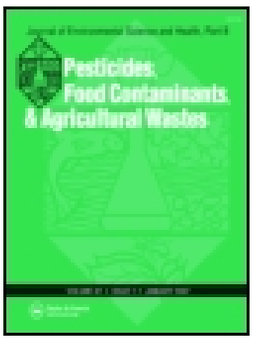

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ELEMENTAL ANALYSIS OF AIRBORNE GRAIN DUSTS

KEY WORDS: dust, grain, chemical composition, occupational medicine

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ABSTRACT

The elemental composition of a group of airborne and settled grain dusts is reported. This survey was undertaken as part of a study to systematically describe the chemistry and morphology of these representative dusts. Our data show that airborne or settled grain dusts differ from each other with respect to elemental composition. Such fundamental differences may be related to previously observed differences in the biological activities of the dusts.

INTRODUCTION

Since the writings of Ramazzini early in the eighteenth century, diseases caused by grain dusts have been documented

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(Ramazzini, 1713). Pulmonary symptoms associated with grain dust are common wherever grain is handled. The exact number of workers at risk is unknown. In the United States there are approximately 500,000 grain elevator workers (Rankin, n.d.). There are additional numbers of longshoremen and workers in flour, feed and seed mills exposed to the potentially harmful effects of grain dust inhalation. The proportion of the approximately 2 million farmers at risk because of grain dust is also unknown. Grain dust has also been identified as a community air pollutant capable of causing epidemics of asthma (Rankin, n.d.). Because of the deleterious effects of airborne grain dust on lung function, it has been suggested that grain dust should not be regarded merely as a nuisance dust (Chan-Yeung et al., 1981); these substances pose a potentially serious threat to the health of a sizable population.

Our laboratories have been engaged in the study of the reaction of grain dusts with the immune system (Olenchock et al., 1978; Olenchock et al., 1980; Olenchock et al., 1983), because there is good reason to postulate that such a reaction can account for much of the pulmonary pathology which follows respiratory exposure to grain dusts. During the course of our studies it has become apparent that grain dusts are very poorly characterized materials. Some investigators have dealt with the composition of grain dusts in terms of specific components such as fumigants (Peters et al., 1982), microorganisms (Lacey, 1980), toxic fungal products (Sorenson et al., 1981; Dashek et al., 1983a; Ehrlich, et

al., 1982) or mites (Cuthbert et al., 1980) but no systematic survey has been undertaken. We feel that on occasion this lack of generalized information has been a distinct disadvantage in designing an experimental approach to study the interactions of grain dusts and the immune system. To obtain more specific information on the composition of grain dust, we have undertaken a systematic study of the chemistry, biochemistry and morphology of 7 representative grain dusts. We expect such information to be useful in designing biochemical, immunological and physiological experiments using these dusts; furthermore, these data will serve as a base with which we can compare dusts collected at other locations and during other growing seasons.

In this communication we report the elemental composition of our 7 representative dusts.

MATERIALS AND METHODS

Airborne dusts of barley (BA), corn (CN), Durum wheat (DW), flax (FX), oats (OA), and spring wheat (SW) were collected as previously described (Peach et al., 1980) at active port grain elevators in the Duluth-Superior areas of the United States. Settled grain dust (SD) was collected at the same grain elevators from the rafters and ledges and represented approximately a 20 year accumulation (Olenchock et al., 1978). All dusts were stored in sealed plastic bottles at 4°C.

Dust samples were analyzed for boron and mercury by IHI-Kemron, Williamstown, WV. Boron analysis was by the Carmine

method (Anonymous, 1980) and mercury by the manual cold vapor technique (Anonymous, 1979). Camp, Dresser and McKee, Inc., Wheat Ridge, CO, carried out the analysis for other elements by spark source mass spectroscopy.

RESULTS AND COMMENT

Elements of atomic numbers 1 through 92 are listed in either Tables 1 or 2. The results of the analytical procedures are in Table 1. For technical reasons the analysis of several elements was omitted; these elements are listed in Table 2. Indium and rhenium were used as internal standards for spark-source mass spectroscopy; i.e. known quantities of these elements were added during sample preparation for calibration purposes. Carbon, hydrogen, oxygen and nitrogen were driven off during sample preparation, and were not determined. Similar considerations apply to the inert gases. Several radioactive elements are absent from the Table 1. Astatine, francium, promethium and technetium are virtually absent from the earth's crust (Weast and Astle, 1979). The other radioactive elements were checked for and are present at less than 0.1 ppm.

