Trace metals in soils and water in the area of a small - medium waste electrical and electronic equipment recycling plant

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Abstract
A research conducted in order to investigate the environmental impact of an e-waste recycling plant to the soil and water resources of the surrounding area. Therefore trace elements in both water and soil samples were determined with Inductively Coupled Plasma – Mass Spectrometry (ICP-MS). Heavy metals in water comply with drinking water criteria, except Pb. Pb, Concentrations of Pb, Cr, Ni, Cu, Mn, Zn were higher in the rainwater collection tank (43.50, 10.90, 18.87, 81.17, 177.99, 330.17 μg/L) than the surficial water inside (8.93, 1.27, 4.97, 17.0, 91.87, 72.97 μg/L) and outside the plant (4.18, 1.28, 1.60, 10.35, 26.21, 12.10 μg/L). Ecological risk of soil samples was assessed with Enrichment Factors. Enrichment factor, for soils showed low to moderate enrichment. The more enriched soil samples in Cu, Pb, Zn, Cd and Hg were two collected west of the company S19 and S20 and two samples collected east S9 and S10.
Keywords: e-waste, WEEE, heavy metals, recycling area; enrichment factor

1. Introduction

The release of heavy metals in the environment has received a considerable amount of attention. Mombo et al.[i] found an increase in lead and cadmium in the soils of gardens close to a lead recycling plant in France due to direct foliar transfer. Owoade et al.[ii] found elevated metal concentrations in the soils of the vincinity of srap yards. Also Rodriguez et al. 2014 [iii] measured high concentrations of Zn and Pb around a spent battery processing facility. Even former industrial areas that have been currently abandoned display high levels of heavy metal concentration as a legacy of their past[iv].

The goal of this study is to characterize the environmental impact of a variety of metals that originate from an e-waste recycling facility, to the soil and water resources of the surrounding area. The aforementioned facility is a small-medium recycling plant where multiple domains of recycling take place: WEEE recycling, end of life vehicles, packaging materials and scrap metals in general. WEEE recycling includes printed circuit boards, and CRT screens.

2. Study Area

The area under investigation (Figure 1) is located in the eastern part of the Greek island of Lesvos, 7 km north of the town of Mytilene. The area consists of quaternary undivided alluvial deposits (grey and red clays, sands, gravels, coastal conglomerates, continental deposits)[v]. The average annual rainfall on the island is 648mm, with the rainy period lasting from October to April. The annual average temperature is 17.6^{o}C[vi]. The company's activities include recycling operations in multiple domains such as: packaging materials, waste electrical and electronic equipment, CRT screens, cables, scrap metals and end of live vehicles. Thus, the plant consists of several subsectors, dedicated to each different recycling process.

3. Materials and Methods

Sampling campaigns took place during the rainy season in early spring of 2016. A total of 8 water samples were collected from 5 streams (W1, W2, W3, W5, W6, W7, Figure 1), 1 well (W4, Figure 1, top right), and 1 sample from the rainwater storage tank of the company (W8, Figure 1). In total, twenty-five surface soil samples (0-10 cm) were collected from the study area. The territory of the S25 sample was chosen as the field blank which was the least affected by weather conditions. Trace elements in both water and soil samples were determined with Inductively Coupled Plasma – Mass Spectrometry (ICP-MS) following standard or widely accepted methods. Further details on the sampling, samples pre-treatment, the analyses and the analytical performance have been reported in Tzoraki et al. 2019.

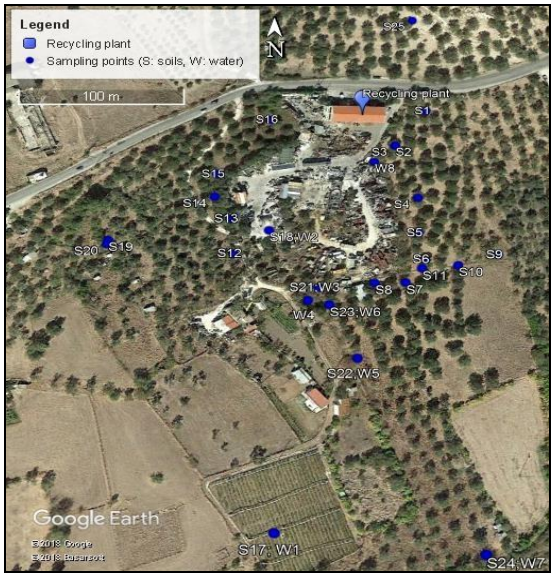

Figure 1 A map of the island with the area of the plant and sampling points (symbols W refer to water samples and S refer to soil samples)

4. Ecological risk- Enrichment factor (EF)

Sediment and soil quality indicators have been used for the assesssment of the accumulation of heavy metals in the sediments and soils. The Enrichment factor (EF) is the ratio of concentration of a target element to a background element. The background element or normalization element is a priori assumed to have no anthropogenic influences, little seasonal variation, and to be inafected by environmental fluctuations (Eq. 1)[vii, viii].

$$EF=(C_i/ C_{ref})sample/(C_i/ C_{ref}) \text{ background} \quad \text{Eq. 1}$$

C_i is the concentration of target element, C_{ref} is the concentration of background element.

This ratio provides with a comparison between the anthropogenic inputs of an element against the inputs of natural (lithogenic, sedimentary e.t.c) origin of the background element. In our work, Li was chosen as the background element. Gong et al[ix]:suggested five contamination categories by usage of the enrichment factor. The background ratio was calculated by a clean sample (S25) taken from the upstream area, that reflects the site background concentrations.

5. Results

Heavy metals in water comply with drinking water criteria, except Pb. Pb, Concentrations of Pb, Cr, Ni, Cu, Mn, Zn were higher in the rainwater collection tank (43.50, 10.90, 18.87, 81.17, 177.99, 330.17 μg/L) than the surficial water inside (8.93, 1.27, 4.97, 17.0, 91.87, 72.97 μg/L) and outside the plant (4.18, 1.28, 1.60, 10.35, 26.21, 12.10 μg/L).

The results of Enrichment factors (EF) of the examined soils of the study area, using normalization to Li, showed that examined soils are moderately enriched in Cu, Pb, Zn, Ni, Cd, Cr and Hg, since median and average Ef values ranged between 2 ≤Ef (Cu, Pb, Zn, Ni, Cd, Cr and Hg) < 5. They are not enriched in As since EFs of As in all samples were below 2. In the study area the more enriched samples in Cu, Pb, Zn, Cd and Hg were soils S9 S10 located in the east side of the company, and S19, and S20 located in the west side of the company.

6. Conclusions

The company's activities do not influence the quality of water samples examined, with the exception of the rainwater storage tank, where Pb, Cr, Ni, Cu, Mn, Zn were higher. Enrichment factors calculations for soils showed low to moderate enrichment. Based on the results of enrichment factors the more enriched soil samples in Cu, Pb, Zn, Cd and Hg were only S19 and S20, that were collected from the west side of the company, and samples S9 and S10 collected from the east side. The Enrichment factors (EF) of the examined soils of the study area showed a low to moderate enrichment in Cu, Pb, Zn, Ni, Cd, Cr and Hg, since median and average Ef values ranged between 2 ≤Ef (Cu, Pb, Zn, Ni, Cd, Cr and Hg) < 5, and depletion in As since EFs of As in all samples were below 2.

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