Journal of Environmental Indicators, 9:17-18, 2015

Heavy Metal Contamination of Soils: Sources, Indicators, and Assessment

HE, Z.,[1] SHENTU, J.,[2] YANG, X.,[3] BALIGAR, V.C.,[3] ZHANG, T.[4] & STOFFELLA, P.J.[1]

[1] University of Florida, Institute of Food and Agricultural Sciences, Indian River Research and Education Center, Fort Pierce, Florida, USA
[2] College of Environmental Science and Engineering, Zhejiang Gongshang University, Hangzhou, China
[3] Ministry of Education Key Laboratory of Environment Remediation and Ecosystem Health, College of Environmental and Resources Science, Zhejiang University at Zijingang, Hangzhou, China
[4] USDA-ARS-Beltsville Agricultural Research Center, Beltsville, MD, USA
[5] Science and Technology Branch, Agriculture and Agri-Food Canada, Ottawa, Canada

Heavy metals are elements with metallic properties and an atomic mass of > 20. The most common contaminants of heavy metal are Cd, Cr, Hg, Pb, Cu, Zn, and As. Heavy metal contamination to soil and the environment has been accelerated in modern society due to industrialization, rapidly expanded world population, and intensified agriculture. Accumulation of heavy metals often results in soil/water degradation and ecosystem malfunction. Moreover, heavy metals enter food chains from polluted soil, water and air, and consequently cause food contamination, thus posing a threat to human and animal health.

Globally, more than 10 million sites of soil pollution have been reported, with >50% of the sites contaminated with heavy metals and/or metalloids (such as arsenic) (Table 1). Heavy metal pollution has a combined worldwide economic impact estimated to be in excess of US $10 billion per year.

Table 1. Soil pollution in the world (EEC, 2007; ADEC, 2010; EPMC, 2014; USEPA, 2014).

Country	Number of pollution sites	% of heavy metal(loid)s pollution
Global	>10000000	>50
USA	>100000	>70
European Union	>80000	37
Australia	>50000	>60
China	1.0 million km^2	>80

Sources of heavy metal pollution include natural processes and anthropogenic activities. Soils may inherit heavy metals from parent materials such as those derived from metal-enriched rocks including serpentine and black shale (He et al. 2005). Anthropogenic sources of heavy metal pollution include mining, smelting, fossil fuel combustion, waste disposal, corrosion, and agricultural practices. For instance, irrigation with industrial waste water has resulted in heavy metal pollution to a large area of arable land and simultaneously led to contamination of millions of tons of grain each year in China.

Many biogeochemical properties/parameters have been proposed and applied to indicate soil contamination with heavy metals. They include, but are not limited to: chemical indicators (total/recoverable content, available/extractable amount, and fractionation); biochemical indicators (enzyme activity, FDA hydrolysis); microbial indicators (microbial biomass, microbial quotient, specific respiration, microbial metabolic quotient and microbial community structure); soil animal indicators (earthworm-quantity and variety); and plant indicators (biomass yield, uptake of metals and metal accumulation in edible parts). However, the most commonly used indicator for soil heavy metal pollution is still total/recoverable content, though extractable amount is often more closely related to plant uptake or availability.

Heavy metal pollution is a global challenge that requires joint efforts of governments, scientists, and communities. Governmental regulations are essential in both source control and pollution remediation. Regulatory standards for heavy metal levels have been established for agricultural soils (Table 2), but wide discrepancy exists among different countries regarding the critical value of each contaminant.

Table 2. Regulatory standards of heavy metals in agricultural soil (mg/kg) (US EPA, 2002; EEA, 2007; TMS, 2007; CME, 2009; EPAA, 2012; NZME, 2012; EPMC, 2015); pH and land use dependent; NZ=New Zealand.

Country	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Australia	20	3	50	100	1	60	300	200
Canada	20	3	250	150	0.8	100	200	500
China	20-40	0.3-0.6	150-300	50-200	0.3-1.0	40-60	80	200-300
Germany	50	5	500	200	5	200	1000	600
Tanzania	1	1	100	200	2	100	200	150
Netherlands	76	13	180	190	36	100	530	720
NZ	17	3	290	$>10^4$	200	N/A	160	N/A
UK	43	1.8	N/A	N/A	26	230	N/A	N/A
USA	0.11	0.48	11	270	1	72	200	1100

Assessment of soil pollution with heavy metals involves sampling of representative soils in a problem area, analysis of metals and related parameters (such as pH), and comparison of soil contamination/pollution quantification against regulatory standards. The most commonly used methods of calculation include Hakanson potential ecological risk index (RI), geoaccumulation index (GI), enrichment factor (EF), Nemero comprehensive index (NCI), and pollution index (PI). Further research is needed to improve regulatory standards and assessment methods.

REFERENCES

Environment Protection Authority of Australia. 2012. Classification and management of contaminated soil for disposal. Information Bulletin 105. Hobart, TAS 7001 Australia.

Canadian Ministry of the Environment (CME). 2009. Soil, Ground Water and Sediment Standards for Use under Part XV.1 of the Environmental Protection Act.

Environmental Protection Ministry of China (EPMC). 2014. National survey report of soil contamination status of China. Environmental Protection Ministry of China, Beijing, China.

Environmental Protection Ministry of China (EPMC). 2015. Standards of soil environmental quality of agricultural land. Huangbanhang 69: Office of Environmental Protection Ministry of China, Beijing, China.

European Environmental Agency (EEA), 2007. Progress in management of contaminated sites (CSI 015/LSI 003), http://www.eea.europa.eu/data-and-maps/indicators

New Zealand Ministry for the Environment (NZME). 2012. Users' Guide: National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health. Wellington: Ministry for the Environment. www.esdat.net.

Tanzania Minister of State (TMS). 2007 The environmental management (soil quality standards) regulations, Vice President's Office – Environment

United States Environmental Protection Agency (US EPA). 2002. Supplemental guidance for developing soil screening levels for superfund sites. Office of Solid Waste and Emergency Response, Washington, D.C. http://www.epa.gov/superfund/health/conmedia/soil/index.htm

United States Environmental Protection Agency (US EPA), 2014. Cleaning up the Nation's Hazardous Wastes Sites. http://www.epa.gov/superfund/