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Thesis - M.SC In Natural Science

Utilization of Coal Fly Ash for the Amendment of Marginal Soils in Israel

שימוש באפר פחם מרחף לשיפור תכונות של
קרקעות שוליות בישראל

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Abstract

Electricity generation in Israel and in many other countries is fueled mostly by coal which after combustion produces in large quantities of fly ash, amounting to about 9% (w/w) of the coal. The fly ash is composed of very fine particles and is typically characterized by a high pH value (pH = 12) and composed mainly of SiO_2 and CaO, in addition to varying quantities of trace elements, such as Cr, Pb, Ni, Se, and B. The fly ash has a pozolanic capacity and therefore it is used as a constituent in cement production, and as an additive in concrete production, in roads construction and also as a soil amendment in agricultural soils.

The continuing increase in demand for electricity generated by coal combustion leads also to an increase in the residual fly ash which reached about 1 million ton of the total 12.5 million ton coal used for power generation in Israel in 2006. Data obtained from the Israeli Coal Co., indicate that, for the current rate of ash generation, the whole amount of fly ash is easily absorbed and reused in cement (0.5 million ton) and concrete (0.5 million ton) production, while smaller quantities are used in roads infrastructure and even lower quantities in agriculture. It is likely that the amounts used for cement and concrete have reached their maximum level and therefore other options for the use of the anticipated quantities of fly ash are being considered and investigated.

The present research is part of a comprehensive programme for the evaluation of use of fly ash in agriculture, concentrating on the use of fly ash as a soil amendment for marginal soils, sand dunes and loess soils, which are highly abundant in the Israeli Negev desert. The research was designed to take advantage of the cementing characteristics of the fly ash and its ability to strengthen the structural stability of the top layer of loose sand dunes on the one hand and to weaken the impermeable crust formed on the surface of loess soils, on the other.

The experiments consisted of treating sand dune and loess soils samples with varying amounts of fly ash, up to 15%. The soil samples were then subjected to tests aimed at estimating the potential of fly ash to:

- Improve the structural stability of the top layer of sandy soils. Increasing the soil's water retention capacity and stability to wind erosion.
- Reduce clay dispersion and aggregate disintegration at the loessial soil's surface, thus improving water infiltration through the crust

The environmental and agricultural impacts of marginal soil remediation with fly ash and especially the impacts of the high salinity, heavy metals and boron contents in the fly ash were also considered.

The results of the experiments clearly indicated that the treatment of marginal soils with fly ash produced significant positive impacts. Treated soil samples that were subjected to subsequent rain and wind storms showed the following characteristics:

- Improved water retention and better aggregate stability to wind erosion (sand dune soil).
- Greater Water infiltration rate and higher susceptibility to wind erosion (Loess soil).

The rainfall simulation experiments demonstrated a statistically significant reduction of 90% in water infiltration rate through the soil profile and up to 800% increase in water retention in the sand dune soil, amended with 15% fly ash, as compared to the control. Furthermore, a repeated addition of a small quantity of 2% fly ash maintained the lower percolation level and the high retention of water. The improvement in hydraulic properties was at least in part due to the accumulation of the fine ash particles within the top soil, in addition to the cementing (pozolanic) properties of the fly ash which induce the formation of small pores and capillary passages in the coarse-textured soil.

Significant improvement in properties was observed in the amended loess soil. The added fly ash greatly weakened the crust formed by interrupting the clay plate's

tendency to organize in parallel orientation. The addition of ash brought about an increase in the infiltration rate by up to 250% as compared to the control.

The stability of the aggregates formed on the top layer of the sand dune soil, amended with fly ash and their susceptibility to wind erosion, was tested by exposing the soil samples to varying wind velocities in a wind tunnel. The results demonstrated the good cementing properties of the fly ash, and the resulting improved stability of the top soil. The amended sand dune soil samples withstood the force of strong winds blowing at a rate of up to 26 m/sec as compared to the total loss of the top soil in the control samples even when subjected to a wind velocity of 9 m/sec. The loess soil amended with fly ash showed a higher susceptibility to wind erosion, the susceptibility gradually increasing with the level of the fly ash. The highest susceptibility to wind erosion was displayed by the soil loaded with 15% fly. When wind velocity was increased to 26 m/sec the top layer was totally eroded as compared to negligible effect at wind in the untreated soil. Their increased susceptibility to wind erosion resulted from the weakening the soil's crust.

The laboratory tests (rain storm simulation), were supplemented with other measurements in an attempt to devise simple tests and a quick reference for monitoring the impact of fly ash amendment in Loess soils. Thus, remote measurements of the reflectance of the treated soils were conducted, in which the spectral reflectance (albedo) and the specific absorbance by the clay fraction were analyzed. Significant correlation was found between the laboratory results (water infiltration rate) and the spectral data, indicating that the remote sensing method could serve as a, practical and effective tool for monitoring changes in the top soil and their impact, including changes in fly ash amended soils, as observed in the present study.

In contrast to the improved properties of the soils amended by fly ash, the amended soil may result in agronomic and environmental adverse effects that need to be considered before widespread application of fly ash on marginal soils. Special attention should be given to the relatively high content of salts, boron and heavy

metals in the ash, as observed in these experiments. The rain storm simulations of the treated soils showed high concentrations of Chromium, Boron, Lead and Selenium in the leachate, much above the permitted levels. The availability of these undesirable elements can be controlled by the rate of water, the dose and frequency of the application of fly ash and the level of pH. Thus, application of fly ash, as a practical soil amendment material, should be adjusted to the specific characteristics of the treated soil, as well as to the rainfall and the wind regime of the particular site. However, it should be added that the application of fly ash at rates of 18% (w/w) to soils in the Northern Negev did not have any adverse effect on the crop.

Conclusions

Taking into consideration the large quantities of coal used in power stations, the anticipated large residues of fly ash in Israel and worldwide and the need for environmentally safe disposal or use of the produced fly ash, it seems that the application of the ash for the treatment of marginal soils is a potentially beneficial use. Providing an alternative that is ecologically and environmentally sounder solution than disposal in landfills.

This study proved that fly ash added to marginal soils, at a rate of 15%, greatly improved the soils structural stability and hydraulic properties.

Considering the relative high salts, Boron and heavy metal content , large scale application of fly ash on soils should be carefully controlled, adjusting the level and the frequency of applications to the specific conditions at the location and the crop. Soil characteristics and the prevailing climatic and water regime should all be considered, and the ash application should conform to the applicable regulations, set by the responsible authorities.