Environmental characterization of Israeli coal ash

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Coal ash – what is it?

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- **In the article "Fly Ash" from Wikipedia - Introduction:**
  - **… fly ash includes substantial amounts of SiO_2 (both amorphous and crystalline) and CaO, both being endemic ingredients in coal beds rock strata.**
  - **… toxic constituents … may include one or more of the following elements/substances in quantities from trace amounts to several percents:**
    arsenic, beryllium, boron, cadmium, chromium, chromiumVI, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium and vanadium, along with dioxins and PAH compounds.

SEM micrograph of fly ash

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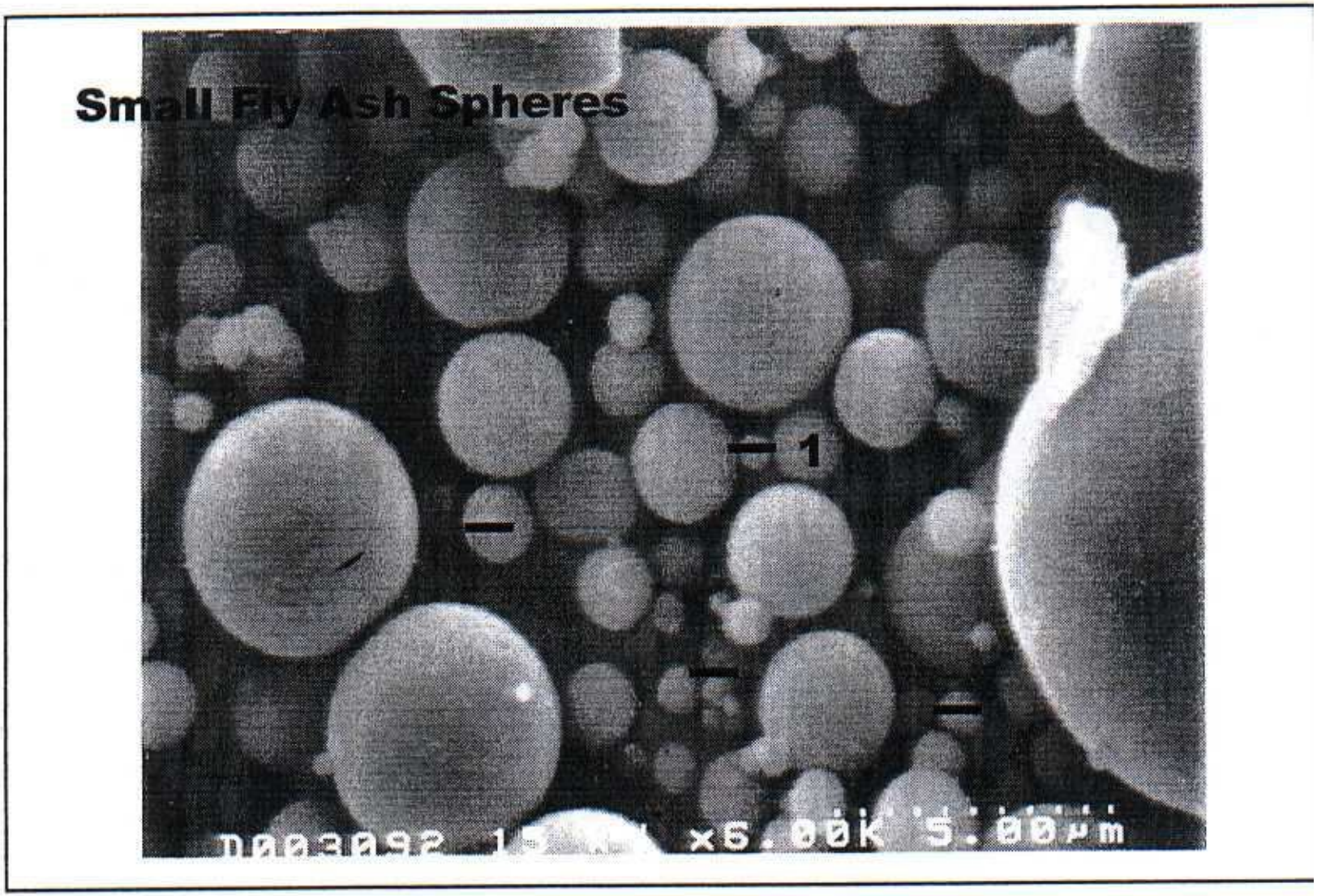

Israeli coal ash chemistry and mineralogy

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- **Si, Al, Fe, Ca and Mg oxides constitute more than 95% of the ash matrix.**
- **Coal ash produced in Israel is alkaline:**
  - **pH of fly ash suspension: 9-13.**
  - **Ash components and contaminants are mainly insoluble in water.**
- **Mineralogical fractions**
  - **Amorphous Al-Si-O phase – Glass on average ~ 75%**
  - **Crystalline phase**
    - **Alumino-silicate phase on average ~ 20%**
      Mullite $2\text{-}3(Al_2O_3).1\text{-}2(SiO_2)$
      Quartz SiO_2
    - **Iron phase on average ~ 5%**

