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Ten-year chemical evolution of leachate and municipal solid waste incineration bottom ash used in a test road site

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ABSTRACT

The use of municipal solid waste incineration (MSWI) bottom ash for road and car-park construction is an appropriate solution to reduce their disposal and the consumption of natural materials. In addition to leaching tests, the environmental impact assessment of such a waste recycling scenario critically needs for reliable long-term field data. This paper addresses a 10-year pilot site where MSWI bottom ashes have been used as road aggregates in Northern France (oceanic temperate climate). The paper focuses on the long-term evolution of leachate chemistry and the mineralogical transformations of MSWI bottom ash over 10 years. Data interpretation is supported by geochemical modeling in terms of main pH-buffering processes. The leachate pH and concentrations in major elements (Ca, Na and Cl) as well as in Al and heavy metals (Cu, Pb and Zn) quickly drop during the first 2 years to asymptotically reach a set of minimum values over 10 years; similar to those of a reference road built with natural calcareous aggregates. SO_4 release makes exception with a slightly increasing trend over time.

Carbonation induced by CO_2 inputs, which leads to the successive dissolution of portlandite, CSH and ettringite, is one of the main phenomenon responsible for the geochemical evolution of leachate. On the other hand, mineralogical observations and batch tests demonstrate a relative stability of the MSWI bottom ash inside the subbase layer. In particular, carbonation may be far to be completed and still in progress after 10 years. This is consistent with preferential rainwater flow and dilution at the road edges combined to diffusion inside the subbase layer.

1. Introduction

The high demand of construction materials compared to the availability of natural materials, as well as the lack of available space for waste disposal, is a problem in many urbanized areas across the world. The use of by-products and wastes for road construction is an appropriate solution to reduce the amount of disposed materials and to provide for alternative construction materials. Municipal solid waste incineration (MSWI) residues produced from the household waste combustion, and reused for road and car-park construction, is a typical case (e.g. [1,2]). For instance, in France, reuse of MSWI residue started during the 1950s in the Parisian Region and spread all over the country during the 1980–1990s, a period during which many incinerators were built [3].

As for some other alternative materials (coal fly ash, blast furnace slag, etc.), the reuse of MSWI bottom ash as road aggregate may impact the environment – both soil and water resources – by releasing salts and heavy metals (e.g. [1,2]). The acceptance criteria for recycling MSWI bottom ash in road construction usually depends on the leaching potential of the material, which is determined through standardized leaching tests (e.g. [2,4]). Batch tests are useful for determining the intrinsic properties of the waste with respect to one or several controlled parameters (e.g. pH). However, these static experiments that are performed on short duration (usually 48 h) on crushed materials are poorly representative of field conditions. Column tests that run over longer duration (weekly to monthly time scales) include a hydrodynamic facet more representative of site conditions. As an example, they can be used to assess scale effects of percolation on element release [4,5]. However, their 1D configuration is far to be as complex as field geometry that present boundary or edge effects for instance. Long-term processes such as carbonation are also not fully taken into account.

Therefore, in complement to lab leaching tests, long-term field scale experimentations are critically needed for supporting environmental impact assessment in a given recycling scenario. To our knowledge, only a few field scale studies have been recently published with respect to MSWI bottom ash reuse for road construction

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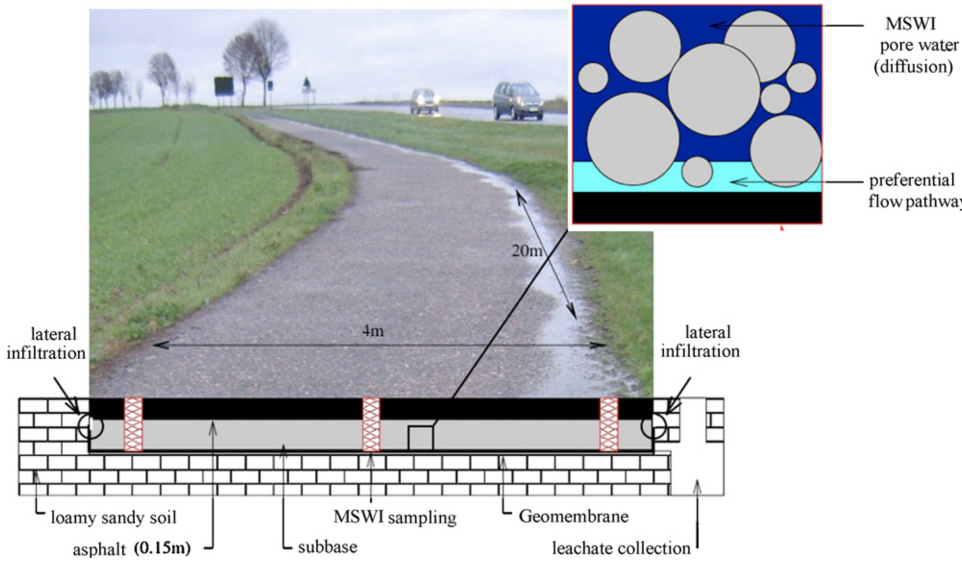

Fig. 1. Schematic transversal cross-section of the road with core sampling locations (subbase layers built either with MSWI bottom ash aggregate or calcareous aggregates).

