UFZ-Bericht Nr. 18/2004

11th Magdeburg Seminar on Waters in Central and Eastern Europe: Assessment, Protection, Management

Proceedings of the international conference
18-22 October 2004 at the UFZ

Walter Geller, Jan Blachuta, Šarka Blažková, Evelyn Claus, Alfred Dubicki, Hildegard Feldmann, Helmut Guhr, Edeltrauda Helios-Rybicka, Hubert Holzmann, Wiwiana Szalinska, Wolf von Tümpling, Gulay Záray (Eds.)

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Variability of metal contamination of floodplain soils of the Elbe River and their risk potential

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1. Aim of the study

A number of studies have indicated that the recent floodplain soils of the Elbe River have become contaminated with heavy metals and organic pollutants in the past. The studies showed that within one site the contamination varied to a large extend with maximum values exceeding action values of the Federal Soil Protection Act. After the summery high flood in 2002 the questions should be answered (1) if the contamination with heavy metals has been increased due to the sedimentation of suspended solids, (2) which factors are responsible for the large variability of contamination within the flooded areas and (3) how is the risk potential correlated to soil contamination.

2. Investigated sites and methods

The study was conducted at four sites: **W:** Wörlitz (Elbe river position: at km 242 above the Mulde mouth, use: pasture and woodland, left side, width from river to dike: 1,62 km), **S:** Steckby (km 285 between the Mulde and Saale mouth, mostly pasture, right side, width from river to natural elevation: 0,61 km); **G:** Glinde (km 301 below the Saale mouth, pasture, left side, width to dike 0,39 km); **P:** Pötnitz (at lower Mulde River 9 km before the confluence in the Elbe, use: pasture and woodland, right side, width from river to dike: 1,16 km).

At each site a transect of soil profiles was surveyed to 2 m depth, the surface elevation in relation to mean water level was measured and the top soils from 0-0,1 m were sampled. Additional at each site 4 to 6 monitoring sites of 256 m^2 area were chosen on selected and comparable morphological situations (levees, first channel near river, plateau areas). The areas were permanently marked, the top soils sampled by mixing 16 subsamples from 0-0,1 m depth and an adjacent soil profile sampled to 2 m depth. From the monitoring sites a mixture of the above ground vegetation was sampled at August and October 2003.

The soil and plant samples were analyzed using standard methods (e.g. aqua regia digestion acc. to DIN ISO 11466, measuring of heavy metal concentrations with GF-AAS and FIMS, additional XRF-analysis of total element concentrations).

3. Results

Table 1 gives the ranges and the coefficients of variation (cv, in % of mean) for the total concentrations of heavy metals and arsenic in the top soils of the studied sites. For the elements Hg and Cd the cv is largest, as for these elements the background concentrations are relatively the smallest. The variation of trace element concentration is highest at the lower Mulde site (P), as here the flooding is not as regular as at the Elbe and upper parts of the floodplain have been contaminated only a bit.

Table 1: Total concentrations of trace elements (mg/kg) in top soils of studied sites
(n : number of samples, cv: coefficient of variation in % of mean)

	W			P			S			G		
	n	range	cv	n	range	cv	n	range	cv	n	range	cv
As	16	35 – 73	23	5	56 – 345	83	28	25 – 83	22	4	25 – 55	33
Pb	58	89 – 188	15	41	93 – 399	43	52	47 – 198	20	19	124 – 300	26
Cd	16	1,5 – 6,7	39	5	1,2 – 14,2	85	28	1,0 – 9,4	53	4	4,2 – 10,3	34
Cr	58	74 – 193	15	41	37 – 303	70	52	24 – 184	29	19	75 – 196	28
Cu	58	54 – 165	26	41	31 – 231	73	52	29 – 173	29	19	85 – 343	38
Ni	58	32 – 65	13	41	19 – 65	32	52	6 – 60	29	19	36 – 96	27
Hg	16	0,6 – 2,4	34	5	0,4 – 13,3	149	28	0,8 – 4,2	46	4	7,4 – 20,1	40
Zn	58	266 – 852	28	41	182 – 902	50	52	42 – 834	41	19	400 – 1343	33