Spark-source mass spectroscopy, which was used for all elements in Table 1 except boron and mercury, is an excellent survey technique which allows one to estimate almost every element of the Periodic Table. But one must bear in mind that a technique of such versatility will have limitations. For example, spark-source mass spectroscopy is best suited for the estimation of trace

elements present up to about 200 ppm; thus if one desires precise data on elements present in high concentrations (e.g. aluminum, calcium, sulfur) techniques specifically designed for these substances should be used. In addition it should be noted that the tantalum values may be artificially elevated; this is because tantalum is used in the construction of the spark source mass spectrometer and is so situated that during the operation of the instrument this element may be vaporized to a small extent and contribute to the determined values. Table 1 shows that tantalum is low in all dusts. In general, if one should find by this survey technique that an element(s) of special interest is present, it would be wise to re-assay that element by a specific method. But with spark-source mass spectroscopy one can conveniently survey many samples for almost all elements.

TABLE 1

Elemental Composition of Grain Dusts

Expressed as parts per million unless percent is indicated. Blank spaces indicate less than 0.1 ppm. Abbreviations defined in MATERIALS AND METHODS.

	BA	CN	DW	FX	OA	SD	SW
Aluminum	> 1%	500	> 1%	~2100	>0.5%	> 1%	> 1%
Antimony	0.72		0.35	0.32	0.50	0.46	1.10
Arsenic	3.20	0.10	0.71	0.55	1.00	0.38	0.98
Barium	150	5.30	110	77	53	100	270
Beryllium	0.34		0.21	0.26	0.23	0.59	0.10

Table 1 (cont.)

	BA	CN	DW	FX	OA	SD	SW
Bismuth	0.23		0.10	0.14		0.10	0.32
Boron	14.90	2.60	105	130	50	65	75
Bromine	20	0.61	21	4.20	12	5.90	22
Cadmium	0.36		0.36	0.67		0.12	0.66
Calcium	> 1%	~1000	~0.5%	~ 1%	~4100	~0.5%	~4600
Cerium	39	0.42	6.80	4.30	5.00	6.20	18
Cesium	0.73		0.43	0.14	0.36	0.43	1.60
Chlorine	320	4.30	240	65	280	23	93
Chromium	16	0.41	11	3.00	4.50	8.60	12
Cobalt	1.40	0.11	1.00	0.44	1.00	1.60	2.50
Copper	16	2.00	13	11	17	10	22
Dysprosium	0.32		0.10	0.16	0.16	0.12	0.84
Erbium	0.24		0.13	0.11	0.34	0.23	0.48
Europium	0.16					0.15	0.56
Fluorine	110	17	79	73	57	76	67
Gadolinium	0.42		0.14	0.16	0.52	0.28	0.97
Gallium	2.10	0.10	1.90	0.79	1.30	1.50	2.10
Germanium	0.58		0.61	0.23	0.55	0.43	0.95
Gold							
Hafnium	0.90	0.10	0.32	0.30	0.35	0.97	1.10
Holmium	0.10				0.10		0.24
Iodine	0.47		0.38	0.37	0.26	0.57	0.79
Iridium							
Iron	~ 1%	540	>0.5%	~2400	~2600	~0.5%	> 1%
Lanthanum	20	0.16	3.10	2.80	1.90	4.00	7.40

Table 1 (cont.)

	BA	CN	DW	FX	OA	SD	SW
Lead	17	3.00	12	6.50	6.80	16	29
Lithium	4.50	0.40	6.20	5.70	2.00	9.90	28
Lutetium							
Magnesium	>0.5%	390	~ 1%	> 1%	~4400	~4200	>0.5%
Manganese	180	11	400	140	160	62	610
Mercury							
Molybdenum	2.70	0.24	1.80	0.98	1.80	1.40	8.90
Neodymium	1.80	0.13	1.90	0.83	0.99	2.40	9.30
Nickel	4.40	0.12	3.20	13	11	3.20	5.00
Niobium	2.70	0.23	2.40	0.86	1.50	0.92	3.90
Osmium							
Palladium							
Phosphorus	> .5%	> .5%	> 1%	~ 1%	~4000	~2800	~ 1%
Platinum							
Potassium	> 1%	~1700	>0.5%	>0.5%	> 1%	~ 1%	> 1%
Praseodymium	2.20		0.47	0.25	1.10	0.94	9.80
Rhodium							
Rubidium	23	2.40	20	12	16	26	80
Ruthenium							
Samarium	0.43		0.29	0.30	0.43	0.51	1.30
Scandium	1.90	0.12	0.47	0.37	0.26	1.10	0.98
Selenium	0.69		0.77	0.25	0.46	0.25	1.10
Silicon	> 1%	~3500	> 1%	> 1%	> 1%	> 1%	> 1%
Silver		1.20		0.10	0.11		
Sodium	~2100	69	~1300	~1000	940	~1300	580

Table 1 (cont.)