[6–10]. In theses studies, leachate sampling has been performed for relatively short durations (3 years at maximum). The present paper copes with a 10-year pilot site, dedicated to study the environmental impact of MSWI bottom ash valorized as road aggregates in Northern France. The paper focuses on the long-term evolution of leachate chemistry and mineralogical transformations of MSWI bottom ash over 10 years. Data interpretation is supported by batch test performed on core samples drilled after 10 years and geochemical modeling.

2. Field site and methods

2.1. Test road properties and materials

2.1.1. Description of the test road

The studied site consists of a small road characterized by a low traffic, about 10 vehicles per day, and built in 1997 at Hérouville (Parisian Region, France). The road is divided into two sections of 4 m wide and 20 m long. The first section contains a 25 cm thick subbase layer of MSWI bottom ash (dry weight of 31.2 tons). The second road section was built by using conventional calcareous aggregates (crushed natural limestone). This second section is used as a reference. The calcareous aggregate presents the same physical properties (granulation, hardness, etc.) than the MSWI bottom ash. Two complementary sections built with MSWI bottom ash stabilized by cement and hydrocarbon binders were also tested at Hérouville to investigate their potential improvement in environmental and geotechnical properties. The corresponding results are not discussed in this study.

As shown in Fig. 1, both sections are covered with a slightly permeable bitumen (asphalt) layer of 15 cm thickness; according to the French recommendations for the use of MSWI bottom ash in road construction [11]. The bitumen cover is flat, i.e. characterized by a nil slope (to be compared to a reference 3% slope for the French public roads) in order to maximize rainwater infiltration. The bitumen cover did not present any major cracks after 10 years of utilization. The two road sections are completely embedded in the surrounding soil, a cultivated loamy and sandy soil. A polyethylene drainage liner (geomembrane) is located at the bottom of the subbase layer. This geomembrane does not completely cover the road sides or edges, allowing for lateral water infiltration into the subbase layer. The depth of the local aquifer varies seasonally, between 3 and 7 m beneath the road.

2.1.2. MSWI bottom ash

The studied MSWI bottom ash comes from a waste incineration facility from the Parisian Region (France). Prior to utilization, the MSWI bottom ash was screened to remove particles larger than 30 mm, magnetic materials, and metallic aluminum, and then weathered outdoor in heaps during 3 months. The MSWI bottom ash was classified "V", i.e. a by-product suitable for valorization as road aggregates according to the French regulation. The bottom ashes are composed of glass, ceramics, natural rocks, metallic compounds and unburnt residues.

2.2. Field monitoring and sampling

2.2.1. Leachate monitoring

A slight inclination of the geomembrane drives leachate by gravity towards the collection system: punctually with hermetic bags used to avoid atmospheric exchange (minimizing carbonation or oxidation) and continuously with larger collectors of 700 L. Precipitation data were collected from a nearby MeteoFrance weather station. The electrical conductivity and the flow rate of leachate were measured and compared to precipitation in a few occurrences.

From 1997 to 2000, EUROVIA and INERIS monitored the road by sampling and analyzing leachate [12]. In 2007, the two road sections were monitored again in order to evaluate leachate chemistry after 10 years of utilization. Electrical conductivity, pH and redox potential were directly measured after sampling. The leachates were filtrated at 0.45 μm and stored at 4 °C (one half was acidified with ultra-pure nitric acid for metal analysis). Total alkalinity was determined using the Merck alkalinity test and dissolved organic carbon (DOC) using a total organic carbon analyser at the laboratory on the filtrated leachates. Anion concentrations were analyzed on the filtrated leachates by ion chromatography, and cation concentrations on the acidified filtrated leachates by inductively coupled plasma-atomic emission spectrometry (ICP-AES).

2.2.2. Sampling of MSWI bottom ash from the road subbase layer

In order to evaluate the material evolution, MSWI bottom ash samples were collected after 10 years (October 2007) in the road subbase layer by drilling cores of 15 cm in diameter. Each core was further divided according to three depths: underneath the bitumen, in the middle of the layer and the bottom of the layer (Fig. 1). The drilled core samples were carefully packed in aluminum coated plastic bags to prevent carbonation, oxidation and dehydration.