A global perspective on the health impacts of coal and coal ash: Facts and fallacies

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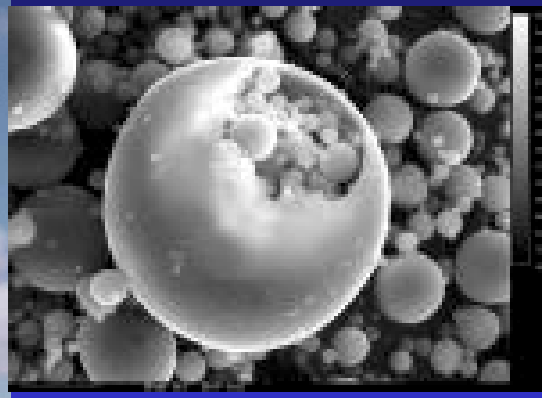
Coal mining


Coal combustion

Fly ash




Acid mine drainage


Storage piles


Spontaneous combustion

Factors affecting the environmental and health impacts of coal

- Composition of the coal
  - Organic, inorganic, mineralogy, element modes of occurrence
- Ash yield
- Mining practices
- Transportation and storage practices
- Boiler type and combustion conditions
- Pollution control technology
- Climate
- Geology
- Ash utilization and disposal technology

Table 2. Arithmetic means and standard deviations (S.D.) for 78 elements in U.S. coal. (All values are on a whole-coal basis. Data are from the U.S. Geological Survey's National Coal Resources Data System (NCRDS) except for estimated values (in parenthes

Component	Arithmetic Mean	Standard Deviation	Maximum Value	No. of Samples
Ash %	13.1	8.3	50.0	7976
Aluminum (Al) %	1.5	1.1	10.6	7882
Antimony (Sb) ppm	1.2	1.6	35	7473
Arsenic (As) ppm	24	60	2200	7676
Barium (Ba) ppm	170	350	22000	7836
Beryllium (Be) ppm	2.2	4.1	330	7484
Bismuth (Bi) ppm	(<1.0)	n.d.	14	128
Boron (B) ppm	49	54	1700	7874
Bromine (Br) ppm	17	19	160	4999
Cadmium (Cd) ppm	.47	4.6	170	6150
Calcium (Ca) %	.46	1.0	72	7887
Carbon (C) %	63	15	90	7154
Cerium (Ce) ppm	21	28	700	5525
Cesium (Cs) ppm	1.1	1.1	15	4972
Chlorine (Cl) ppm	614	670	8800	4171
Chromium (Cr) ppm	15	15	250	7847
Cobalt (Co) ppm	6.1	10	500	7800
Copper (Cu) ppm	16	15	280	7911
Dysprosium (Dy) ppm	1.9	2.7	28	1510
Erbium (Er) ppm	1.0	1.1	11	1792
Europium (Eu) ppm	.40	.33	4.8	5268
Fluorine (F) ppm	98	160	4000	7376
Gadolinium (Gd) ppm	(1.8)	n.d.	39	2376
Gallium (Ga) ppm	5.7	4.2	45	7565
Germanium (Ge) ppm	5.7	14	780	5689
Gold (Au) ppm	(<0.05)	n.d.	n.d.	n.d.
Hafnium (Hf) ppm	.73	.68	18	5120
Holmium (Ho) ppm	(0.35)	n.d.	4.5	1130
Hydrogen (H) %	5.2	0.9	9.5	7155
Indium (In) ppm	(<0.3)	n.d.	n.d.	n.d.
Iodine (I) ppm	(<1.0)	n.d.	n.d.	n.d.
Iridium (Ir) ppm	(<0.001)	n.d.	n.d.	n.d.
Iron (Fe) %	1.3	1.5	24	7882
Lanthanum (La) ppm	12	16	300	6235
Lead (Pb) ppm	11	37	1900	7469
Lithium (Li) ppm	16	20	370	7848
Lutetium (Lu) ppm	.14	.10	1.8	5008
Magnesium (Mg) %	.11	.12	1.5	7887
Manganese (Mn) ppm	43	84	2500	7796
Mercury (Hg) ppm	.17	.24	10	7649

Palladium (pd) ppm	(<0.001)	n.d.	n.d.	n.d.
Niobium (Nb) ppm	2.9	3.1	70	6843
Nitrogen (N) %	1.3	0.4	13	7153
Osmium (Os) ppm	(<0.001)	n.d.	n.d.	n.d.
Oxygen (O) %	16	12	60	7151
Phosphorus (P) ppm	430	1500	58000	5079
Platinum (Pt) ppm	(<0.001)	n.d.	n.d.	n.d.
Potassium (K) %	.18	0.21	2.0	7830
Praseodymium (Pr) ppm	(2.4)	n.d.	65	1533
Rhenium (Re) ppm	(<0.001)	n.d.	n.d.	n.d.
Rhodium (Rh) ppm	(<0.001)	n.d.	n.d.	n.d.
Rubidium (Rb) ppm	21	20	140	2648
Ruthenium (Ru) ppm	(<0.001)	n.d.	n.d.	n.d.
Samarium (Sm) ppm	1.7	1.4	18	5151
Scandium (Sc) ppm	4.2	4.4	100	7803
Selenium (Se) ppm	2.8	3	150	7563
Silicon (Si) %	2.7	2.4	20	7846
Silver (Ag) ppm	(<0.1)	0.35	19	5038
Sodium (Na) %	.08	0.12	1.4	7784
Strontium (Sr) ppm	130	150	2800	7842
Sulfur (S) %	1.8	1.8	25	7214
Tantalum (Ta) ppm	.22	0.19	1.7	4622
Tellurium (Te) ppm	(<0.1)	n.d.	n.d.	n.d.
Terbium (Tb) ppm	.30	0.23	3.9	5024
Thallium (Tl) ppm	1.2	3.4	52	1149
Thorium (Th) ppm	3.2	3	79	6866
Thulium (Tm) ppm	(0.15)	n.d.	1.9	365
Tin (Sn) ppm	1.3	4.3	140	3004
Titanium (Ti) %	.08	0.07	.74	7653
Tungsten (W) ppm	1.0	7.6	400	4714
Uranium (U) ppm	2.1	16	1300	6923
Vanadium (V) ppm	22	20	370	7924
Utterbium (Yb) ppm	(0.95)	n.d.	20	7522
Yttrium (Y) ppm	8.5	6.7	170	7897
Zinc (Zn) ppn	53	440	19000	7908
Zironium (Zr) ppm	27	32	700	7913

