Methodological approach in rehabilitating coal ash disposal sites from thermoelectric power plants and mitigation of environmental risks

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Abstract: The amount of the ash and cinder that is generated from thermoelectric energy production in Bosnia and Herzegovina exceeded 2.784 Mg for 2015 according to annual report of "Elektroprivreda BiH". Electricity production is the greatest environmental ballast for the city of Tuzla. Excavation of coal and deposition of coal combustion products influence drastic and many times terminate degradation of natural landscapes and soil habitat. There are five coal ash disposal sites in the city covering an area of approximately 170 hectares. It is known that this artificial substrate is the main cause of soil contamination; water/groundwater contamination due to leaching toxins (effluents and process waters); dust dispersion; and toxins entering the food chain. The objective of our research study was to explore the adequate practices of stand remediation through compiling the data on properties of ash from five disposal sites in Tuzla area. Long term study determined that the major characteristics of coal ash and effluents at the disposals sites are high alkaline reaction (pH >10) and presence of metals with high potential for toxicity (Ni, Cr, As and B), which concentrations exceeded permitted limits. Based on study results, how model of site rehabilitation would work and how it can be incorporated by applying green infrastructure approach in spatial planning is discussed.

Keywords: coal ash, disposal sites, environmental risk, remediation, reintegration

Introduction

Ash and cinder or coal combustion residues (CCR) are normal by-products in the power production at the thermal power plants (TPP), as they are incombustible fraction of coal. At the Tuzla TPP, which is located in northeastern part of Bosnia and Herzegovina, the incineration of coal produces approximately 200 kg of CCR per ton of fuel, which is a specific yield of 0.4 to 0.9 m^3 per MWh of energy produced. The annual volume of CCR is approx. up to 800,000 m^3, or 1,660 to 2,000 m^3/day. The CCR has been disposed of over the years at several disposal sites around the TPP, which are all located in the vicinity of the city of Tuzla. So far, more than 40,000,000 m^3 of CCR have been deposited at these locations. Energy production from coal produces large amounts of coal ash that needs to be land-filled if it cannot be used as a raw material for other industrial processes or products. These technogenic deposits, which belong to the category of brownfields since they are industrial land with developed basic infrastructure, just in Tuzla cover more than 170 hectares.

Ash substrate is characterised with predominantly coarse fragments and sand highly erodible, with low sorption capacity, small humus content (<2,1%) and significantly high concentrations of heavy metals (As, B, Cd, Cu, Cr, Pb, Ni, Zn). Average *coal ashes* pH values of the *one year old* ash is *high and varies from 10 to 12 (Čustović* et al.*, 2011).* In general*,* coal ashes taken from disposals in Tuzla were found to be highly alkaline. For exam*p*le at the site Jezero, which had been abandoned in 2003, the mean pH of disposed ash was 9.2 at the surface (0-20 cm) and 9.7 at 40-60 cm depth.

In comparison, water coming from ash disposal sites has very high alkalinity (pH values range from 10-12) (Dellantonio et al.*,* 2008; Ćerić et al.*,* 2009*;* Čustović et al., 2016).

Gradual decline of the leachate pH happens over time, but at a very slow rate. The following model was used for the estimate of the leachate pH in time (Čustović *et al*., 2011):

$$pH_t = (pH_o - pH_n)\cdot e^{-\alpha\cdot(t-t_o)} + pH_n$$

where pH_o represents the leachate pH value at the time CCR disposal site was closed (t_o), pH_t is the leachate pH measured at the time interval t, pH_n is the pH of the surface water that enters the respective disposal site, t_o represents the initial time, that is, the time when the site was abandoned (in years), t is the time of measurement of pH (in years), and α is a decay coefficient (-). The results of the model are presented on Figure 2.

