From monitoring to measures: Historical contaminated sediments in the Elbe river basin

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1. Title

2. Introduction

In a recent editorial for Journal Soils and Sediments, Wim Salomons has stressed the fact that the dynamic nature and the propagation of pollutants in the catchment areas is the key issue in various policy regulations, in particular in the European Water Framework Directive.

In the following 15 minutes we present our view, how problem solutions for contaminated sediments can be supported by a mixture of older and younger information from the river basin.

3. From Monitoring (2006) to Measures (2009)

The title of the presentation refers to the actual steps under the Water Framework Directive: 2006 Monitoring programmes to be operational (Article 8) and 2009 Establishment of the programme of measures (Article 11).

In 2004, two Expert Groups under the Common Implementation Strategy had a closer look on sediment-related issues:

The AMPS-Group (Analysis and Monitoring of Priority Substances) stated that “Compliance monitoring for sediment is not appropriate because of the lack of definition of valid Environmental Quality Standards (EQS) in a European context”, and

The Expert Advisory Forum on Priority Substances and Pollution Control proposed, that the program of measures (for the first step: screening of generic sources that can result in releases of priority substances and priority hazardous substances) should include the specific source or pathway “historical pollution from sediments”.

During the SedNet Round Table Discussion at the Venice Meeting, November 2006, definitions in both subject areas - monitoring and measures – found their majorities:

“Environmental Quality Standards should only be regarded as high-level screening values as a start of diagnostics, using different lines of evidence, and linking sediment state to impacts”,

“For certain measures target values and a good understanding of the system are necessary”

4. Monitoring Historical Pollution from Sediments: Rhine Basin and Elbe Basin

Historical pollution from sediments was studied from the Rhine Basin (2004, for Port of Rotterdam) and from the Elbe River basin (commissioned by HPA and Elbe Commission. The basis was the 3-step approach of Dr. Heise, which has been presented in an earlier lecture here: (1) Substances of Concern, (2) Areas of Concern and (3) Areas of Risk.

In the example of the Rhine River basin we found four favourable conditions for the interpretation of data:

(i) full cycles of suspended particulate matter and pollutant load during flood events,
(ii) set of target levels in the form of the so-called CTT-regulation, that determines whether DM from Rotterdam Hr. goes to the sea or to the confined disposal site,
(iii) the most critical pollutant hexachlorobenzene occurred in the main river and the most important effect downstream was dilution, and
(iv) experiments, for example by Westrich of Stuttgart University, which demonstrated that resuspension occurred at a certain erosion stress.

5. Analysis of Flood Events, e.g., in 1999 in the Rhine system

Regarding suspended matter sampling, best data would cover the particle quantity and quality through a full flood stage. An example is presented from the 1999 flood in the Rhine system

(1) The upper figure shows the water discharge curve during an extreme flood event in the River Rhine in 1999 (Maxau). (2) 500 km downstream, at the border to The Netherlands, the concentration curves of hexachlorobenzene widely follows the upstream water discharge curves. (3) The dilution during the 500 km travelling – time delay is 5 days - is approximately factor 5. (4)At high water flows, the concentrations of HCB are significantly higher than the CTT levels for this pollutant – 20 Mikrogramm -, set by the Dutch authorities to give permit for relocation of dredged material from Rotterdam harbour to the North Sea.

6. Risk for Port of Rotterdam to Exceed CTT

From the analysis of several flood events, there is a clear relation between the hydrological situation, the erosion potential, the increase of suspended matter load and the load of pollutants, which enters Port of Rotterdam. With regard to hexachlorobenzene, there is a certain risk already at “Business as Usual” conditions. With increasing flood water discharge – annual, 10 years and 50 years return of flood - the effect of Hexachlorobenzene from the Upper Rhine barrages to the downstream neighbours could reach extreme concentrations.

7. Monitoring and Measures in the Elbe River Basin

Compared with the Rhine Basin, the information on the Elbe system are much more complicated. (1) There are different data sets from different organisations. (2) Contrary to the Rotterdam situation, there are no target values for dioxin concentrations, and (3) Floodplains as intermediate sink for contaminated sediments are difficult to predict. (4) On the other hand, the Elbe study contains proposals for measures, in particular for in-situ remediation strategies. There are big efforts in the United States under the Superfund program with technologies such as environmental dredging, sediment capping and monitored natural recovery.

