries, rias and lagoons) and coastal surface waters that prevents habitat deterioration and protects and enhances the status of aquatic ecosystems, as well as the terrestrial ecosystems and wetlands linked to them. There has also been a movement from addressing problems in isolation on land, in freshwaters, in estuaries or the coastal zone, to integrating these zones, and extending the ecosystem approach to whole shelf areas. The Integrated Coastal Zone Management Recommendation (ICZM) calls for the "...combination of instruments designed to facilitate coherence between sectoral policy objectives and coherence between planning and management" and "improved coordination of the actions taken by all the authorities concerned both at sea and on land, in managing the sea-land interaction", via a national stock-taking exercise, followed by the development of national strategies, international cooperation, reporting and review, ultimately leading to EC legislation on Coastal Zone management (COM 2002b). The adoption of the EU Marine Strategy (COM 2002a) and the recent suggestion of the need for an accompanying Marine Framework Directive will take integrated ecosystem management philosophies from the terrestrial and freshwater areas through the estuaries and coasts to the open sea, including to the shelf (200 nautical miles) areas. None of these initiatives deal explicitly with soil, sediment, or their relationships, but successful holistic management will require that these are managed as the interrelated issues that they are.

Enshrined in the European Treaty are the precautionary principle and the principles that pollution should be rectified at source, that the polluter should pay and that priority should be given to preventative action. As can be seen from the above, environmental management in Europe will now be based mainly upon biological and ecological (rather than physico-chemical) elements, with ecosystems at the centre of management decisions, applied to all European water bodies (Borja 2005, in press). An important part of achieving ecosystem management is the principle of integration embedded in the European Treaty which requires all other policy areas to take full and proper consideration of the European Community's environmental objectives when making policy decisions (COM 2001a). Thus, the Strategic Environmental Assessment (SEA) Directive (COM 2001b) was developed to ensure that environmental consequences of certain plans and programmes are identified and assessed during their preparation and before their adoption. In contrast to Environmental Impact Assessments (COM 1985), required to determine the consequences to proposed projects, these will look at the impacts of decisions above or below the project level. As will be briefly discussed below, many activities have both intended and unintended impacts upon soil and sediment balance and function, as well as on the many systems with which they interact. If SEAs and EIAs are to properly address these issues, soil and sediment scientists must work together to provide better science and models in support of these goals.

3 Interdependency of Soil and Sediment Management

In the eyes of many practitioners, it is accepted that soils will eventually erode and become sediments in rivers and ultimately the sea. For example, many coastal wetlands have been productive agricultural fields only a decade ago, and many deltaic areas are challenged by dynamic coastal geomorphological processes. Thus, many soil scientists state that sediment managers must consider soil issues, but that soil scientists need not be concerned with sediment issues. However, this perception of a unidirectional flow of materials is not correct, either currently or historically. In fact, much of early civilization in arid areas was dependent upon the conversion of sediments into soils. The Nile delta, for instance, flourished because of the rich deposits of sediments on soil in the annual floods. Less benignly, the recent floods in Europe have exposed previously buried contaminated material and deposited contaminated sediments on flood plains. Climate change and sea level rise will also change patterns of erosion and deposition in many areas of the globe. Sediments, deposited naturally or by humans, will produce the wetlands, beaches, dams, flood plains and dykes that will protect our resources and structures from storms, erosion and flood. However, the fate and impact of nutrients, metals and other contaminants after the placement of dredged material, whether contaminated or clean, on soils (a practice that is gaining prevalence in many EU countries), is an issue that must be examined by both soil and sediment scientists.

Properly functioning river systems, in both ecosystem and socioeconomic terms, are dependent upon a balance of the aspects of sediment quality and sediment quantity. Both an excess and a lack of sediments (and their source soils), either due to past, present or future natural or anthropogenic processes, can put various functions of a river at risk. Rivers have a certain capacity to transport sediment – if that amount of sediment is not supplied from outside the river system then river flow will try to pick up particles from the banks and bed. A river starved of sediment inputs (e.g. any river downstream of a large dam) will tend to cut downwards. This starvation may be because of a dam, urbanization (covering the soil with tarmac), or due to soil conservation programmes etc. There are degrees of sediment starvation, so any changes made to sediment supply from the catchment will have an impact in the river. Bridges are particularly vulnerable because there has normally already been some narrowing of the channel because of bridge piers built in the flow, and thus flow is going faster and can move larger particles. Sediment starvation may not come as a single impact. Urbanization tends to increase peak flows as well as cutting off the sediment supply (and resulting in an irreversible loss of soil resources), which can result in significant down cutting of rivers, to the scale of several metres in some cases, at times affecting groundwater zones.

The converse is also true, as too much sediment (for instance from excessive soil erosion) results in rivers silting up, and can cause ecological impacts (e.g. fish spawning grounds being affected by fine particles), flooding impacts (less water carrying capacity) navigation impacts (less depth), water resource and hydropower impacts (reservoirs filling with sediment, which is also not good for turbines), as well as a loss of valuable top soil and nutrients. In some developing countries, dam construction encourages development in the area, which can result in increasing erosion and hence sedimentation over a number of years. Clearly, soil must be considered both as a valuable resource in situ and as the potential sediment of tomorrow. They are part of the same dynamic system, and should logically be seen as part of a continuum and not as individual entities or disciplines.

