Urban soil and water leaching processes: implications for human and environmental health

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INTRODUCTION

In Europe, numerous urban sites exist where top layers of soil are enriched in potentially toxic elements. The land uses in urban environment are a matter of concern for human health and food security in cities, also in the context of the growing trend in Europe and elsewhere for using urban soil to grow food [1][2]. Nonetheless, the risk to the subsoil and groundwater may be minimal, depending on the nature and chemistry of the constituents released, as well as on the local conditions [e.g. climate, soil type, chemical conditions (pH, EC, redox and dissolved organic matter), and hydrogeology (permeability, dispersion, preferential flow paths)] [3][4][5].

The evaluation of the variability and mobility of potentially toxic element from contaminated materials and soil into water is essential. Judgment based on dynamic leaching experiments can be a valuable tool to assess long-term impact from contaminated sites. Long-term risk assessment therefore relies on dynamic leaching experiments rather than in assessing the maximum potential release capacity in equilibrium conditions, based on the total soil composition.

In this study, the release of inorganic constituents from soils is assessed for different urban allotment soils from Scotland [4] and Portugal [6] using soil-column laboratory facility for tracer tests, for which the methodology is described in [7]. The release of inorganic constituents (metals) into waters provide the boundary conditions for the analysis of implications in human and environmental health, namely through plant uptake in urban allotments.

METHODS

This research is focused on sensitive land uses in urban environments, namely urban allotment gardens of Scotland and Portugal. It refers to laboratory experiments conducted to assess the urban soil retention capacity.

Urban allotment gardens opportunities and threats came from environmental impacts of:

- The city on allotment gardens;
- The allotment gardens on the city.

Figure 1 – Urban soil within the city pressures

Table 1 – Urban soil allotments: opportunities and threats

	Opportunities (e.g.)	Threats (e.g.)
flora	Biodiversity increase	Invasive species
fauna	Green corridors (bugs)	Plagues
soil	Soil improvement	Soil pollution; food security
water	Increase infiltration/buffer zones	Water pollution
Social bhv	Improve management strategies	Bad use of chemicals

Leaching tests using LNEC soil-column facility allowed the determination of the dynamic contaminant concentration in water as it percolated the soils analysed.

In the leaching tests, the natural water dynamic of the porous formation dictates the solid/liquid contact time, and therefore the mass transfer rate into the aqueous phase, giving a more realistic pollutant leaching value.

