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Physico-chemical properties of coal ash produced in Israel

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Coal ash in Israel – production and uses

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Year	Coal import (kton AR)	Ash production (kton DW)	Use by building industry (%)
2008	13,245	1,160	92.9
2009	12,248	1,198	98.0
2010	12,511	1,195	97.7
2011	12,695	1,191	97.1
2012	13,735	1,338	94.4

SEM micrograph of fly ash

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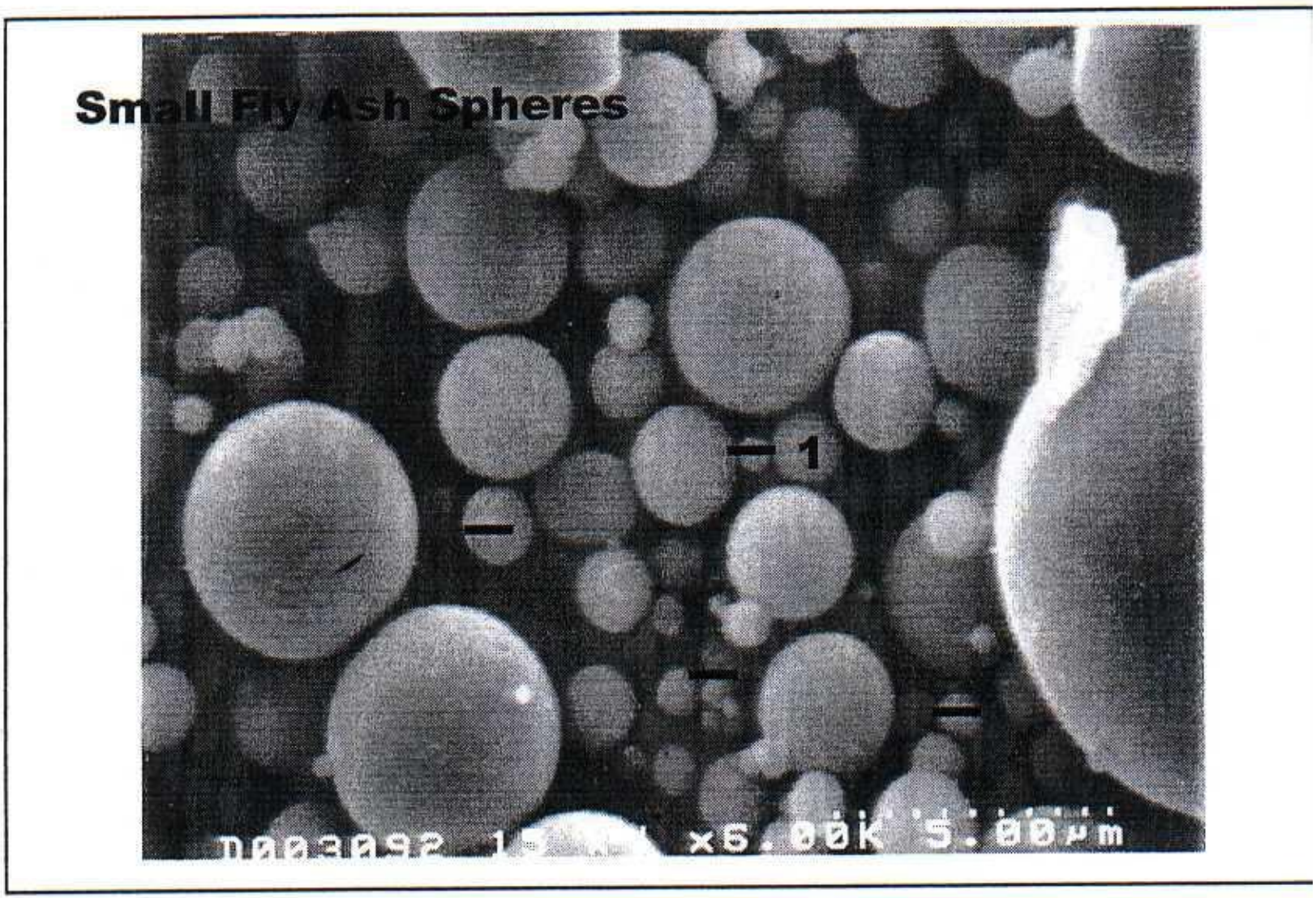

