Materials : Sports Equipment and facility

Leaching of Heavy Metals from Infills on Artificial Turf by Using Acid Solution

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[Received May 23, 2008 ; Accepted December 5, 2008]

The present study is aimed at determining the concentration of heavy metals leached from various types of infills on artificial turfs by using acid solutions as a representative of acid rain. Acid solutions with pH values of 3.0, 3.5, 4.0, and 4.5 were prepared from 0.1 mol/ℓ sulfuric acid and distilled water. Leaching was carried out according to the standard method prescribed by the Ministry of Environment in Japan. The concentrations of heavy metals such as zinc leached in the acid solutions were determined by inductively coupled plasma spectrometry (ICP-MS). The concentrations of heavy metals in the infills were analyzed using an ICP analyzer after the infills were burnt to ashes and dissolved with aqua regia. Zinc (Zn), Iron (Fe), Barium (Ba), and Manganese (Mn) in styrene-butadiene rubber (SBR) infills were leached in acid solutions. Their concentrations increased with increasing acidity of the leaching solutions. In the case of the SBR infill, the concentrations of Zn exceeded the effluent standard (2 mg/ℓ) in Japan, but decreased with aging time, and were less than the effluent standard for aging time greater than 1.25 years. The concentrations of Zn leached from SBR coated with polyurethane (PU-SBR), ethylene-propylene rubber (EPDM), Eco-fill, and the bark of a cedar tree were less than the effluent standard of Zn in Japan, and were approximately proportional to the Zn contents (%) in all these infills except for the cedar bark.

Keywords: artificial turf, infills, leaching of heavy metals, acid solution

[Football Science Vol.5, 51-53, 2008]

1. Introduction

Artificial turfs are used for football pitches around the world. These turfs facilitate the extension of time for play, independently of the weather. Approximately 740 football pitches of the long-pile artificial turf have been installed in Japan by March 2007. Most of the artificial turfs were sand-based and used rubber (styrene-butadiene rubber; SBR) infills that were derived from recycled used car tires. There are concerns produced from the rubber infills, such as the leaching of chemicals from infills (KEMI, 2006). For example, zinc oxide is added as an activator during the vulcanizing process in the manufacture of car tires (Smolders and Degryse, 2002).

Generally, heavy metals in materials are soluble in acid solution. As of 2000, most of the acid rainwater in the U.S.A. had a pH of about 4.3 (U.S.EPA, 2008). The results of surveys in Japan from2000-2002 showed that the pH of about 5% of the acid rainwater was less than pH4.0 (Ministry of Environment in Japan, 2006). Verschoor (2007) reported the possibility of leaching zinc from SBR infills under various conditions. Zinc can pose significant environmental risks, particularly for aquatic life. Birkholz, et al., (2003) reported that toxicity to all aquatic organisms was observed. In Japan, the concentration of zinc in effluents is regulated to be less than 2 mg/ℓ (Ministry of Environment in Japan, 2006). Untill now, there is insufficient information on the quantitative leaching of heavy metals containing zinc from rubber infills other than SBR under the condition of various low pH values.

The present study is aimed at determining the concentration of heavy metals containing zinc leached from rubber infills such as SBR that are filled in the long-pile artificial turf by using acid solution as the representative of acid rain. Furthermore, alternative infills are investigated in comparison with SBR.

2. Methods

2.1. Material

Styrene-butadiene rubber (SBR), SBR coated with poly-urethane (PU-SBR), ethylene-propylene rubber (EPDM), polyolefin-based material (Eco-fill), and debris of outermost layer of ceder tree (Bark) were selected as infill materials. The sizes of infills except of the Bark (5-10mm) are 3-5mm in length. The aging samples for SBR infill were obtained from three football pitches constructed in different years; these samples were used in the leaching procedure.

Rainwater was collected in our college during rainfall on 12 days between Jan.22, 2007 and Oct.26, 2007.

2.2. Leaching procedure

Leaching was carried out according to a standard method (Ministry of Environment in Japan, 2001). The leaching procedure was as follows,

- Acid solutions of pH3.0, 3.5, 4.0, and 4.5 were prepared from 0.1 mol/ℓ sulfuric acid and distilled water.
- Five grams of infills were separately mixed with 50 mℓ of each acid solution in bottles.
- The mixtures in the bottles were stirred for 6 h in a water bath at 20 ℃.
- The mixtures were filtrated using a 0.45 μm membrane filter.
- Heavy metals in the filtrates were analyzed.