MINERALS IN COAL
Accessories

- Galena (PbS)
- Sphalerite (Zn, CdS)
- Clausthalite (PbSe)
- Chalcopyrite (CuS)
- Crandallite Group (Ca, Ba, Sr, Al, P)
- Monazite (REE, P)
- Apatite (Ca, P)
- Barite (Ba, S)
- Rutile (Ti)
- Zircon (Zr, Si)
- Feldspars (Ca, Na, K, Al, Si)
- Zeolites (Ca, Na, K, Al, Si)
- Ankerite (Fe, Mg, Ca)
- Micas (K, Fe, Mg, Ti, Al, Si)

Table 4. Probable modes of occurrence of selected elements in coal
[Modified from Finkelman (1982)]

Element	Modes of Occurrence
Aluminium	- Clays, feldspars, perhaps some organic association
Antimony	- Accessory sulfide, some organic association
Arsenic	- Solid solution in pyrite
Barium	- Barite, crandallite, organic association in low-rank coal
Beryllium	- Organic association, clay
Bismuth	- Accessory sulfide
Boron	- Organic association, illite
Bromine	- Organic association
Cadmium	- Sphalerite
Calcium	- Calcite, organic assoc., sulphates, phosphates, silicates
Cesium	- Clays, feldspar, mica
Chlorine	- Organic association
Chromium	- Clays (?)
Cobalt	- Accessory sulfides, pyrite
Copper	- Chalcopyrite
Fluorine	- Perhaps apatite, clays, mica, amphiboles
Gallium	- Clays, organics, sulfides
Germanium	- Organic association
Gold	- Native gold
Hafnium	- Zircon
Indium	- Probably sulfides
Iodine	- Probably organic association
Iron	- Pyrite, siderite, sulfates, oxides, some organic assoc.
Lead	- Galena, PbSe

Lithium	- Clays
Magnesium	- Clays
Manganese	- Siderite, calcite
Mercury	- Solid solution with pyrite
Molybdenum	- Unclear; perhaps with sulfides or organics
Nickel	- Unclear; perhaps with sulfides, organics, or clay
Niobium	- Oxides
Phosphorus	- Phosphates
Platinum	- Native alloys, perhaps some organic association
Rare-earths	- Phosphates, some organic association
Rubidium	- Probably illite
Scandium	- Unclear; clays, phosphates, or organics
Selenium	- Organic association, pyrite, PbSe
Silicon	- Quartz, clays, silicates
Silver	- Perhaps silver sulfides
Sodium	- Organic association, clays, zeolites, silicates
Strontium	- Carbonates, phosphates, organic association
Tantalum	- Oxides
Tellurium	- Unclear
Thorium	- Rare-earth phosphates
Tin	- Inorganic: tin oxides or sulfides
Titanium	- Oxides, clays, some organic association
Tungsten	- Oxides, organic association
Uranium	- Organic association, zircon
Vanadium	- Clays, perhaps some organic association
Yttrium	- Rare-earth phosphates
Zinc	- Sphalerite
Zirconium	- Zircon

FACT

Trace Elements in Coal

Can Kill or Maim

FALLACY

Trace Elements in Coal Are Known to Have Killed or Maimed Millions Around the World

Known Health Impacts from Trace Elements in Coal

- **China –** arsenic poisoning from residential coal use
- **China –** fluorine poisoning from residential coal use
- **China –** Selenosis from stone coal ash
- **Czechoslovakia –** Impaired hearing in children attributed to arsenic emitted from power plant
- **Czechoslovakia –** Increased antibodies attributed to beryllium exposure from power plant
- **India –** Various health problems from uncontrolled mine fire
- **Global –** Mercury affect on fetuses???

