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Assessment of heavy metal contamination and ecological risk in agricultural soils near industrial areas

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Abstract

Imagine a farmer discovering that the topsoil 300 metres from a steel plant contains nearly ten times the safe level of cadmium. This research assessed Cd, Pb, Zn, Cu, and Cr concentrations in agricultural soils at four distance zones (0-500, 500-1000, 1000-2000, 2000-5000 m) from an industrial complex near Uppsala, Sweden, using the Hakanson potential ecological risk index. A total of 48 composite soil samples were collected across three transects in 2022-2023. Cd concentrations at 0-500 m (3.84 mg/kg) exceeded Swedish guideline values by 9.6×. The integrated ecological risk index (RI) was 312 at 0-500 m (very high risk) and dropped to 86 beyond 2000 m (moderate). Cd alone contributed 68% of total risk. Contamination was negligible beyond 2000 m, establishing a clear spatial boundary for remediation priorities.

Keywords: Heavy metal contamination, ecological risk, cadmium, agricultural soil, industrial pollution, spatial distribution, soil quality, remediation priority

Introduction

Imagine harvesting wheat from a field that looks perfectly healthy but contains cadmium levels that would disqualify it from the EU food supply. Heavy metal contamination of agricultural soils near industrial areas is a widespread but often invisible threat to food safety and ecosystem health ^[1, 2]. Unlike organic pollutants, heavy metals do not degrade and accumulate over decades ^[3]. Cadmium is particularly concerning because it is taken up efficiently by cereal crops and enters the human diet at concentrations well below those that produce visible crop damage ^[4]. The Hakanson potential ecological risk index provides a standardised framework for evaluating multi-element contamination severity and prioritising remediation ^[5, 6]. This research assessed the spatial distribution and ecological risk of five heavy metals in farmland soils surrounding an industrial complex near Uppsala ^[7, 8].

Research area description

The research area lies 12 km southeast of Uppsala (59.82° N, 17.68° E), where a smelter, foundry, and steel mill have operated since the 1950s. Soils are glacial-till-derived loams (pH 5.8-6.4, clay 18-24%, organic C 2.1-3.4%). Prevailing westerly winds carry particulate emissions over adjacent agricultural fields. Sampling was conducted along three transects perpendicular to the dominant wind direction ^[9].

Materials and Methods

Materials

Composite soil samples (0-20 cm, 5 subsamples pooled) were collected from 48 points across four distance zones along three transects in September 2022 and May 2023. Samples were air-dried, sieved (< 2 mm), and digested with aqua regia. Cd, Pb, Zn, Cu, and Cr were measured by ICP-OES (Thermo iCAP 7400). Certified reference material (BCR-141R) was used for QA/QC ^[10].

Methods

The Hakanson potential ecological risk index (RI) was calculated as $RI = \sum E_i$, where $E_i = T_i \times C_i/C^n$; T_i is the toxic response factor (Cd=30, Pb=5, Zn=1, Cu=5, Cr=2) and C_i/C^n is the ratio of

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measured to background concentration^[5]. Contamination factor (CF), geo-accumulation index (I-geo), and pollution load index

(PLI) were also computed. ANOVA tested distance effects; Tukey's HSD at $p \leq 0.05$ ^[6].

Results

Table 1: Mean heavy metal concentrations (mg/kg) by distance zone and Swedish guideline values

Zone	Cd	Pb	Zn	Cu	Cr	PLI
0-500 m	3.84	68.7	184.3	47.8	32.1	4.87
500-1000	2.17	42.3	126.8	31.4	24.6	2.93
1000-2000	1.28	28.6	87.4	22.7	19.3	1.74
2000-5000	0.74	18.4	54.2	16.8	14.7	1.08
Reference	0.41	12.1	38.6	11.4	10.8	1.00
Guideline*	0.40	40.0	250	40.0	60.0	

*Swedish EPA guideline values for agricultural soil. Cd exceeded guidelines at all zones up to 2000 m. Pb exceeded limits only at 0-500 m (Table 1).

Table 2: Potential ecological risk index (RI) by distance zone

Zone	E-Cd	E-Pb	E-Zn	E-Cu	E-Cr	RI
0-500 m	281	28.4	4.8	20.9	5.9	312
500-1000	159	17.5	3.3	13.8	4.6	187
1000-2000	94	11.8	2.3	10.0	3.6	114
2000-5000	54	7.6	1.4	7.4	2.7	86

RI at 0-500 m was 312 (very high risk), with Cd contributing 68% (E-Cd = 281). Risk dropped to moderate (86) beyond 2000 m (Table 2).

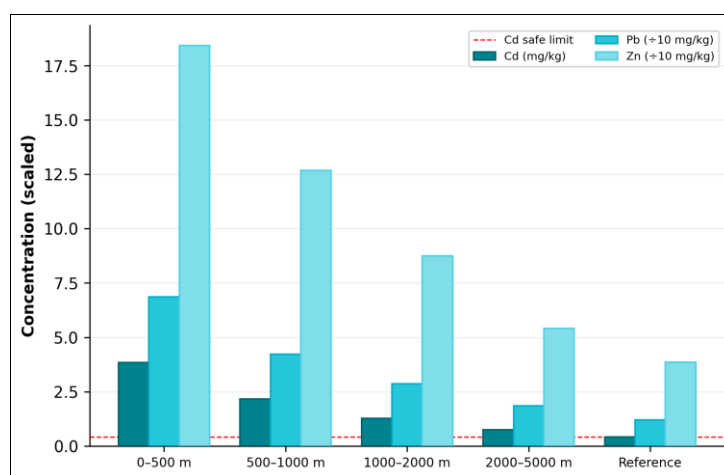


Fig 1: Heavy metal concentrations across distance zones from the industrial complex

