Mobility of redox sensitive elements due to organic matter in contaminated soil; bottom ash and residual waste fraction

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Introduction

According to the EU criteria for waste acceptance at landfills (2003/33/EC), concentration of total organic carbon (TOC) should not exceed 3% for inert waste, 5% for non hazardous waste and 6% for hazardous waste. For waste from incineration (e.g. ashes) the limit is 18% TOC. The lowered limit values might affect the redox conditions and hence, the mobility of redox sensitive elements in landfilled waste. The aim of this study was to investigate the distribution of elements between different chemical fractions in wastes and to investigate OM effect on the mobility of redox sensitive elements.

Materials and methods

Three types of materials representing emerging waste streams to Swedish landfills were used in the experiment: chromium, copper and arsenic (CCA) contaminated soil; bottom ash from waste incineration and residual waste fraction, after material reclamation, containing lots of gypsum. Sequential extraction (Tessier, *et al.*, 1979) and a 3-step leaching test described below were performed on the materials with and without addition of OM (sewage sludge).
3-steps leaching test: soil, ash and residual fraction, respectively were filled in glass bottles in triplicates, mixed with distilled water and sealed with butyl rubber stoppers.

– Air in the bottles was replaced with methane. Bottles were stored in darkness at 30 °C for 2 weeks. After 24 h rotation, redox was measured and 5 ml leachate was sampled.
– The bottles were left open for 50 h until redox had stabilized. Then another 5 ml leachate was sampled.
– OM was added and the air in the bottles was replaced with methane again. The bottles were placed in darkness at 30 °C for 2 weeks. Redox was measured three times during the period. After 24 h rotation, redox was measured and 5 ml leachate was sampled.

Leachates <0.45 µm were analyzed for As, Cr, Cu, Pb, Zn, Fe and Mn with ICP-OES.

Results and discussion

The redox potential in the leachates varied during the 3-steps leaching test (Fig. 1). After addition of OM and 2 weeks incubation (step 3) the redox decreased to levels lower than after 2 weeks initial incubation without addition of OM (step 1).

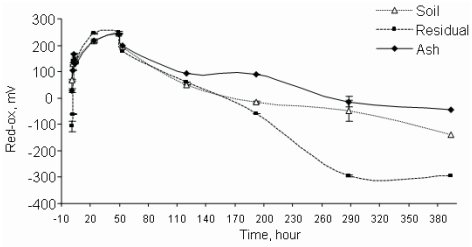

Figure 1 Variations in redox potential in wastes due to atmospheric conditions with and without addition of OM.

Leachability of risk elements varied according to changes in redox potential and OM. Leaching of Cr and Cu decreased in all materials in a reduced environment while the leaching of As and Pb increased (Table 1). The mobility of Zn decreased in soil and residual fraction and increased in ash.

Table 1 Partitioning of elements in wastes according to their leaching pattern under low redox conditions during 3-steps leaching test.

Waste	Decreased mobility (low redox)	Increased mobility (low redox)
Soil	Cr, Cu, Zn	As, Pb
Residual waste	Cr, Cu, Zn	As, Pb
Ash	Cr, Cu	As, Pb, Zn

Arsenic is often bound to redox sensitive Fe and Mn oxides in soil. Increased mobility of As due to addition of OM could be a result of reduced redox potential and a reductive dissolution of Fe and Mn oxides. According to the sequential extraction, the largest amount of Pb in the soil, the ash and a significant amount in the residual fraction was mobilized under reducing conditions. The ash also had a large amount of Zn in that fraction. Pb and Zn have amphoteric properties with minimum of leachability between pH 9 and 10 for Pb and between 9 and 11 for Zn. A successive decrease in pH was observed in the ash samples which also could explain the elevated mobility of Zn and Pb. Lower redox in the wastes with elevated levels of OM caused decreased mobility of Cr, Cu and Zn (except Zn in ash). Those metals occurred mostly in the non- reactive and oxidising phases in the wastes according to the sequential extraction which means that the addition of OM contributed to the immobilization of those elements. The difference between Cr mobility in the samples with and without addition of OM was particularly apparent in the ash. In ash Cr occurs mostly as Cr^{+6}, which is more mobile than the reduced Cr^{+3}.

Conclusions

OM contributed to a reduced environment in specific waste streams and increased the mobility of As and Pb and decreased the mobility of Cr and Cu. Less amount of OM in emerging waste may affect the redox ratio in landfills. Changes in leachate quality should be considered.

References

Tessier, A., Campbell, P.G.C. and Bisson, M. (1979) Sequential extraction procedure for the speciation of particulate trace metals. Analytical Chemistry, vol.:51, n:7, pp:844.