International Journal of Coal Geology 196 (2018) 139–147

Contents lists available at ScienceDirect

International Journal of Coal Geology

journal homepage: www.elsevier.com/locate/coal

Distribution and Mobility Potential of Trace Elements in the Main Seam of the Most Coal Basin

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ARTICLE INFO

Keywords:
Trace elements
Mobility potential
Lower bench
Holešice member
Most basin

ABSTRACT

The Most Basin represents a coal basin with a long mining history in the Czech Republic. The majority of palaeoenvironmental and geochemical studies have been focused on the upper part of the coal-bearing Most Formation where the coal is generally enriched in As, Cr, Ni, Cu and Zn. This study evaluated the distribution of V, Cr, Ni, Cu, Zn, Pb, Se, As, and Mn from the lower part. Regarding to the transport of inorganic elements into environment, the evaluation of mobility potential was also conducted.

The total of 51 samples were collected from the Lower Bench in the Holešice Member. The chemical analyses were performed together with optical microscopy. The X-ray spectroscopy and ICP-MS were used to detect trace element contents in the study set of samples. 4 samples were subjected to the Sequential Extraction Procedure. The prepared leachates were analysed using the ICP-MS method.

In total, 13 elements were screened in samples within the study profile. The mode of occurrence is the key factor for identifying a potential source of the trace elements. All evaluated trace elements (V, Cr, Ni, Cu, Zn, Pb, Se, As and Mn) leached most in the oxidisable fraction. On the other hand, As, Mn, Ni, Zn and Cd leached in more mobile fractions, e.g. reducible and acid.

1. Introduction

The study of trace elements in coal provides not only useful data related to the sedimentological environment, but also reveals information required to minimise the environmental impact during the use of coal. Inorganic components in the coal can originate from several sources: 1) original organic matter, 2) formation during the stages of coalification, 3) carrying away by water or wind, 5) products of alteration of primary minerals. Trace elements, as a part of the inorganic components of coals, have deserved much attention and many studies have been done on trace element content and their distribution on subbituminous and bituminous coals (Adedosu et al., 2007; Finkelman, 1995; Lewinska-Preis et al., 2009; Ren et al., 1999; Suárez-Ruíz et al., 2006; Swaine, 1990; Zhuang et al., 2012, among many others). On the contrary, such conventional studies are scarce for low-rank coals (Gentzis et al., 1996). The modes of occurrence of trace elements vary greatly among coals. In low-rank coals, elements are usually organically bound, but with the progress of coalification, the elements are removed by expulsion of moisture and by changes in the chemical structure of the organic matter (Ward, 2002; Li et al., 2007; Finkelman et al., 2018). Elements bound with discrete minerals remain unchanged (Ward, 2002). The fate of trace elements during coal conversion processes has become a matter of concern due to the large amount of coal that is often used for energy production. The behaviour of trace elements during coal combustion depends on their concentration, mode of occurrence, and combustion parameters. The organically associated trace elements tend to be vaporised, either escaping into the atmosphere or adsorbed on the fine fly ash particles upon combustion in the furnace. The inorganically associated elements are generally non-volatile and tend to retain in the bottom ash and/or the fly ash particles upon combustion. On the other hand, the presence of trace elements in coal may help in understanding phenomena such as the geological history of coal-bearing sequences in sedimentary basins, the conditions ongoing due to coal seam formation, the depositional environment, and the influence of tectonics (Dai et al., 2012).

The mobility potential has been successfully evaluated in coal by the modified Sequential Extraction Procedure (SEP) (Cabon et al., 2007). The general principle of the method is to gradually leach the elements

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https://doi.org/10.1016/j.coal.2018.07.005
Received 29 November 2017; Received in revised form 29 June 2018; Accepted 12 July 2018