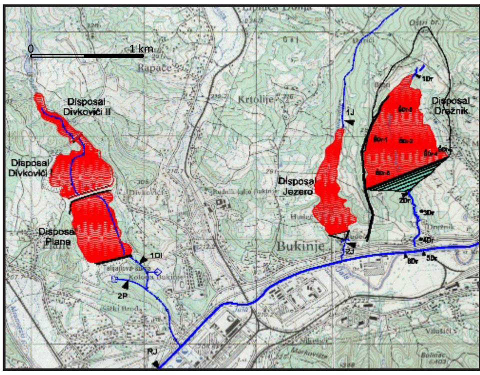

Figure 1. Location map of the CCR disposal sites in Tuzla

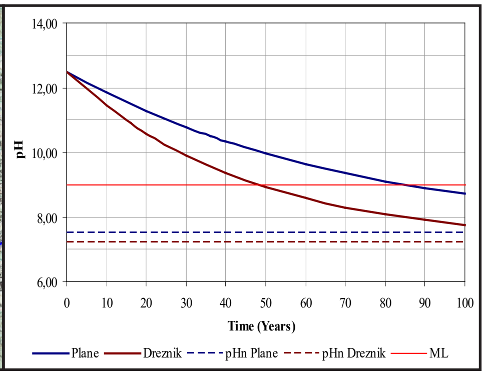

Figure 2. Modeled change of pH in time at the Dreznik and Plane disposal sites

Thick solid lines indicate the leachate pH from the two sites, and the dashed lines the surface water pH. The red solid line is the maximum level allowed in the effluent discharged to surface waters according to the water legislation in the Federation of B&H. The model indicates that the natural process of pH decline will require approx. 48 years for the leachate from the Dreznik site to reach national standards. For the Plane site, this process is estimated to be even slower, some 85 years. It has to be considered that the model was developed with very limited data, and the estimates are therefore not perfectly accurate. It was assessed that the model for the Plane disposal site is more realistic, as it is based on a longer observation period of 36 years.

Remediation means decontamination as well as containment procedures to eliminate or interrupt the contaminants pathways to different receptors such as humans, plants and groundwater. Solutions for coal ash disposal remediation are context-dependent and need to be based on the actual documentation on spatial planning, which had already integrated local community needs and technical concerns. Frame methodology for remediation of coal ash disposal sites needs to be designed according to previous risk assessment (Meuser, 2013). In addition, risk assessment should be provided for every planed land use.

Materials and methods

„Reintegration of coal ash disposal sites and mitigation of pollution in the West Balkan Area" Project (RECOAL) has developed a basic conceptual structure – a framework – offering a route to structure coal ash management decisions that recognizes the importance of contextual factors. Its objective is twofold:

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- provide a framework for researchers and engineers involved in coal ash management to communicate their results to a wider audience of decision-makers and stakeholders; and

- guide policy-makers in the interpretation and synthesis of coal ash-related research for its incorporation into decision-making.

Results and discussion

RECOAL has developed a basic conceptual structure – a framework – offering a route to structure coal ash management decisions that recognizes the importance of contextual factors. A four-step procedure is proposed: 1) Problem definition; 2) Short listing of options; 3) Development of remediation strategy; 4) Monitoring program, (RECOAL, 2008). First step consider defining the objectives and motivations behind the remediation strategy.

Remediation palette is a second step and considers evaluation processes in which the best option is chosen as it is presented in the modified flow chart (Figure 3). In some cases one single criterion will be enough to eliminate an option. For instance, a high-cost remediation option may be discarded immediately if there are no available resources for its implementation. Also, ex-situ remediation methods were discarded for the case of Tuzla disposals, because the project's focus was explicitly on locally available low-cost methods. Alternatively, an option may be included even if it does not meet all the criteria. This question arises from the needs of local rural population that needs arable land and pastures for livestock production. The suitability of a remediation strategy) rather than a one-off linear process. The following steps are the development of remediation and monitoring designs. Usually, several remediation proposals will be available to address a particular site problem and these should be systematically compared and evaluated. Different approaches can be used, such as a multi-criteria assessment, scenario analysis, cost-benefit analysis and a variety of recently developed participatory mixed method approaches (Dodgson *et al*., 2000).

Development of an overall remediation strategy for the setting combining several options from the 'remediation palette' to address the multiple dimension of the pollution problem is the third step of a framework. Fourth step is focused on monitoring and evaluation of strategy in order to ensure its long-term sustainability.