8. Sediment Remediation at the River Basin Scale

Predominantly in the upper and middle course of river systems, sediments are affected by contamination sources like mine water from flooded mines and atmospheric deposition. In the upper Elbe river basin, more than 20 billion € have been spent for the sanitation of the short interval of Soviet uranium mining from 1945 to 1990. In-situ techniques in deep ore mines include active barriers (e.g., fly ash, red mud) to prevent heavy metal dispersion during flooding. Another 10 billion € has been spent for the renaturation of 215 open pit coal mines in the middle Elbe basin during the last 15 years.

The other three types of in-situ remediation will be treated in more detail in the following slides: (II) Floodplain soils and sediments by in-situ stabilization; (III) confined disposal areas by subaquatic deposition and capping, and (IV) temporal retention in reservoirs.

9. Dioxin: from Spittelwasser to the Elbe River

One of the most problematic remains from former industrial activities in the Elbe basin are the soils and sediments in the Chemical Triangle around Bitterfeld, lower Mulde River. Concentrations are between 1 and more than 100 Mikrograms Toxicity Equivalents of dioxin in the inner part of this floodplain, and the inflow of the Mulde River seems to undergo a certain way of dilution by the Elbe River along the following 400 km until the entrance into the North Sea from 140 ng/kg to 35 ng/kg.

Monitoring of the dioxins in the Elbe River basin can make of typical congeneric patterns of this group of chemicals. On the other hand, a major deficiency in the Elbe River is the lack of target values for dioxin, in particular for so-called relocation, e.g. from Hamburg harbour to the North Sea.

10. Remedial Option A: Monitored Natural Recovery

A first option to treat wide-spread pollution in soils and sediment is the monitored natural recovery. Magar & Wenning have listed four prerequisites for the consideration of this approach: (1) Contaminants are buried under a clean sediment cover, (2) or they are chemically or mechanically stabilized by diagenetic processes, (3) or they are chemically or biologically degraded, mostly the latter. (4) A forth mechanism – dilution by dispersion – in most case will cause more problems to downstream areas than local benefits.

In the Spittelwasser floodplain, there no clean sediment cover and the erodibility of older sediments is high. Recently the work of Bunge and colleagues has shown, than the degradation of critical Bitterfeld chemicals is low, most probable due to toxic effects of these chemicals.

11. Option B Excavation

The only way for the hot spots in the Mulde and Spittelwasser area will be environmental dredging and excavation. There is, for example, one pond containing approx. 5.000 m³ fine grained sediment, with maximum dioxin concentrations of more than 100.000 ng/kg.

Already in 1993, shortly after German unification, a feasibility study undertaken by two competent engineering groups. Of the six alternative measures, the excavation approach was considered realistic. Nothing happened in the last 15 years.

The next flood event will again mobilize sediments from the pond and from the floodplain. A rough estimate shows that 5.000 m³ sediment containing on an average 20.00 ng toxicity equivalent dioxin per kg dry mass could pollute 10 million m³ Elbe sediment to 10 ng TE dioxin per kg – a reasonable target value for relocation in Hamburg harbour

12. Excavation, Structural Isolation, and Capping

The techniques are available. In 2002 my institute provided a plan for a pilot study at a yachting harbour on the Elbe river. The excavation should apply a patented procedure by pumping the sediment without addition of water. For the deposition, a channel should be used, which is closed on both sides by sheet piling. The subaquatic depot should finally be secured by a reactive cap. I still do not know, why the proposal was not put into reality.

13. Bitterfeld Mulde Reservoir

Perhaps the most efficient problem solution is the use of river reservoirs. One example has been studied for several years by the Saxony Academy of Science at Leipzig. The Bitterfeld Mulde Reservoir provides a capacity of 18 million m³, and this would last for 500-1000 years. The retention capacity for the contaminants in the Mulde Rivers are quite high – 84 % for lead, 72 % for cadmium, 86 % for mercury. Approximately 50 % of the mercury in the Elbe system is stopped in this reservoir.