Israeli coal ash chemistry and mineralogy

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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 $3(Al_2O_3), 2(SiO_2)$
      Quartz SiO_2
    - **Iron phase on average ~ 5%**

Major chemical constituents in coal ash

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Concentrations given in %

Component	South Africa	Australia	Colombia	Indonesia	Russia
SiO_2	48.6 – 60.4	50.6	55.1 – 64.9	38.4 – 55.8	56.7 – 59.0
Al_2O_3	30.3 – 32.3	31.6	19.2 - 20.4	14.9 – 21.8	21.5 – 21.8
Fe_2O_3	2.7 - 3.7	6.0	7.4 – 9.5	8.7 – 19.1	6.1 – 6.2
CaO	1.4 – 9.3	4.9	1.5 - 3.4	2.4 – 9.6	3.4 – 4.8
MgO	0.7 – 1.6	1.0	1.0 – 2.2	2.5 – 5.4	1.7 – 2.2
TiO_2	1.3 – 1.8	1.5	0.8 – 1.3	0.6 – 1.0	0.9
K_2O	0.5 - 0.7	0.7	1.5 – 2.1	1.3 – 1.9	1.9 – 2.0
Na_2O	0.1 - 0.2	0.2	0.6 - 2.3	1.3 – 1.9	1.9 – 2.0
SO_3	0.9 - 2.5	1.1	1.0 - 4.4	4.2 – 8.8	2.7 – 3.4
P_2O_5	0.6 - 1.5	1.3	0.2	0.4	0.6 - 0.7
% in coal /2012	31.4	5.9	40.7	2.1	19.2
% in ash/2012	42.9	8.0	28.0	1.0	19.5

Coal ash – classification

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

- **According to the coal sources, two kinds of ash are produced:**
  - **Fly ash with high CaO content (5-9%)**
  - **Fly ash with low CaO content (1-4%)**

For fly ash produced in Israel there is continuous control of the unburnt carbon content (LOI).

For sewage sludge stabilization (N-Viro soil production) use of FA with high CaO content is preferable.

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Trace elements in Israeli coal ash

Concentrations given in ppm, dry weight basis

Element	Bottom Ash		Fly Ash	
	Range	Average	Range	Average
As	1.0 – 25	4.9	9 – 64	23
Cd	<0.05 – 1.3	0.27	0.2 – 3	0.9
Cr	65 – 243	125	78 - 205	135
Hg	<0.01 – 0.34	0.11	0.03 – 0.30	0.14
Pb	8 – 89	20	25 – 140	53
Se	<0. 6 – 6.0	2.7	1 – 35	8
B	40 – 315	101	75 – 550	233
Mo	1.6 – 15.0	4.7	6 – 43	13
V	90 - 221	141	100 – 455	194

Summary of analyses performed on semi-annual ash samples during the period 7/91 – 6/13

Trace elements composition of fly ash in comparison with other materials (ranges)

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Concentrations given in ppm, dry weight basis

Element	Israeli FA 7/91 - 6/12	Soils*	Sewage sludges*
As	9 - 64	<0.1 - 97	1.2 - 49
Cd	0.2 - 2.3	<0.1 - 8	0.2 - 12
Cr	78 - 205	<1 - 2000	7 - 1160
Hg	0.03 - 0.3	<0.2 - 5	0.2 - 8
Pb	25 - 140	<10 - 700	6 - 450
Se	1 - 35	<0.1 - 4	1 - 25
B	75 - 550	<20 - 300	6 - 204
Mo	6 - 43	<3 - 15	3 - 132
V	100 - 455	<7 - 500	2 - 617

