International Journal of Coal Geology 86 (2011) 12–19

Contents lists available at ScienceDirect

International Journal of Coal Geology

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

Evaluation of pollution levels at an abandoned coal mine site in Turkey with the aid of GIS

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ARTICLE INFO

Article history:
Received 30 May 2010
Received in revised form 2 November 2010
Accepted 21 November 2010
Available online 28 November 2010

Keywords:
Geographical information system
Coal mining
Pollution transport
Surface runoff
Case study

ABSTRACT

Determination of the level of pollution at contaminated sites can be costly due to the number of samples required to identify the areas with higher contaminant concentrations. Yet, if pollution transport pathways can be found, then contamination level can be detected with fewer samples. In this case study, pollution levels at an abandoned coal mine site at Ovacik–Yaprakli (Cankiri, Turkey) are evaluated with respect to topography and surface runoff pathways derived using Geographical Information System (GIS) tools. First, surface runoff pathways are identified using ArcGIS 9.3. Then, the concentrations of trace elements (Mn, Cr, V, Cu, Ni, Zn, Ba, and Sr), pH, Fe and S contents in soil samples taken at random locations around the mine area are determined in a laboratory. In addition, pH and electrical conductivity (EC) are measured in flowing waters in-situ at different locations using pH and EC probes. The spatial distribution of pollutant concentrations is evaluated with respect to the surface runoff pathways and locations of potential contamination sources (i.e. open pit, coal storage and dump sites). Finally, the contamination level in the study area is assessed based on the limit values stated in the Soil Pollution Control Regulation of Turkey (SPCR). Results indicate that the site is contaminated with Cr, Ni, and Cu. In general, pollutant concentrations are higher close to the contamination sources and along the surface runoff pathways determined by the ArcGIS. Results indicate that GIS can aid in locating the areas that are more likely to have high pollutant concentrations. This would in return prevent overlooking highly contaminated spots which may be located far away from contamination sources. Moreover, these areas can be determined using a smaller number of samples which would decrease the sampling costs.

1. Introduction

Coal mining can be an economical asset for a nation. However, it may lead to substantial environmental damage if precautions are not taken. Mining activities can lead to land degradation, changes in topography, soil and water pollution, and ecological deterioration (Bell et al., 2001; Bhattacharya et al., 2006; Ribeiro, 2010; Si et al., 2010). Acid mine drainage is another environmental problem related to coal mining that can result in acidification of soil and receiving water bodies (Bell et al., 2001). Acidification would increase the dissolution of toxic metals from water-permeable tailings, waste rock piles and open pits. In return, soil and water ecosystems will be impacted (Bell and Donnelly, 2006; Sams and Beer, 2000). These problems can be associated with abandoned mining sites as well. These sites may continue to pollute soil and water for years (Bell et al., 2001; Navarro et al., 2004). For example, Navarro et al. (2008) show that an abandoned mine site in Cabezo Rajao (Spain) still continues to pollute the environment with metals dispersed downstream and downslope from tailings by surface runoff.

Contaminants originating from coal mining activities can be transported to long distances. Surface runoff and mechanical dispersion due to wind action are the main transport mechanisms (Navarro et al., 2004). Enhanced dissolution of toxic metals via acidification further improves the transport. In limited number of case studies, the importance of surface runoff pathways and streams on the transport of contaminants from coal mining sites has been shown. For instance, water draining freely from the Handlova–Cigel brown coal district transported large amounts of toxic elements into surface streams, which in turn contaminated a broader area (Klukanova and Rapant, 1999). The Allegheny and Monongahela Rivers transported 1.2 and 1.35 million tons of sulfate, respectively, to the Ohio River in Pittsburgh in 1980 (Sams and Beer, 2000). Sams and Beer (2000) showed that the trends observed in contaminant concentrations within years are in line with the trends in coal production rates in sub-basins contributing to pollution transport.

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doi:10.1016/j.coal.2010.11.012

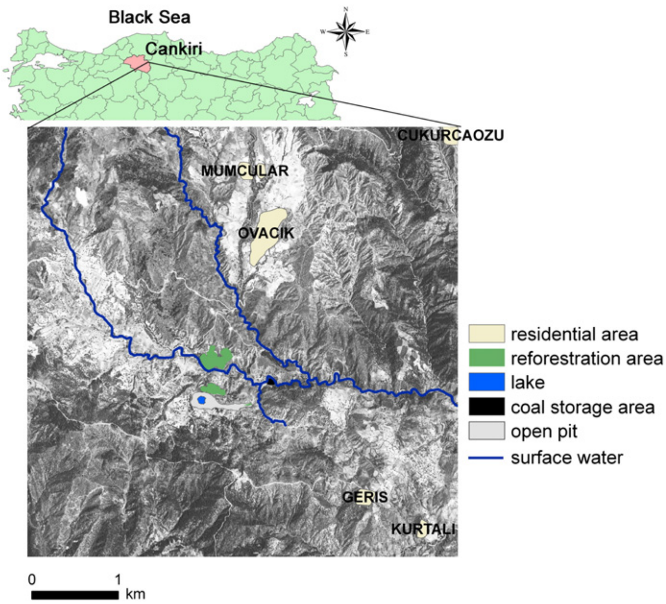

Fig. 1. Location of the Ovacik–Yaprakli abandoned coal mine site.

