Evaluation of ASR landfill impact through lysimetric tests

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Abstract

With regards to European waste, Catalogue ASR can be classified both as a hazardous or non hazardous waste according to its hazardous properties (H1-H14). It is thus important to carry out an adequate chemical-physical characterization to identify the presence and concentration of those substances able to give, to this extremely heterogeneous material, the hazardousness character of.

The issue of waste characterization, to identify the proper site for appropriate waste disposal, is based, according to the relevant laws, to the use of leaching tests. The analysis of the potential effects of landfilled waste in laboratory, however, run into several difficulties in reproducing phenomena depending both on the characteristics of small, heterogeneous quantity of waste and on the local boundary condition. These difficulties are much more significant as the waste is heterogeneous at the small scale of the laboratory. This is one of the main problem often leading to scattered results even when starting from the same waste parcel.

Present research aimed to overcome the above mentioned difficulties deriving from waste heterogeneity and was based on a lysimetric simulation. Experimentation with lysimeter has shown it effectiveness in the comparison between leachate from the Lysimeter and a fluff landfill leachate, from which similar distribution of metals mass ratios, close values for both BOD_5 and COD, as well as the absence, in both the fluids, of organochlorinated compounds, emerge.

Keywords: *ASR, fluff, landfill, leachate, metals*

1. Introduction

In Europe and in many industrial sectors of the world, end-of-life vehicles (ELVs) are collected and partly dismantled. Vehicles arrive at an authorized treatment facility (ATF) as the result of an accident (premature ELVs) or because they reached the end of their useful lives (natural ELVs) [1]. The remaining wreck is shredded. This results in several recovered material streams: ferrous materials, aluminium, copper, zinc, stainless steel. and automotive shredder residue (ASR, which consists of mainly nonmetallic materials).

Recycling in car wrecking is thus mainly focused on metallic fraction recovery constituting about 75% in weight of the vehicle that is profitably utilized as second first matter to new steel production [2,3].

The remaining 25% after the majority of the metal content has been removed, is called fluff or ASR (Automative Shredder Residues) and it is mainly intended for landfill disposal. It generally consists of a heterogeneous mix of glass, plastic, rubber, oil, petrol, coolant additives, brake fluid, some metals, stones, mud, felt and other natural fibre, wood, water and general road dirt [4].

The percentage of each material within the ASR is highly variable due to the inconsistent state of vehicles at the end of their life. The use of materials such as plastics and aluminium in automobiles has however increased, over the last years, at the expense of ferrous metals, because the former are lightweight and have some desirable mechanical and physical properties resulting in the reduction of the total mass of the car and of its fuel consumption. The use of plastics increased by 50% over the past 20 years; the EU-Directive on ELVs might stimulate, however, using aluminium rather than plastics, as the recycling of aluminium is easier and more cost effective [5].

There is a growing concern about the environmental impact of ELVs as the amounts of ELVs generated are expected to sharply increase after the economic crisis of the last decade and because the waste generated during the final treatment may still contain hazardous compounds. The interest in choosing the proper way of disposal for or Automotive Shredder Residue (ASR) has grown, at European level, with the coming into force of the directive 2000/53/EC on the end of life vehicles (ELV) and the directive 1999/31/EC on landfills [6].

However, nowadays, with the exception of a minority fraction converted into recyclable materials [7] or simply burned, the remaining ASR is currently disposed in landfills, both in EU member and non-member states [8].

In Europe, ASR can be classified as hazardous waste according to the list of hazardous wastes 2000-532-EEC. It is thus important to carry out an adequate chemical-physical characterization to identify the presence and concentration of those substances able to give, to this extremely heterogeneous material, the hazardousness character of.

The issue of waste characterization, to identify the correct site for appropriate waste disposal, is based, according to the relevant laws, to the use of leaching tests [9]. The analysis of the potential effects of landfilled waste in laboratory, however, run into several difficulties in reproducing phenomena depending both on the characteristics of small, heterogeneous quantity of waste and on the local boundary condition [10]. These difficulties are much more significant as the waste is heterogeneous at the small scale of the laboratory. This is one of the main problem often leading to scattered results even when starting from the same waste batch [1]. summarized leaching results for different ASR fractions and compared them to the European limit values for non hazardous waste. They concluded that there is a very large variety among the different literature sources and no unambiguous conclusion can be made. The authors highlight as further research concerning contaminants leaching of heavy metals from ASR and from its different fractions (subdivided by origin and/or size) is necessary to correctly assess its hazardous nature [11].