Major chemical constituents in coal ash - for 2008

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Concentrations given in %

Component	South Africa	Australia	Colombia	Indonesia	Russia
SiO_2	47.8 - 52.2	53.8	57.0 - 60.3	43.2 - 53.3	48.3 - 60.2
Al_2O_3	29.7 - 38.9	31.1	20.2 - 21.1	15.5 - 22.3	20.7 - 21.9
Fe_2O_3	3.0 - 4.5	6.6	6.9 - 8.3	9.3 – 13.8	6.7 - 12.2
CaO	1.2 - 8.7	3.0	2.3 - 3.8	3.0 - 9.9	2.6 - 13.1
MgO	0.3 - 2.4	1.0	1.6 - 2.2	2.1 - 4.8	1.5 - 2.9
TiO_2	1.6 - 2.1	1.4	0.9 - 1.0	1.0 - 1.2	0.8 - 1.0
K_2O	0.5 - 0.8	0.7	1.2 - 2.2	0.3 - 1.8	0.9 - 2.0
Na_2O	0.1 - 0.3	0.3	0.6 - 2.0	0.6 - 1.0	0.3 - 0.7
SO_3	0.7 - 2.9	1.2	2.1 - 4.0	3.9 - 8.5	1.9 - 3.6
P_2O_5	1.0 - 1.9	0.4	0.2	0.2 - 0.3	0.3 - 0.7
% in coal	36	4	19	34	5
% in coal ash	52	6	15	19	5

Coal ash – classification

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- All the coal burnt in Israeli power stations is bituminous, so all the fly ash produced is Class F fly ash, according to ASTM classification (pozzolanic, not cementitious ash).

- According to the coal sources, two kinds of ash are produced:
  - Fly ash with high CaO content (8-11%)
  - Fly ash with low CaO content (1-4%)

  There are few experimental applications for which highly alkaline fly ash is preferable:
    - Heavy soil stabilization under road basements
    - Sewage sludge stabilization with lime and fly ash

Trace elements in Israeli coal ash

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Concentrations given in ppm, dry weight basis

Element	Bottom Ash		Fly Ash		Range for soils
	Range	Average	Range	Average	
As	1.0 – 25	4.7	9 – 60	22	0.1 – 40
Cd	<0.05 – 0.7	0.23	0.2 – 1.5	0.8	0.01 – 7
Cr	80 - 243	138	80 - 205	138	5 – 3000
Hg	<0.01 – 0.34	0.11	<0.02 – 0.30	0.15	0.02 – 0.2
Pb	8 - 89	21	29 - 140	56	2 - 200
Se	<0. 6 – 5.5	2.4	1 – 24	7	0.1 - 2
B	40 - 315	104	75 - 550	235	2 – 100
Mo	1.6 – 15.0	4.7	6 – 26	12	0.2 – 5
V	95 - 200	140	100 - 455	193	20 – 500

Summary of analyses performed on semi-annual ash samples during the period 7/91 – 6/09

Trace elements composition of fly ash in Israel in comparison with Europe

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Concentrations given in ppm, dry weight basis

Element	Israel 7/91 - 6/09	Nertherlands* 7 PS	Spain* 10 PS
As	9 - 60	22 - 55	22 - 162
Cd	0.2 - 1.5	1 - 2	1 - 6
Cr	80 - 205	133 - 196	47 - 177
Hg	<0.02 - 0.3	0. 2 - 0.4	<0.01 - 0.4
Pb	29 - 140	52 - 208	40 - 145
Se	1 - 24	11 - 30	3 - 15
B	75 - 550	24 - 305	89 - 407
Mo	6 - 26	7 - 16	5 - 22
V	100 - 455	202 - 514	154 - 289

* From ash composition survey by Moreno et al., 2005 – bitum. alkaline FA

Trace elements in Israeli fly ash leachates

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Leaching test procedure: TCLP

Concentrations given in ppb in leachate

Element	Fly Ash 7/98 – 6/09	Israeli MEP Criterion	EPA Criterion
As	<2 – 960	2000	5000
Cd	0.3 – 26	100	1000
Cr	20 - 610	2000	5000
Hg	<0.01 – 4	25	200
Pb	0.1 - 8	150	5000
Se	23 – 480	700	1000
B	3350 – 19950	20000	-
Mo	115 - 675	2000	-
V	150 – 1550	5000	-

Coal ash – water pollution potential

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- Coal ash produced in Israel is characterized by low trace element concentrations, similar with those found in soils and rocks .
- Trace element concentrations in fly ash produced in Israel are similar with those reported for power stations in Europe burning high quality coal.
- From the summary of all TCLP leachate analyses performed until now, fly ash is considered as “utilizable” according to the guidelines issued by the Ministry of Environmental Protection.
- According to the results of the leaching tests, the potential release of trace elements from the ash is low, thus there is only a minor risk of groundwater contamination under ash use sites.
- Environmental specifications imposed on any source of coal proposed to Israel Electric ensure that the ash quality will not be impaired in the future.

Monitoring at ash storage & utilization sites

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- Data collected from environmental monitoring performed close to ash storage and utilization sites confirmed that there is no risk of groundwater pollution as a result of ash utilization.
- No modification of groundwater quality was found during the monitoring programs performed at Orot Rabin & Rutenberg power stations, close to the ash storage sites.
- According to the results of the environmental monitoring program performed near the road to Jassar A'Zarka, there is no sign of any environmental damage due to ash utilization.

  → Groundwater quality monitored after 1-3 and 6 years
- **All data collected until now in the laboratory and the field lead to the conclusion that ash utilization in Israel is safe for the environment.**