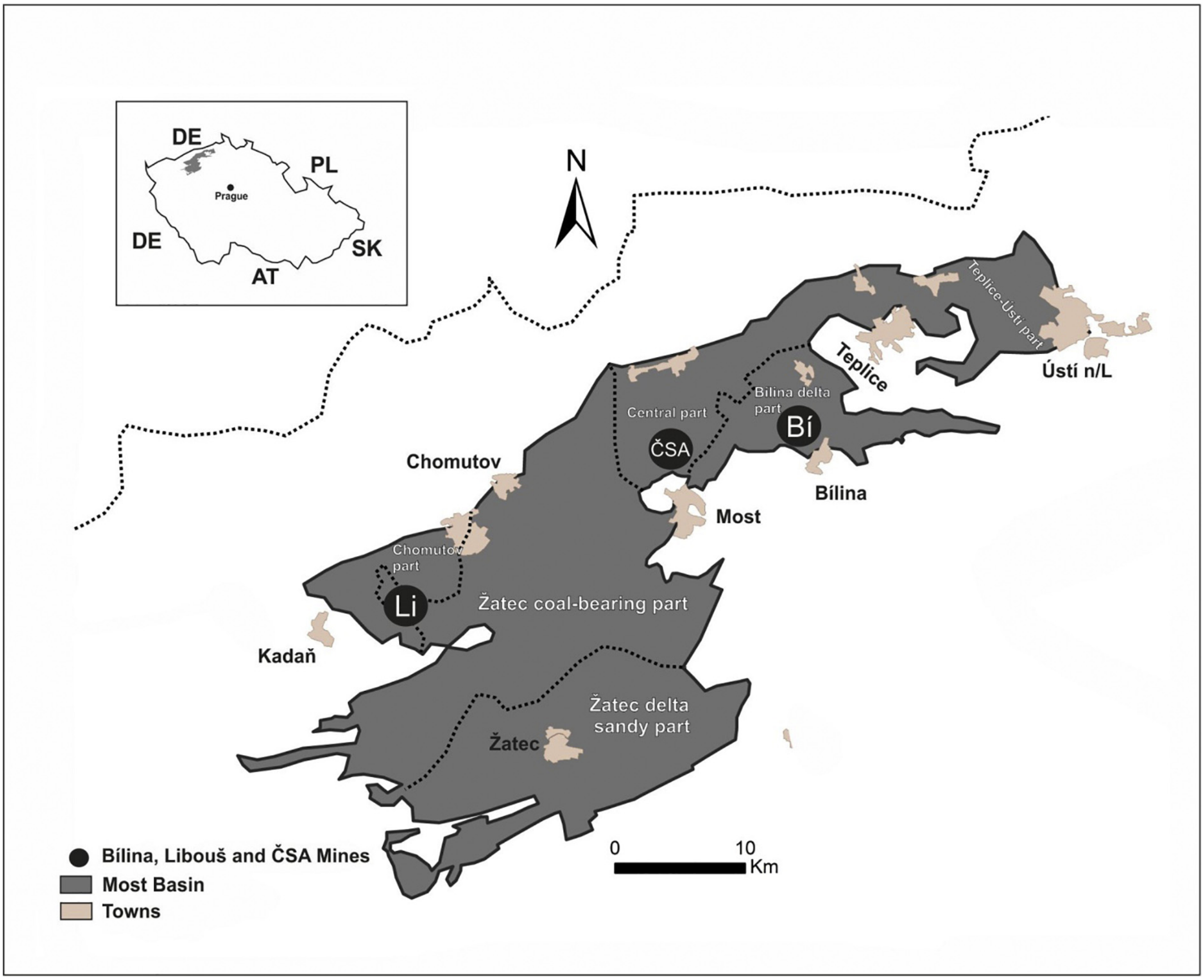

Fig. 1. Location of the Most Basin with a marked position of the active Bílina (Bi), Libouš (Li) and ČSA open cast mines (modified from Mach et al., 2013).

with a decreasing pH agent. The mobility potential of any trace element increases in the following order: oxidisable, reducible and acid and allows to predict its behaviour in environment under given conditions.

The Most Basin (Late Eocene-Early Miocene) represents an economically significant coal basin for the Czech Republic with only surface mining (Rajchl et al., 2009). The basin belongs to the group of Podkrušnohorská basins (Fig. 1), being a subject of detailed palaeoenvironmental and geochemical studies for its unique sedimentary sequence (Havelcová et al., 2012, 2013, 2015; Mach et al., 2013; Matys Grygar and Mach, 2013; Rajchl et al., 2008; Teodoridis et al., 2011; Teodoridis and Sakala, 2008). The basin formation started during the late Eocene and Oligocene by the intensive volcanic activity. The sedimentation followed by the clastic and organic deposits from the end of the Oligocene to the early Miocene (Mach et al., 2014). During the late Eocene-Oligocene, an intense alkaline volcanism mainly of basaltic character brought the pyroclastic materials and lava thick-bodies into the sedimentary basin, establishing the volcanic Střezov Formation. The following Most Formation is a unique coal-bearing strata (Fig. 2) subdivided to the Duchcov, Holešice, Libkovice and Lom members. The lowermost Duchcov Member contains alluvial sediments, followed by the Holešice Member. The last-mentioned member represents the Main Seam gradually passing to the Libkovice Member. The fine-grained lacustrine clays and lacustrine clay sediments form the uppermost Lom Member (Pešek and Sivek, 2016).

According to the geochemistry and mineralogy, two main complexes were distinguished in the Most Basin. The Lower Bench, including Duchcov Member and lower part of the Holešice Member, contained a higher content of Al, Ti, Nb, Zr, Cr. While the high content of Si, Mg, K, Rb and Cs was typical for the Upper Bench, forming the upper part of the Holešice Member (Elznic et al., 1998). This division was further supported by Mach et al. (2014) with using the significant correlation proxies, e.g. Al, K, Ti.

Taking into account these previous findings, the present work evaluates the mobility potential and the final distribution of V, Cr, Ni, Cu, Zn, Pb, Se, As, Mn in the Lower Bench (Holešice Member) of the Main Seam in the Most Coal Basin.

2. Material and methods

2.1. Samples and methods

Fifty-one samples were collected from the Bílina Mine in the Most Basin. The evaluated set represents a continuous vertical profile of the Holešice Member in the Lower Bench (Fig. 2). The proximate (moisture content W^a, volatile matter content V^d and ash yield content A^d) and ultimate analyses (CHNS), together with the calorific value $Q_s{}^d$, were conducted in all samples according to ISO 17246, 17247 and ISO 1928. The element migration potential in environment was evaluated based on the Sequential Extraction Procedure (SEP). In order to postulate conclusion for the Holešice Member, two samples from the Lower Bench (Bil 26 and Bil 0) and two from the Upper Bench (ČSA 48 and Lib 21) were chosen according to variation in the ash yield A^d and the sulphur content S^d. The sample set was evaluated with the principal component analysis (PCA) using the Statistica software. Variables in the