Based on the framework, the case study from Tuzla showed a series of methodological steps for site remediation focusing on three major risks 1) food chain contamination, 2) ash dispersion by wind and water erosion and 3) contamination of ground and surface waters (landfill leachate and ash transport water).

Defined risks for site rehabilitation usually involve only establishment of a soil cover. This is most urgent measure that follows after end of landfilling process which prevents ash dust dispersion. Cover substrate that is usually applied represents a by-product of coal excavation and has low productivity. Uncertainties which need to be addressed are depth of cover layer and the long-term potential harmful effects if the soil cover is unable to neutralise pollution. Ash amendments, usage of adequate cultivars and crop rotation systems are measures that should be explored from technical and financial aspect for successful revegetation. Revegetation with high biomass production is hardly to be

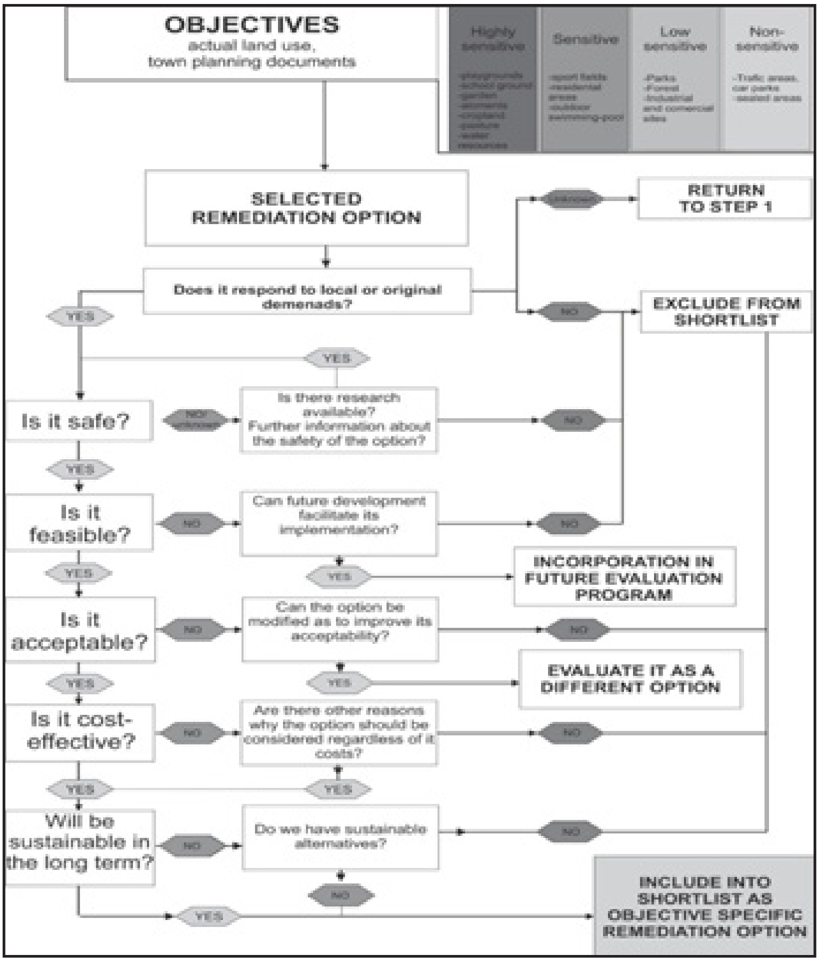

Figure 3. Modified RECOAL study flowchart for selecting remediation option

expected in actual cover substrates. Compost amendments improved the fertility of the ash substrates with respect to N, P and K and the microbial activity of the ashes (Dellantonio *et al*., 2008). To address dust dispersion from active disposal sites - second important issue - wind barriers are proposed as effective measure. The dominant species of trees growing in the areas surrounding the disposal sites are Willows, Poplars, Maple, Beech, Alder, Hazel, Hornbeam, Elder, Ash and Horse Chestnut. Using native species in shelterbelts would help establish a stable wind barrier (species are used to local biotic and abiotic conditions) and preserve/improve local ecosystems. Reforestation of the disposal sites would be an initially costly but potentially highly effective and multi-purpose solution for the long term benefiting local residents and ecosystems.

