Proceedings of the Iowa Academy of Science

Volume 60 | Annual Issue

Article 47

1953

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This paper is a discussion of W. J. Thomsen's prize-winning paper presented to the Geology Section of the Iowa Academy of Science in 1952 and entitled "The Annual Contribution of Meteoritic Dust to the Mass of the Earth" (1). The present paper presents evidence that Thomsen's unusually high estimate for the annual deposition of meteoritic dust may be due to the presence of fly-ash in the magnetic dust samples he collected.

Meteoritic Dust

Recently a popular trend among meteorite collectors has been to collect meteoritic dust. The dust is commonly collected by magnets mounted in down spouts which drain roofs. Methods of collection used by Thomsen were (a) to catch it in cans and on microscope slides, (b) to collect and melt snow, and (c) to gather up the dust from roofs of buildings with a magnet. In past studies nearly all attention has been focused on magnetic meteoritic dust, primarily because of its ease of collection, but the evaluation of the composition of meteorites shows that about 80 percent of meteoritic dust should be non-magnetic. Magnetic meteoritic dust differs from terrestrial dust in that the former contains nickel.

Shape

Meteoritic dust particles are either spherical or angular in shape. The magnetic spheres are described as being shiny and black, although roughened or pitted black spheres are described by Buddhue (2), and hollow spheres with a tiny, vase-like neck were, according to Buddhue, described by Jung in 1883. Thomsen (1) in his Iowa study deals mainly with shiny, black, magnetic, spherical dust.

Annual Deposition

Estimates for the annual deposition of meteoritic dust are given in Table I. Buddhue collected dust in New Mexico, where sources of coal smoke were considered too far away to contaminate the samples. Buddhue's estimate is considerably lower than Thomsen's, both of which are shown in Table I.

Particle Size

Particles of meteoritic dust vary in size from 5 to 200 microns;

Proceedings of the Iowa Academy of Science, Vol. 60 [1953], No. 1, Art. 47

some 99 percent are between 10 and 50 microns, and over 50 percent are between 10 and 20 microns. Particles finer than 10 microns are easily lost or overlooked in collecting.

Table 1

Estimates of Annual World Deposition of Meteoritic Dust.

Authority	Date	Estimate	Remarks
J. D. Buddhue	1950	65×10^6 kg.	Magnetic meteoritic dust calculated on basis of rainfall.
W. J. Thomsen	1952	2000×10^6 kg.	Magnetic spherical meteoritic dust.

Fly Ash

Annual Production

Fly ash is the solid constituent of smoke and, according to Industry and Power (3), is the most common contaminant in the air. It is not soot, but is a gray inorganic glassy ash high in silica, alumina and iron. Nearly all fly ash is produced in industrial plants burning powdered coal. Of the 100 million tons of coal consumed

