Waste Management 34 (2014) 2674–2686

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Leaching behaviour of different scrap materials at recovery and recycling companies: Full-, pilot- and lab-scale investigation

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ARTICLE INFO

Article history:
Received 22 May 2014
Accepted 24 August 2014
Available online 16 September 2014

Keywords:
Polluted rainwater run-off
Leaching behaviour
Scrap materials

ABSTRACT

Scrap material recovery and recycling companies are confronted with waste water that has a highly fluctuating flow rate and composition. Common pollutants, such as COD, nutrients and suspended solids, potentially toxic metals, polyaromatic hydrocarbons and poly chlorinated biphenyls can exceed the discharge limits. An analysis of the leaching behaviour of different scrap materials and scrap yard sweepings was performed at full-scale, pilot-scale and lab-scale in order to find possible preventive solutions for this waste water problem. The results of these leaching tests (with concentrations that frequently exceeded the Flemish discharge limits) showed the importance of regular sweeping campaigns at the company, leak proof or covered storage of specific scrap materials and oil/water separation on particular leachates. The particulate versus dissolved fraction was also studied for the pollutants. For example, up to 98% of the polyaromatic hydrocarbons, poly chlorinated biphenyls and some metals were in the particulate form. This confirms the (potential) applicability of sedimentation and filtration techniques for the treatment of the majority of the leachates, and as such the rainwater run-off as a whole.

1. Introduction

Recovery and recycling companies – also known as scrap collecting companies – have to deal with polluted rainwater run-off, characterised by a fluctuating composition and flow, due to their specific activities and the variable weather conditions. The majority of the scrap materials is stored outside and uncovered, which causes leaching of numerous pollutants. Preliminary water analyses and literature data on related (waste) water (Boxall and Maltby, 1997; Mangani et al., 2005; Chys et al., 2013) suggest that common pollutant (COD, nutrients (i.e. nitrogen en phosphorous), suspended solids) as well as potentially toxic metal, polyaromatic hydrocarbon (PAH) and polychlorinated biphenyl (PCB) concentrations can be high and may exceed the discharge limits imposed by the government, in this case of Flanders (the northern part of Belgium). As no specific discharge limits exist for recovery and recycling companies, they must fulfil the discharge limits set out by the Flemish government in the VLAREM II legislation (http://www.emis.vito.be). More specifically; these companies must fulfil the limits for discharging water – containing one or more dangerous components – to surface water or the sewage system, depending on the specific company situation.

Current literature contains some information about the origin and leaching behaviour of the different pollutants at scrap collecting companies. Hydrocarbons can originate from oil (residue), while metals can originate from historical leaded fuel and paint (Pb), brake linings (Cu), tires (Zn), fences (Zn), different types of alloys (B, Ni, Cr, Zn,…), printed circuit boards and other e-waste such as cell phones and computers (Cu, Pb, Zn, Ni and Cd) (Chys et al., 2013; Legret and Pagotto, 1999; Davis et al., 2001; Mckenzie et al., 2009; Swamikannu, 1994; Zhou et al., 2013; Luo et al., 2011; Maragkos et al., 2013; Kolias et al., 2014). The composition of the material at a scrap yard is not always known in detail which makes it difficult to predict the resulting pollutants concentration.

To determine possible (preventive) solutions against pollution, the leaching behaviour of different scrap materials (Table 1) and scrap yard sweepings was verified at full-scale, pilot-scale and

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http://dx.doi.org/10.1016/j.wasman.2014.08.019
0956-053X/

lab-scale on a systematic basis. The novelty is that the leaching behaviour of different materials is compared on different scales in the same study. As this leachate will eventually be discharged, also a comparison will be done with the governing Flemish discharge limits. This would indicate the need for further treatment in case the limits are not met. Based on the test results, and as such the obtained concentrations, different preventive measures such as covered storage, sweeping campaigns at the scrap yard, separated sewage systems and corresponding water treatment solutions can be proposed.

2. Materials and methods

2.1. Origin of investigated scrap materials and on-site leachates

The hereinafter investigated scrap materials and scrap yard sweepings are originated from three different scrap yards as shown in Table 1.

The main difference between the three scrap yards is their size. Scrap yard 1 is the largest of all three (±9 ha), while scrap yard 2 (±2 ha) and 3 (±1 ha) are two smaller enterprises. None of the three is a shredding company, only the first company performs operations on the scrap (such as cutting and squeezing), while the other two are scrap collecting companies only. All of them are located in Flanders and store both ferrous and non-ferrous scrap materials. Most of the investigated materials were not 'fresh', as they had been stored outside for several days or weeks. Only the metal (aluminium) turning scrap from scrap yard 2 was 'freshly' delivered. The sweepings of scrap yard 3 were swept together (not vacuumed). In order to sweep the yard, a prior dry period at the company is needed. The sweep action preceding the one from which the samples were collected took place a few months earlier.

