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# Environmental studies in Western Europe using overbank sediment

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ABSTRACT There is particular concern in Western Europe about the environmental problems, and urgent and concerted international action is warranted. An evaluation of the present state of pollution requires systematic, compatible data on the present distribution as well as the preindustrial, natural distribution of chemical elements in surface environments. The appliance of overbank sediments from river plains as a sampling medium in regional geochemical mapping is discussed. A vertical section of overbank sediment reflects the history of sedimentation back through time. Samples from the upper horizons will show the present day distribution influenced by pollution, while samples taken at depth will reflect the natural environment. The experience so far indicates that overbank sediment is a suitable sampling medium for local and regional environmental geochemical studies.

## INTRODUCTION

Geochemical maps are based on sampling and analysis of natural material and show the distribution of chemical elements in the surface environment. Chemical elements form distinct geographical distribution patterns with great contrasts in element contents both on regional and local scales. Geochemical maps are an important tool in the exploration of mineral deposits. In the last decade or so geochemical maps have also become increasingly important for environmental research.

Traditionally, active stream sediments are the most used samples in regional geochemical mapping for both prospecting and environmental purposes. It has been assumed that the composition of active sediments in the stream channel represents the geochemistry of the catchment area upstream from the sample site. Regional geochemical maps have therefore normally been produced by the analysis of samples of active stream sediments collected at certain intervals along streams of high order (usually 1-20 $km^2$ drainage basins). The assumption that stream sediments are representative for drainage areas can, however, be questioned. It has been shown that the sediments in stream channels are often derived from point sources of limited extensions when compared with whole catchment areas. (Ottesen et al., 1989). Samples of active stream sediments from small drainage areas may thus be dominated by material from single point sources.

In exploration active stream sediments also have another drawback: they are sensitive to heavy metal contamination from mining and other human activities (Rose et al., 1979 page 453, Levinson, 1980, p. 204-210).

For environmental, purposes geochemical maps should provide information not only about pollution, but disclosure of natural features is also warranted. Knowledge about these is a prerequisite for an evaluation of the degree of pollution and its possible harmful effects. The use of stream sediments as the sole sampling medium in environmental geochemical mapping in populated or industrialized areas is, therefore, insufficient and poses problems in addition to those of the representativeness of the samples.

Realizing the need for more basic knowledge about processes controlling migration of material in streams, a co-operation was initiated between geochemists and sedimentologists of the Geological Survey of Norway, the University of Oslo and the Norwegian Water Resources and Energy Administration concerning river dynamics. This project lead to development of techniques for using overbank sediment (alluvial soil, levee or river plain sediment) as a sample medium in regional geochemical mapping for environmental and exploration purposes. In this report some aspects of the application of overbank sediment in environmental studies are discussed, emphasis being put on the methodology. An introductory study in Norway (Ottesen et al., 1989) and a pilot project carried out by the Western European Geological Surveys (Bølviken et al., 1990, Demetriades et al., 1990) provide the main sources for the examples of results that are given.

## OVERBANK SEDIMENT VERSUS STREAM SEDIMENTS AS A SAMPLING MEDIUM

In recent years a number of sediment budget studies have shown that distribution of erosion and deposition often are subject both to great time variations and to spatial variations within catchment areas (Coleman and Scatena, 1986, Mou, 1986, Bogen, 1986, Walling and Bradley, 1988). The sediment producing processes are often episodic events (Bergstrøm, 1982, Swanson et al., 1982). Thus, a sample from the present sediments in a stream channel may be dominated by a source that was particularily active in the time preceeding the sampling. In Scandinavia it has been found that areas contributing to the sediment budget are in general increased both in size and numbers during large magnitude floods. During such events, intense rain may trigger a number of land slides, runoff may destroy protective vegetation cover, and a number of new sediment sources may be opened up.

To obtain representative samples from river basins with such discrete sources, composites consisting of material from several flood layers must be collected. Such composites can be taken by sampling several layers of overbank sediment profiles, since the combined layers represent a great number of sediment sources that has been active at different times. Results from investigations in Austria, Greece and Norway corroborates this assumption (Ottesen, 1990, Demetriades et al., 1992).

A vertical section through overbank sediments reflects the history of sedimentation back through time. For this reason, flood deposits on riverplains have frequently been used in paleohydrological constructions (e.g. Gonera and Kozarski, 1987, Kochel and Baker, 1988, Webb et al., 1988,).

