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Trace elements in Israeli coal ash and its leachates

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Coal ash in Israel – production and uses



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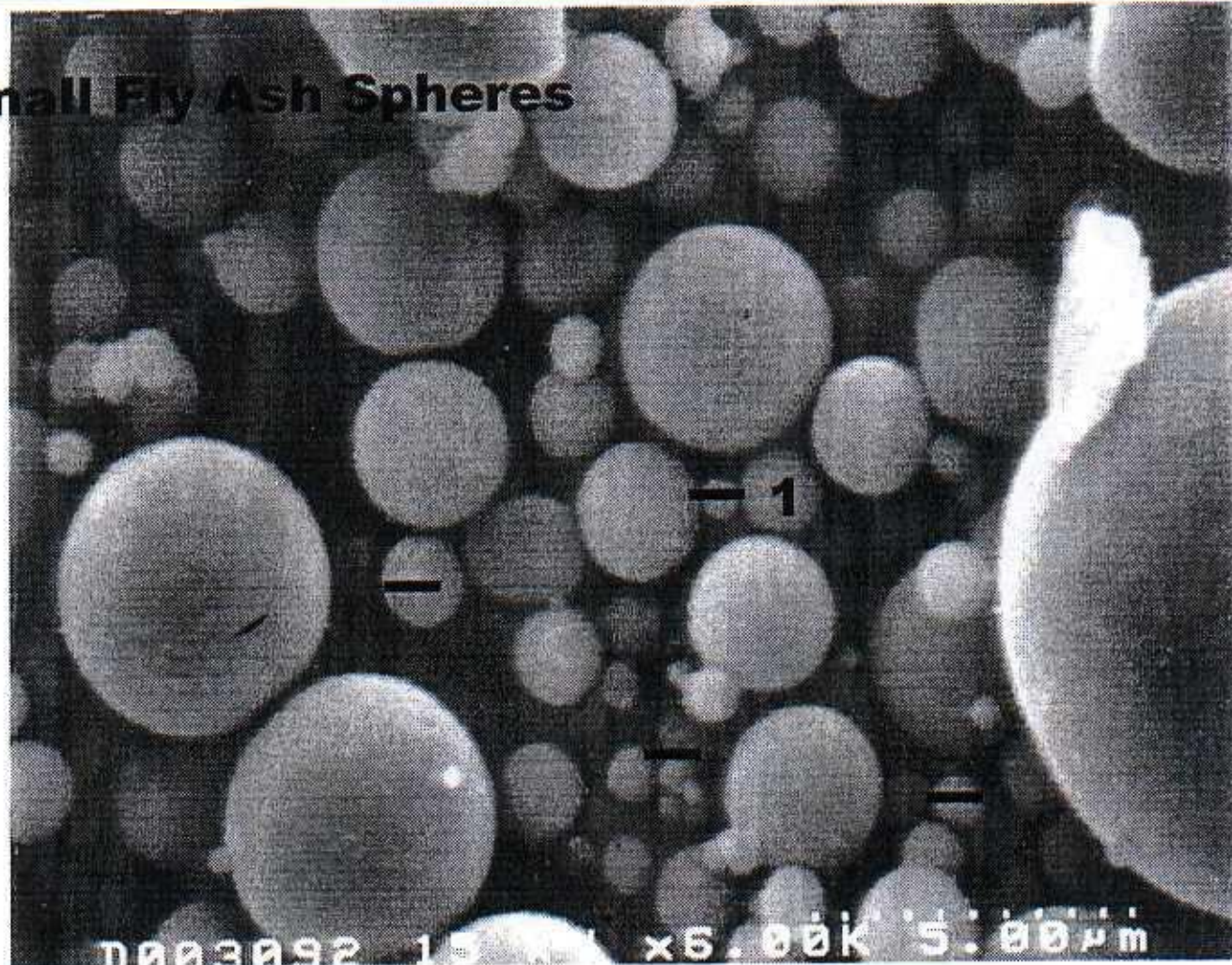
Year	Coal import (kton AR)	Ash production (kton DW)	Use by building industry (%)
2008	13,245	1,160	92.9
2009	12,248	1,198	98.0
2010	12,511	1,195	97.7
2011	12,695	1,191	97.1
2012	13,735	1,338	94.4