FACT

Burning Coal Beds and Stockpiles are Significant Health Hazards

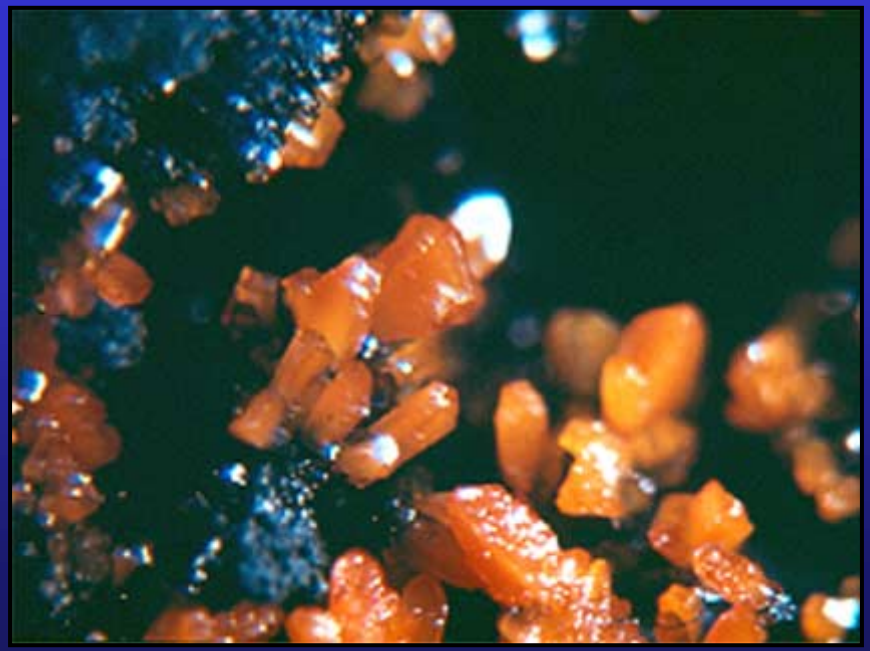
Jharia Coalfield, India

Witbank Coalfield – South Africa

Open Cast Mine Fire, Northern China

Anthracite Region, U.S.A.

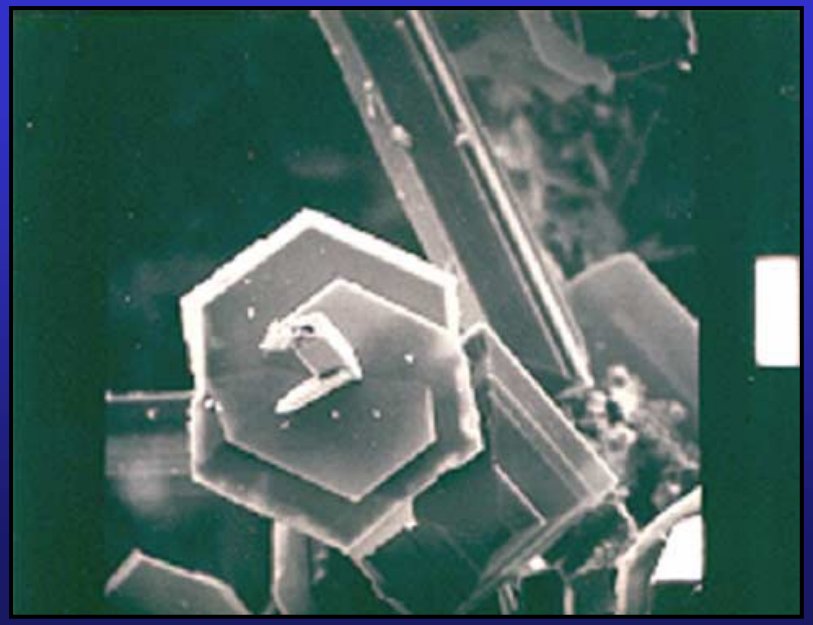
Arsenic Phases



Selenium Minerals

Fluorine

Minerals

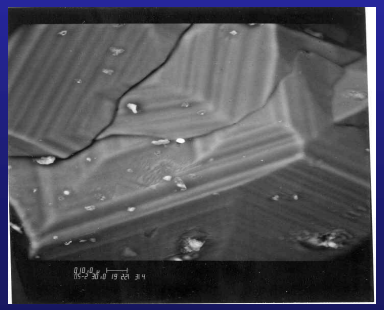


Impacts of Spontaneous Combustion

Collected samples of gas and condensates from a coal mine in the Witbank area, SA.

Huge concentrations of benzene, toluene, xylene, and ethylbenzene

Small (<10 µm) grains containing mercury and minute (~ 1 µm) globules containing arsenic.



• (M.Sc. student – Jean Denis Poné)