Of course, as discussed above, contaminants also partition, transfer and move through a dynamic river ecosystem through various media, including air, sediment, soil, water and biota. Management of risk in such an ecosystem, or within a given river basin, suggests that sediment and soil management should be integrated into water, contaminant and ecosystem management. Thus, a conceptual appraisal of any proposed sediment management framework in light of water- and biota- focused perspectives is required. A decision-making hierarchy, which encompasses priority setting at a basin scale down through site-specific risk assessment at a local level, is a necessary approach for managing water, soil, sediment and biota, as well as point and diffuse contaminant sources. This is entirely in line with the philosophy and requirements of the WFD, ICZM and the Marine Strategy, and will permit a more effective implementation of EIA and SEA. The future should lead towards a better integrated environmental policy, directly linked to the knowledge of 'environmental interfaces' (including soil-sediment, but not only) and how this knowledge could be used to ensure an efficient environmental protection policy.

Successful implementation of ecosystem management and strategic assessment will require integration to an unprecedented degree: integration of environmental objectives from the catchment to the coast and, ultimately, to European seas; of the various water and land uses, functions and values; of different skills and disciplines; of previous and emerging legislation and policy into common and coherent frameworks; of technical, socioeconomic and legislative instruments; of stakeholders in decision-making; of the different decision-making levels, affecting ecosystem and water status and management among the Member States (Borja 2005 in press, Apitz et al. 2005b). This integration will require extensive collaboration and research to adapt current systems of environmental assessment and management to the basin and ecosystem level.

4 Conclusions

As WEH Blum stated at the workshop on the Thematic Strategy for Soil Protection, we need to integrate "soil protection issues with the other environmental policies, CAP, transport policy, etc. Research is a cross-cutting issue. It relates to biodiversity, health and other issues. It is important to show these links as politicians will not recognise the scope of the problem without this. Research has to look into cross-cutting issues. Creative thinking in science and politics is mainly concerned with searching for fresh, meaningful combinations of old pieces of information. To create is to re-combine (Blum 2002)." Soil and sediment scientists should work together to achieve these goals.

Some would argue that, in this world of specialization, the division between 'soil and sediment' scientists is a little 'old-fashioned'. In fact, in some fields of research (such as environmental sciences) many scientists already study both sediments and soils from the viewpoint of their own speciality (e.g., speciation chemistry, ecotoxicology, biogeochemistry, soil transport, hydrology etc.). Thus it can be stated that to face the problems of soils and sediments there is a need for the collaboration of scientists of different soil and sediment disciplines rather than between 'soil and sediment scientists'. These collaborations are a promising move forward, but it is also true that many universities, regulatory agencies and companies have soil and sediment related divisions that are barely aware of each others' existence, even if they have complimentary specialities. Whether cross-speciality or cross-media, further collaboration and integration is to be encouraged.

Rather than being distinct materials, soils and sediments are intensively interlinked and thus soil and sediment scientists and managers should co-operate in order to solve the many existing problems which often exist at the interface of both media. In fact, the contributions of sediment and soil science must be combined with many other 'sciences' including the social ones to solve issues around catchment and coastal management at various spatial scales. At the temporal scale, there is a need to create models and make predictions for catchments and smaller systems that will require a collaboration of scientists from both fields (again with collaboration from many other fields as well).

Soil and sediment scientists now face a rare opportunity to help determine how effectively European and other environmental regulatory frameworks evolve from sectoral issues to ecosystem management. Clearly, the critical role soil, sediment, and their relationships play in habitat type and quality, economic sustainability and contaminant fate, behaviour and control must be better understood, predicted and communicated if holistic and sustainable ecosystem management is to be achieved. Reform of the Common Agricultural Policy also provides new opportunities for soil and sediment managers to work together in creative ways. The similarity and interconnectivity between soil and sediment management suggest that many soil and sediment scientists have much to learn from each other, and much work to do together.

As their historical differences and constituencies remain, there are many research and management issues for which soil and sediment scientists will never need to collaborate. However, the topics covered in this journal – pollution research and environmental problems – are similar for soils and sediments, and therefore, experts from each field may well be interested in results from the 'other' field. Many topics, including harbour sludge problems, remediation technology, ecotoxicology, ecological aspects, speciation and analytics are relevant for both fields, and thus this journal provides an excellent forum for communication between fields, as well as an opportunity for soil and sediment scientists to communicate to the public and policy makers what these links are and how they should be addressed.

Acknowledgements. This paper was written as a result of email discussions between many individuals from the JSS-Editorial Board and associates, including (in alphabetical order) Wolfgang Ahlf, Winfried Blum, Eric DeDeckere, Almut B. Heinrich, Ralph Portier, Phillippe Quevauviller, Winfried Schröder, Gilbert Sigua, Wim Solomons, Stefan Trapp and Sue White. SEA (Sabine E. Apitz) acknowledges the contribution of thoughts, words, references and suggestions by these individuals, who were essential to the development of this paper, but are in no way responsible for its final form and conclusions.

