Bull. Environm. Contam. Toxicol. 23,207-210 (1979)

Concentration of Elements in Marine Organisms Cultured in Seawater Flowing through Coal-Fly Ash

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Coal-burning, electric power generating plants produce fly ash which is trapped by electrostatic precipitators. It is estimated that approximately 50 million tons of fly ash were produced in the United States during 1977 (ANONYMOUS 1978). While about 13% of this total is used as a base material for road construction and as an additive to concrete and ceramic products (ANONYMOUS 1978), the bulk of the material is disposed in landfills.

Power plants are typically located near lakes, rivers or other bodies of water for cooling and equipment cleaning purposes and this can lead to water pollution. Also leachates from fly ash landfills may contain many elements solubilized from the ash which can reach receiving waters (CHERRY and GUTHRIE 1977, DREESEN et al. 1977). Fly ash has been studied as a material to add to lakes to decrease the phosphorus concentration by fixation and thereby hopefully limit algal growth (HIGGINS et al. 1976). In the work reported, marine organisms were cultured in seawater flowing through a bed of coal fly ash. The organisms were then analyzed for 40 elements by neutron activation and other methods.

MATERIALS AND METHOD

Fly ash was obtained from Milliken Station, a coal-burning electric power-generating plant located in Lansing, New York, about 20 miles north of Ithaca on the eastern shore of Cayuga Lake. A rectangular wooden tank divided longitudinally into two 10' X 2' X 19" compartments was used to expose the organisms. A 6-inch layer of the fly ash was placed in the bottom of one compartment of the tank over which running seawater at a temperature ranging from 14° to 22° C flowed at the rate of 2 gallons per minute. In the bottom of the other side of the tank was placed a 6-inch layer of clean beach sand with the same rate of flow of seawater in which the control organisms were exposed.

The organisms cultured and studied were: soft shell clams (*Mya arenaria*), hard shell clams (*Mercenaria mercenaria*), American oysters (*Crassostrea virginica*) and sand worms (*Nereis virens*). The oysters lay on top of the fly ash or sand, the other organisms burrowed down into the bottom sediment but in contact with the overlying water by means of tubes in the case of the worms or siphons in the case of the clams which extended to the surface. The period of exposure of the organisms was 4 months. The rearing procedure is described by Ryther et al. (1975).

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0007-4861/79/0023-0207 $01.00

The entire sandworms and the edible flesh of the shellfish were taken for analysis. All samples were first thoroughly rinsed with distilled water. The samples were then subdivided, mixed and freeze-dried. Subsamples were analyzed for 40 elements using nondestructive neutron activation analysis as previously described (FURR et al. 1976). Arsenic analysis was performed by dry ashing (EVANS and BANDEMER 1954), distillation of arsine and determination using the silver diethyldithiocarbamate spectrophotometric procedure (FISHER SCIENTIFIC CO. 1960). Boron was determined by the curcumin spectrophotometric procedure (GREWELING 1966). Selenium was determined by the fluorimetric method of OLSON (1969).

RESULTS AND DISCUSSION

The elemental concentrations (ppm, dry wt) in the fly ash are listed in Table 1. In Table 2 are listed those elements in the marine organisms which were found at higher concentrations in certain of them. Various of these elements have been shown to concentrate in fresh water organisms as well when exposed to fly ash and effluents from it (CHERRY and GUTHRIE 1978, CHERRY et al. 1976, GUTHRIE and CHERRY 1976, GUTENMANN et al. 1976). Boron has been reported at significant levels in aqueous leachates of coal fly ash (COX et al. 1978).

TABLE 1

Elemental Content of Fly Ash

Element	ppm	Element	ppm	Element	ppm
Al	105,800	Eu	2.7	Sc	18
As	197	Fe	66410	Se	6.2
Au	0.01	Hf	6.3	Sm	60
B	24	I	105	Sn	442
Ba	734	K	26360	Sr	1021
Br	1.7	La	64	Ta	1.4
Ca	8900	Lu	0.6	Th	51
Ce	189	Mg	17890	Ti	6617
Cl	2888	Mn	145	U	5.6
Co	34	Mo	10	V	203
Cr	142	Na	2126	W	6.1
Cs	10	Rb	193	Yb	4.3
Cu	62	Sb	4.3	Zn	170
Dy	17				

The toxicology of several of the elements in Table 2 has been reviewed (BROWNING 1969). In terms of toxicity the elements of most concern would be arsenic and selenium. Arsenic in marine species is present in various organic combinations (EDMONDS and FRANCESCONI 1977, LUNDE 1972, COONEY et al. 1978) which in shrimp have been shown to be largely excreted when fed to rats as compared to inorganic arsenic which is stored (COULSON 1935). Selenium, although toxic is also essential and deficient in the diet

TABLE 2

Concentration (ppm, dry wt) of Specific Elements in the Marine Organisms

Element	Soft shell clams		Hard shell clams		American oysters		Sandworms	
	Control	Fly Ash	Control	Fly Ash	Control	Fly Ash	Control	Fly Ash
Al	1058	8218	47	268	72	1373	934	9645
As	4.8	66	3.0	5.6	2.4	4.4	5.2	19
B	25	47	22	26	30	46	5.0	8.0
Br	4.7	226	356	323	321	308	288	315
Ca	12600	5390	3920	6247	3050	13230	1600	4333
Co	2.9	5.0	4.1	2.7	2.4	3.3	2.6	6.2
Fe	1977	576	175	270	409	729	616	5617
I	16	22	---[a]	---	---	---	168	248
La	2.0	4.6	0.7	0.6	0.6	0.7	0.8	4.1
Mg	4314	5309	8210	7587	8410	8944	3306	4570
Se	1.1	3.9	0.9	1.2	1.0	1.3	1.3	3.3
Sm	1.3	4.7	0.3	0.3	0.1	0.6	0.2	3.9
V	4.5	24	0.9	0.8	0.5	3.0	1.6	22
Zn	81	100	141	121	281	255	108	219

[a] Interference prevented analysis.

of many animals and probably humans. Considering the relatively small proportion of marine species in the typical American diet and the relatively modest increase in selenium concentration in the fly ash-exposed organisms, this would not appear to constitute a hazard. It is probable that a certain proportion of the total element increase (Table 2) in the fly ash exposed organisms was due to intake of whole intact fly ash particles by them. In this regard, it is interesting to note that when sheep were fed a ration containing up to 7.5% by weight of fly ash for 124 days no toxic symptoms or abnormal internal lesions were observed (FURR et al. 1978).

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