Figure 1 gives an example of the ground level (GL), the distribution of top soil properties and the metal contamination for site W. As channels and depression are longer flooded they are typically more contaminated than levees and plateau areas. For all sites this is true for the channels near the river. The contamination between elements is strongly correlated ($p<0{,}001$) with some shifts in element-relation between sites. The top-

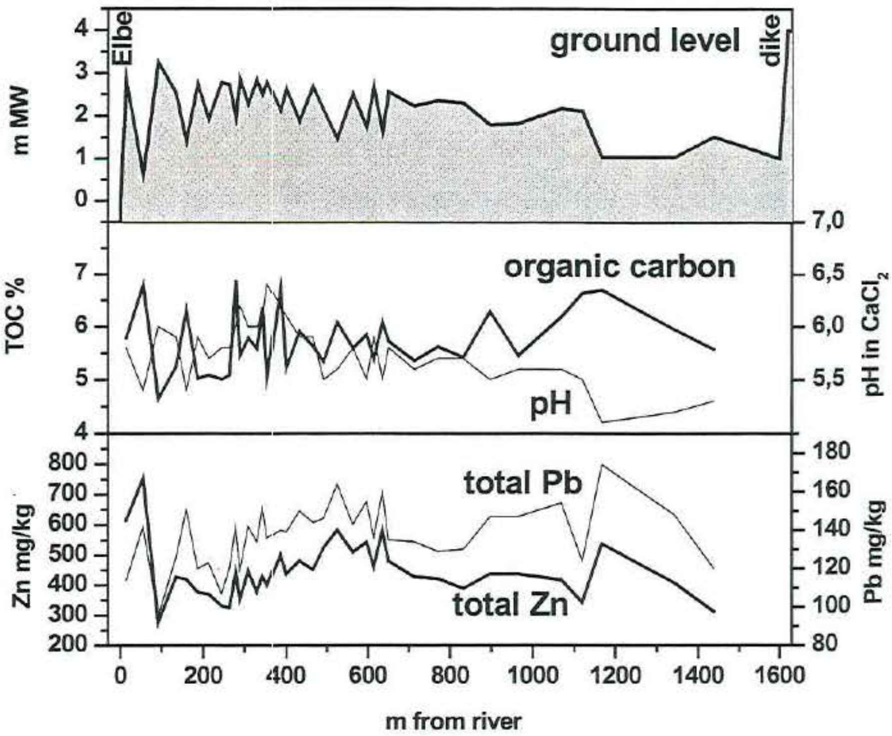

Figure 1: Ground level, top soil properties and contamination with Pb and Zn at site W

soil concentration of zinc is regarded as an indicator for contamination with other substances. With multiple regression analysis on data of all Elbe sites, the zinc content could be predicted with $r^2=0{,}764$ using the independent variables GL, TOC, pH and distance from river (D) ($Zn=-370 + 60{,}5*TOC - 116{,}0*GL + 146{,}5*pH - 0{,}217*D$). The observed variability of top-soil metal contamination thus can be reduced markedly, if simple topographical and pedological factors are taken into account.

4. Meaning for risk potential

The transfer of metals in the food web is correlated with the mobility of the elements in the soils being measured by NH_4NO_3-extraction. For the example of Cd the mobile proportion exceeds 40 % of the total content at the lowest pH of 4.0. Four processes of metal uptake are responsible for the contamination of plants and foodstuff in the floodplains. In comparison with the EU directive on maximum levels for contaminants in foodstuff the contamination of plant samples is critical for As, Cd, Hg and Pb. The variability of soil contamination as well as of the transfer processes has to be known to react with effective actions on the soil use by measures being required by law.