Spatial Variability of Total and Bioavailable Zn in the Canton of Fribourg, Switzerland

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Introduction

Zinc is an essential element for all life, and soil is the primary source of Zn to plant, animal and human nutrition. Maps illustrating the spatial distribution of total and plant available Zn should contribute to the improvement and sustainability of agriculture and livestock production, to improvements in diet quality, and to a better understanding of the nature and extent of plant, human and animal Zn deficiencies. Maps will be useful in considering the consequences of land application of Zn-laden solid waste from agriculture and sewage sludge.

Micronutrients in soil are necessary for plant nutrition, but their high content may provoke phytotoxicity and to stop biological transformation in soil of other nutrients (N and P). Heavy metals in trophic chain are hazardous for human health. Tests using plants, however, are time consuming. Chemical extraction is an alternative way of resolving bioavailability problem (in our case water extraction and DTPA method for micronutrients determination).

Main objective of the investigations was to obtain some spatial relations between bioavailable and total forms of soil zinc and to assess the possibility of transfer of Zn from soil with high Zn concentration (polluted soils) to soils with lower concentration.

Materials and Methods

Investigations have been carried on 250 soil samples from the soil monitoring network FRIBO (**Fri**bourg **Bo**den) in the canton of Fribourg, Switzerland (JULIEN and MORAND, 1997). Between 1987 and 1991, 250 observation sites were established, each site representing 400 hectares of agricultural land - 46 sites are located on high altitude summer pastures, 69 on permanent meadows and 135 on cultivated land.

Water extractable Zn was determined by sampling soil suspension (soil/solution ratio 1/10 obtained with ultra pure water) in 250 ml polyethylene vials that had been mixed on a rotating agitator for 3 days until constant concentration of Zn in soil solution. Aliquots of the suspension were sampled with a syringe and filtered by 0,2µm Sartorius filters. Zn content in soil solution was measured by ion chromatography (Dionex system DX 500). Zn extractable in DTPA was determined by procedure described by LINDSAY and NORVELL, 1978 by AAS.

Results and Discussion

The spatial distribution of potentially toxic elements in soil is not uniform. Uneven distribution within underlying rocks, and variation in airborne pollution, and the spreading of waste add to its heterogeneity. Evaluating the risk of soil pollution must involve investigation of spatial distribution of possible contamination.

The soil varies from place to place, and it is apparent from many studies that variation of its properties is almost always spatially correlated at some scale (WEBSTER and OLIVER, 1990).

Higher content of total and bioavailable Zn was found in mountain regions of the canton (*Table 1*). Average values for total Zn (*Table 1*) increase with increasing soil sampling altitude, from 42.2 mg kg^{-1} for cultivated land (average altitude 624 m) to 62 mg kg^{-1} in alpine pastures (average altitude 1275 m). It can be related with high Zn content in parent rock of concerned soils. No pollution from human activity was found. The mean concentration of Zn in HNO_3 is 48.5 mg kg^{-1}, and maximum is 143 mg kg^{-1}. Compared with a guide value of 200 mg kg^{-1}, they present no problem for agriculture use and human health (FOEFL, 1987). Results with similar spatial distribution were obtained for Zn DTPA and water soluble Zn.

Table 1: **Comparison of some soil characteristics as depend of agriculture utilization**

Values	Altitude m	pH	Zn $_{HNO3}$ mg.kg^{-1}	Zn $_{DTPA}$ mg.kg^{-1}	Zn $_{H2O}$ mg.kg^{-1}
Alpine pastures					
Max	1590	7.4	143	24.4	0.435
Min	770	4.7	20.5	0.4	0.024
Average	1275	6	62	4.1	0.119
Median	1314	5.9	52.6	2.42	0.105
Permanent meadows					
Max	1290	7.7	114.0	7.7	0.318
Min	460	5.1	28.8	0.4	0.024
Average	795	6.3	52.6	2.6	0.091
Median	820	6.3	51	2.43	0.076
Cultivated land					
Max	995	8	107.8	9.5	0.308
Min	433	5.2	20.5	0.4	0.017
Average	624	6.5	42.2	2.0	0.082
Median	635	6.4	38.8	1.63	0.073

