



## Effect of ash from forest fires on leaching in volcanic soils



Mauricio Escudey<sup>a,b,\*</sup>, Nicolás Arancibia-Miranda<sup>a,b,1</sup>, Carmen Pizarro<sup>a,b,1</sup>, Mónica Antilén<sup>b,c,2</sup>

<sup>a</sup> Universidad de Santiago de Chile, Facultad de Química y Biología, Av. B. O'Higgins 3363, Santiago 7254758, Chile

<sup>b</sup> Centro para el Desarrollo de la Nanociencia y Nanotecnología (CEDENNA), Santiago, 725475, Chile

<sup>c</sup> Pontificia Universidad Católica de Chile, Facultad de Química, Vicuña Mackenna 4860, 6904411, Santiago, Chile

### ARTICLE INFO

#### Article history:

Received 18 December 2013

Received in revised form 29 July 2014

Accepted 12 August 2014

Available online 1 September 2014

#### Keywords:

Forest fire ashes

Trace elements leaching

Column leaching simulation

Volcanic soils

### ABSTRACT

In Chile, significant amounts of native forests as well as pine and eucalyptus plantations are lost yearly as a result of forest fires. Besides the effect of high temperatures on the soil and destruction of the plant cover, the ashes originating from these fires end up spread out over the soil. The effects associated with the distribution of ash produced by burning of native forests, pine plantations, or eucalyptus plantations were studied over five different types of soil of volcanic origin by means of leaching columns. Testing columns 25-cm deep were prepared at each soil bulk density; 30 g of ash was added to the top of the column and irrigated by adding one pore volume of water every week for 12 weeks. Control soil and ash columns were prepared and treated similarly. Leachates were collected weekly and the pH, organic carbon (OC) content, and concentration of various cations and anions were analyzed (via ICP and HPLC); at the end of the experiments all columns were cut into 5 cm sections and the residual soil was analyzed.

In general,  $\text{Na}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{K}^+$ , and  $\text{Mg}^{2+}$ , and  $\text{Cl}^-$ ,  $\text{NO}_3^-$ , and  $\text{SO}_4^{2-}$  were the most significant cations and anions in the leachates respectively, with concentrations on the order of mmol. Most of the  $\text{PO}_4^{3-}$  (99%) was retained in the column. Trace elements ( $\text{Cu}^{2+}$ ,  $\text{Zn}^{2+}$ ,  $\text{Pb}^{2+}$ , and others) were absent in the leachates in concentrations on the order of  $\mu\text{mol}$ ;  $\text{Fe}^{3+}$  and  $\text{Al}^{3+}$  were the most significant metals in the leachates, and their presence was most relevant in Andisols. Dissolved OC in the soil, due to the alkaline nature of the ash, was mostly retained at soil depths of 25 cm. Because of the ashes, an increase in the leachate pH was observed, with the most significant increase occurring in Andisols during the first 1–6 pore volumes of irrigation. At the end of the experiment, soil pH was higher in the ash-treated columns at depths of 0 to 15 cm but similar to the pH of control columns at depths of 20–25 cm, confirming the high buffer capacity of the soils.

© 2014 Elsevier B.V. All rights reserved.

### 1. Introduction

Forest fires, a common occurrence around the world, result not only in direct loss of existing plants and alterations in scenery, but also in long-lasting, residual changes to soil caused by the widespread distribution of ashes over the soil. The ashes of forest fires have been used, in a controlled manner, as agricultural amendments due to the high concentration of potassium (K), calcium (Ca) and other important plant growth nutrients found in such ashes (Bodí et al., 2014; Campbell, 1990; Etiégni and Campbell, 1991; Goforth et al., 2005; Pereira et al., 2011, 2012; Voundi Nkana et al., 1998, 2002). However, ashes distributed in a natural and uncontrolled setting (Pereira et al., 2014), are later

affected by the action of water (either from rain or from irrigation), which results in the dissolution of soluble elements which ultimately seep into the soil (Kutiel et al., 1995; Piirainen et al., 2013). In general, the ashes produced in these kinds of events have a variable load of trace elements as well as highly alkaline pH (Escudey et al., 2010; Liodakis and Tsoukala, 2009; Pereira et al., 2012).

The composition of the leachates will be affected by the conditions of the leaching process (pH, elution time) as well as by the chemical and mineralogical composition of the soil (Demeyer et al., 2001; Moilanen et al., 2013). The water infiltration rate, which is affected by the thickness and type of ash, is another important parameter in the soil leaching process. It has been demonstrated that after a forest fire, the infiltration rate either increases in the soil due to the ash effect (León et al., 2013) or decreases due to generation of water repellency (Bodí et al., 2012). An adequate estimation of the environmental damage caused to soils and superficial and groundwater streams close to areas seriously affected by forest fires must include a study of the leachates generated when the ashes interact with water by rain or irrigation.

