Treatment of landfill leachate: Removal of ammonia by struvite formation

CC Camargo[1], JR Guimarães[1] and AL Tonetti[1]*

[1]School of Civil Engineering, Architecture and Urbanism, FEC/UNICAMP, Avenida Albert Einstein, 951, Cidade Universitária 'Zeferino Vaz', PO Box 6021, 13083-852, Campinas, SP, Brazil

ABSTRACT

This paper presents a study of ammoniacal nitrogen removal by chemical precipitation resulting in the formation of ammonium and magnesium phosphat ($MgNH_4PO_4 \cdot 6H_2O$), known as struvite, from the leachate in the Delta A landfill, located in the city of Campinas, São Paulo, Brazil. After the addition of a magnesium source ($MgCl_2 \cdot 6H_2O$), and phosphorus ($Na_2HPO_4 \cdot 12H_2O$), ammoniacal nitrogen was precipitated as highly insoluble salt. The removal of ammoniacal nitrogen from the leachate exceeded 85% when the reaction was performed at an initial pH of 10.0. The highest efficiencies were achieved when the molar ratio between the ions involved in the reaction, i.e., Mg^{2+}:PO_4^{3-}:NH_4^+, was 1.2:1.0:1.0, respectively.

Keywords: landfill, leachate, ammonia, nitrogen removal

INTRODUCTION

Brazil has a daily production of about 260 000 tons of municipal solid waste (IBGE, 2008). Of this total, approximately 65% is disposed in landfills, considered to be the most appropriate form of disposal within the Brazilian context (Povinelli and Além Sobrinho, 2009). However, from an environmental point of view, there are problems that should be addressed inside the landfill, such as the emission of greenhouse gases (GHG), and the generation of leachate from rainwater and residue decomposition.

The leachate has unique characteristics, such as a high concentration of ammoniacal nitrogen (NH_3 and NH_4^+), high chemical oxygen demand, low potential for biological degradation, and the presence of metals and other organic and inorganic substances that confer a high toxicity to this type of waste, and hinder its treatment. Studies by Clément and Merlin (1995) indicate that ammoniacal nitrogen in its non-ionized form (NH_3) is the major contributor to the toxicity of the leachate. Li and Zhao (1999) argue that its concentration in leachate must be reduced to at least 100 mg·ℓ$^{-1}$ prior to its entry into biological reactors for activated sludge.

Chemical precipitation in the form of the double salt of magnesium and ammonium phosphate, also known as struvite, is one of several options for removing ammoniacal nitrogen from this matrix. Struvite is an inorganic mineral in the form of a white crystal, with a chemical formula of $MgNH_4PO_4 \cdot 6H_2O$. Struvite is highly soluble in acid, and insoluble in a basic medium; the pH of minimum solubility is around 9.0 (Munch and Barr, 2001). Moreover, as a slow release source of phosphorus, magnesium, and nitrogen, struvite is a potentially valuable fertiliser (Iaconi et al., 2010).

Based on these facts, the aim of this work was to reduce the ammoniacal nitrogen concentration of a landfill leachate by chemical precipitation in the form of struvite, by evaluating the efficiency of the treatment, the pH of the medium, and the ratio between the reagents.

MATERIALS AND METHODS

The leachate used for the experiments originated in the main landfill of the city of Campinas, in the state of São Paulo, Brazil. This landfill occupies an area of 400 000 m^2, and responded to the completion of this work by receiving 100% of household waste generated in the city, averaging 1 000 t·day^{-1}. Operations began in 1992, and in 2011 the production of leachate was approximately 10.4 m^3·h^{-1}.

The raw leachate samples were collected and brought to the Laboratory of the School of Civil Engineering, Architecture, and Urbanism (FEC), at the University of Campinas (Unicamp).

The reagents used in the precipitation test were chosen based on the work of Li et al. (1999). According to these authors, the combination of $MgCl_2 \cdot 6H_2O$ with $Na_2HPO_4 \cdot 12H_2O$ is the most efficient in removing ammoniacal nitrogen.

Before conducting the tests, a sample of the raw leachate was analysed to determine the ammoniacal nitrogen (NH_4^+ + NH_3) concentrations. From the obtained values, the amounts of reagents ($MgCl_2.6H_2O$ and $Na_2HPO_4.12H_2O$) to be used in each test were calculated, according to the desired molar ratio of Mg^{2+}:NH_4^+:PO_4^{3-}. Table 1 shows the ammoniacal nitrogen concentrations found, in addition to the molar ratios and pH values evaluated in the various experiments.

The experimental part was carried out according to the flowchart shown in Fig. 1. The leachate was placed in 6 jars and pH was adjusted with solutions of NaOH 15 mol·ℓ$^{-1}$ and H_2SO_4 6 mol·ℓ$^{-1}$, followed by the addition of the reagents $MgCl_2 \cdot 6H_2O$ and $Na_2HPO_4 \cdot 12H_2O$.

The tests were conducted in a jar test apparatus, consisting of 6 vessels with the following dimensions: 20.0 x 11.5 x 11.5 cm. Each vessel had a capacity of 2 ℓ, which resulted in a water depth of 15 cm and surface area of about 132 cm^2.

* To whom all correspondence should be addressed.
☎ +55 19 3521-2369; e-mail: adriano@fec.unicamp.br
Received 27 September 2013; accepted in revised form 30 June 2014.

http://dx.doi.org/10.4314/wsa.v40i3.12
Available on website http://www.wrc.org.za
ISSN 0378-4738 (Print) = Water SA Vol. 40 No. 3 July 2014
ISSN 1816-7950 (On-line) = Water SA Vol. 40 No. 3 July 2014