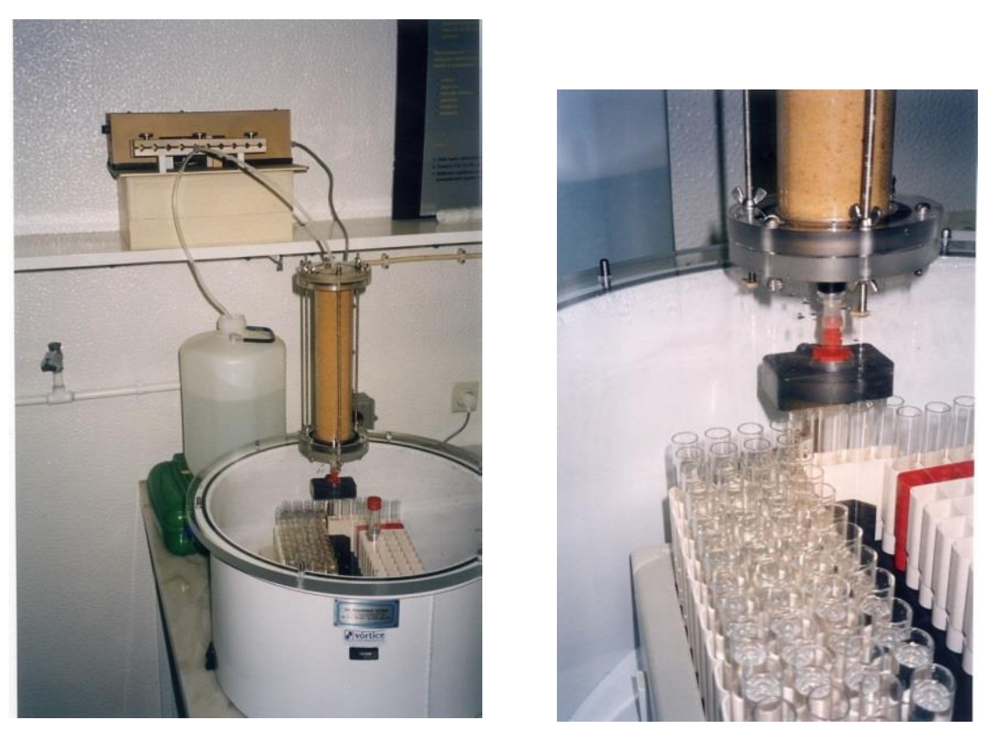


Figure 2 – LNEC soil-column facility at LASUB, http://www.lnec.pt/organization/dha/nre/laboratorios_equipamentos

RESULTS

Table 1 presents the main characteristics of the soils used. LNEC soil is composed of sands (68.2-54.7%), with some clay and silt (31.8-45.3%), from top to bottom. The organic matter content is 1.7-1.5%, for top to bottom. UWS_LH is a rock rich waste with high carbonate from the rock in the mineral deposit hosting a ore which is mined.

The results obtained are shown in the Figures 3 and 4.

Table 1 – Soil characteristics

Soil	Porosity	Apparent density (g/cm3)	Weight of dried soil sample (g)	Water in soil sample (cm3)	Flow rate (ml/min)	K (Darcy) (m/d)
LNEC Zn	40.8	1.48	871.6	240.2	0.29	0.22
LNEC Cu	38.7	1.48	870.0	227.8	0.27	0.20
UWS LH&W	35.0	1.80	1059.8	206.1	0.28	0.21