In general terms, ashes generated by forest fires contain essential plant nutrients, such as potassium (K) and phosphorous (P), but they can also include a considerable amount of trace elements (Pereira and

\* Corresponding author at: Facultad de Química y Biología, Universidad de Santiago de Chile, Av. B. O'Higgins 3363, Santiago 7254758, Chile. Tel.: +56 2 27181047.

E-mail addresses: [mauricio.escudey@usach.cl](mailto:mauricio.escudey@usach.cl) (M. Escudey), [Nicolas.arancibia@usach.cl](mailto:Nicolas.arancibia@usach.cl) (N. Arancibia-Miranda), [Carmen.pizarro@usach.cl](mailto:Carmen.pizarro@usach.cl) (C. Pizarro), [mantilen@puc.cl](mailto:mantilen@puc.cl) (M. Antilén).

<sup>1</sup> Facultad de Química y Biología, Universidad de Santiago de Chile, Av. B. O'Higgins 3363, Santiago 7254758, Chile.

<sup>2</sup> Pontificia Universidad Católica de Chile, Facultad de Química, Vicuña Mackenna 4860, 6904411, Santiago, Chile.

Cerdà, 2013). The main environmental risk is that leaching of these elements affects not only the soil, but also water systems, and can even alter normal plant growth (Reijnders, 2005). Studies of ash leachates in soils at various pH values have shown that between 76% to 95% of  $\text{Cr}^{3+}$  contained in the ash is released, depending on the origin of the ashes, while for  $\text{Pb}^{2+}$  the value reached 70% and for  $\text{Cd}^{2+}$  more than 99% (Lioukakis et al., 2009). The release of elements from ashes depends on the chemical characteristics of the ash (Pereira et al., 2012), in terms of form and solubility, and can be classified as: i) water soluble salts (like chlorides), whose concentration depends more on a dilution effect than on the pH of the ash or of the soil solution; ii) elements forming compounds that dissolve in acidic media (carbonates or oxides), and iii) elements chemically in the form of oxides or hydroxides that can be released gradually through a process of dissolution in aqueous media (Ludwig et al., 2005).

In Chile significant amounts of native forests as well as pine and eucalyptus plantations are lost every year as a result of about 3000 forest fires that affect more than 50,000 ha every summer season (CONAF, 2013). In addition to the effect of high temperature on the soil and the destruction of the plant cover, the ashes produced by these fires end up spreading out over the soil, which is generally volcanic in origin.

Soils derived from volcanic materials are highly productive, and in Chile they comprise about 70% of the arable land surface. In this context, Ultisols and Andisols are the most significant; the Ultisols have undergone important transformations over time, exhibiting decreased organic matter content and a progression of their clay fraction towards more crystalline structures. Andisols are recent soils of volcanic origin, with a predominance of inorganic components of low crystallinity, like allophane and iron oxides. In general terms, soils derived from volcanic materials have a variable surface charge and present high retention/accumulation of phosphorus species such as phosphates, therefore causing major difficulties for crops as a result of low soil P availability (Shoji et al., 1993).

In a natural system, it is not always possible to discriminate the effects of fire from those of residual ashes distributed in burned soils (Badía et al., 2013). The origin of ashes (pine, eucalyptus and native forests in our study) can have differentiated effects on the leaching of exchangeable bases, anions, and trace elements – it has been shown, for example, that the availability of P in burnt volcanic soils depends on the origin of the ashes (Escudey et al., 2010).

The objective of this research was to investigate the effect of ash-treatment on various soils of volcanic origin, and to analyze the impact of ash-treatment on the pH of the soils and on the capacity of the soil to leach or retain various exchangeable bases (cations), anions, and trace elements. Five different volcanic soils treated with ash originating from three different sources were utilized to determine how soil type and ash-origin affect the ash-treatment process.