Third issue considers treatments of water: water-aeration process and filter materials. Aeration of alkaline wastewater for passive remediation was previously suggested by geoscientists from Newcastle University (Mayes *et al*., 2005). At Drežnik a column system was installed to test different sorbents' capability and capacity to retain pollutants. Locally available material brand (red shist) was able to reduce the pH and was effective in

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reducing Arsenic but was not able to filter out Boron (RECOAL, 2008). Constructed wet lands have been designed to purify waste waters with large nutrient and organic loads by microbial decomposition.

Integration of ash disposal brownfields includes preliminary, oriented and detailed risk assessments in the process of town planning (Meuser, 2013). European practices, based on soil protection strategies, indicate that old industrial land can be used as parks, forest land, for biomass production, for new industrial objects, residential housing etc. (Stadt Leipzig, 2008). The area for ash and cinder disposals sites in Tuzla could be used for plant nurseries, forest-parks, recreation, industrial - electricity production from solar panels and the town graveyard. Higher sensitivity use playgrounds, school grounds, arable land, recreational fields demand more intensive remediation, which is due to high cost, reduced to smaller areas of usually <3 ha which are economically feasible. On the other hand, highly contaminated land are usually restricted to low or non-sensitive use.

Conclusions

RECOAL's research demonstrates that coal ash remediation solutions are context-dependent, i.e. local factors are a crucial influence on decisions. Hence, it is necessary to examine every case independently attending to its local environmental characteristics and social conditions. The decision-support tools are presented within a simple four-step framework that can be used flexibly, according to the needs of the problem and the knowledge available. The results of RECOAL study can serve as a corner stone for the future remediation plans which need to be developed according to Regulatory Plans adopted by Tuzla Town Council in recent period and new land-uses assigned to the space.

Acknowledgement

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References

Ćerić, A., Zerem, N., Čustović, H. (2009): Study of the impact of the Tuzla Thermopower plant on the soil quality. International scientific thematic conference „Soil Protection Activities and Soil Quality Monitoring in South Eastern Europe". Proceedings. Sarajevo.

Čustović, H., Ljuša, M., Cero, M. Hukić, E. (2016): The impact of emissions of ash and slag from Thermal power plant Tuzla on the environment. Eurosoil Congress (Poster Presentation). Istanbul.

Čustović, H., Zerem, N., Ćerić, A. (2011): Impact of ash and cinder from thermal power plants on environmental conditions in the Tuzla Region. Soil Protection Activities and Soil Quality Monitoring in South Eastern Europe. Conference papers. European Union. doi:10.2788/36675 (pdf)

Dellantonio A., Fitz W.J., Custovic H., Repmann F., Schneider B.U., Grunewald H., Gruber V., Zgorelec Z., Zerem N., Carter C., Markovic M., Puschenreiter M. and Wenzel W.W. (2008): Environmental risks of farmed and barren alkaline coal ash landfills in Tuzla, Bosnia and Herzegovina. Environmental Pollution 153 (3): 677-686

Dodgson, J., M. Spackman, A. Pearman and L. Phillips (2000): Multi-criteria Analysis: A Manual, London: Department for Transport, Local Government and the Regions (DLTR), http://www.communities.gov.uk/documents/corporate/pdf/146868.

Handbook of Regeneration Solutions for Coal Ash Disposal Sites in the Western Balkans. (English and Bosnian language versions) available at www.forestresearch.gov.uk/fr/INFD-63KE8

Mayes, W. M.. Aumonier, J., Lawso, C. J., Batty, L.C. (2005): Project report of Newcastle University: Passive remediation of alkaline water to neutral pH (PRAWN).

Meuser, H. (2013): Soil Remediation and Rehabilitation: Treatment of Contaminated land and Disturbed Land, Environmental Pollution 23, DOI 10.1007/978-94-007-5751-6_1.

Stadt Leipzig. (2008): Leipzig – "Plagwitz" (Saxony) . http://www.eukn.org/Germany/de.

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