



Natural restoration of soils on mine heaps with similar technogenic parent material: A case study of long-term soil evolution in Silesian-Krakow Upland Poland

Krystyna Ciarkowska^{a,*}, Laura Gargiulo^b, Giacomo Mele^b

^a Soil Science and Soil Protection Department, University of Agriculture, Aleja Mickiewicza 21, 31-120 Krakow, Poland

^b Istituto per i Sistemi Agricoli e Forestali del Mediterraneo, Consiglio Nazionale delle Ricerche, via Patacca 85, 80056 Ercolano, Italy

ARTICLE INFO

Article history:

Received 22 March 2015

Received in revised form 14 July 2015

Accepted 26 July 2015

Available online 3 August 2015

Keywords:

Zn–Pb post mining sites

Image analysis

Dehydrogenase activity

Soil temporal changes

ABSTRACT

The study focused on the variability in properties and pedogenesis of soils located at post mining sites in the old industrial area in the Silesian-Krakow Upland, southern Poland. The investigated sites were comparable in terms of Zn–Pb mining history, soil texture and climate, but differed in duration of pedogenesis, which started after the waste materials were accumulated and covered 30, 70, 100 and about 400 years of self-restoration. A wide spectrum of soil parameters including: Zn, Pb and Cd contents, dehydrogenase activity, pores space and aggregate formation, organic matter decomposition were studied by chemical and micromorphological image analyses with the aim of tracing the evolution of soils and checking if the results of image analysis could be integrated with results obtained by chemical and biological determinations. Stepwise progressive regression equations were obtained to establish the parameters that varied over time. Zn, Pb and Cd contents exceeded several times permissible values in all soils studied. The evolution of these soils was significantly different from each other. During the process of self-restoration of the soil, the contents of organic carbon and total nitrogen, available potassium and phosphorus including dehydrogenase activity increased with increasing age of soils. Pedogenesis resulted also in the increasing amounts of aggregates of small sizes, which were set close to one another together with narrow pores, which was able to store water. A synchronisation between soil properties, obtained by chemical, biological and micromorphological analyses indicating their usefulness for the demonstration of temporal changes.

© 2015 Elsevier B.V. All rights reserved.

1. Introduction

Metal mining activities in the area near Olkusz and Bytom (South Poland) started centuries ago. Zn Pb, and Cd ores have been mined and processed since the 14th century. As a result of mining activity, a large amounts of wastes have been deposited in heaps that were not been reclaimed. Heaps are composed of mining residues and waste rocks which are characterised by properties unfavourable for ecosystem development such as sensitivity to erosion, poor water retention, nutrient deficiency and very high contents of heavy metals. For these reasons pedogenesis at these sites is occurring very slowly and full recovery of soils takes a long time (Krzaklewski et al., 2004; Pająk et al., 2015).

The most important soil processes occurring in soils are: the accumulation of organic matter; formation of soil aggregates with a new pore structure; and development of biological activity (Šourková et al., 2005; Monserié et al., 2009; Séré et al., 2010; Huot et al., 2014). Aggregation is a primary property of soils and it is related to pore size distribution which in turn strongly affects water movement and retention, as well as the distribution of chemical compounds (Bottinelli et al.,

2010; Hallaire and Curmi, 1994; Jangorzo et al., 2013, 2014; Mermut et al., 1992). Aggregation also influences the activity of soil microorganisms which often depends on aggregate size (Coppola et al., 2009; Dexter and Richard, 2009; Six et al., 2004). The total population of active soil microorganisms can be assessed by determining the activity of intracellular enzymes such as dehydrogenases (Mukhopadhyay and Maiti, 2010).

Quantitative analysis of soil organic matter including the degree of its decomposition and soil aggregation can be performed using micromorphological image analysis (Jangorzo et al., 2014). With the same technique the amount, size, shape and development of pores in soils under different management systems may also be explored (Gargiulo et al., 2013; Mermut et al., 1992). Using image analysis the early pedogenesis of constructed technosols has been studied both for pore structure and for aggregation (Ciarkowska and Hanus-Fajerska, 2008; Séré et al., 2008; Monserié et al., 2009; Badin et al., 2009; Zanuzzi et al., 2009; Jangorzo et al., 2013).