14. Conclusions I - Monitoring

We have shown that the study of full flood cycles for suspended particulate matter and pollutant concentration is needed to understand the transport dynamics in river basins

We have further shown that target values are needed to prediction of possible risks, in particular for the relocation of sediments from the harbours into the estuary or sea.

The propagation concept needs information on the hydrology and on erosion potentials

15. Sediment Monitoring Schemes

Three monitoring schemes can be deducted from these finding: A relative simple scheme allowing trend monitoring on the basis of comparable data sets. The scheme respects the traceability concept in that measurement data are linked to stated references through an unbroken chain of comparison, all with stated uncertainties: Low in the “Standard” scheme.

The other extreme is the prediction of propagation effects. The combination of data on chemical and hydraulic stability leads to very high uncertainties in the scheme “Dynamics”.

For process studies, for decision on measures, information on the In-situ sediment chemistry and biology is needed – Basic Characterization fits into the terminology of EU.

16. Conclusion II – Measures

Understanding of the system is required, that is hydrology, morphology, geology

Diffuse contamination, for example, in flood plains, require more soft options options compared with the situation of the big harbours, and

One consistent approach is required from monitoring via measures up to the aftercare

All this only works with a basin-wide cooperation

17./18. Acknowledgements

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Introduction: Sediment management under the EU Water Framework Directive will need a wider scope with *in situ* technologies embedded in a modern system of risk assessment and communication on the river basin scale. A new initiative for Europe-wide activities in the field of sediment management technology could start in the course of the forthcoming strategies against chemical pollution of surface waters (WFD article 16), i.e. establishment of a program of measures until 2009 for sources of priority substances including the specific source/pathway "historical pollution from sediment"[1]. In the view of the size of the problems in Europe[2], the guidance to innovative remedial measures and the experience from successful problem solutions in the United States cannot be ignored[3]. Our presentation refers to chapter. 6 "Risk reduction of contaminated sediments in the Elbe river basin" in a study on behalf of the Hamburg Port Authority and River Basin Community of the Elbe[4].

Methods: The different objectives of risk assessment and monitoring on solid material involve specific techniques favoring different media (suspended particulate matter, sediments, biota)[5]: (i) Surveillance, i.e., source screening and preliminary site characterization; (ii) survey, i.e., identification of anomalies and basic characterization on the regional to river basin scale; (iii) mass balances, including "weight of evidence"-approaches (see abstract by Heise et al.[6]). A fourth sediment monitoring issue under the WFD will be assessing risks and functioning of measures, in particular, monitoring before and after remediation of contaminated sediments. In this field, initial recommendations have been presented in a guidance document of the U.S. Environmental Protection Agency[7] and for remediation dredging by the U.S. National Research Council[8]: How to assess and monitor the five "R's" – the *risks* arising from *residuals, resuspension, release and recontamination?* U.S. focus is on remediation dredging, in-situ capping and monitored natural recovery (MNR); these technologies all rely on contaminant source control; monitoring programs should include multiple lines of evidence that include chemical, physical, geotechnical, and biological metrics, and modelling in order to evaluate, with adequate certainty, the effectiveness of the chosen approach at a site[9, 3].

Results: The examples from the upper Elbe River catchment give special emphasis on the utilization of geochemically-based technology for sediment remediation, which can be applied in different parts of a river basin[10]. For a yachting harbor, a draft approval has been made which involves a patented excavation procedure; monitoring of the subaqueous depot with an active barrier system was performed using dialysis sampler and diffusional gradient technique probes[11]. The MNR potential is assessed according to typical lines of evidence, e.g., contamination burial, mechanical and chemical mobility, transformation to less toxic forms and dilution due to dispersion[7]. Although strict criteria are not fulfilled in many floodplains of the Elbe river catchment area, it can be stated that the alluvial soils offer a high natural retential potential for a wide spectrum of contaminants[12]. In the historical contamination of the Mulde river, the high concentration of PCCD/F's and their low degradation potential is the limiting factor for applying MNR[13].

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