	BA	CN	DW	FX	OA	SD	SW
Strontium	67	3.00	20	18	27	32	86
Sulfur	~1500	52	~4200	~1700	~1800	740	~1300
Tantalum	0.12	0.10	0.42	0.15	0.15	0.83	2.40
Tellurium			0.10				
Terbium							0.35
Thallium	0.20			0.15		0.10	0.55
Thorium	1.40	0.10	0.59	0.55	0.58	0.46	2.90
Thulium	0.13				0.11		0.10
Tin	0.94		0.30	0.15	0.18	0.35	1.70
Titanium	240	24	170	120	140	340	360
Tungsten	0.52		0.10	0.35	0.10	0.18	0.42
Uranium	1.40		0.34	0.25	0.30	0.27	0.90
Vanadium	10	0.85	7.50	6.90	7.30	20	14
Ytterbium	0.45		0.17	0.15	0.26	0.24	0.36
Yttrium	4.00	0.13	1.70	1.20	3.40	2.00	4.80
Zinc	140	16	430	130	87	89	220
Zirconium	26	3.30	11	6.50	38	69	46

On scanning Table 1 it is apparent that corn dust is "cleaner" than the others. That is, the concentration of the listed elements (with the exception of silver and phosphorous) is lower in corn dust than in the other dusts; presumably corn is correspondingly higher in carbon, hydrogen, oxygen and nitrogen. The fact that corn dust is "cleaner" probably reflects the nature of

TABLE 2

Elements Not Included in Analysis	
Indium Rhenium	Used as internal standards.
Carbon Hydrogen Nitrogen Oxygen	Constitute bulk of dust samples. Expect loss during sample preparation.
Argon Helium Krytpon Neon Radon Xenon	Rare gases. If present, only in trace amounts. Expect loss during sample preparation.
Actinium Astatine Francium Polonium Promethium Protactinium Radium Technetium	Rare, or absent from Earth's crust.

the kernal and the plant and the fact that this dust is relatively free of leaf material (Dashek et al., 1983b).

When Table 1 is compared to published values for the mineral content of the corresponding grains (Miller, 1958), it can be seen that there are a number of similarities (Table 3). Generally these elements are present at similar or somewhat higher concentrations in the grain dusts compared to the grain. Iron is notable in this regard because it is considerably higher in the grain dusts; in 3 cases it is 2 orders of magnitude higher than in

TABLE 3

Mineral Content of Grains Compared to Corresponding Dusts

Expressed as parts per million. Upper value of each pair refers to grain and the bottom value to corresponding dust. Abbreviations defined in MATERIALS AND METHODS. Blank spaces indicate values not reported in Miller, 1958.

	BA	CN	DW	OA	SW
Calcium	900	300	1700	1100	600
	> 10,000	~ 1000	~ 5000	~ 4100	~ 4600
Copper	9	3	9	7	12
	16	2	13	17	22
Iron	60	30	50	80	60
	~ 10,000	540	> 5000	~ 2600	> 10,000
Magnesium	1400	1700		1900	
	> 5000	390	~ 10,000	~ 4400	> 5000
Manganese	18	6	32	43	80
	180	11	400	160	610
Phosphorous	4700	3200	4500	3900	4500
	> 5000	> 5000	> 10,000	~ 4000	~ 10,000
Potassium	6300	3500		4200	
	> 10,000	~ 1700	> 5000	> 10,000	> 10,000

the grain (barley, durham wheat, spring wheat) while in the other 2 cases (corn, oats) it is at least an order of magnitude higher. The iron content of these dusts, which is high in both absolute and relative terms, might have its origin in the machinery used to harvest and transport the grain; alternatively the iron might originate in the soil dust of the northern Midwest (the probable region of harvest) where iron is so plentiful near the surface it is mined, in certain areas, by open-pit methods. It should be noted that the mineral content of grains (TABLE 3 and Miller, 1958) is based on moisture free samples, while the dust

samples reported here were analyzed as collected from the grain elevators. This will not significantly affect the comparisons of TABLE 3 because the major differences are in the order of magnitude range. Nevertheless, the values for these dusts can be converted to a moisture free basis by using the following data for moisture content as determined by Dashek et al. (1983b): barley dust, 8.3%; corn dust, 13.2%; durham wheat dust, 13.5%; flax dust, 16.6%; oat dust, 10.6%; settled dust, 9.2%; spring wheat dust, 7.9%.

Our data demonstrate that airborne or settled dusts which were collected at the workplace differ from each other with respect to elemental composition. Such fundamental differences may be related to differences which were observed in biologic activity (Olenchock et al., 1980). Likewise, these differences in composition may be exploited in the laboratory by careful experimental design to explore the relationship between chemical differences and biologic (toxic) reactivity.

Studies on the organic constituents of these dusts are underway.

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