To allow comparison between the leaching tests and the measured leachate concentrations on-site, Tables 2–7 (see below) also mention the effluent (rainwater run-off) concentrations of the corresponding scrap yards. The indicated concentrations of scrap yard 1 and 2 are the mean of two single measurement values from two different sampling dates (September 2012 and December 2012 for scrap yard 1, October 2012 and March 2013 for scrap yard 2), while scrap yard 3 concentrations are the result of only one analysis (December 2012). Measured concentrations of rainwater run-off for scrap yard 3 originates from a sampling in the measurement flume (i.e. point just before discharge) during rather heavy rainfall. As there is no buffer tank or pump pit present, sampling is only possible during sufficiently heavy rain periods. Scrap yard 1 and 2 are both equipped with a pump pit and/or a buffer tank, making sampling possible at almost any time. At scrap yard 2 and 3, all of the rainwater run-off passes an oil/water separation tank, while at scrap yard 1 only a small part of the water (the most polluted run-off, accounting for less than 10% of the total stream) passes a separator. An important final remark, regarding the effluent concentrations shown in Tables 2–7, is that the displayed values should only be read as an indication of the pollutant concentrations present in the rainwater run-off. A statistical analysis of gathered effluent data of different Flemish scrap collecting companies, often shows large variations in concentrations within the rainwater run-off samples of the same scrap yard throughout the year, due to changing scrap yard compositions, variable weather conditions, etc. (Verachtert et al., 2014). Especially the metals, PAH and PCB concentrations show large variations between different sampling times. For example, some of the measured values for scrap yard 1 and 2 (Tables 2–7) – which are the mean of two measurement values – have relative standard deviations of up to 100% and even more.

2.2. Investigation of leaching behaviour

2.2.1. Full-scale measurements

Contrary to the pilot- and lab-scale investigation (see further, Sections 2.2.2 and 2.2.3) there was no leaching test performed as such for the full-scale investigation. After a rainy day (1.9 mm precipitation, i.e. 0.8 $L/m^2/h$, www.hydronet.be) in November 2012, a mixed 2 L sample was taken of the water retained under and next to the storage piles of seven different scrap materials. The investigated storage piles consisted of scrap from metal (iron) turnings (by-product of the metal industry), printed circuit boards and loudspeakers, "fines de fonte" (by-product of the metal industry), households, electric motors and transformers, steel wires (on spool) and empty barrels.

In this test rain water was used instead of deionized water. This could possibly give rise to somewhat higher concentrations as the rain water may be already polluted (as discussed below).

2.2.2. Pilot-scale investigation

For the pilot-scale investigation an adapted version of the French AFNOR X31-210 leaching procedure at lab-scale (Sebag et al., 2009) was developed. This test does not use an acid source (to obtain a pH = 5) which could greatly overestimate the leaching potential of a waste. Whereas the French procedure is mainly used to investigate the leachates of landfill materials, the developed pilot-scale procedure attempted to take the lifelike leaching conditions at recovery and recycling companies into account. In recovery and recycling companies rain water falls on piles of waste (as demonstrated in the graphical abstract). The contact time is very short (typically 1–24 h) after which the rain water is collected in the sewer system of the company. As such the conditions vary from a typical landfill were waste is stored in the landfill pits. By adapt-

Table 1
Overview of the 12 different scrap materials that were investigated and their corresponding experiment scale and scrap yard origin.

Material	Principal metal component	Scale of experiment	Origin: scrap yard 1, 2 or 3
Metal (iron) turning scrap	Fe	Full	Scrap yard 1
Printed circuit boards and loudspeakers scrap	Miscellaneous	Full	Scrap yard 1
Fines de fonte scrap	Miscellaneous	Full	Scrap yard 1
Household scrap	Miscellaneous	Full	Scrap yard 1
Electric motor and transformer scrap	Miscellaneous	Full	Scrap yard 1
Steel wire (on spool) scrap	Fe	Full	Scrap yard 1
Empty barrel scrap	Miscellaneous	Full	Scrap yard 1
Zinc scrap	Zn	Pilot, Lab	Scrap yard 1
Lead scrap	Pb	Pilot	Scrap yard 1
Electric motor scrap	Miscellaneous	Pilot	Scrap yard 1
Metal (aluminium) turning scrap	Al	Pilot, Lab	Scrap yard 2
Scrap yard sweepings	Miscellaneous	Pilot, Lab	Scrap yard 3