Present research aimed to investigate the leaching behaviour of this waste showing marked heterogeneousness characteristics at the small (laboratory) scale.

Research activity developed along two main approaches. First, an accurate characterization of the waste was carried out [12], both on the solid matrix and through the use of different leaching tests, according to the previous [13] and more severe leaching test and current (less severe leaching test) Italian regulation on waste classification for landfill disposal (Italian Decree 36/2003). The second research approach, aimed to go beyond the above mentioned difficulties caused by waste heterogeneity and was based on a long-lasting lysimetric simulation.

2. Materials and methods

2.1 Sampling and pre-processing of the ASR

The ASR was collected directly from a steel production plant located in Sicily and transported to the University laboratory over several sampling days (about 100 kilograms/sample for 10 samplings over 3 weeks). Samples of about 1.2 ton were mixed and quartered by the ring and cone method in order to get a material as independent as possible from the specific lot treated each day. A particle size analysis was carried out and, to further reduce the ASR heterogeneousness, samples to be analysed were also reconstructed according to the mass ratios of the different particle-size fractions. Particle size distribution was determined using standard sieves to separate bulk ASR into the following particle size fractions d < 5 mm, d < 10 mm, d < 20 mm d > 20 mm.

2.2 Solid samples characterization

Analysis were carried on the fluff solid matrix to evaluate metals concentration as well as other anions and cations concentration, pH, electrical conductibility, moisture content, lower calorific power, apparent density, TOC, dioxins, free cyanides, phenols and PCB. Metals determination, both on solid and liquid matrix (dilution ratio 10 to 1), were carried out by ICP-OES (Perkin–Elmer Optima 4300DV) analysis of the liquid solutions as obtained through acid digestion (1:3 v/v concentratedHNO_3 + HCl solution). Total organic carbon (TOC) was analysed by a Shimadzu TOC-V CSH/CSN analyser. Metals determination both on solid and liquid matrix (dilution ratio 10 to 1) were carried out by ICP while Anions and cations were detected by ionic chromatography.

2.3 Standard leaching test

Standard Leaching tests were mainly aimed to evaluate heavy metals release from the examined material. Operative conditions for each of the tests, carried out in triplicate, were differentiated [14] for waste quantity, liquid/solid ratio, waste size distribution, contact time, solution pH, extracting solution and mixing velocity (Table 1). Ultra-pure water with electrical conductivity less than 16 μS/cm was utilized for all the leaching tests and reagents preparation. Ultra-pure water was prepared through a reverse osmosis Millipore system coupled with ionic exchange cartridges. All the utilized reagents were of an analytical grade (Carlo Erba, Milan). Leaching solutions were vacuum filtered through membranes of 0,45 μm, acidified by nitric acid to pH 2 and kept, in propylene bottles, at a constant temperature (4°C) untill the analysis time. pH, electrical conductivity, redox potential were measured directly on the filtered leaching solution. Metals were analysed through ICP-OES (Optima 4300 DV, Perkin Elmer, Ca).

Table 1: Leaching tests operating conditions.

Test (leaching solution)	pH	Contact time	Sample characteristics	Liquid to solid ratio	Mixing
Acetic Acid	pH = 5 ± 0,2	24 ore	100 gr.; ϕ< 9,5 mm	16	Not indicated
Carbonate water	pH = 4,5	6	100 gr.; ϕ < 9,5 mm	20	40 rpm
Demineralised water (UNI 10802)	Not controlled	24 hours	100 gr.; ϕ < 4 mm	10	Not indicated

2.4 Lysimetric Test

Standard laboratory leaching tests require the waste to be put into intimate contact with an extracting solution to rapidly reach the equilibrium, within the test duration.

Wastes are thus crumbled to increase specific surface and solutions are mixed to increase turbulent dispersion coefficient so to accelerate the leaching process [15]. This is however far from landfill conditions where leachate retention time and solid/liquid contact, within the waste heap, is sensibly different from usual laboratory operating conditions.

