Evaluation of heavy metal availability in playground surfacing based on leaching procedures for environmental assessment

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1. Introduction

During the last few years, a large number of playgrounds and green areas have been built all over the world. Architects and engineers have used elastic materials and shock absorbers for the floors of playgrounds. For this purpose, rubber flooring has been a widely used alternative. However, the environmental evaluation of this material from recycled rubber is key. For this reason, the present investigation proposes to address an environmental evaluation through compliance and diffusion leaching tests. These procedures will help to assess whether their use is harmless to users of playgrounds. This work analyses the release levels of heavy metals regulated by the European Union which allows classify the materials according to their hazardous potential. The starting point is previous research studies developed by Llompart (2013) and Rokade (2012), but the novelty of is the proposal of a new method of tank leaching test performed outdoor. The test equipment was placed outdoors in the roof of a building of the University Campus. Therefore, the comparative between the conventional laboratory procedures and the proposed method is evaluated and the pollutant emissions of chemical species are discussed.

2. Material and methods

2.1-Materials

Mainly, there are two types of rubber flooring: resin bound rubber granules and flat panels. Pavement made of resin bound rubber granules is a combination of rubber granules (unbound) and polyurethane resin, while flat panels are unitary (monolithic) materials that are formed into solid surfaces such as tiles. Both pavements are specifically designed to reduce the risk of serious injury associated with falls from playground equipment. Panel flats are generally composed by two-layer system consisting of a basemat of 100% post-consumer recycled SBR (Styrene Butadiene Rubber) and polyurethane and a top surface consisting of recycled post-industrial EPDM (Ethylene Propylene Diene Monomer) rubber and polyurethane. The unbound rubber granules can be composed by recycled rubber or SBR-EPDM materials.

The present study evaluates two flat panels and unbound granulates, being the samples named as follows: (1) N-CP: commercial flat panel pavement acquired in a manufacturing company (new material), (2) U-CP: flat panel pavement used as playground surfacing for 5 years (used pavement) and (3) N-GR: unbound granules.

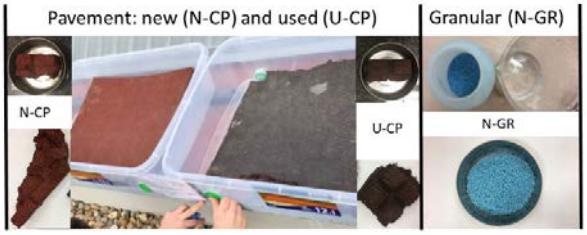

Figure 1. Tested materials for playground surfacing: N-CP, U-CP, N-GR.

2.2-Experimental methods

This research is focused on the study of the pollutant release (heavy metals and anions indicated by EU Landfill Directive (2003) on leachates obtained according to three different methodologies:

a) The *Compliance Batch Test (UNE-EN 12457-3:2003)* for basic characterisation of leaching levels of material for liquid to solid ratios of 2 and 10 l/kg, and the data will be compared with the legal limit established by the Landfill Directive. The tests must be carried out on materials with a particle size of less than 4 mm in 95% of the mass. Therefore, panels were crushed reducing the sample to granules and being named as: RN-CP and RU-CP.

b) The *Tank test (XP-X31-211:2012)* for estimation of the leaching behaviour of monolithic samples was performed to the panels: N-CP and U-CP. The test must be carried out on materials with a size of 80x40x40mm. So, the panels were split to obtain the normalised size. Then, specimens were immersed in a given volume of demineralised water reaching a liquid to solid ratio of 10 l/kg and were placed in a stirring device for 24 hours at a speed of 120 ± 20 rpm at a temperature of 20 ± 5 ° C. The samples were named as: U-CP-T and N-CP-T.

c) The *Outdoor Tank test (OUT-TANK) was* performed outdoors of laboratory on the roof of a building of the University Campus. The flat panels U-CP and N-CP were tested and were exposed to weather conditions. Eluates

after four rain episodes were extracted. Dimensions of panels were not reduced, and they were tested at commercial size and placed in tanks with a capacity of approximately 60 liters. After each rain episode, a sample was extracted for analyzing named as: U-CP-O1, U-CP-O2, U-CP-O3, U-CP-O4, N-CP-O1, N-CP-O2, N-CP-O3 and N-CP-O4.