FALLACY

Coal in the Ground Does Not Present Any Health Threats

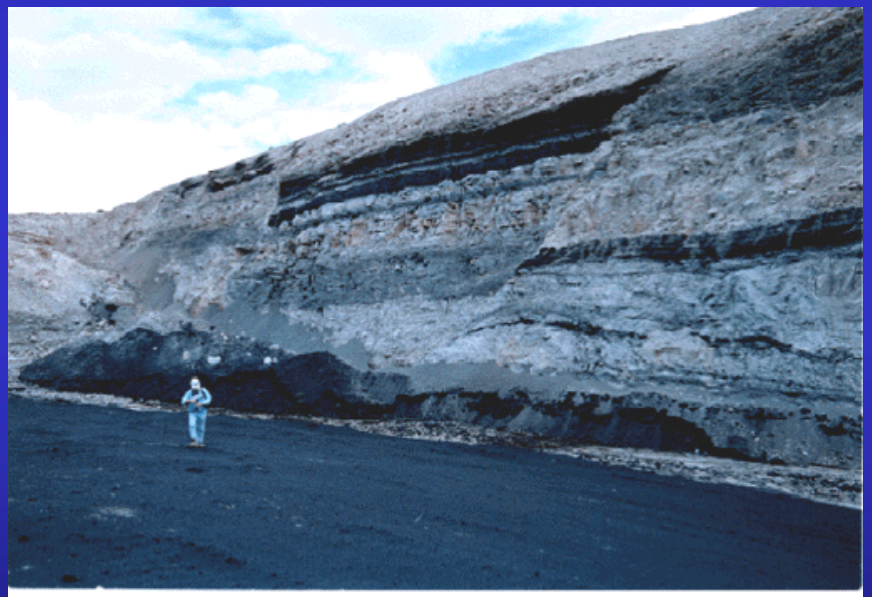
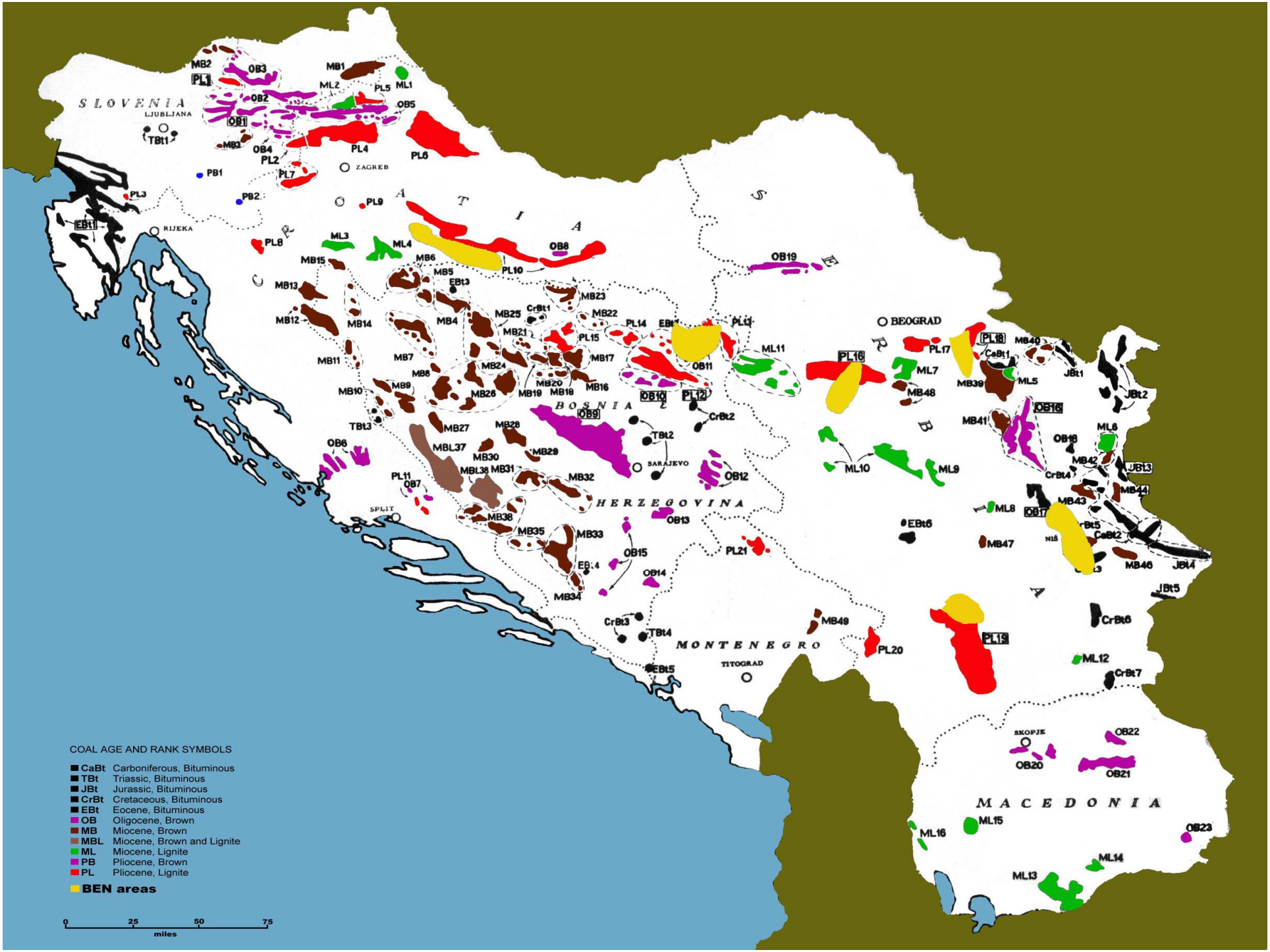


Figure IN-5. Ferris coal beds.

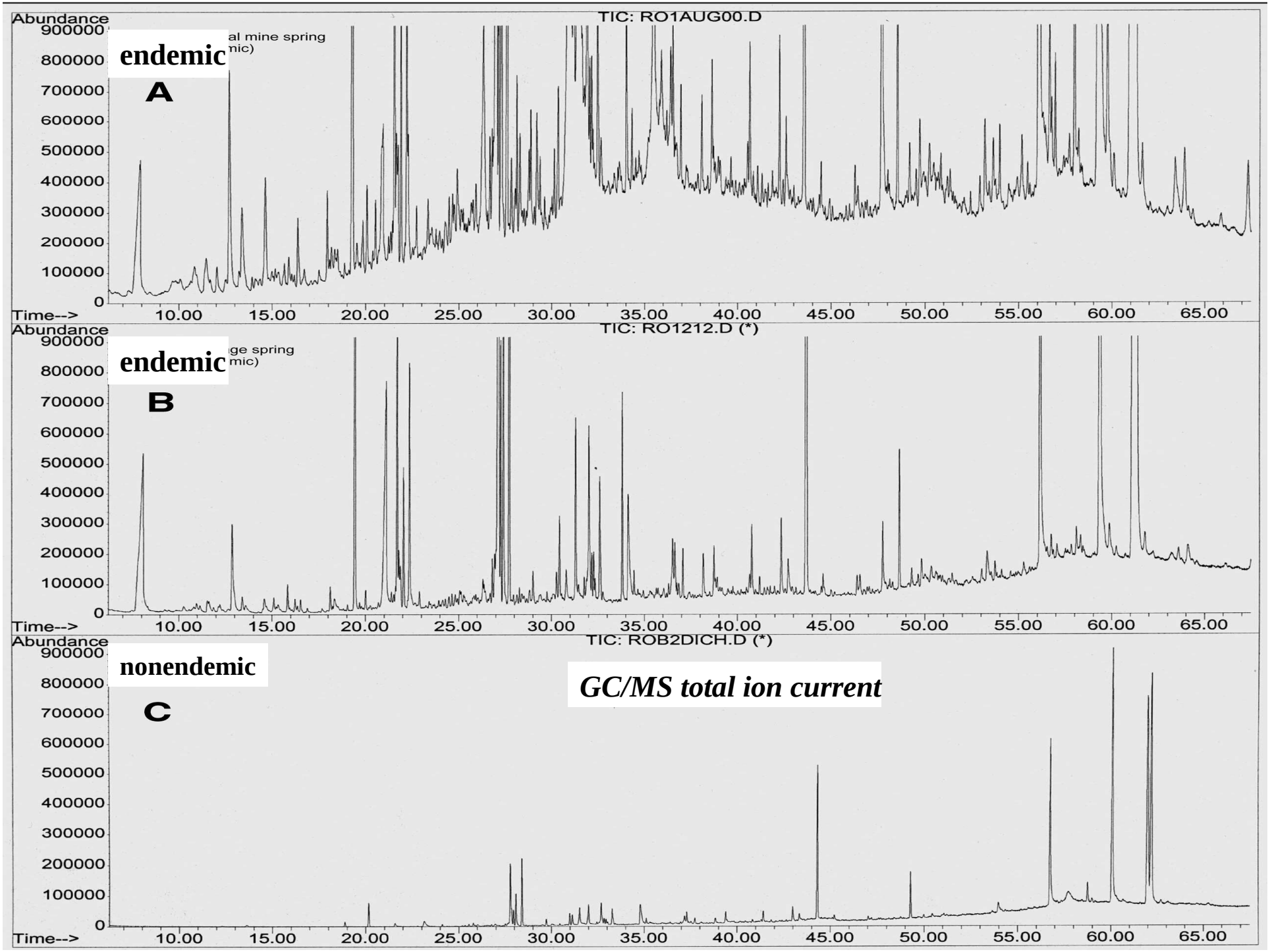
BALKAN ENDEMIC NEPHROPATHY (BEN)