In geochemical studies such time scales may be used in a delineation of chemical conditions in the past. Because young sediments overlay older ones, the uppermost layers may be contaminated by pollutants from industrialized or populated areas, while those at depth may have remained pristine since deposition reflecting the composition of the natural, preindustrial environment. Utilisation of the sedimentary record to analyse the chemical composition of overbank sediment through time, therefore, offers a good opportunity to study former changes in the environment.

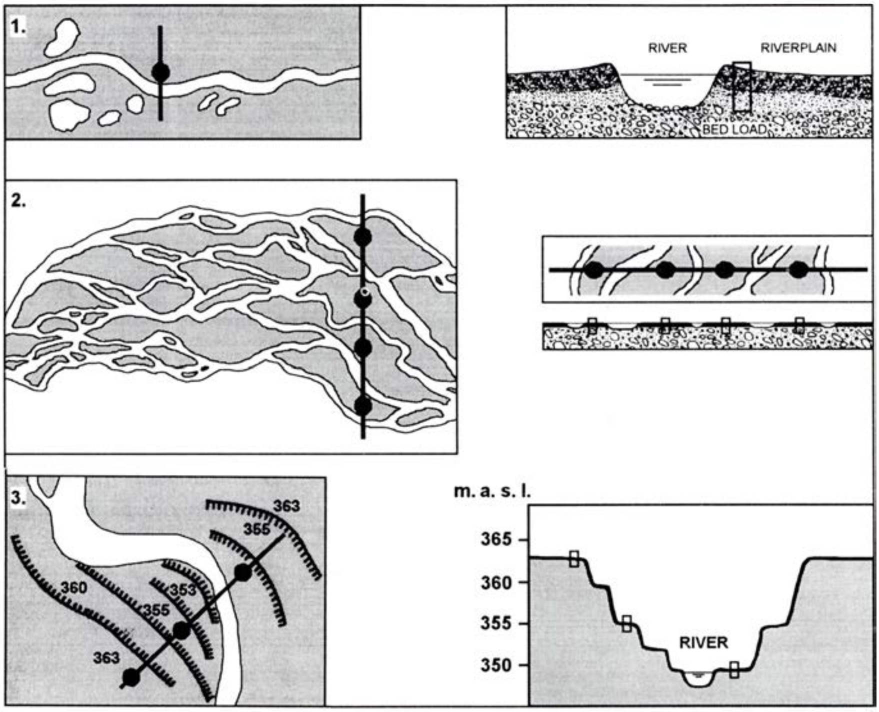


FIG. 1 Sample locations (dots) of overbank sediment in three types of river systems: 1) meandering channel, 2) braided river channels, and 3) river plain terraces.

## SAMPLING OF OVERBANK SEDIMENT

It is necessary to have some general knowledge about the sedimentation rates at the river plains to be able to judge the best locations for taking pristine and polluted overbank sediments. In regional surveys a number of different types of river plains have to be dealt with. If the channel pattern of a river is complicated, a study of the sedimentary units at the sampling locations may have to be carried out before a sample is collected.

In some of the fluvial systems, older sediments are being reworked during floods. In such cases it may be difficult to identify material that represents preindustrial conditions, and a more thorough study of sediment sequences may be necessary. Essentially, sample locations may be classified in three categories according to river type (Fig. 1):

1) In meandering or straight reaches the natural levee or slack water positions of the river plain may provide sites for both a recent and a preindustrial sample.
2) In braided rivers the layer of overbank sediment is generally thin and spread out over large areas. The ages of the braides, however, vary across the channel and it

is also in this case, possible to distinguish between pristine and polluted deposits, provided sufficient sedimentological knowledge of the area.

3) If river terraces are present, the relative ages thereof have to be taken into account in order to identify locations for samples of old and young material.

The following case histories illustrate these three categories:

Meandering or straight reaches Element distributions in overbank sediment profiles at river plains along the Innerste river in Germany were studied by Hindel (1990). These plains have been polluted by heavy metal containing mine waste that has been deposited further up in the catchment areas during more than 500 years of mining in the Hartz Mountains. Sediment samples were collected in 80-200 cm deep pits. After drying and sieving of the samples, the minus 2 mm fractions were analyzed by atomic absorption spectrometry following digestion in a $HF/HClO_4$ mixture. Table 1 shows an example of the obtained results.

At Getter, Innerste River the Pb content in the upper 50 cm of the profile is up to 1.9%, which is more than 200 times the content at a depth of 120 cm, where 142 ppm Pb is assumed to be indicative of natural concentrations in preindustrial, presumably pristine, material.