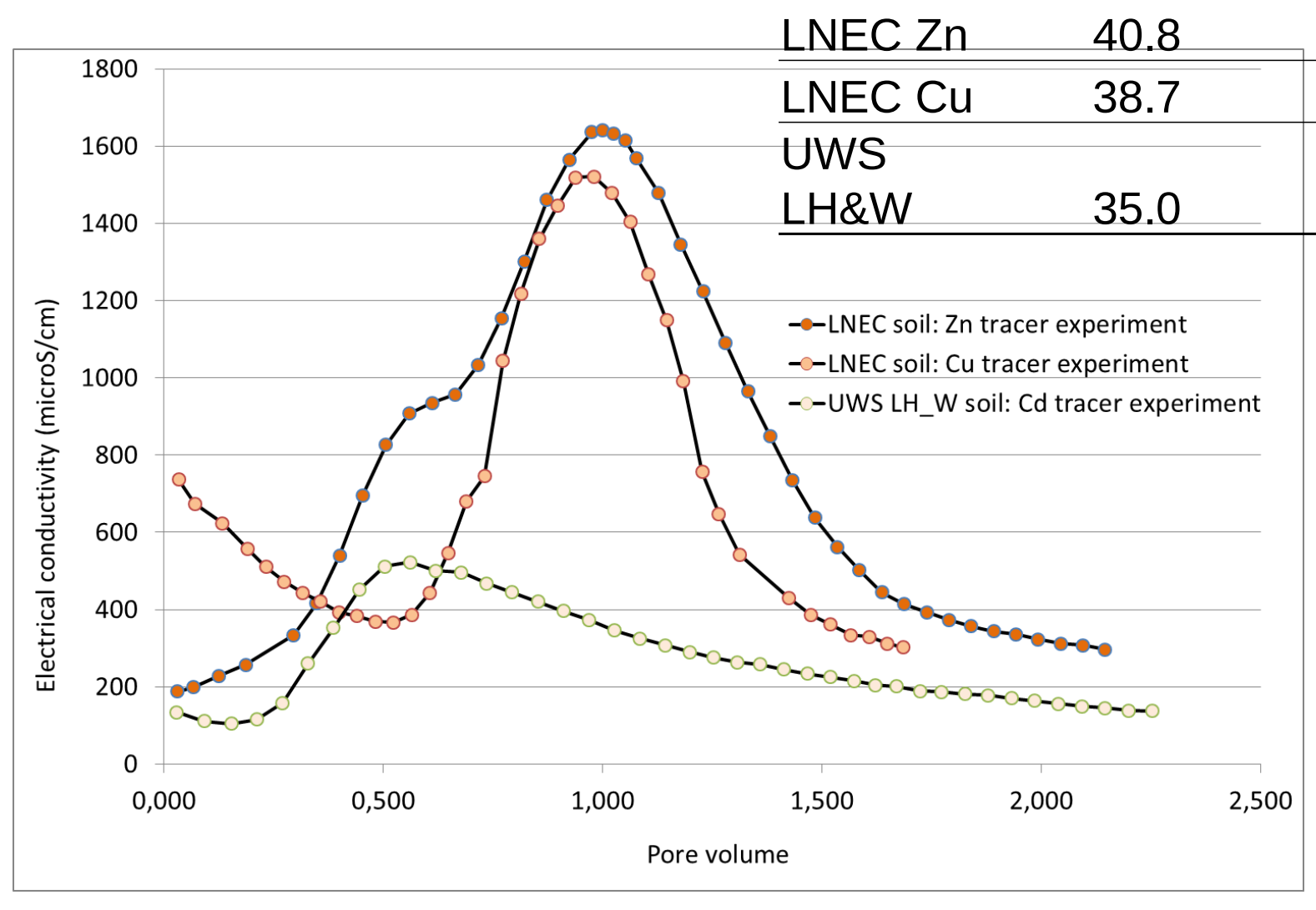
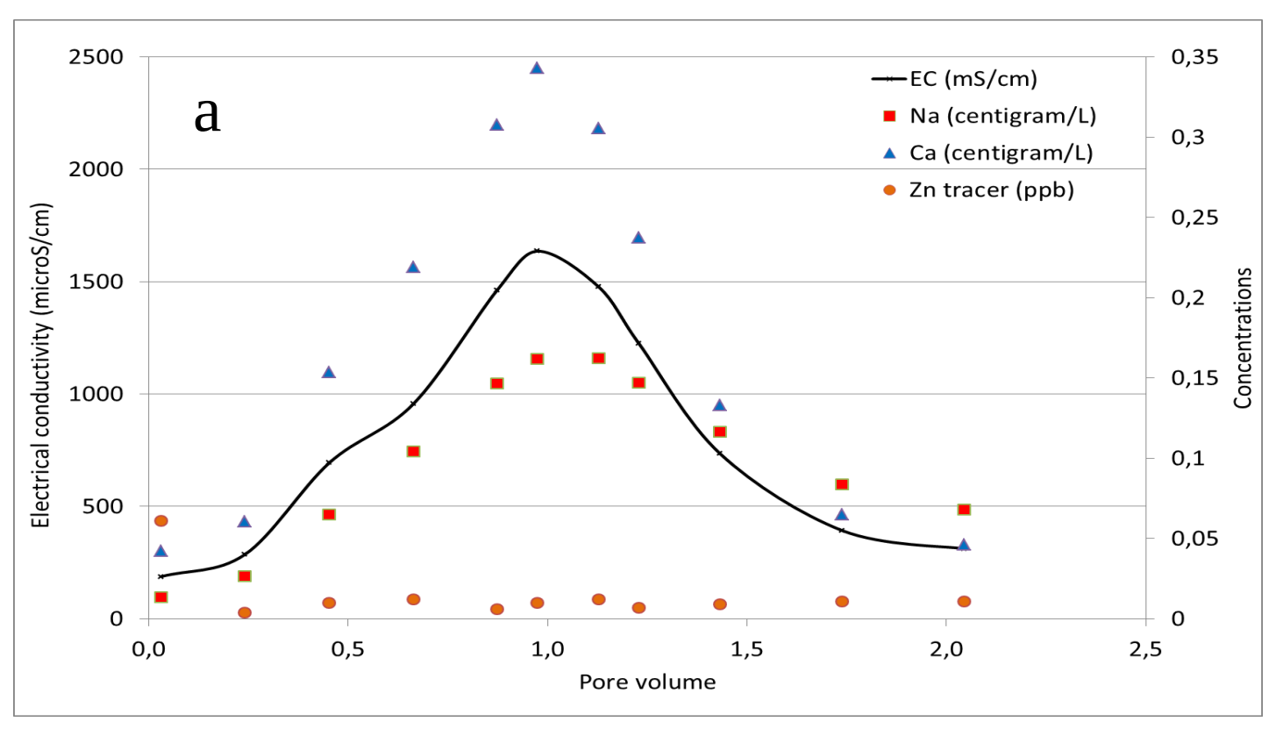