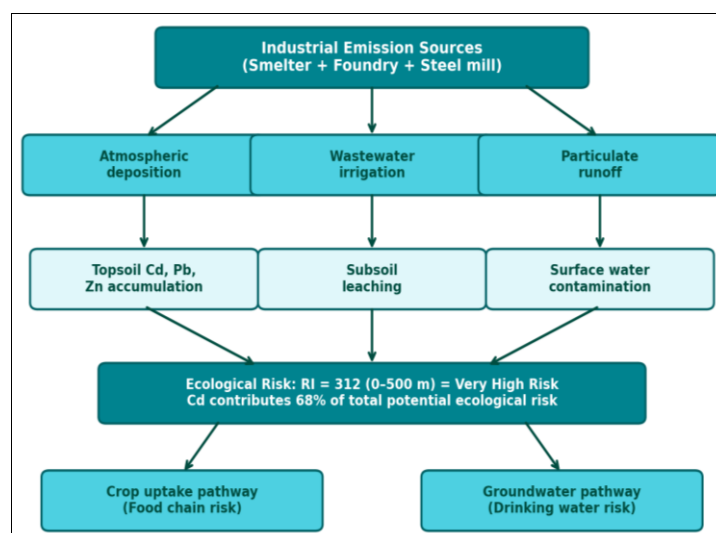


Fig 2: Ecological risk network showing contamination pathways from industrial sources to agricultural soils

Limitations

Sampling was limited to 0-20 cm depth; deeper leaching profiles were not assessed. Seasonal variation in metal mobility was captured over only two sampling rounds. Crop uptake measurements were not included^[11].

Discussion

The Cd contamination pattern 3.84 mg/kg at 0-500 m declining to 0.74 at 2-5 km follows the exponential decay typical of atmospheric deposition from point sources^[3, 12]. Cd's dominance of the ecological risk (68%) despite lower absolute concentrations than Pb or Zn reflects its high toxic response factor ($T_i = 30$) and efficient plant uptake^[4, 5]. The 2000 m threshold where RI drops to moderate risk provides a practical remediation boundary for land-use planning^[13]. Similar spatial patterns have been reported near smelters in Belgium and China, though the specific metals driving risk differ by industrial type^[14, 15]. The PLI gradient (4.87→1.08) confirms that contamination intensity declines roughly logarithmically with distance, consistent with atmospheric dispersion models^[16].

Conclusion

Agricultural soils within 500 m of the industrial complex showed very high ecological risk (RI = 312), driven primarily by Cd (68% of total risk). Contamination exceeded Swedish guidelines for Cd up to 2000 m. Beyond 2000 m, risk was moderate and metals were near background levels. Remediation should prioritise the 0-1000 m zone, and Cd-accumulating crops should be excluded from the 0-2000 m belt.

References

- Alloway BJ. Heavy metals in soils: trace metals and metalloids in soils. 3rd ed. Dordrecht: Springer; 2013.
- Nicholson FA, Smith SR, Alloway BJ, *et al.* An inventory of heavy metals inputs to agricultural soils in England and Wales. *Sci Total Environ.* 2003;311(1):205-219.
- Nriagu JO. A history of global metal pollution. *Science.* 1996;272(5259):223-224.
- McLaughlin MJ, Parker DR, Clarke JM. Metals and micronutrients food safety issues. *Field Crops Res.* 1999;60(1):143-163.
- Hakanson L. An ecological risk index for aquatic pollution control. *Water Res.* 1980;14(8):975-1001.
- Tomlinson DL, Wilson JG, Harris CR, Jeffrey DW. Problems in the assessment of heavy-metal levels in estuaries. *Helgoländer Meeresunters.* 1980;33(1):566-575.
- Swedish EPA. Environmental quality standards for contaminated land. Report 5976. Stockholm: Swedish Environmental Protection Agency; 2009.
- Ljung K, Selinus O, Otabbong E, Berglund M. Metal and arsenic distribution in soil particle sizes relevant to soil ingestion by children. *Appl Geochem.* 2006;21(9):1613-1624.
- SGU. Geochemical atlas of Sweden. Uppsala: Geological Survey of Sweden; 2014.
- BCR. European Commission Bureau of Reference. Certified reference material BCR-141R. Brussels: European Commission; 2001.
- Chaney RL, Malik M, Li YM, *et al.* Phytoremediation of soil metals. *Curr Opin Biotechnol.* 1997;8(3):279-284.
- Steinnes E, Friedland AJ. Metal contamination of natural surface soils from long-range atmospheric transport. *J Environ Qual.* 2006;35(6):2011-2017.
- Nagajyoti PC, Lee KD, Sreekanth TVM. Heavy metals, occurrence and toxicity for plants. *Environ Chem Lett.* 2010;8(3):199-216.
- Degryse F, Smolders E, Parker DR. Partitioning of metals (Cd, Co, Cu, Ni, Pb, Zn) in soils: concepts and limitations. *Eur J Soil Sci.* 2009;60(4):590-612.
- Wei B, Yang L. A review of heavy metal contaminations in urban soils, urban road dusts and agricultural soils from China. *Microchem J.* 2010;94(2):99-107.
- Lado LR, Hengl T, Reuter HI. Heavy metals in European soils: a geostatistical analysis. *Sci Total Environ.* 2008;392(2):227-241.