Similar results to those found by Hindel (1990) were also obtained in polluted areas of the Aachen, Ardenne and Limburg regions of Germany, Belgium and The Netherlands (De Vos et al., 1992), and in Poland (Maklin and Klimek, 1992), while unpolluted areas of Finland, Greenland, Norway and Sweden show more homogeneous distributions of element concentrations with depth (Volden, 1990).

Braided rivers Overbank sediment were sampled in the braided system of the Manzanares river, which draines the Madrid area of Spain (Locutura and Lopez Paloma, 1990). The contents of Cu, Pb and Zn in one of the youngest braides vary with depth in a way that indicates pollution in the upper layers (Fig. 2).

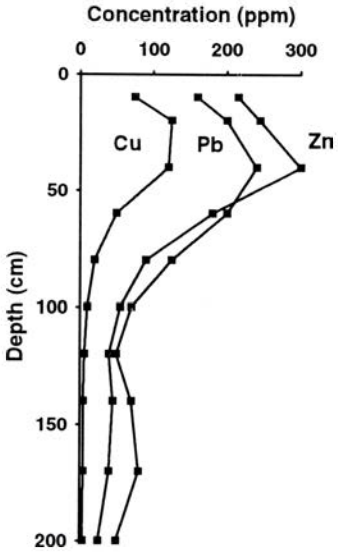


FIG.2 Vertical distribution of Cu, Pb and Zn in a young profile of overbank sediment, the Manzanares River, Spain (Locutura and Lopez Pamo,1990).

River terraces In Germany, close to the Belgian and Dutch borders, overbank sediment from three different terraces has been studied by Schalich (1968) and Hindel (1992, pers.comm.).

Three different sequences of overbank sediment can be distinguished; the sediment from the old sequences may indicate the natural conditions, whereas the two younger ones also reflect anthropogenic influences.

The oldest sediments lie on a terrace three to four meters higher than the most recent deposits. This sequence has high content of clay and driftwood. The second terrace, which accumulated between the 3th to the 15th centuries, contains relics of bricks from the Roman period. The youngest deposits of overbank sediment profile consists mainly of 1.2 m of sand and gravel with anthropogenic relics of the last 200 years.

Hindel (1992 pers. comm.) collected samples from the two youngest terraces in the Aachen area of Germany and found that the most recent deposits of overbank sediment close to the river have been polluted by mine waste, having nearly ten times higher contents of Pb and Zn than the older terrace at depth.

## NATURAL GEOGRAPHICAL DISTRIBUTION OF ELEMENTS IN OVERBANK SEDIMENT

Ottesen et al. (1989) collected samples of overbank sediment from 690 sites uniformly scattered over Norway (320,000 km$^2$), each site representing drainage areas of 60-300 km$^2$. A vertical section of the sediment was cut with a spade, and after excluding the upper 5-10 cms, a bulk sample was taken from the rest of the section. The samples were dry sieved to minus 0.062 mm fraction, and analyzed by various methods (Faye and Ødegård, 1975, Ødegård, 1981, Kuldvere, 1988).

Figure 3 shows an example of the obtained maps (acid soluble Pb); other examples have been presented by Ottesen et al. (1986), Bølviken et al. (1987), Ottesen et al. (1989), and Bølviken et al. (1990), and Bølviken (1991).

All the elements depict broad regional patterns with pronounced contrasts between high and low concentrations. The patterns are believed to reflect natural compositional features of the overburden, ultimately that of the bedrock.

## OVERBANK SEDIMENT AS A MEASURE OF STATE OF POLLUTION

Streams are the main avenues whereby the products of weathering and products of man are carried off the land (Schumm, 1977). Heavy metals in the products are supplied to the rivers and deposited on the plains during floods.

Arguments in favour of sampling overbank sediment in environmental studies include:

Overbank sediment is easy to collect and analyze. It may represent large drainage areas, and samples can be taken at low density and, consequently, at low cost per unit area. A small number of large samples facilitates the use of complex multi-element chemical analysis with various techniques.

Overbank sediment seems to be present in all river systems that have fluctuating water levels caused by floods.

The composition of overbank sediment reflects the history of the chemical (natural and anthropogenic) environment back through time.

