Benefits and Risks of the Agricultural Uses of Coal Fly Ash

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Coal Fly ash is composed principally of SiO$_2$ (~ 45%) and Al$_2$O$_3$ (~ 35%) and in most cases is highly basic (pH ~12).

It usually also contains significant quantities of calcium and a variety of elements at trace levels.
The fly ash is pozzolanic and serves as an additive in concrete and in cement and road construction.

It can also be used for soil reclamation, e.g., of acid soils (Chang et al., 1977 etc.) and improvement of the hydraulic properties of marginal soils (Ghodrati et al., 1995 etc.).

Possible risk from loads of trace and heavy metals (Adriano et al., 2002)
Adding fly ash to the soil may bring about the following physical and physico-chemical changes:

• Narrow the pore size distribution in sandy soils and slightly cement sand particles especially at the surface. Thus, increase water holding capacity, decrease hydraulic conductivity, and reduce wind erosion.

• Reduce crusting of vulnerable loessial soils thus increasing their infiltration rates.

• Prevent swelling in swelling clayey sodic soils, (high Ca\(^{2+}\) content).
We will also present data on possible adverse effects especially on heavy metals leaching and uptake in plants grown on a soil loaded with fly ash.
Results
Rain simulator studies (30x50x2 cm³)
Fly ash-treatment of loess
Final infiltration rate after consecutive storms in fly ash-treated loessial loamy soil
Electrical conductivity in the leachates
(Na & K; Ca dominates after the 1st storm)
### Rain simulation study: Leachate composition from dune sand (μg/l)

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<th>Storm #</th>
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<th>B</th>
<th>Ni</th>
<th>Pb</th>
<th>Se</th>
<th>Cr</th>
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<table>
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<th>Israeli drinking water standard</th>
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<td>Recommended dietary allowances (RDA) &amp; Upper Limit (μg/day)</td>
<td>- (20,000)</td>
<td>- (1,000)</td>
<td>55 (400)</td>
<td>35 (nd)</td>
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</table>

Leaching ratio per storm ≈ 9 L/3.5-4.5 kg soil (1:2 – 1:2.5)
Loessial soil: Ash addition inhibited the formation of crust and increased water infiltration up to 2.5 fold by.

Weakening the crust increased the susceptibility of the soil toward wind erosion.

Sand: The addition of fly-ash (up to 20%) increased water retention by up to 8 fold, reduced the infiltration rate, and reduced the sand's susceptibility to wind erosion.

While the untreated sand moved already at wind speed of 9 m/sec, the ash-treated sands withstood wind speeds of up to 26 m/sec.
Wind tunnel study of wind erosion in fly ash treated dune sand
Wind Tunnel simulation

PLAY
Field experiments

Addition of fly-ash to a swelling clayey, sodium-rich soil reduced swelling to such a degree that the treated soil did not display any cracks, while the untreated soil cracked severely upon drying.
Effect of fly ash addition on cracking of a sodic clayey soil
(summer of the 3rd year after application)
Addition of fly ash (up to 800 tones/ha) to a clayey sodic soil did not result in a reduction in yield of corn in the year of application or of yield of the crops in consecutive years (cotton, chickpeas, and corn again) nor did it affect NPK contents.
Addition of fly ash (up to 800 tones/ha) to a clayey sodic soil did not result in a reduction in yield of corn in the year of application or of yield of the crops in consecutive years (cotton, chickpeas, and corn again) nor did it affect NPK contents.
Concentration of trace elements in corn plants (cobs and canopy) grown of a clayey soil heavily amended with fly ash
Concentration in corn cobs of Cr in plots receiving 800 tones/hectare fly ash was 3 mg/kg. Yet, no effect on plant composition was evident in the next three consecutive years (cotton, chickpeas, corn).
Fly ash addition improved water infiltration in flood-water collecting systems constructed in loessial dry-river beds in the Israeli desert
Pond after flood
Water height in a pond treated with 8% fly ash and an adjacent control pond.
No fly ash

200 tons/hectare fly ash
• Fly ash adds to the soil a significant load of boron and a number of trace metals such as chromium, lead and selenium, as well as soluble salts.

• The effect of the added, undesirable elements can be controlled and attenuated by the rate of ash application, rate of water addition and the pH levels maintained in the soil.
However, the crops grown in a clay soil field plots with 200 tones FA/ha did not display any negative effect on crop yield or quality and did not display accumulation of trace elements. At 200 tones FA/ha, Cr accumulated at significantly higher amounts in the corn cobs grown in the 1st season after application.
Conclusions:

Fly ash can be used to improve soil productivity

Even very high loads, fly ash did not harm yield quantity or quality

Fly ash can be applied to soils without harm to the environment or human health, yet due caution should be practiced mainly with respect to leaching of oxyanions.
Thank you