References

Apitz SE, Carlon C, Oen A, White S (2005, in press): Strategic Frameworks for Managing Sediment Risk at the Basin and Site-Specific Scale. In: Heise S (ed), Sediment Risk Management and Communication: Elsevier

Apitz SE, Davis JW, Finkelstein K, Hohreiter DL, Hoke R, Jensen RH, Kirtay VJ, Jersac J, Mack EE, Magar V et al. (2005a): Assessing and Managing Contaminated Sediments: Part I, Developing an Effective Investigation and Risk Evaluation Strategy. Integrated Environmental Assessment and Management 1, 2–8

Apitz SE, Elliot M, Fountain M, Galloway T (2005b, in press): European Environmental Management: Moving to an Ecosystem Approach. Integrated Environmental Assessment and Management

Apitz SE, Power B (2002): From Risk Assessment to Sediment Management: An International Perspective. JSS – J Soils & Sediments 2 (2) 61–68

Apitz SE, White S (2003): A Conceptual Framework for River-Basin-Scale Sediment Management. JSS – J Soils & Sediments 3 (3) 132–138

Blum WEH (2002): How can we achieve a holistic and integrated approach towards soil protection? EEB workshop on the Thematic Strategy for Soil Protection: Workshop Report, 27 October 2002. Brussels: The European Environmental Bureau (EEB), pp 31–33

Borja A (2005, in press): The European Water Framework Directive: a challenge for nearshore, coastal and continental shelf research. Continental Shelf Research

Bridges T, Apitz SE, Evison L, Keckler K, Logan M, Nadeau S, Wenning RJ (2005, in press): Making Decisions to Manage Risks from Contaminated Sediments. Integrated Environmental Assessment and Management

Brils JM (2003): The SedNet Strategy Paper: The opinion of SedNet on environmentally, socially and economically viable sediment management. SedNet <www.SedNet.org>

COM (1985): Council Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment. Official Journal of the European Communities L 175, 05/07/1985:0040–0048

COM (2000): Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. Official Journal of the European Communities L 327, 22/12/2000:0001–0073

COM (2001a): Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions. On the sixth environment action programme of the European Community 'Environment 2010: Our future, Our choice' – The Sixth Environment Action Programme – Proposal for a Decision of the European Parliament and of the Council Laying down the Community Environment Action Programme 2001–2010. Brussels. Report nr COM (2001) 31 final 2001/0029 (COD). 24.1.2001

COM (2001b): Directive 2001/42/EC of the European Parliament and of the Council of of 27 June 2001on the assessment of the effects of certain plans and programmes on the environment. Official Journal of the European Communities L 197/30, 21.7.2001

COM (2002a): Communication from the Commission to the Council and the European Parliament: Towards a strategy to protect and conserve the marine environment. Brussels: Commission of the European Communities. Report nr COM(2002) 539 final

COM (2002b): Recommendation of the European Parliament and of the Council of 30 May 2002 concerning the implementation of Integrated Coastal Zone Management in Europe (2002/413/EC). Official Journal of the European Communities L 148/24, 6.6.2002

Crommentuijn T, Sijm D, de Bruijn J, van den Hoop M, van Leeuwen K, van de Plassche E (2000): Maximum permissible and negligible concentrations for metals and metalloids in the Netherlands, taking into account background concentrations. Journal of Environmental Management 60 (2) 121–143

Ducrotoy J-P, Elliott M (1997): Interrelations between science and policy-making: the North Sea example. Marine Pollution Bulletin 34, 686–701

EEB (2002): EEB workshop on the Thematic Strategy for Soil Protection: Workshop Report, 27 October 2002. Brussels: The European Environmental Bureau (EEB). 38 pp

Elliott M, Fernandes T, Jonge VD (1999): The impact of recent European Directives on estuarine and coastal science and management. Aquatic Ecology 33, 311–321

Heise S (2005, in press): Sediment Risk Management and Communication: Elsevier

Long ER, Macdonald DD, Smith SL, Calder FD (1995): Incidence of Adverse Biological Effects within Ranges of Chemical Concentrations in Marine and Estuarine Sediments. Environmental Management 19 (1), 81–97

NRC (2001): A risk-management strategy for PCB-contaminated sediments, National Research Council. Washington, D.C.: National Academy Press

Read S, Elliott M, Fernandes T (2001): The possible implications of the Water Framework Directive and the Species & Habitats Directive on the Management of Marine Aquaculture. In: Read Pea, editor. The Implications of Directives, Conventions and Codes of Practice on the Monitoring and Regulation of Marine Aquaculture in Europe (MARAQUA). Aberdeen: Publ. Fisheries Research Services. pp 58–74

SedNet (2004): Contaminated Sediments in European River Basins. Salomons W, Brils J, editors. The Netherlands: TNO

USEPA (2002): Contaminated Sediment Remediation Guidance for Hazardous Waste Sites. United States Environmental Protection Agency, Office of Solid Waste and Emergency Response. Report nr OSWER 9355.0-85

Received: August 2nd, 2005
Accepted: August 5th, 2005
OnlineFirst: August 6th, 2005