Based on the previous considerations a large lysimeter (0.8 m wide) was specifically designed to simulate the landfill behaviour of the considered waste. Large lysimeters are experimental systems commonly utilised to carry out agronomic studies [16] and somentimes even in waste research activities [17]. The lysimeter geometry was conceived to have a sufficiently large volume with respect to the waste characteristic dimensions. Three independent segments subsequently coupled by flanges (Figure 1) were designed to better control simulated landfill conditions.

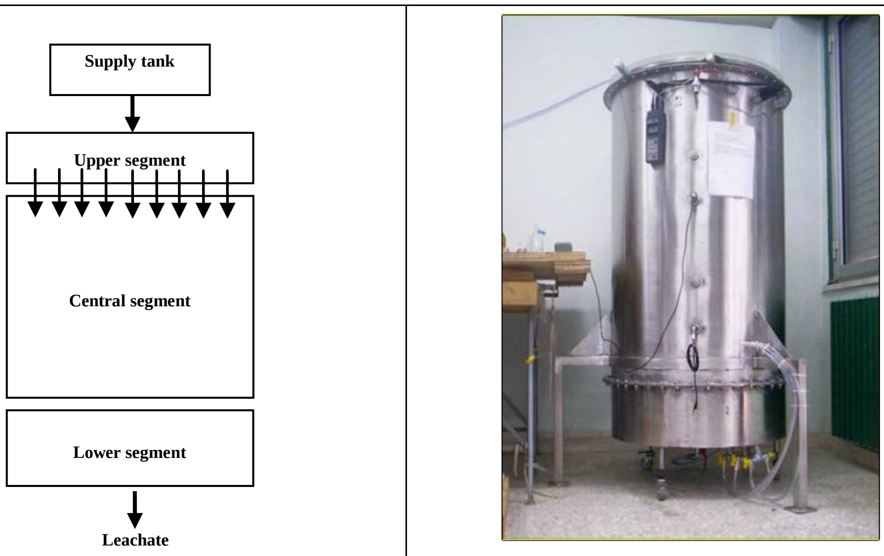
Lysimeter, 100% steel made (inox 316), has a circular section (80 cm diameter) and it is equipped with temperature, pressure and humidity probes, as well as with several valves for solution extraction and biogas sampling. Central segment contains two layers, 40 cm thick, of fluff separated by a sand covering layer (10 cm thick). The first layer required about 150 kg of fluff (r=0,75 ton/m^3) while the second about 160 (r=0,80 ton/m^3). The lower segment is split into the three annular sectors, hydraulically separated, all of equal surface The annular sectors were conceived to identify potential not uniform behaviour of the filtration process in hydraulic and pollutants migration terms as well as the influence of lysimeter walls. A central funnel was also included, with a surface of 1/10 of the central sector from which leachate could be collected directly without going through the lower gravel filter.

Two solution were utilized during the test:

- Demineralised water with a pH of 7 (first 22 days);
- CO$_2$ saturated water (carbonate water) with a pH of 4 (22°-85° day);

Measures of water volumes adsorbed by the waste, of metals release (Cd, Co, Cr, Fe, Ni, Cu, Pb, Zn), as well as of several physical-chemical characteristics (pH, redox potential, electrical conductivity, temperature) were continuously carried out over the entire monitoring period.

Leachate from the central sector (funnel) was also analysed for detecting dioxins and PCB presence [4,18]. Further measured parameters were chlorides, sulphides, nitrates, fluorides, Ammonia, organic Nitrogen, free cyanides, COD, BOD$_5$ and TOC.



Lysimeter layout **Lysimeter with instrumentation**

Upper segment **Lower segment**

Figure 1: Lysimeter design main features.

3. Results and discussion

3.1 Solid samples characterization

Results from solid samples characterization (2 samples) are shown in Table 2 and Table 3. Metals concentration in solid samples were well in line with those in literature [19,20,1].

Table 2: Characterization of fluff solid samples.

Element (mg/kg)	Samples			Element (mg/kg)	Samples		
	I	II	Mean		I	II	Mean
Fe	35766	34900	35333	Co	20	15	18
Zn	8392	6886	7639	Cd	17	11	14
Pb	3557	2922	3240	Sulphides	149,57	173,91	161,74
Cu	1638	2153	1896	Chlorides	35,44	36,39	35,91
Ni	128	86	107	Nitrates	5,69	5,96	5,83
Cr	118	93	106	Ammonia	0,940	0,558	0,75
As	22	19	21	Fluorides	0,13	0,17	0,15

Table 3: Lower calorific power, apparent density, free cyanides, phenols, TOC, dioxins and PCB in the examined fluff.