SLOVENIA
LJUBLJANA
ZAGREB
RIJEKA
SPLIT
SARAJEVO
BOSNIA
HERZEGOVINA
CROATIA
SERBIA
BEOGRAD
MONTENEGRO
TITOGRAD
SKOPJE
MACEDONIA
COAL AGE AND RANK SYMBOLS
CaBt Carboniferous, Bituminous
TBt Triassic, Bituminous
JBt Jurassic, Bituminous
CrBt Cretaceous, Bituminous
EBt Eocene, Bituminous
OB Oligocene, Brown
MB Miocene, Brown
MBL Miocene, Brown and Lignite
ML Miocene, Lignite
PB Pliocene, Brown
PL Pliocene, Lignite
BEN areas
0 25 50 75
miles

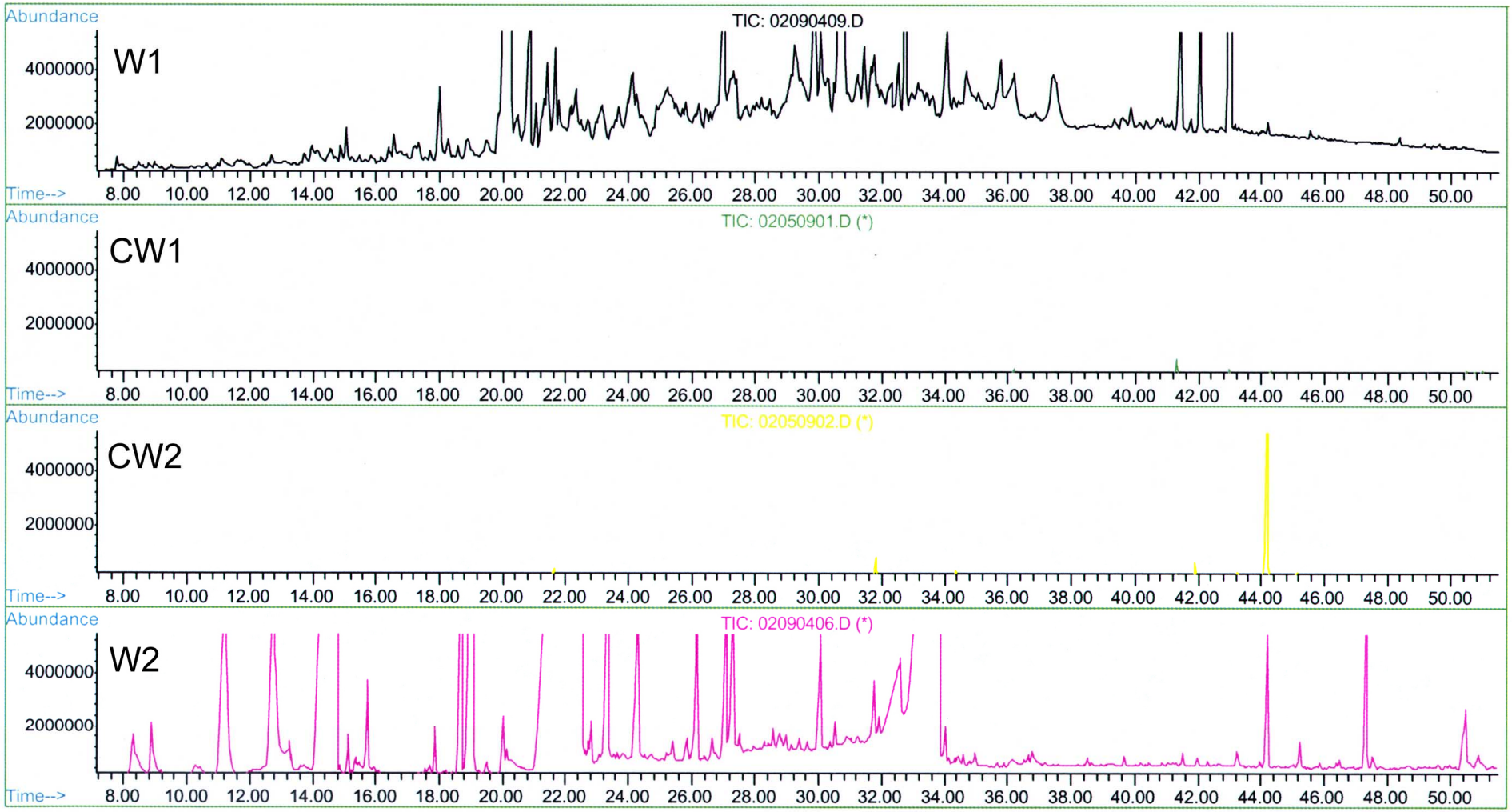
rural wells may supply tainted drinking water