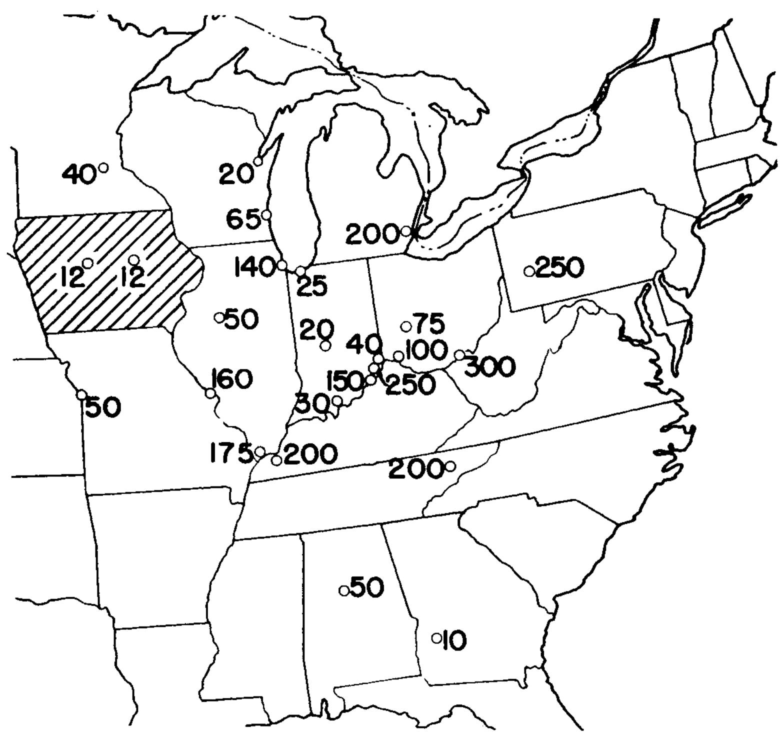

Figure 1. Major centers of fly ash production in the Eastern United States. Figures indicate thousand tons of annual production in each location.

annually in the United States, approximately 70 percent is burned as powdered coal. About 10 percent of the powdered coal burned is non-combustible, and of this about 95 percent is fly ash. This amounts to about 7 million tons of fly ash produced annually. Most of the fly ash is collected, but the rest goes out of the smoke stack. Large plants lose 5 percent or less of their fly ash; small plants lose all of it. A conservative estimate gives between 10 and 15 percent, or about one million tons, of fly ash released to the air in the United States each year. Figure 1 shows that total annual production of the major sources of fly ash in the Eastern United States. In Iowa, Cedar Rapids and Boone are shown; other production is at Spencer, Des Moines and Davenport.

As may be surmized, disposal of collected fly ash is a major problem, especially since once hauled away and dumped it doesn't stay put. Therefore it is usually handled wet and covered up. Fortunately, uses are being found for fly ash in soil-cement and concrete, where as a pozzolan it reacts with lime to produce a cementing material. The lime may be that which is liberated upon hydration of Portland cement, or if no cement is used lime must be added. Fly ash, or other pozzolans such as volcanic ash, has been used to replace up to 30% of Portland cement in concrete, giving higher ultimate strengths, inhibiting alkali aggregate reactions and efflorescence, and lowering the heat of hydration. Because of the spherical shape of fly ash particles, fly ash concrete is easily pumped, and it is now extensively used in grouting and oil well cementing.

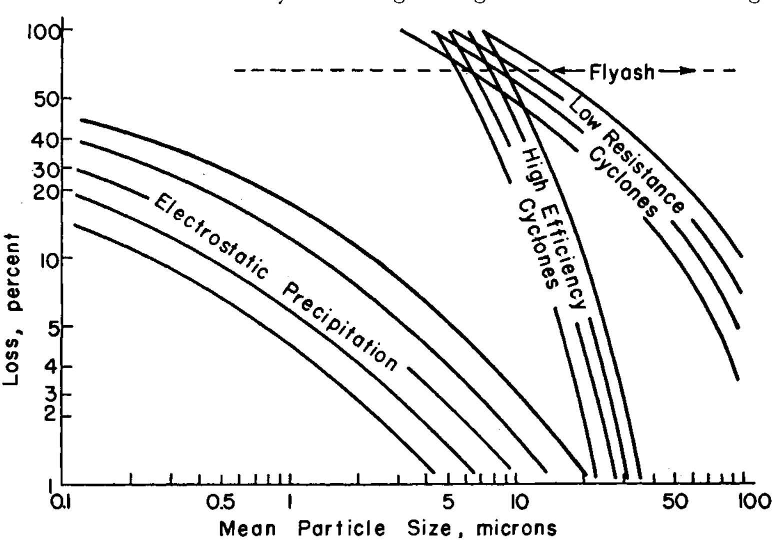

Figure 2. Losses from various types of fly ash collectors as related to mean particle size. Modified from compilation by S. Sylvan, 1952. American Air Filter Co., Inc.

Among the factors acting against more extensive use of fly ash are the somewhat slower strength gain in concrete, higher requirements of air-entraining agents, and high freight rate.

Particle Size

The particle size of fly ash varies from 1 to 150 microns; usually about 90 percent passes the No. 325 sieve (43 microns). The particle size of fly ash in the air is predominantly fine mainly because coarse fly ash is more easily collected at the source. This is illustrated in Figure 2.