* Composition of soils and sludges according to EPRI report, 2010 "Comparison of CCP's to other common materials"

Trace elements composition of FA in comparison with other materials (median/average)

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Concentrations given in ppm, dry weight basis

Element	Israeli FA 7/91 - 6/13 Average	Soils* Median	Sewage sludges* Median
As	23	6	5
Cd	0.9	0.2	1.8
Cr	135	50	35
Hg	0.14	0.05	0.9
Pb	53	15	49
Se	8	0.3	6
B	233	30	33
Mo	13	-	11
V	194	70	14

* According to EPRI report, 2010 “Comparison of CCP’s to other common materials”

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 - 6/12	Netherlands* 7 Pow. Plants	Spain* 7 Pow. Plants
As	9 - 64	22 - 55	22 - 162
Cd	0.2 - 2.3	1 - 2	1 - 6
Cr	78 - 205	133 - 196	47 - 177
Hg	0.03 - 0.3	0. 2 - 0.4	<0.01 - 0.4
Pb	25 - 140	52 - 208	40 - 145
Se	1 - 35	11 - 30	3 - 15
B	75 - 550	24 - 305	89 - 407
Mo	6 - 43	7 - 16	5 - 22
V	100 - 455	202 - 514	154 - 289

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

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Trace elements in Israeli fly ash leachates

Leaching test procedure: TCLP

Concentrations given in ppb in leachate

Element	Fly Ash 7/98 – 6/13	Israeli MEP Criterion	EPA Criteria
As	<2 – 960	2000	5000
Cd	0.3 – 35	100	1000
Cr	13 - 610	2000	5000
Hg	<0.01 – 4	25	200
Pb	0.1 - 8	150	5000
Se	15 – 590	700	1000
B	3350 – 19950	20000	-
Mo	115 - 675	2000	-
V	150 – 1550	5000	-

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Trace elements in Israeli fly ash leachates

Leaching test procedure: EN-12457/2

Concentrations given in mg/kg DW leachable

Element	Russia Glencore	SA Billiton	Colombia La Loma	NHW Criteria*
As	0.4	0.04	0.05	2
Cd	0.02	0.008	0.03	1
Cr	1.4	2.5	5.7	10
Hg	0.0005	<0.0002	<0.0002	0.2
Pb	0.006	0.003	0.004	10
Mo	5.9	2.9	11.2	10
Se	0.2	0.2	2.5	0.5
pH	10.6	12.0	12.1	-

*** EU criteria for landfills for non-hazardous wastes (Landfill Directive 1999/31/EC)**

Trace elements composition of fly ash leachates in comparison with Europe

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Leaching test procedure: EN-12457/2 or equivalent

	NHW criterion * mg/kg	Israel	NL (1)	NHW criterion* ppb	Germany (1)	UK (1)
As	2	0.02 – 0.8	0.03 – 0.28	200	2-54	60-160
Cd	1	0.01 – 0.08		100	<10	<5
Cr	10	0.5 – 5.7	0.24 – 2.48	1000	10-630	20-60
Pb	10	0.001 – 0.007	0.02 – 3.8	1000	<10	10-500
Se	0.5	0.05 – 7.8	0.11 – 4.8	50	21-710	40-160
Mo	10	2.9 – 28.8	3.0 – 10.3	1000	290-1510	150-880

* EU criteria for landfills for non-hazardous wastes (Landfill Directive 1999/31/EC)

1: ECOBA presentation on Landfill Directive and coal ash – June 2013

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Coal ash environmental quality – in the future

Preservation of the ash quality

After installations of new Flue Gas Cleaning equipments (FGD & SCR) at “Orot Rabin” & “Rutenberg” PS, coal ash quality could change:

The imported coal basket will possibly include high S coals

Fly ash enriched in ammonia could be produced

Alternative fuels

- Presently IEC is not allowed to mix wastes, biomass or low-quality fuels (petcoke) with coal
- If this will be allowed after upgrading the coal-fired units, it will be necessary to check if the ash quality is modified