groundwater percolates through coal seam

BEN patient being treated in dialysis clinic (Romania)


endemic
A
TIC: RO1AUG00.D
endemic
B
TIC: RO1212.D (*)
nonendemic
C
TIC: ROB2DICH.D (*)
GC/MS total ion current
Abundance
Time-->

Water from wells in areas of Louisiana with high incidence of renal pelvic cancer and with lignite deposits (W1 and W2) have much higher levels of organic contaminants compared to control sites (CW1 and CW2)



Total ion currents (TICs) of Lousiana drinking well water samples collected from areas with high incidence of urinary tract cancer and underlying coal deposits (W1, W2) and control drinking well water samples from areas lacking coal deposits (CW1, CW2).

FACT

Trace Elements in Fly Ash Can Present a Health Hazard

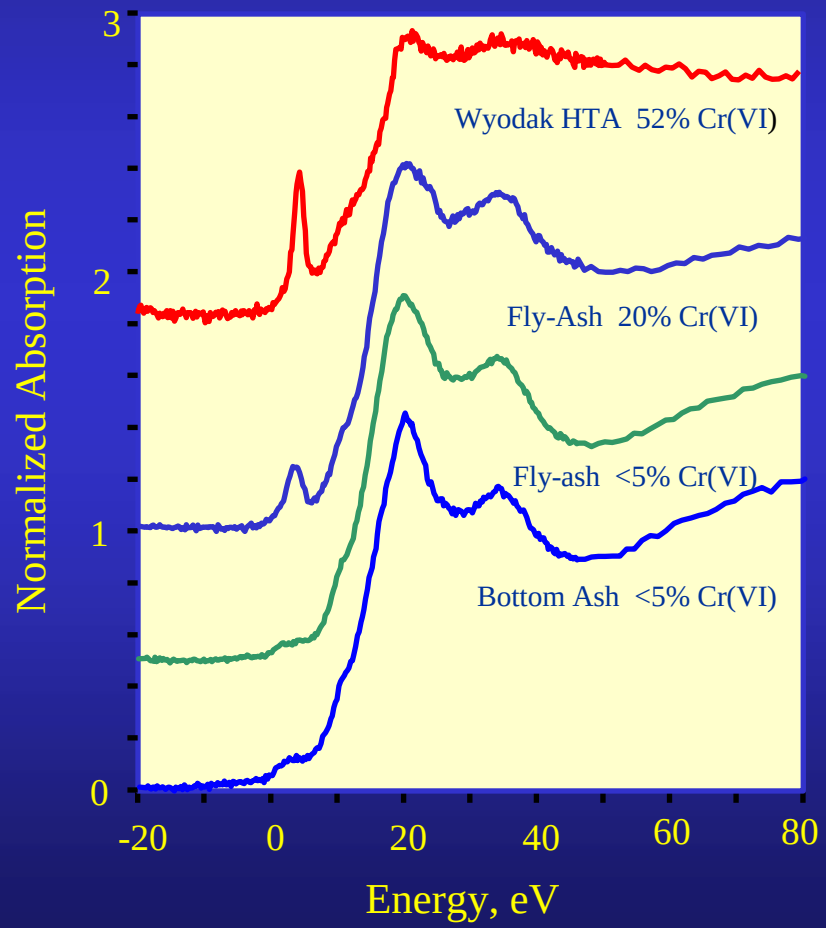
TABLE 25 Effect of Fly-Ash Particle Size on the Concentration of Some Trace Elements (ppm) [a]

Element	Size Range (um) >15	8-15	3-8	<3
As	13.7	56	87	132
Be	6.3	8.5	9.5	10.3
Cd	0.4	1.6	2.8	4.6
Co	8.9	16.3	19	21
Cr	28	49	59	63
Cu	56	89	107	137
Ga	43	116	140	178
Mn	207	231	261	317
Mo	9.1	28	40	50
Ni	25	37	44	40
Pb	73	169	226	278
Sb	2.6	8.3	13	20.6
Se	19	59	78	198
U	8.8	16	22	29
V	86	178	244	327
W	3.4	8.6	16	24
Zn	71	194	304	550

a Source: Ondov *et al*. (1979).