Figure 3 – Electrical conductivity variation in the outflow water along three tracer experiments



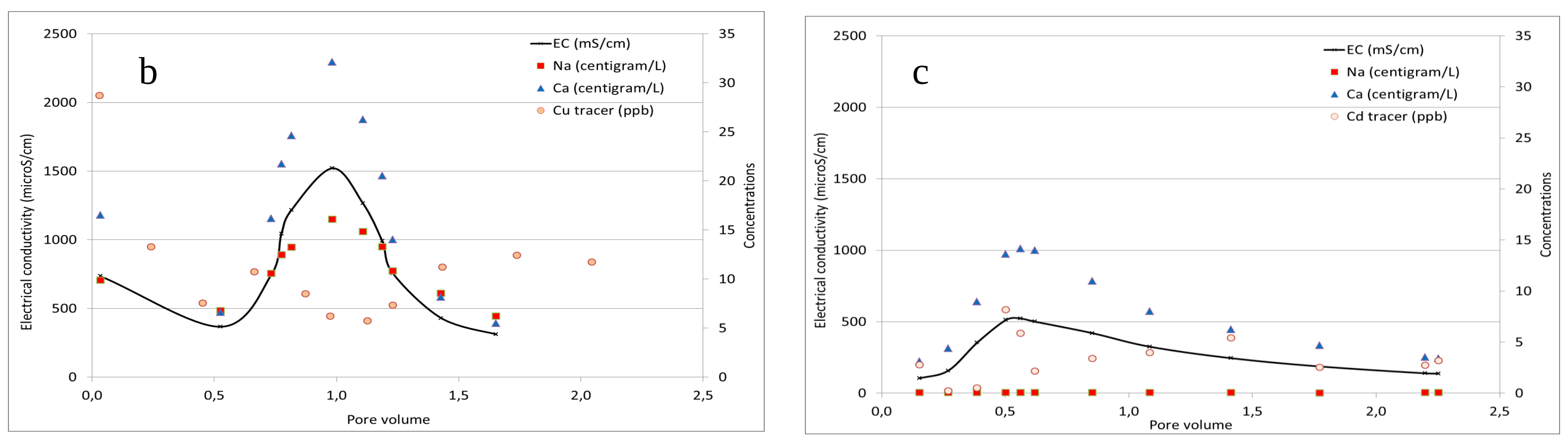


Figure 4 – Electrical conductivity and metal concentration variation in the outflow water along tracer experiments

DISCUSSION

The results obtained (cf. Figure 3) allowed concluding that:

- LNEC allotment soils (Cu and Zn tracers) show sharp peak of electrical conductivity (and Na and Ca), reproducible between two different experiments, with similar velocities, but a dispersion value higher during the Zn experiment;
- UWS_LH mining soil shows lower strength (due to the less EC of the tracer), and smoothed and slower migration (with no Na), and much higher dispersion coefficient.

Figure 6 presents the depth distribution of metal tracer on leached soil columns, in the portions indicated in Figure 5.