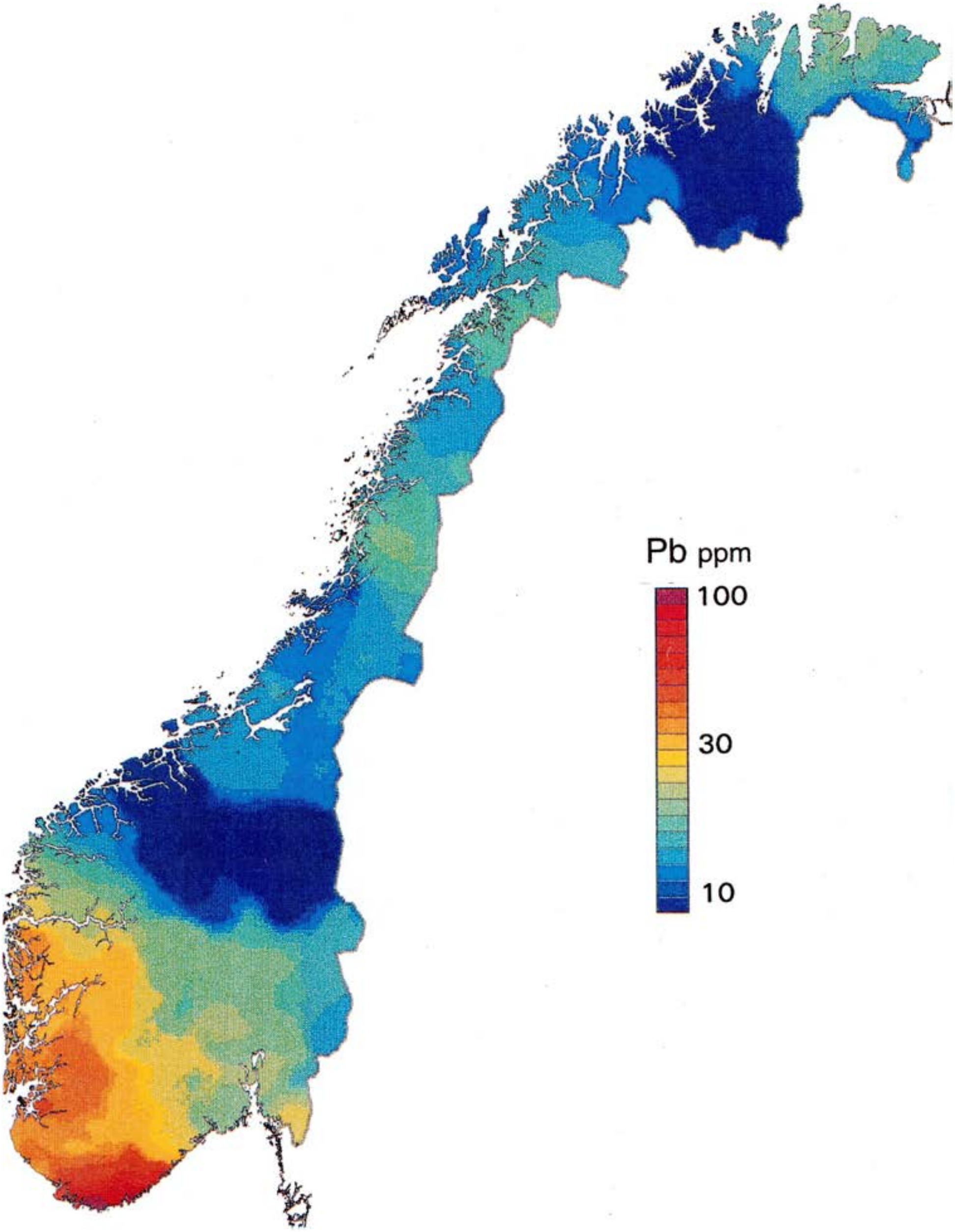


FIG. 3 Contents of hot nitric acid extractable in overbank sediment, Norway. The map is based on the analysis of 690 samples and shows the rolling median within a window of diameter 100 km.

## CONCLUSION

An evaluation of the present state of pollution requires systematic, compatible data on the anthropogenic distribution as well as the preindustrial, natural distribution of chemical elements in surface environments. The experience so far indicates that overbank sediment is a suitable sampling medium for large scale environmental geochemical studies in local and regional scales.

TABLE 1 Content of HF-$HClO_4$ soluble lead in stream sediment and overbank sediment from the Innerste River, Germany (After Hindel, 1990).

| Active stream sediment | Overbank sediment Depth(cm) | Pb(ppm) |
|---|---|---|
| 8000 | 0-8 | 19000 |
| | 8-15 | 17300 |
| | 15-24 | 15600 |
| | 24-33 | 16500 |
| | 33-40 | 14000 |
| | 40-48 | 11800 |
| | 48-53 | 3733 |
| | 53-75 | 3323 |
| | 75-80 | 3718 |
| | 80-85 | 1696 |
| | 85-95 | 617 |
| | 95-100 | 314 |
| | 100-120 | 142 |

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