Element	Samples	U.M.	Element	Samples	U.M.
Lower calorific power	21688	kJ/kg	1.2.3.4.7.8 HxCDD	< 0,02	ng/kg
Apparent density	0,41	g/cm3	1.2.3.6.7.8 HxCDD	< 0,02	ng/kg
Free cyanides	< 1	mg/kg	1.2.3.7.8.9 HxCDD	< 0,02	ng/kg
Phenol	< 5	mg/kg	1.2.3.4.6.7.8. HpCDD	578	ng/kg
4-Nitrophenol	< 5	mg/kg	1.2.3.4.6.7.8.9 OCDD	4593	ng/kg
2-Chlorophenol	< 5	mg/kg	2.3.7.8 TCDF	55,3	ng/kg
2,4-Dinitrophenol	< 5	mg/kg	1.2.3.7.8 PeCDF	26	ng/kg
2-Nitrophenol	< 5	mg/kg	2.3.4.7.8 PeCDF	22	ng/kg
2,4-Dimethylphenol	< 5	mg/kg	1.2.3.4.7.8 HxCDF	< 0,02	ng/kg
4-Chlorine-3-Methylphenol	< 5	mg/kg	1.2.3.6.7.8. HxCDF	< 0,02	ng/kg
2,4-Dichlorophenol	< 5	mg/kg	2.3.4.6.7.8. HxCDF	< 0,02	ng/kg
2-Methyl-4,6-dinitrophenol	< 5	mg/kg	1.2.3.7.8.9. HxCDF	< 0,02	ng/kg
2,4,6-Trichlorophenol	< 5	mg/kg	1.2.3.4.6.7.8.HpCDF	60,6	ng/kg
Pentachlorophenol	< 5	mg/kg	1.2.3.4.7.8.9. HpCDF	12,5	ng/kg
TOC	53800	mg/kg	1.2.3.4.6.7.8.9.OCDF	91,1	ng/kg
2.3.7.8 TCDD	< 0,02	Ng/kg	Sum PCDD/PCDF	29,5	Ng TE/kg
1.2.3.7.8 PeCDD	< 0,02	Ng/kg	PCB	1,83	mg/kg

Highest concentration metal was iron, by itself constituting 3.5% of all metals present in the fluff. High concentration were also detected of Zinc, Lead and Copper. TOC values slightly exceeded the limits established by 36/2003 (art.3 paragraph 3, point b) for non hazardous waste disposal (*…5% of the chemically active organic substances,…. with exclusion of polymers, resin or other not biodegradable substances*). It must be pointed out, however, as the obtained value of 5.3%, was measured over the entire TOC, thus including all the organic compounds.

All the measured parameters showed concentration values below the limits set by Italian decision 27.07.84 (legislation in force when the examined landfill activity started) thus becoming acceptable, according to the characterization on solid matrix, the disposal of the examined fluff in a non hazardous waste landfill.

The Decree 36/2003 sets limits on PCB and Dioxin concentrations that are not exceeded by the considered waste. As regards this first characterization step, on the solid matrix, the examined fluff could thus be disposed of in a landfill for non hazardous wastes.

3.2 Leaching test

Table 4 shows metals concentration values of leaching solution as obtained from the three leaching tests (mean value of three repetitions for each test). Comparison for the the same parameters is provided with the leachate of a full scale (600.000 tons) mono-material landfill, receiving the same fluff.

Table 4: Comparison between the different leaching tests and the fluff landfill leachate.

Element	Landfill leachate (mg/l)		Leaching test (mg/l)					
			H_2O		CO_2		CH_3COOH	
	Mean	σ	Mean	σ	Mean	σ	Mean	σ
As	0,054	0,011	< 0,0001	0,000	< 0,0001	0,000	14,20	2,272
Cd	0,007	0,006	0,040	0,000	0,040	0,000	0,177	0,021
Cu	0,008	0,007	0,027	0,006	0,050	0,010	5,053	0,299
Fe	2,662	2,164	0,190	0,070	2,153	0,146	115,3	4,726
Ni	0,127	0,079	0,001	0,000	0,010	0,000	0,213	0,006
Pb	0,040	0,009	0,017	0,006	0,017	0,006	0,050	0,010
Zn	0,163	0,191	< 0,0002	0,000	0,002	0,000	0,040	0,000

Results from Table 4 and Table 5 show that all the parameters fall within the limits for the Italian regulation regarding the admission to a non hazardous waste landfill with the exception of COD that exceeds (195 mg/l), in all the analysed samples. This parameter also exceeds the threshold for the admission to a hazardous waste landfill (100 mg/l).