4.Results and discussion

4.1-Base characterisation of pollutant potential of tested materials

At the end of each test, eluates were separated, filtered (using a membrane filter of 0.45 μm). After that, leachates were analysed by inductively coupled plasma mass spectrometry (ICP-MS) using a Perkin Elmer ELAN DRC-e spectrometer. This analysis quantified the heavy metals specified by the European Landfill Directive: Ni, Cr, Sb, Se, Mn, Hg, As, Pb, Cd, Cu, Ba and Zn. The release levels are showed in Table 1:

Table 1. Concentration levels of heavy metals on leachates according to compliance test (in mg/kg).

Element	N-GR		RN-CP		RU-CP	
	2 l/kg	**10 l/kg**	**2 l/kg**	**10 l/kg**	**2 l/kg**	**10 l/kg**
As	*0,382*	0,385	**0,592**	*0,762*	**1,785**	0,481
Ba	1,918	0,913	**35,774**	15,781	**34,904**	14,035
Cd	*0,039*	0,041	**5,3**	*0,101*	**0,9**	*0,252*
Cr	*0,38*	0,438	*1,742*	0,38	*3,722*	*1,063*
Cu	*1,226*	0,731	*19,379*	1,388	**102,937**	*17,484*
Hg	*0,004*	0,003	*0,006*	0	*0,04*	0,008
Mo	*1,845*	*0,531*	*0,512*	0,221	*2,822*	0,457
Ni	*0,657*	*0,568*	**29,25**	*3,074*	**13,253**	*2,098*
Pb	0,078	0,058	*0,949*	0,044	*3,17*	*0,948*
Sb	*0,065*	0,04	**0,31**	*0,079*	**0,904**	*0,206*
Se	**0,614**	*0,257*	**1,784**	**0,695**	**0,767**	*0,198*
Zn	*6,816*	*5,293*	**5588,838**	**120,737**	**9446,633**	**2338,323**

After comparing the concentration levels measured with the legal limit imposed, in Table 1 can be observed in **bold** the elements that exceed the hazardous limit, and in *italic* the elements that exceed the non-hazardous limit. Thus, all materials were classified as hazardous, both panels (RN-CP, RU-CP) and the unbound granules (N-GR). While the granules N-GR presents the lowest release levels, the flat panel RU-CP (used as playgroud flooring during 5 years) presents the highest release levels, probably due to degradation processes.

4.2. Comparison between the normalised tank test and the designed outdoor tank leaching procedure.

Tank leaching tests were carried out to both flat panels: normalised tank test (U-CP-T, N-CP-T) and the outdoor leaching tank test (U-CP-O, N-CP-O). According to the results, the elements released in the highest levels were Cu and Cd, and in Figure 2 data from both methods are compared:

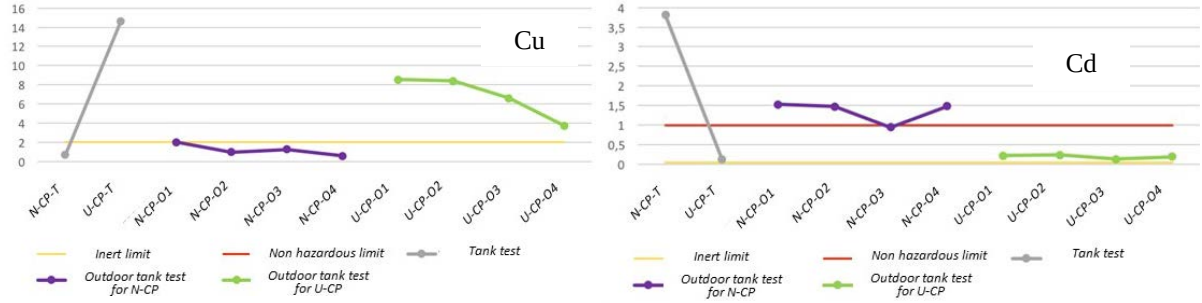

Figure 2. Comparison between release levels (in mg/kg) according to tank leaching tests.

According to Figure 2, lower release values were observed when panels are exposed to regular meteorological conditions with respect to the conditions imposed in the laboratory by the normalised tank test.

5-Conclusions

The present research confirms the pollutant potential of playground surfacing composed by EPDM-SBR, being necessary to deepen in chemical analyses and environmental tests that prove the feasibility of using these materials in playground flooring.

6-References

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