SEM micrograph of fly ash



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Small Fly Ash Spheres



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** $3(\text{Al}_2\text{O}_3), 2(\text{SiO}_2)$
 - 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
SiO₂	50.1 – 53.2	52.3	54.5 - 60.6	46.4 – 54.1	51.1 – 59.6
Al₂O₃	28.7 – 39.4	28.9	18.3 - 20.1	20.5 – 21.1	21.8 – 22.6
Fe₂O₃	3.1 - 4.7	9.6	7.4 – 10.8	8.9 – 14.0	6.1 – 8.8
CaO	1.4 – 7.9	3.3	2.3 - 3.9	2.8 – 6.5	2.5 – 6.2
MgO	0.4 – 2.1	0.9	1.2 – 2.2	2.4 - 3.8	1.5 – 2.5
TiO₂	1.6 – 1.9	1.2	0.8 – 1.0	0.6 – 0.9	0.8 - 1.7
K₂O	0.3 - 0.6	0.4	0.8 – 1.0	1.6 – 2.0	1.6 – 2.6
Na₂O	0.1 - 0.2	0.2	0.6 - 2.3	0.9 - 1.3	0.3 – 1.9
SO₃	0.8 - 2.4	1.8	1.4 - 4.9	4.1 – 7.8	2.0 – 4.2
P₂O₅	1.0 - 1.8	0.2	0.2 - 0.3	0.3 – 0.8	0.5 - 0.7
% in coal /2012	31.5	4.9	41.2	1.8	20.6
% in ash/2012	41.7	7.0	25.4	1.0	24.9



Coal ash – classification

- **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.

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	4.7	9 – 64	23
Cd	<0.05 – 1.3	0.24	0.2 – 2.3	0.9
Cr	65 - 243	126	78 - 205	137
Hg	<0.01 – 0.34	0.11	0.03 – 0.30	0.15
Pb	8 - 89	21	25 - 140	54
Se	<0.6 – 6.0	2.4	1 – 35	8
B	40 - 315	103	75 - 550	237
Mo	1.6 – 15.0	4.6	6 – 43	13
V	95 - 221	140	100 - 455	196

Summary of analyses performed on semi-annual ash samples during the period 7/91 – 6/12

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 - 60	<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 - 6/12 Average	Soils* Median	Sewage sludges* Median
As	23	6	5
Cd	0.9	0.2	1.8
Cr	137	50	35
Hg	0.14	0.05	0.9
Pb	54	15	49
Se	8	0.3	6
B	237	30	33
Mo	13	-	11
V	196	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

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

Trace elements in Israeli fly ash leachates

Leaching test procedure: TCLP

Concentrations given in ppb in leachate

Element	Fly Ash 7/98 – 6/12	Israeli MEP Criterion	EPA Criteria
As	<2 – 960	2000	5000
Cd	0.3 – 35	100	1000
Cr	20 - 610	2000	5000
Hg	<0.01 – 4	25	200
Pb	0.1 - 8	150	5000
Se	23 – 590	700	1000
B	3350 – 19950	20000	-
Mo	115 - 675	2000	-
V	150 – 1550	5000	-



Trace elements in Israeli fly ash leachates

Leaching test procedure: EN-12457/2

Concentrations given in mg/kg DW leachable

Element	Russia Glencore	Indonesia KPC	SA Billiton	Colombia La Loma	NHW Criteria*
As	0.4	0.8	0.04	0.05	2
Cd	0.02	0.01	0.008	0.03	1
Cr	1.4	0.5	2.5	5.7	10
Hg	0.0005	0.0003	<0.0002	<0.0002	0.2
Pb	0.006	0.007	0.003	0.004	10
Mo	5.9	3.9	2.9	11.2	10
Se	0.2	0.7	0.2	2.5	0.5
pH	10.6	8.9	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

Concentrations given in mg/kg DW leachable

Element	Israel Ash survey	Netherlands* 7 Power Plants	Spain* 10 Power Plants
As	0.02 – 0.8	0.04 – 0.5	0.1 – 1.2
Cd	0.01 – 0.08	0.004 – 0.2	0.001 – 0.012
Cr	0.5 – 5.7	0.02 – 4.1	0.2 – 9.2
Pb	0.001 – 0.007	0.007 – 0.03	0.01 – 0.05
Se	0.05 – 7.8	0.2 – 3.7	0.2 – 1.9
B	1 - 136	10 - 69	15 - 121
Mo	2.9 – 28.8	2.4 – 6.2	0.9 – 6.4
V	<0.1 – 1.7	0.1 – 1.1	0.05 – 4.1

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

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 utilization sites confirmed that there is no risk of soil or groundwater pollution as a result of ash utilization:**
 - **Near the road to Jassar A'Zarka (FA and BA use)**
Groundwater quality monitored after 1-3 and 6 years
- **No modification of groundwater quality was found during the monitoring program performed at Rutenberg power station, in the vicinity of the ash storage sites.**
- **These field data confirm coal ash characterization by leaching tests showing that the potential of water resource pollution by trace elements is very low.**