Distribution

Fly ash that goes up the stack is not popular with city dwellers, and at present smoke stacks are being designed to make it go as high and as far as possible. Aviators have reported a noticeable clearing of the air over Chicago above 20,000 feet, and according to Buddhue (2), convection currents in the air carry terrestrial dust to at least 36,000 feet. Rising convection currents are common over our cities due to reflected heat. According to figures given by Buddhue, a 20-micron sphere of magnetite (specific gravity 5.17) would require slightly over 24 hours to fall from an elevation of 20,000 feet, disregarding convection currents. With a 30-mile wind such a dust particle would be carried some 720 miles before reaching the ground or a roof top. While this distance would enable it to travel, for example, from Kansas City to Iowa City and back again, it is suspected that the wind does not operate entirely in this manner. Nor is it suggested that 100 percent of Chicago's fly ash lands in Des Moines nor that all Des Moines fly ash is deposited in Chicago, although this might be an interesting idea for debate in the legislatures of Iowa and Illinois.

Magnetic Fraction

A number of fly ash samples were separated magnetically in the Soil Research Laboratory of the Iowa Engineering Experiment Station at Iowa State College. Each sample of fly ash was placed in a test tube, and a magnet held against the side of the tube while the non-magnetic portion was flushed out with a jet of water. Most of the particles collected in this manner were spherical, shiny, and black; a few resembled clinkers or were attached to non-magnetic glassy material. The spheres were slightly pitted or smooth, and the proportion of pitted to smooth particles varied in the different samples investigated. According to Nininger (4), the magnetic portion of coal smoke is lighter in color, lower in specific gravity, and less magnetic than meteoritic dust. No specific gravity or magnetic data are available from Thomsen's meteoritic dust study for comparison with fly ash. Nearly all of the magnetic material separated from fly ash was jet black; some particles appeared steel blue, and rarely one was found which was red or brass-yellow in color. Figure 3 shows magnetic material from a fly ash. Incident

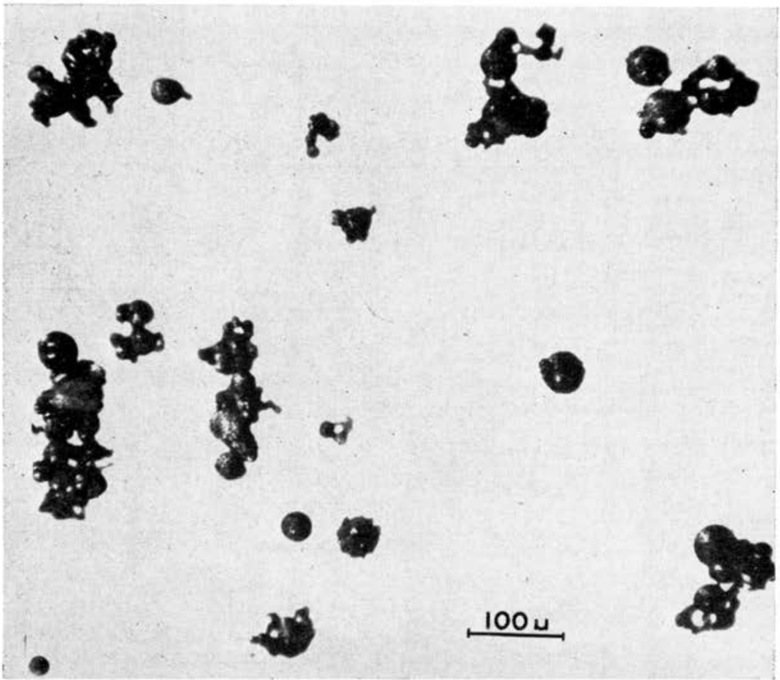

Figure 3. Photomicrograph of a strongly magnetic fraction of a fly ash. Note the shiny surface and the spherical shape of most of the particles. The line $100\mu = 0.1$ millimeters.

as well as substage lighting was used to show the surface characteristics of the particles. The particles were so magnetic they were extremely difficult to keep separate, and they appear as clusters in the photograph.