The larger metals extraction by acetic acid is justified by the different metal hydroxides solubility as a function of the pH [21]. The test utilizing water saturated with CO_2 even thought characterized by an acid pH, has not the same extracting efficiency of the CH_3 COOH test. This is partially justified, firstly, by the different operating conditions that do not require a continuous check and adjustment of the pH (carried out only at the beginning), and secondly, by the sensibly lowest contact time (six hours vs. twenty-four). This is further confirmed by the comparison with the test utilizing demineralized water, established by the Italian Decree 13/03/03 and carried out according to UNI 10802. Results from this test are comparable with those obtained with CO_2 even operating with a less acid pH [22]. This is possibly due to the longer contact time and waste higher fragmentation.

When comparing concentration obtained from acetic acid leaching test with limits established by Italian decision 27.07.84 for II category landfill, type B (non hazardous waste), the following conclusions can be drawn:

- Arsenic Mercury and hexavalent chromium show concentrations below the respective threshold values;
- Copper concentration exceeds the limit established for this type of landfill. If the landfill has been designed with sufficient guaranties to prevent pollution, the threshold values can be increased by 10-fold thus allowing the waste acceptance;
- Cadmium and Lead concentration exceed limits for more than ten-fold; thus the waste does not pass the test and can not be accepted by a II category landfill type B (with regards to the old classification).

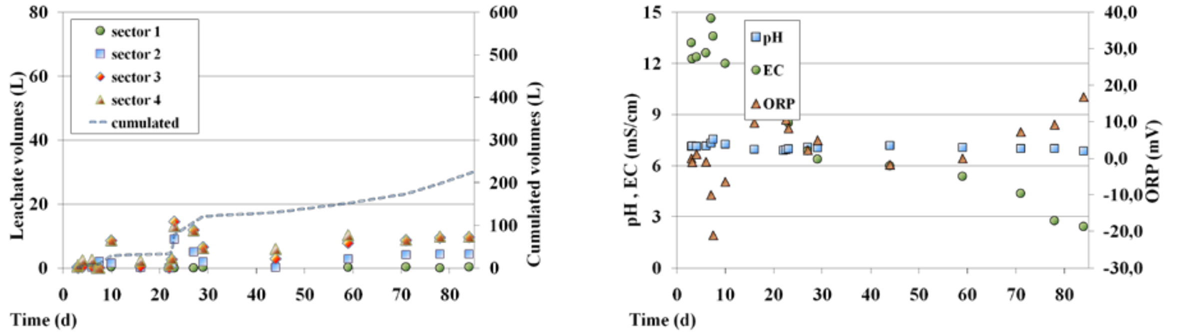
Table 5: Leaching test according to UNI 10802 (demineralised water)