Table 2: **Comparison of some soil characteristics as depend of pH range**

Values	Altitude m	*pH*	Zn $_{HNO3}$ mg.kg^{-1}	Zn $_{DTPA}$ mg.kg^{-1}	Zn $_{H20}$ mg.kg^{-1}
pH 4.7-5.5					
Max	1580	*5.5*	67.2	5.87	0.332
Min	568	*4.7*	20.5	0.44	0.041
Average	1071	*5.3*	46.3	2.44	0.149
Median	1150	*5.3*	46.9	2.39	0.143
pH 5.6-6.5					
Max	1520	*6.5*	125.4	9.51	0.318
Min	433	*5.6*	20.5	0.42	0.020
Average	768	*6.1*	46.0	2.11	0.088
Median	730	*6.1*	42.2	1.78	0.081
pH 6.6-7.0					
Max	1590	*7.0*	141.6	17.65	0.435
Min	435	*6.6*	27.6	0.47	0.024
Average	798	*6.7*	53.2	3.56	0.083
Median	690	*6.7*	46.3	2.19	0.067
pH 7.1-7.5					
Max	1461	*7.5*	143.0	24.39	0.134
Min	433	*7.1*	28.5	0.42	0.017
Average	697	*7.3*	57.1	3.37	0.065
Median	675	*7.4*	53.0	2.08	0.059
pH 7.6-8.0					
Max	713	*8.0*	70.1	6.50	0.163
Min	433	*7.6*	29.9	0.67	0.044
Average	551	*7.7*	45.2	2.27	0.073
Median	550	*7.7*	43.2	1.69	0.058

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Table 3: **Comparison of some soil characteristics as depend of Zn $_{(HNO3)}$ content**

Values	Altitude m	pH	Zn $_{HNO3}$ mg.kg^{-1}	Zn $_{DTPA}$ mg.kg^{-1}	Zn $_{H20}$ mg.kg^{-1}
20-30 mg Zn.kg^{-1}					
Max	1450	7.8	29.9	3.63	0.185
Min	433	4.9	20.5	0.50	0.037
verage	702	6.1	27.1	1.70	0.096
Median	621	6.0	27.7	1.37	0.084
30-40 mg Zn.kg^{-1}					
Max	1465	7.8	39.6	3.64	0.266
Min	433	4.7	30.2	0.42	0.032
verage	662	6.3	35.0	1.61	0.087
Median	612	6.4	34.8	1.53	0.076
40-50 mg Zn.kg^{-1}					
Max	1590	8.0	49.4	8.82	0.435
Min	440	5.1	40.2	0.42	0.017
verage	783	6.4	44.4	2.20	0.091
Median	723	6.3	44.3	1.90	0.075
50-60 mg Zn.kg^{-1}					
Max	1515	7.7	59.4	5.87	0.332
Min	433	4.8	50.2	0.44	0.020
verage	851	6.2	54.3	2.22	0.083
Median	833	6.2	53.9	2.02	0.064
60-70 mg Zn.kg^{-1}					
Max	1580	7.6	69.1	7.30	0.170
Min	470	5.3	60.8	0.60	0.034
verage	976	6.2	64.9	3.16	0.108
Median	876	6.1	64.7	2.89	0.113
>70 mg Zn.kg^{-1}					
Max	1495	7.6	143.0	24.39	0.308
Min	435	5.8	70.1	1.14	0.027
verage	991	6.7	96.1	7.07	0.098
Median	1013	6.6	90.6	5.98	0.088

Results for studied parameters were grouped as depend of soil pH, total Zn content in soil and agricultural use of different soil. Obtained results showed relations between soil pH, water extractable Zn, Zn in DTPA and total Zn content. Higher content of bioavailable forms of Zn spatially correlate with higher content of total Zn in soils. In soils ranged by their total Zn content (*Table 3*), Zn extracted by DTPA increase with increasing total Zn content - r=0.943 (*Table 4*). Water extractable Zn content did not depend as strongly to the total Zn content in soils (r=0.386). High negative correlation of pH of soil groups and water extractable Zn corresponds to the notorious fact of higher metal availability in acid soils.

Table 4: **Correlations between grouped soil samples as depend of pH and Zn $_{HNO3}$ values**

	compared to pH (table 2)	compared to Zn HNO_3 (table 3)
pH	-	0.762
Zn HNO_3	0.339	-
Zn DTPA	0.279	0.943
Zn H_2O	-0.889	0.386
Altitude	-0.937	0.908

Higher total and water soluble Zn content in soil was found mainly in acid soils with higher altitude. That is why transfer of soil particles with high Zn content to the areas with lower altitude is possible due to soil erosion and leaching.

Conclusion

Our study did not find any Zn pollution due to human activity. Spatial distribution of total and bioavailable Zn depends of parent rocks. Use of geostatistical analysis of obtained data will give more precise and detailed view of studied problems and will be useful for a better agronomic and environmental management of Zn.

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