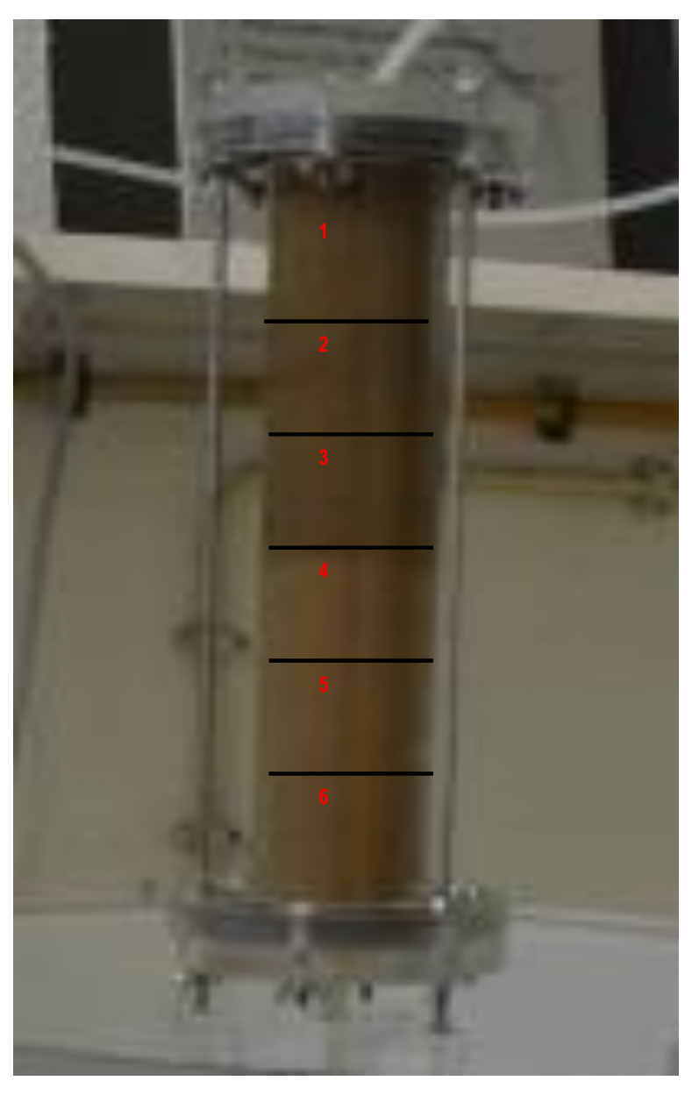
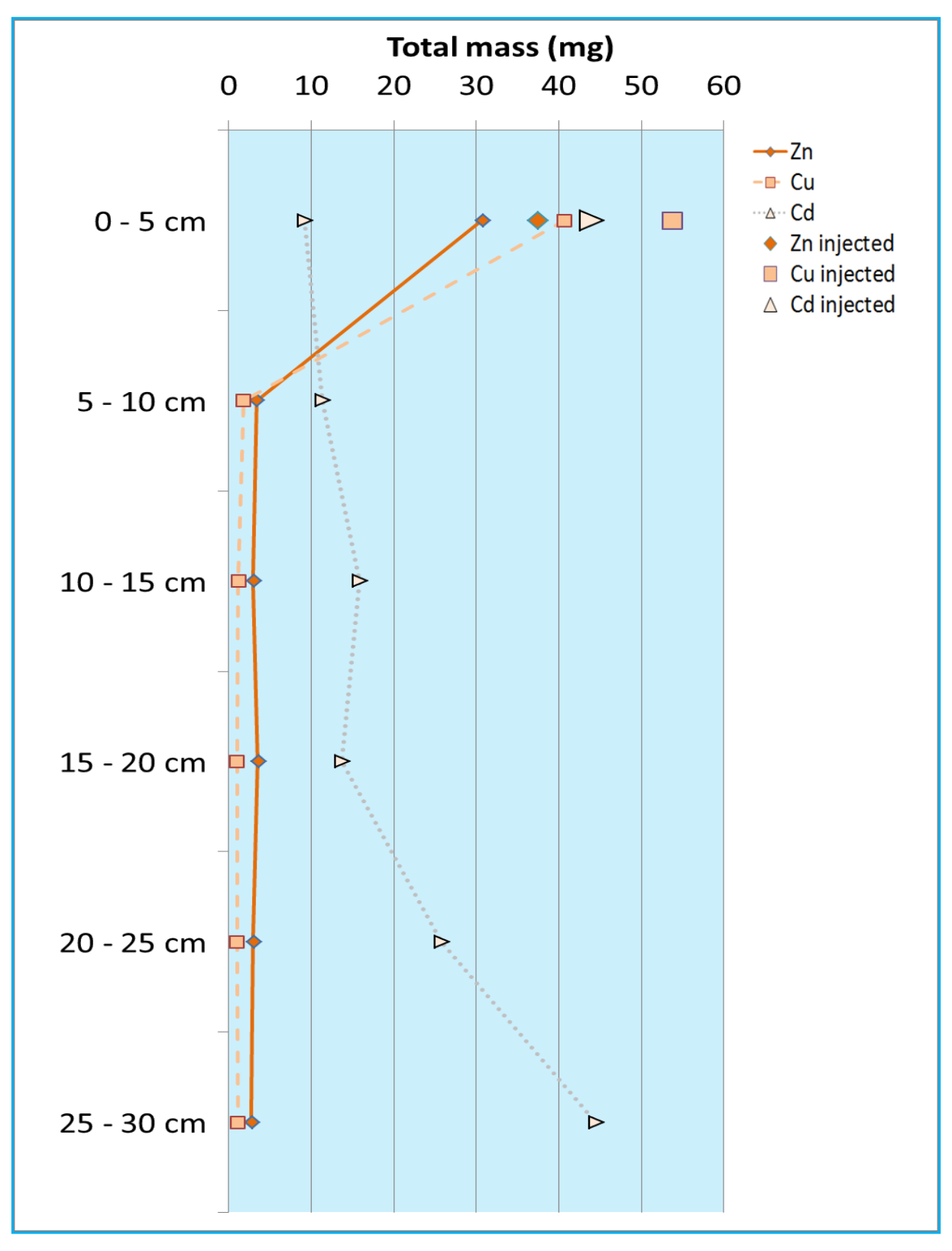