Parameter	**U.M.**	**Sample 1**	**Sample 2**	**Parameter**	**U.M.**	**Sample 1**	**Sample 2**
pH		7,51	7,4	**Chlorides**	mg/l	85	58
eH	µS/cm	984	893	**Fluorides**	mg/l	< 1	< 1
Ba	mg/l	0,13	0,14	**Cyanides**	mg/l	< 0,1	< 0,1
Cr totale	mg/l	< 0,050	< 0,050	**COD**	mg/l	190	205
Hg	mg/l	< 0,005	< 0,005	**TDS**	mg/l	750*	726
Mo	mg/l	< 0,050	0,07	**Sulphides**	mg/l	261	286
Sb	mg/l	< 0,050	< 0,050	**T. Phosph Pesticides**	mg/l	< L.R.*	< L.R.*
Se	mg/l	< 0,030	< 0,030	**Non Phosp.T.Pestic.**	Mg/l	< L.R.*	< L.R.*
Aromatic organic solvents							
Benzene	mg/l	< 0,1	< 0,1	o-Xilene	mg/l	< 0,1	< 0,1
Toluene	mg/l	< 0,1	< 0,1	m-Xilene	mg/l	< 0,1	< 0,1
Ethylbenzene	mg/l	< 0,1	< 0,1	p-Xilene	mg/l	< 0,1	< 0,1
Nitrated organic solvents							
Acrilonitril	mg/l	< 0,1	< 0,1				
Pyridin3	mg/l	< 0,1	< 0,1				
Chlorinated organic solvents							
1,1-Dichloroethylene	mg/l	< 0,01	< 0,01	dibromochlorometha	mg/l	< 0,01	< 0,01
Dichloromethane	mg/l	< 0,01	< 0,01	1,1,2-trichloroethane	mg/l	< 0,01	< 0,01
1,1-Dichloroethane	mg/l	< 0,01	< 0,01	Tetrachloroethilene	mg/l	< 0,01	< 0,01
Trichloromethane	mg/l	< 0,01	< 0,01	Chlorobenzene	mg/l	< 0,01	< 0,01
1,2-dichloropropane	mg/l	< 0,01	< 0,01	Bromodichlorometan	mg/l	< 0,01	< 0,01
Tetrachlorometane	mg/l	< 0,01	< 0,01	Tribromomethane	mg/l	< 0,01	< 0,01
Trichloroethilene	mg/l	< 0,01	< 0,01				

3.3 Lysimetric tests

3.3.1 Input-Output fluid volumes, pH, redox potential and electrical conductivity

Quality trends of collected leachate from each of the bottom sector as well as from the cumulated one (about 500 lt. in total), are shown in Figure 2 with the time series of pH, Electric Conductivity and Oxidation/Reduction Potential in the leachate. The weighted mean with respect to the quantities collected in each of the sectors is plotted as well. pH value in the leachate was observed to vary very smoothly from 7.26 to 6.38 at the end of the reported observation period, regardless of the adopted leaching solution, showing a high buffer behaviour of the waste. Electrical conductivity showed a larger variability varying from about 14 mS/cm, in the initial flushing period, to a stationary value of about 2 mS/cm after 75 days of flushing. The initial high values for EC are attributable to high levels of anions and cations subsequently flushed off. Redox potential, varied from the negative values (-21 mV) at the beginning of the flushing to values around 35 mV towards the end of the observation period.



a)

b)

Figure 2: a) Time series of collected leachate volumes; b) Time series of pH, Electric Conductivity and Oxidation/Reduction Potential in the leachate.

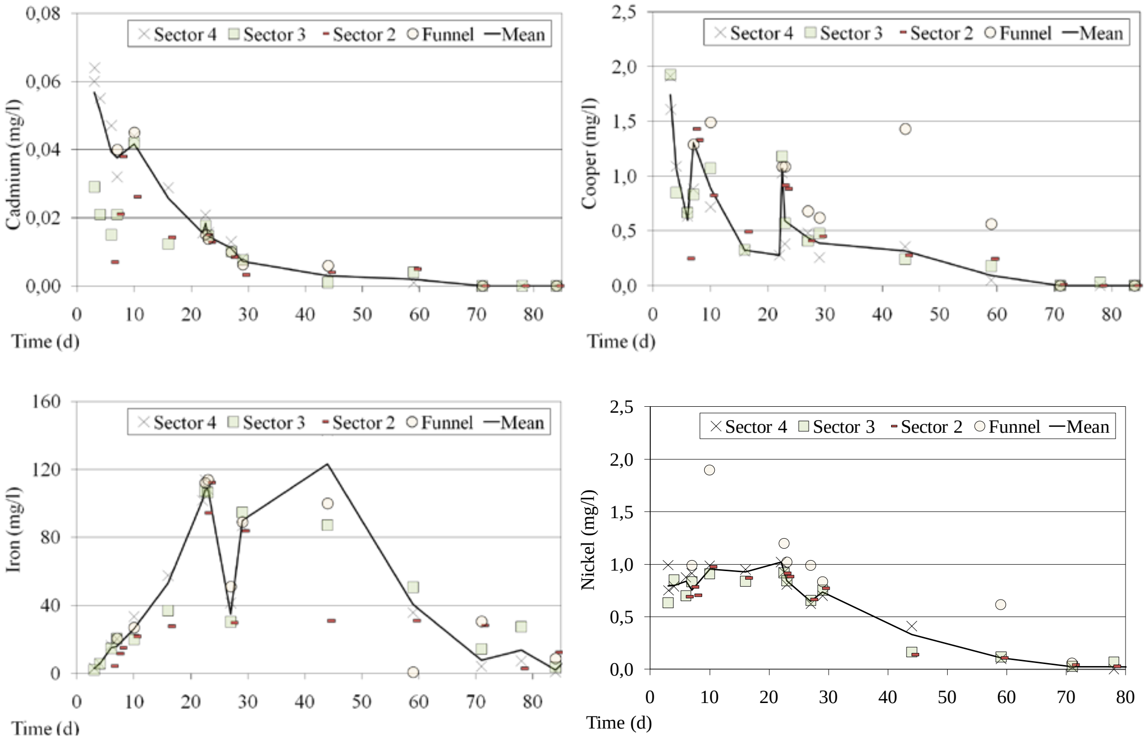
3.3.2 Metals concentration patterns in leachate over the time