Cr in Ash: XAFS

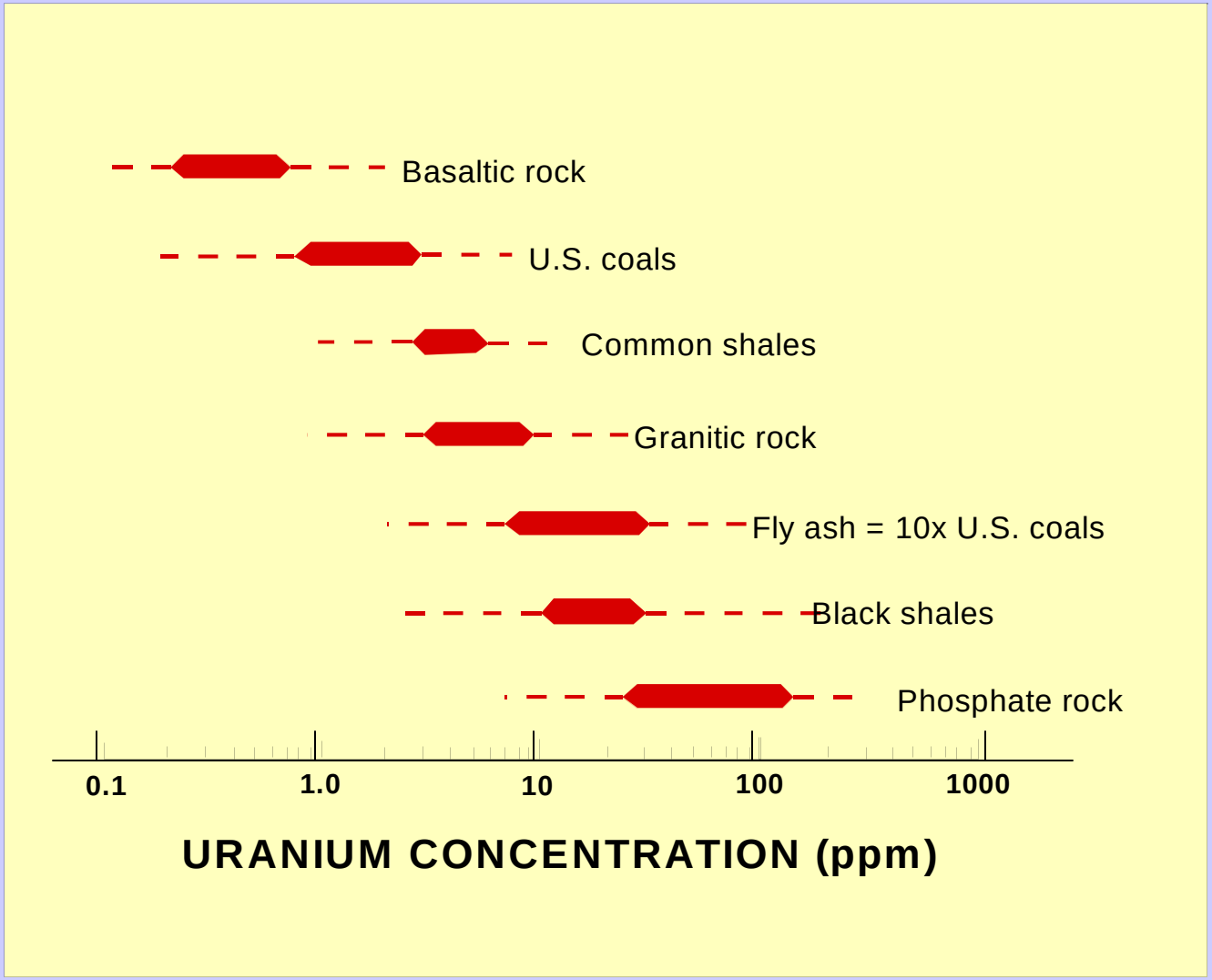
- Cr can be found as:
  - Cr/spinel associated with magnetic iron oxides.
  - Cr associated with alumino-silicate glass.
- Oxidation State of Cr
  - Often <5% Cr as Cr(VI) in bottom ash and fly-ash from bituminous coals.
  - Rarely up to 20% Cr as Cr(VI) in fly-ash from lower-rank coals.