2.3. Analysis

The concentrations of heavy metals leached in the acid solutions were determined by inductively coupled plasma mass spectrometry (ICP-MS) (Agilent Technologies Co., model 7500a). The relative standard deviations (RSD) for repetition of measurements by the ICP-MS analysis were 0.81% (Zn), 6.3% (Fe), 1.2% (Ba), and 0.39% (Mn), respectively. The RSDs in repeating the leaching procedure four times by using SBR at pH 3.5, were 4.9% (Zn), 10% (Fe), 11% (Ba), and 3.5% (Mn), respectively. The larger RSDs in the leaching procedure seem to be caused by the deviation of size (3-5 mm) for the infill. The contents of heavy metals in the infills were analyzed using an ICP analyzer after the infills were burnt to ashes and dissolved in aqua regia.

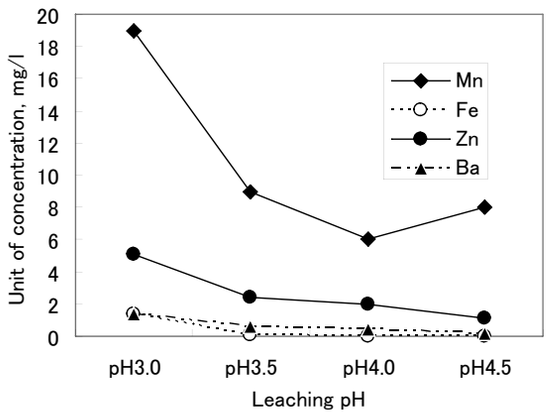

Figure 1 Leaching heavy metals from SBR infills. Unit of concentration : Fe, Zn, Ba mg/ℓ ; Mn μg/ℓ.

The electrical conductivity (EC) and pH of the rainwater were measured with a conductivity meter (Lutron, Model CD4302) and a pH meter (Line Seiki, Model EH-1000), respectively. The conductivity meter and the pH meter were calibrated with standard solutions before the measurements.

3. Results and discussions

3.1. pH and EC of rainwater

The EC and pH of the rainwater collected on 12 days were measured. The range and average value of pH were 3.7 – 5.9 and 4.5, respectively. Highly acidic rainfalls with pH values of less than pH4.0 were observed on three days (Feb. 7, July. 4, Aug. 22 in 2007). The range and average value of the EC (unit: μS/cm) were 9 – 97 and 42, respectively.

The pH values of the acid solutions in the following leaching experiments were set to 3.0, 3.5, 4.0, and 4.5.

3.2. Leaching heavy metals

Zinc (Zn), Iron (Fe), Barium (Ba), and Manganese (Mn) in the SBR infills were leached in acid solutions.

The concentrations of leaching heavy metals increased with an increase in the acidity of the acid solutions, as shown in **Figure 1**. The concentrations of Zn which pH was less than 4.0 exceeded the Japanese effluent standard (2 mg/ℓ) (Ministry of Environment in Japan, 2006).

The concentrations of Zn in the SBR infill were

Table 1 Concentration of Zn leached from SBR infills with aging.

year	pH3.0	pH3.5	pH4.0	pH4.5
0	5.1	2.4	2.0	1.1
0.67	3.0	1.4	0.74	0.38
1.25	1.1	1.0	0.83	0.57
4.0	1.2	0.97	0.62	0.42

unit of concentration : mg/ ℓ

Table 2 Leaching concentration of Zn from other infills.

infill	pH3.0	pH3.5	pH4.0	pH4.5
PU-SBR	1.1	0.56	0.23	0.13
EPDM	0.030	0.063	0.016	0.061
Eco-fill	0.049	0.013	0.021	0.028
Bark	0.27	0.33	0.26	0.25

unit of concentration : mg/ ℓ

limited. Therefore, the leaching of Zn from SBR appeared to decrease with time. The concentrations of Zn decreased with the aging of the SBR infills, and in the case of aging time greater than 1.25 years, the concentrations of Zn were less than the effluent standard in Japan, as shown in **Table 1**. The leaching of Zn appeared to decrease with time and not to decrease to zero.

The leaching of Zn from infills other than the SBR infill was investigated. The concentrations of Zn leached from each infill at any pH value were less than the effluent standard as shown in **Table 2**. The Zn content of SBR, PU-SBR, EPDM, Eco-fill, and the bark were 1.2%, 1.0%, 0.55%, 0.28%, and 0.001%, respectively. The concentrations of Zn leached from the infills were approximately proportional to the Zn contents in all these infills except for the bark.

We acknowledge the assistance provided by Yousuke Muramatsu in obtaining a part of the data.

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