The pedogenic processes of soils forming on coal mining sites have been well studied using the pioneer plant cover, the function of soil fauna and the accumulation of organic carbon (Frouz et al., 2006, 2007, 2008; Arocena et al., 2010). The evolution of constructed soil structure and its physical properties, as well as the properties of soils

* Corresponding author.

E-mail address: k.ciarkowska@ur.krakow.pl (K. Ciarkowska).

formed on reclaimed sites have also been reported (Hartmann et al., 2010; Šourková et al., 2005; Frouz et al., 2006, 2008).

Limited studies are available regarding the properties of soils widely differing in age formed from spoil material after Zn, Pb and Cd ore mining and smelting. We hypothesised that differences in properties such as aggregate development, porosity and dehydrogenase activity in soils formed on post-mining sites are mainly caused by the passage of time and the properties of the spoil material (content of heavy metals and nutrients). We questioned if the content of soil nutrients and organic carbon content increased with time together with the increase of soil profile complexity, in spite of persisting strong pollution with heavy metals.

Objective of our work were to: integrate data obtained from micromorphological image analysis (regarding aggregated soil organic matter and pore structure) with chemical analysis (mainly the content of macronutrients and enzyme activity) and establish changes in selected soil properties during the long term evolution of soils formed from technogenic materials.

2. Materials and methods

2.1. Study sites and sampling methods

The study was conducted during 2013–2014 on the Silesian-Krakow Upland in the Bytom and Olkusz region in the Zn and Pb ore mining area, South Poland (N 50°17' E 19°29' and N 50°45' E 18°84') (Fig. 1). The average altitude of the study area is 400 m a.s.l., the mean annual precipitation is 700 mm and the mean annual atmospheric temperature 7.2 °C.

The bedrocks of the soils studied are sludges after floatation of Pb and Zn ores collected on a settler (site 1) or Triassic dolomitic-limestone waste rock with metal ore residues and Pleistocene sand (sites: 2–5). The investigation sites varied in age and vegetation cover resulting from natural succession (Table 1) and none of the investigated soils had ever been reclaimed.

Soil samples were collected in October 2013 from five mine waste deposits. Heaps had flat tops of the surface of about 700 m². In each mining area three plots of 5 m × 5 m were randomly selected for the collection of samples. The sampling quadrates were located at least about 5 m from the margin and from each other. Samples were taken from the surface, organic layers (0–10 cm) and subsurface layers (10–30 cm). In each sampling location, from the same spot, samples for chemical analyses and undisturbed soil samples for micromorphological analyses were taken (in three replicates from each location). Undisturbed soil samples were collected in Kubiena boxes and impregnated under vacuum with Araldite epoxy resin for thin section preparation. In sites 2 and 3 undisturbed soil samples for micromorphological analysis were taken only from the surface layers, because in the subsurface layers only fissures among fragments of waste rock contained soil.

For the analysis of physical, chemical and biological properties, the fine fraction of the soil (<2 mm) was used. Samples for microbial analysis were stored at 4 °C, while samples for chemical and physical analyses after drying for at least 48 h were stored in room conditions. Three replications of each measurement were collected, and the results were expressed as a measure of the dry mass of the materials studied.

2.2. Image acquisition and analysis

Images of thin soil sections were acquired with circular polarized light (CPL) and transmitted light (TL) using a motorised stage (Prior H116) and using a Nikon D200 (3872 × 2592 pixel) camera with AF Micro Nikkor 60 mm lens fixed on a desktop stand. Each frame had a FOV of 23.2 mm (pixel size 6 µm) and images of the whole area of the thin section (about 60 × 40 mm) were acquired with 30 partially overlapping frames in both directions in the plane. The frames were recorded in order to obtain a mosaic image using Microsoft ICE software. In the images organic matter and porosity were assessed with two different software programs as detailed below.

Porosity was assessed in CNR ISAFOM in Ercolano (Italy). Mosaic images of the soil thin sections were pre-processed and segmented using a



Fig. 1. Map of the area, 1–5 sites studied, see Table 1.

Download English Version:

<https://daneshyari.com/en/article/6408406>

Download Persian Version:

<https://daneshyari.com/article/6408406>

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