Figure 5 – Soil-column portions analysed



This figure shows that in LNEC urban allotment soils the metals are retained in the first 5 cm of the soil, whereas in Scotland mining soil the tracer migrates to the lower parts of the column

Figure 6 – Depth distribution of total metal tracer mass recovered from leached column slices

Table 2 – Original soil concentrations in heavy metals, electrical conductivity and pH

	(mg/kg)					(mS/cm)
	Zn	Cu	Cd	Pb	pH	EC
LNEC Zn	0.23	0.06	0.02	0.38	9.27	43.4
LNEC Cu	0.26	0.06	0.02	0.38	9.20	39.4
UWS _LH mining	135.54	3.45	0.82	180.6	9.07	38.5

This table shows the original heavy metal concentrations in the soil. Higher heavy metal content is recognized for UWS _LH mining

Figure 4 and 6 show that:

- For both of the LNEC soil allotment experiments, Zn & Cu are enriched in the surface layer;
- For UWS_LH mining soil, Cd tracer shows deeper migration through the soil column;
- A simple mass balance for each tracer shows for Zn and Cu > 66% of the added tracer is retained in the upper 5 cm of soil. For Cd ~50% of the added tracer recovered in the lower parts of the column;
- Zn is less mobile than Cu;
- The % Zn vs. Cu recovered in the outflow water is 100 x higher for Cu, but both are below 0.02%;
- Lower Zn mobility could be linked to its adsorption to clay minerals and/or to Fe and Mn oxides (Figure 4a);
- Cu higher mobility should be linked to soluble organic matter (Figure 4b);
- UWS_LH mining soil high calcium carbonate content renders Cd less available;
- Soil metals release with time is high for UWS_LH mining soil and it is likely it continues due to dissolution kinetics (Figure 4b).

CONCLUSIONS

In this paper urban allotments soils of Portugal and Scotland, with accumulated effect of the existing and past urban pollution, were used to:

- Determine the existing heavy metals concentrations;
- Evaluate their retention capacity in hypothetic pollution episodes, using tracer experiments in soil-column, and therefore their ability to:
  - Migrate further to groundwater or
  - Retain in soil and be available for plants and/or human contact.

The results allowed us to conclude that:

- LNEC soils are non-polluted and have a strong heavy metal retention capacity in the first soil centimetres;
- UWS_LH mining soils are moderately polluted and have a very small capacity for retaining Cd. The risk for groundwater pollution is higher.

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