Figure 3 show the metals concentration trends in the leachate collected from the different sectors. Mean values (continuous line) were calculated as a weighted mean with respect to the quantities collected in each of the sectors. Single values from these last figures can thus be regarded as a dispersion indicator of the metals concentration with respect to a leachate collectable by a single unique filter. The concentrations trends of the analyzed heavy metals (As, Cd, Cu, Fe, Ni, Pb, Zn and Cr) are reported in Table 4 and plotted in Figure 3. High concentration of Cd, Pb, Ni, and Zn suggest the contamination by refused batteries, paint products, metallic items, and fluorescents lamps. Concentrations of Cr reveal the presence of wood preservatives and paint products in the waste.

With regards to mean values of the metals concentration it can be observed:

1) Higher concentrations were measured in the initial phases even though a weaker leaching solution (demineralized water) was used. An exception is represented by Iron, probably because of the oxidation process of the metallic fraction.

2) During the simulation utilizing carbonate water, Cadmium, Cobalt, Nickel, Copper and Zinc showed a decreasing trend tending to values below the instrument detectability threshold after about 70 days of leaching.



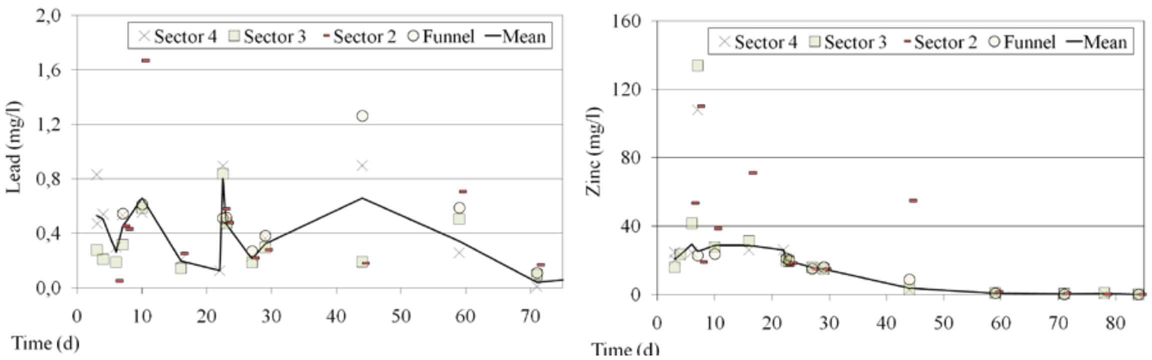


Figure 3: Metals concentration patterns in leachate over the time.

3.3.4 *Other parameters*

Further results obtained from the leachate sampled from the central sector of the lower segment of the lysimeter at the third month of the monitoring period are shown in Table 6. The same parameters are also shown, for the leachate sampled at the real fluff landfill where the examined fluff is currently disposed.

Table 6: Comparison between lysimeter (third month) and landfill (third year) leachate parameters.