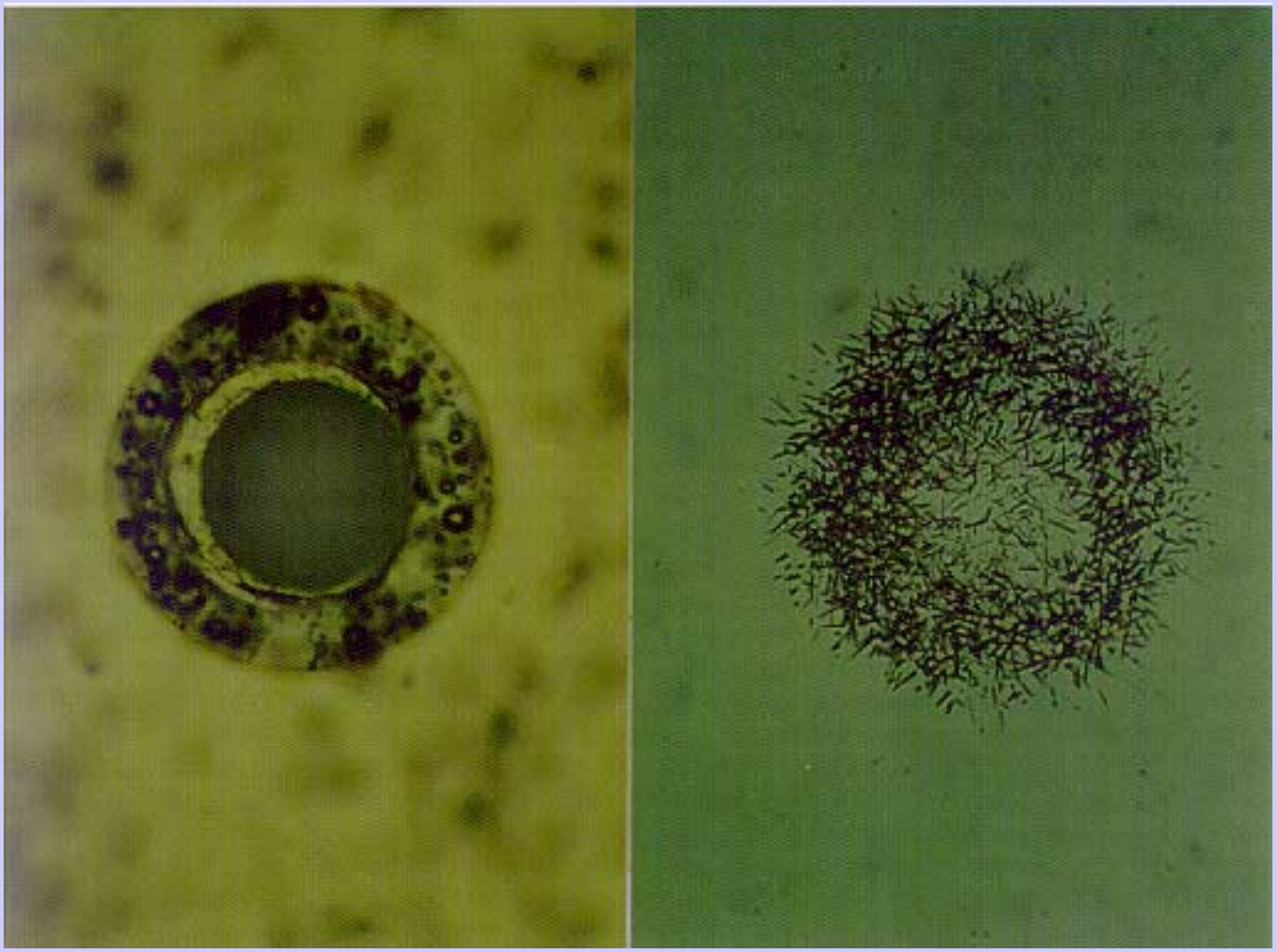


FALLACY

Radioactivity from Coal and Coal Ash Presents a Threat to Health

Typical Range of Uranium concentration in coal, fly ash, and a variety of common rocks



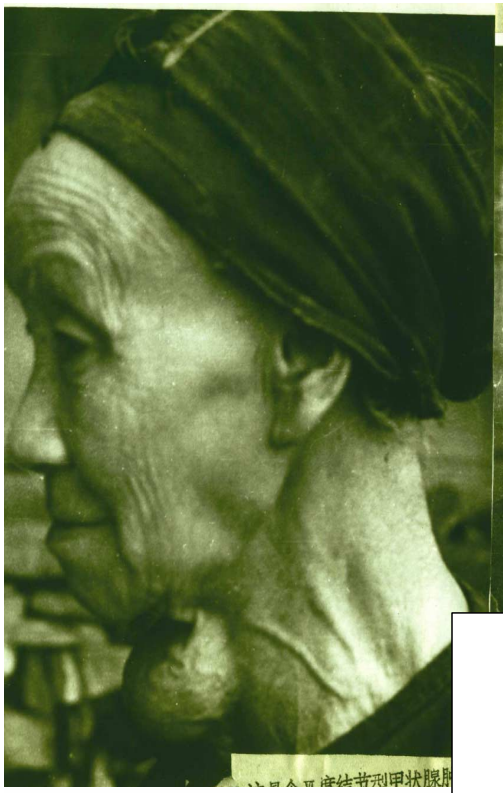


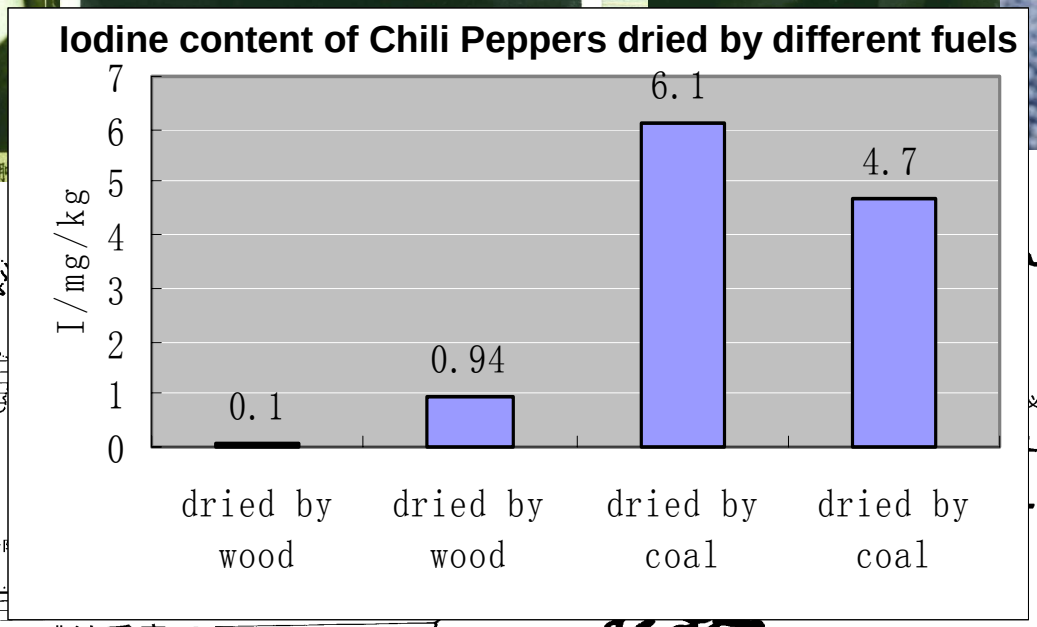
Photograph of hollow glassy fly ash particle (0.01 cm D)

Fission track radiograph of the same particle

FACT

Burning Coal Can Be Good For Your Health





US and World ave. I in coal = 1ppm, Guizhou coal = 8 ppm