## 2. Materials and methods

### 2.1. Description of soils and ashes

Soil samples were collected in southern Chile, from a depth of 0–15 cm from uncultivated areas of Collipulli (C), Ralun (R), Diguillín (D), Metrenco (M), and Nueva Braunau (NB). Andisols (R, NB and D) exhibit a mineralogy dominated by low crystallinity compounds such as allophane, while in Ultisols (C and M), halloysite and kaolinite predominate (Cáceres-Jensen et al., 2013). Ashes from native forests (N, *Nothofagus dombeyi*, *Nothofagus obliqua*, *Nothofagus pumilio*, *Laurelia sempervirens*), pine (P, *Pinus radiata* D. Don) and eucalyptus (E, *Eucalyptus globulus*) plantations were obtained from the burning of plant material from the respective plantations. Branches and leaves were burnt on the soil in an open area inside each plantation; after the burning process, the ashes were collected separately and mixed to make homogeneous ash samples of differing origins. Inside the fire, temperatures higher than 500 °C were measured with type K Ni–Cr thermocouples. All the

samples were air-dried and sifted through a 2 mm sieve. Detailed description and characterization of the soils and ashes are presented in Tables 1 and 2.

### 2.2. Soil column procedure

Although soil sampling considered the 0–15 cm depth (not related with the horizon depth), columns of 25 cm thickness were packed to facilitate soil comparison. For all the soils considered, properties of the soil at depths of 0–15 cm are very similar to those at depths of 15–30 cm (Briceño et al., 2004; Escudey et al., 2001).

Soils were packed to a depth of 25 cm, according to their respective field bulk densities, into acrylic columns with a diameter of 10 cm and a total length of 35 cm. A fiberglass cloth disk was placed on the perforated plate at the bottom of each column to prevent the loss of solid materials. A 30-g sample of ash was incorporated into the top 5 cm layer of the packed column. The experimental controls received no ash treatment. The columns were set up in a vertical position, flooded once a week with one pore volume of distilled water, and drained by gravity for a period of 12 weeks. Columns containing only 30 g of ash were prepared and treated in an equivalent way. The drainages from each weekly leaching cycle were analyzed for pH, organic carbon (OC) content, exchangeable bases ( $\text{K}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Na}^+$ ), and trace elements (Cu, Zn, Pb, Al, Fe, Ni, Cr, Mo, Mn, Cd) by ICP-OES, and anions ( $\text{Cl}^-$ ,  $\text{NO}_3^-$ ,  $\text{SO}_4^{2-}$ , and  $\text{PO}_4^{3-}$ ) by HPLC. The detection limits in  $\mu\text{mol L}^{-1}$  for trace elements and phosphate were: Cu = 0.1, Zn = 0.07, Pb = 0.1, Al = 0.5, Ni = 1.0, Cr = 0.1, Mo = 0.2, Mn = 0.05, Cd = 0.01,  $\text{PO}_4^{3-}$  = 0.3.

At the end of each leaching experiment, each soil column was cut open lengthwise and the profile was sectioned into five equal length segments for analysis of the soil's pH and OC.

### 2.3. Chemical determinations

The bulk density, OC content, and exchangeable cations of the soils were determined by standard methods. The bulk density was determined by the average air dried weight of the soils in undisturbed soil cores of the 0–25 cm soil profile in 5 cm diameter and 5 cm high brass rings, while the OC content was determined by the Walkley–Black method (Allison, 1965). The exchangeable cations were determined as the concentrations of  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Mg}^{2+}$  and  $\text{Ca}^{2+}$  in ammonium acetate extracts (Chapman, 1965). The pH was measured in soil suspensions with a 1:2.5 w/v soil to water ratio. The electrical conductivity (EC) was measured in the saturation extract (Bower and Wilcox, 1965).

The total alkalinity of ashes was determined by adding 200 mL of 0.1 M HCl to about 2.5 g of ash, and then heating close to boiling temperature until no reaction was observed. The excess of acid was titrated with 0.1 M NaOH until pH = 7.0. Ash alkalinity was finally expressed as grams of  $\text{CaCO}_3$  per kg of ash.

### 2.4. Data analysis

For each type of soil, a one way analysis of variance was carried out to establish the effect of each treatment on cations and anions. The average values ( $n = 3$ ) were compared using the Tukey test ( $p < 0.05$ ). Significant differences were considered at a  $p < 0.05$ .

## 3. Results

### 3.1. Chemical characterization of starting soils

Each of the starting soils (Table 1) was acidic, with pH varying from 4.5 to 5.9 with low EC and low exchangeable base content ranging from 1.5 to 10.4  $\text{cmol}_{(+) } \text{kg}^{-1}$ . The OC content in the Andisols (R, NB and D) was higher than in the Ultisols (M and C).

In contrast to the soils, the pH of ashes of native, pine, and eucalyptus was 13.1, 12.1 and 12.8, respectively. The ashes contain 1.3 to 1.9% of

Download English Version:

<https://daneshyari.com/en/article/4571112>

Download Persian Version:

<https://daneshyari.com/article/4571112>

[Daneshyari.com](https://daneshyari.com)