Identification of the spatial extent and levels of pollution at mining sites are critical in determining the best approaches and techniques in pollution prevention and environmental reclamation. For this purpose, contaminant transport pathways should be identified as well as the locations of contaminant sources (i.e. excavation area, dump site, storage area, etc.). This can be achieved by rigorous sampling (i.e. systematic and regular grid sampling, simple random sampling, stratified sampling, etc). The number of sampling locations is dependent on the geometric features of the area and the characteristics of contamination (Cuccu, 2002; EPA, 2002). Nevertheless, it is a fact that sampling can be highly costly. This is mostly due to the number of samples that should be taken to assure data quality and the need to locate the areas that have high contaminant concentrations (hot spots) (EPA, 2002). However, if locations that are prone to contamination can be predicted, then the sampling program can be designed accordingly. Several studies, as mentioned before, point out that it is more likely to observe contamination closer to the source. Moreover, contaminants can be transported by surface runoff. Therefore, if surface runoff flow pathways can be derived, then it may be possible to identify the locations of higher contaminant concentrations (other than the ones in the vicinity of contamination sources), the direction of transport and to which distance contaminants may have been transported using a smaller number of samples compared to sample sizes required for traditional sampling methods. In this manner, GIS can be an effective tool for determination of the areas that are contaminated as a result of contaminant transport via surface runoff.

GIS helps to integrate various types of information spatially to aid in characterization and decision making. Yet, its application in the analysis of pollution transport, prevention and reclamation at coal mining sites is limited. Ayad (2006) used GIS in the prioritization of stream remediation in the Clarion River basin in northwestern

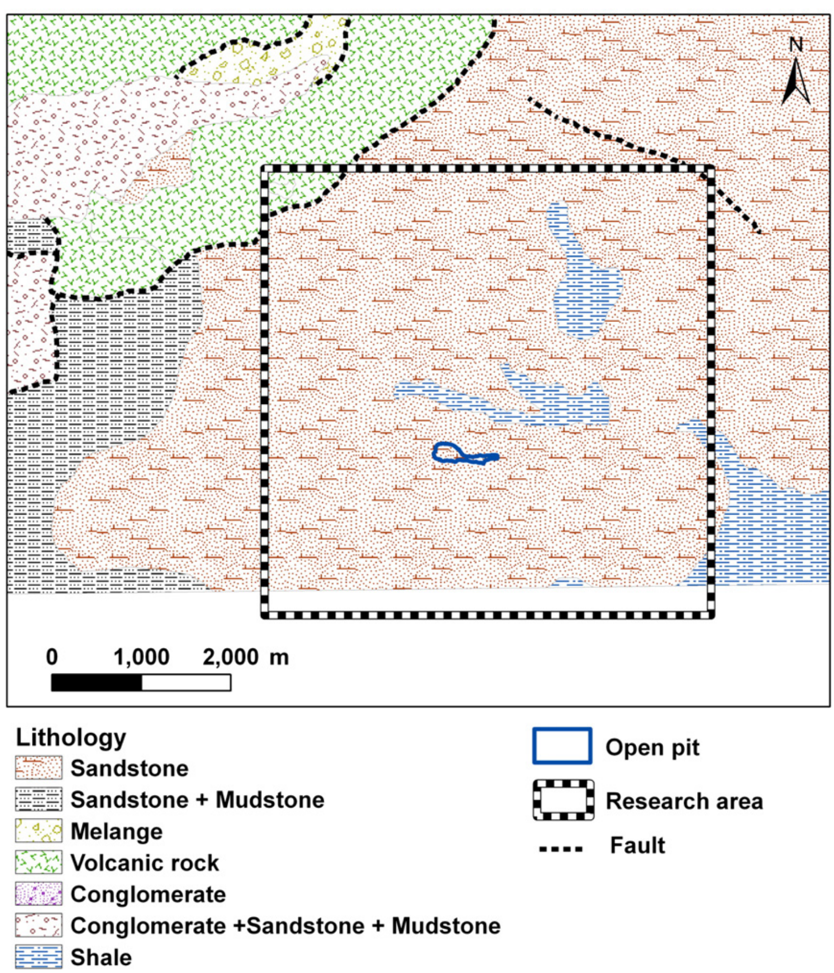

Fig. 2. Geological map of the study area.