Parameter	U.M.	Lysimeter	Landfill	Parameter	U.M.	Lysimeter	Landfill
As	mg/l	-	0,054	Fe	mg/l	-	2,662
Cd	mg/l	-	0,007	Ni	mg/l	-	0,127
Cu	mg/l	-	0,008	Pb	mg/l	-	0,040
Cr III	mg/l	< 0,050	< 0,050	2.3.7.8 TCDD	ng/l	< 0,005	<0,0001
Cr VI	mg/l	< 0,050	< 0,050	1.2.3.7.8 PeCDD	ng/l	< 0,005	<0,0002
Hg	mg/l	< 0,005	< 0,005	1.2.3.4.7.8 HxCDD	ng/l	< 0,005	<0,0002
Residual at 180°C	g/l	2,704	7,4	1.2.3.6.7.8 HxCDD	ng/l	< 0,005	<0,0003
pH	-	7,5	7,05	1.2.3.7.8.9 HxCDD	ng/l	< 0,005	<0,0002
eH	mS/cm	3,055	8,45	1.2.3.4.6.7.8.	ng/l	0,006	<0,0003
Chlorides	mg/l	72	2797	1.2.3.4.6.7.8.9	ng/l	0,029	<0,0004
Sulphides	mg/l	< 1	24,13	2.3.7.8 TCDF	ng/l	< 0,005	<0,0004
Ammonia	mg/l	10,4	137,99	1.2.3.7.8 PeCDF	ng/l	< 0,005	<0,0001
Organic Nitrogen	mg/l	21,2	47,70	2.3.4.7.8 PeCDF	ng/l	< 0,005	<0,0001
Nitrates	mg/l	< 1	0,69	1.2.3.4.7.8 HxCDF	ng/l	< 0,005	<0,0001
Fluorides	mg/l	1,28	13,36	1.2.3.6.7.8 HxCDF	ng/l	< 0,005	<0,0001
Free Cyanides	mg/l	< 0,1	< 0,1	2.3.4.6.7.8 HxCDF	ng/l	< 0,005	<0,0001
BOD_5	mg/l	270	250	1.2.3.7.8.9 HxCDF	ng/l	< 0,005	<0,0001
COD	mg/l	2860	550	1.2.3.4.6.7.8.HpCDF	ng/l	0,005	<0,0002
TOC	mg/l	835	439	1.2.3.4.7.8.9 HpCDF	ng/l	< 0,005	<0,0002
PCB	mg/l	< 0,001	<0,01	1.2.3.4.6.7.8.9	ng/l	< 0,005	<0,0006

4. Conclusions

The characterization of waste behaviour needed to verify the acceptance in landfill is usually referred to the use of leaching tests established by the specific regulation. For heterogeneous materials, however, the small waste quantitative required from the test, implies not a few difficulties of execution and a high results dispersion, even when, as in the present case, appropriate methodologies are utilized to guarantee the reproducibility of the samples.

A different approach was thus proposed, in this research, combining traditional leaching test with a lysimetric simulation utilizing significant waste amount.

In the comparison between the different leaching tests, the acetic acid test determines the severest classification, causing, for the examined waste, the attribution of the hazardous characteristic, with all the economic implication in terms of disposal costs.

Leaching test with carbonated water appears to be more representative giving concentrations similar to those characterizing the real landfill leachate.

Different results and, consequently waste classification, emerge from the leaching test with demineralised water. All the parameters fall within the limits for waste admission in non hazardous waste landfills with the exception of COD, exceeding, for all the examined samples, also the threshold value for admission in hazardous waste landfills.

Experimentation with lysimeter has shown it effectiveness in the comparison between leachate from the Lysimeter and a fluff landfill leachate, from which emerge similar distribution of metals mass ratios, close values for both BOD_5 and COD, as well as the absence, in both the fluids, of organochlorinated compounds.

Although, in the lysimeter leachate, metals concentrations were generally higher than in landfill leachate, it was observed, in contrast with leaching tests results, as the two metals showing higher concentrations were Fe and Zn both in the Lysimeter and in the landfill leachate.

According to the leaching test results, the examined fluff gives rise to significant concentrations of Cadmium and Lead (tests with carbonate water and acetic acid). These relevant releases were not detected in lysimeter and landfill leachate. Furthermore, leaching tests did not show appreciable iron concentrations, while this metal was largely found both in the landfill and lysimeter leachate.

Lisimetric tests thus appear to be more realistic in the simulation of landfilled waste behavior, making allowance for the time evolution of the phenomena, the contact condition and the lower liquid to solid ratio.

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