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Israeli coal ash characterization

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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
2013	12,533	1,241	90.9

SEM micrograph of fly ash

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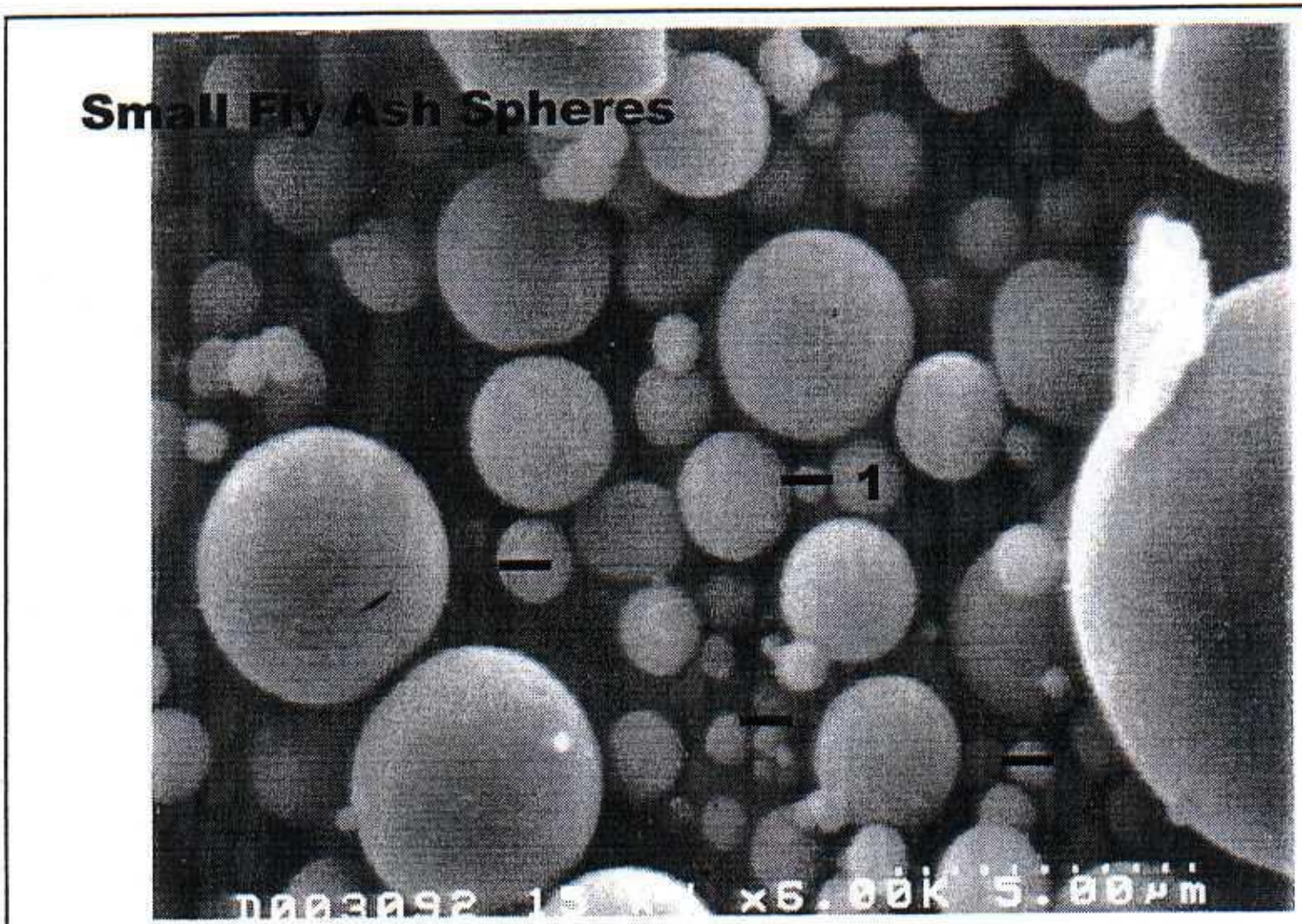

Israeli coal ash chemistry and mineralogy

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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

Concentrations given in %

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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 2013	32.0	4.0	41.8	1.3	20.9
% in ash/2013	42.2	5.4	30.4	0.5	21.5

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	100	75 - 550	230
Mo	1.6 – 15.0	4.7	6 – 43	13
V	90 - 221	141	100 - 455	193

Summary of analyses performed on semi-annual ash samples during the period 7/91 – 12/13

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 - 12/13	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	193	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	Nertherlands* 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 criteria * mg/kg	Israel	NL (1)	NHW criteria* 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

Radioactive elements in Israeli fly ash in comparison with other countries

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Concentrations given in Bq/kg, dry weight basis

Country	^{226}Ra	^{228}Th	^{40}K
World#	170	114	652
Germany	186	110	785
Italy	170	140	-
Netherlands	181	150	730
Israel*	144	141	306

 # UNSCEAR, 2008 Sources and effects of ionizing radiation

*** Summary of analyses performed on semi-annual ash samples during the period 7/91 – 12/13**

Is there a radiological risk from coal ash utilization?

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- Coal ash is slightly enriched in radioactive elements, thus it is a NORM – naturally occurring radioactive material.
- According to the International Atomic Energy Agency guidelines (2004) a material with concentrations of radioactive elements like in Israeli FA is exempted from control and reporting (e.g. for international transport).
- Ash addition to concrete affects radioactivity by two ways:
  - Increase in gamma radiation (external).
  - Increase or decrease in exposure to radon (internal)
- Since January 2010, exposure to radioactivity from building products is controlled by the standard IS 5098.
- In the case of "open applications" such as agriculture, the radiological risk is not significant, in view of the small radionuclide concentrations and the very low water solubility of Uranium and Thorium contained in the ash.

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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