The magnetic separation treatment was designed to wash out all but strongly magnetic particles. The percentages of such particles present in each of the samples studied are given in Table 2, along with pertinent data available from chemical analyses of the samples of whole fly ash. From the data the average content of strongly magnetic material was found to be about 8 percent. From spectroscopic analyses Thomsen in his study found iron, silicon and magnesium (nickle-doubtful) to be present in his magnetic meteoritic dust. The corresponding chemical data for fly ash are in Table 2.

Non-Magnetic Fraction

The non-magnetic fraction of the fly ash investigated largely consisted of glassy or milky-white spheres. A few contained enclosed gases so that they floated on water; many simply looked like tiny marbles. Thomsen mentions that some 20 percent of his material consisted of non-magnetic spheres; he indicates that they were rather difficult to find since they were mixed with terrestrial dust. Non-magnetic dust was not included in his calculations.

Table 2

Results of Magnetic Separations and Chemical Analyses of Fly Ash.

Source of Fly Ash	Strongly Magnetic Fly Ash, Percent by Weight	Chemical Data for Whole Fly Ash by Percent Fe_2O_3*	SiO_2*	MgO*
Kansas City, Mo., Hawthorn Sta.	13.5	24.73	46.44	1.14
Cedar Rapids, Ia., No. 8 boiler	14.8			
Chicago, Ill., State Line Sta.	13.8			
Milwaukee, Wis., Commerce Sta.	10.3	16.77	43.40	0.70
Milwaukee, Wis., Lakeside Sta.	8.5	17.54	41.28	1.22
Michigan City, Ind.	5.8			
Ind. & Mich. Elect. Co., Tanners Creek Sta.	1.5			
Louisville, Ky., Canal Sta.	17.3			
London, England	3.6			

*Calculated as oxides.

Fly Ash VS. Meteoritic Dust

It will be noted in Table I that Thomsen's figure for the annual world deposit of meteoritic dust is 2 billion kilograms, or about 2 million tons. Over an area the size of North America this would amount to some 80,000 tons annually. As previously stated, the annual amount of fly ash released to the air in the United States is about 1 million tons; if some 8 percent of the fly ash is strongly magnetic (Table II) the 80,000-ton estimate for meteoritic dust is accounted for. The assumption that fly ash produced in this country is evenly distributed over the whole of North America is obviously not true, or our cities would not be such a curious gray. As seen from the map (Figure 1) Iowa is along the western border of the zone of major fly ash production in the United States. Therefore Iowa probably gets more than an average amount of fly ash. Prevailing winds from the northwest during the winter probably decrease the amount of the fly ash carried to Iowa, and prevailing summer winds being from the Gulf would have the reverse effect. Offsetting this is the fact that less fly ash is produced in the summer when many utilities burn gas.

Conclusion

Perhaps the most reliable test for differentiation between magnetic fly ash and meteoritic dust is the presence of nickel, since both dusts are similar in particle size and appearance. Nickel is reported as present in meteoritic dust; it is absent in fly ash. From a spectroscopic analysis Thomsen reported nickel as "doubtful" in his samples; the authors believe that the identical adjective applies to the meteoritic origin of at least a part of his samples. Thomsen's unusually high estimate for amounts of dust deposited can be explained by the production and distribution of magnetic fly ash.

Acknowledgements

The subject matter of this paper was obtained as part of the research being done under Project 283-S of the Iowa Engineering Experiment Station of Iowa State College. This project, entitled "The Loess and Glacial Till Materials of Iowa; An Investigation of Their Physical and Chemical Properties and Techniques for Processing Them to Increase Their All-Weather Stability for Road Construction", is being carried on under contract with the Iowa State Highway Commission and under the sponsorship of the Iowa Highway Research Board. It is supported by funds supplied by the Commission and the U. S. Bureau of Public Roads.

Thanks are due to the Walter N. Handy Company, Evanston, Illinois, for making the samples and much of the data available for this study, and to W. N. Handy for checking the manuscript.

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