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INDUSTRIAL DUSTS AS FACTORS IN PUBLIC HEALTH ENGINEERING

by

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ABSTRACT

Dust is considered as to classification, sources, fallout distributions, diurnal and annual variations, and physical properties. Dusts may also be classified with regard to the physiological reactions produced.

The four basic methods of removing industrial dusts are filtration, electrical precipitation, wet methods and dynamic precipitation. The electrostatic precipitation method is considered to be the best available method for obtaining air practically particle-free.

In most instances 95 percent of the industrial contaminants can be mechanically or electrically removed; however, this is not sufficient to prevent air pollution. For any given source of industrial dust, severity of air pollution is determined largely by the weather. The existing conditions of turbulence, wind speed and wind direction indicate the capacity of the atmosphere for the dilution and dispersion of contaminants. Some important applications of meteorology to the control of industrial dust are: (1) determination of allowable emission rates, (2) stack design, (3) planning and interpreting air pollution surveys, (4) plant-site selection, and (5) meteorological control.

INDUSTRIAL DUSTS AS FACTORS IN PUBLIC HEALTH ENGINEERING

General Remarks

A Wisconsin dustfall study of two limestone plants indicated an average dustfall of 158 tons of dust per square mile per month. One of the sampling locations experienced the equivalent of 710 tons per square mile per month over a period of 16 days. This is equal to a half a thimble of fine powdery dust on a standard office desk, coating the desk and everything on it day after day.

This information was presented to the two plant managers along with a request from the local citizens that the plants take corrective action. The reply was, "Why should we spend thousands of dollars to stop the dust when it isn't considered directly hazardous to health?" Public opinion finally forced action on the grounds of a nuisance of the first order. The first year's operation of a wet-type collector netted over 800 tons of dust for one plant alone. Today the community problem is greatly improved [1].

Another community dust problem concerned a cork company. Little progress was made convincing the plant officials of the nuisance involved with regard to the cork dust from the plant. The solution to the problem was rather ingenious. The high school principal extended an invitation to the chairman of the board for this particular plant to be a guest speaker at the June graduation exercise. The program was planned for outside and with the assistance of Mother Nature the speaker was polluted with cork dust by the completion of the ceremony. Needless to say, an order was soon forthcoming for a mechanical dust collector.

Both of the above mentioned cases are extreme cases of dust problems, and one can be sure that industry today is more receptive to community pollution affairs.

General Information

The unwanted effects of polluted air readily fall into two overlapping categories: (1) economic damage to material properties, and (2) physiologic damage to human and lower animal life forms. The present comment is foremostly directed to the second category [2].

Air contaminants, when defined according to their physical state, can be arranged into five major classes:

1. Dusts: solid particles projected into the air by crushing, grinding, milling, drilling, bagging, sweeping and similar processes, some of which actually produce dust while others simply disperse materials that are already dusty or pulverized. Particles generally are not called dust unless they are smaller than 100 microns in size.

2. Fumes: solid particles commonly formed by condensation of vapors usually rising from molten metals in industrial environments.

3. Smokes: arbitrarily considered as combustion products of organic origin, such as the burning of tobacco, wood, oil, coal and other carbonaceous materials.

4. Mists: extremely fine airborne droplets of materials that are ordinarily liquid at normal temperatures and pressures. They may be formed by atomizing, spraying, agitating, electrolytic evolution of gas, etc.

5. Fogs: limited by some classifications to airborne droplets formed by condensation from the vapor state [3].

Probably the most important of the particulate contaminants from the industrial standpoint are the dispersoids (dusts). These dusts may be classified as a pneumoconiosis-producing and nuisance dusts, and toxic dusts. They are usually divided into organic and inorganic according to their origin and are similar to the substance or substances from which they are derived. Organic dusts contain carbon and are largely of plant or animal origin. Inorganic dusts are mostly metallic and mineral. From the practical standpoint, however, classifications of dust are not of much importance. In industry the harmful effect is exercised more frequently by dusts of mixed composition [4].

The lower atmosphere varies markedly in its content of gaseous and particulate contaminants from place to place. It is cleanest over the ocean. If this standard is taken as unity, then the average pollution of rural air would be 10 times greater; pollution over small towns would be about 35 times as much; and over cities, pollution would be 150 times greater than that of ocean air. The larger particles of smoke and dust eventually settle out and can be measured in dustfall containers. The contributed wind-blown dust of natural origin, such as sand and soil particles, is not likely to exceed the smoke and dust from chimneys in city areas by more than about 10 percent, except during severe dust storms or when smoke is brought in from distant forest fires.

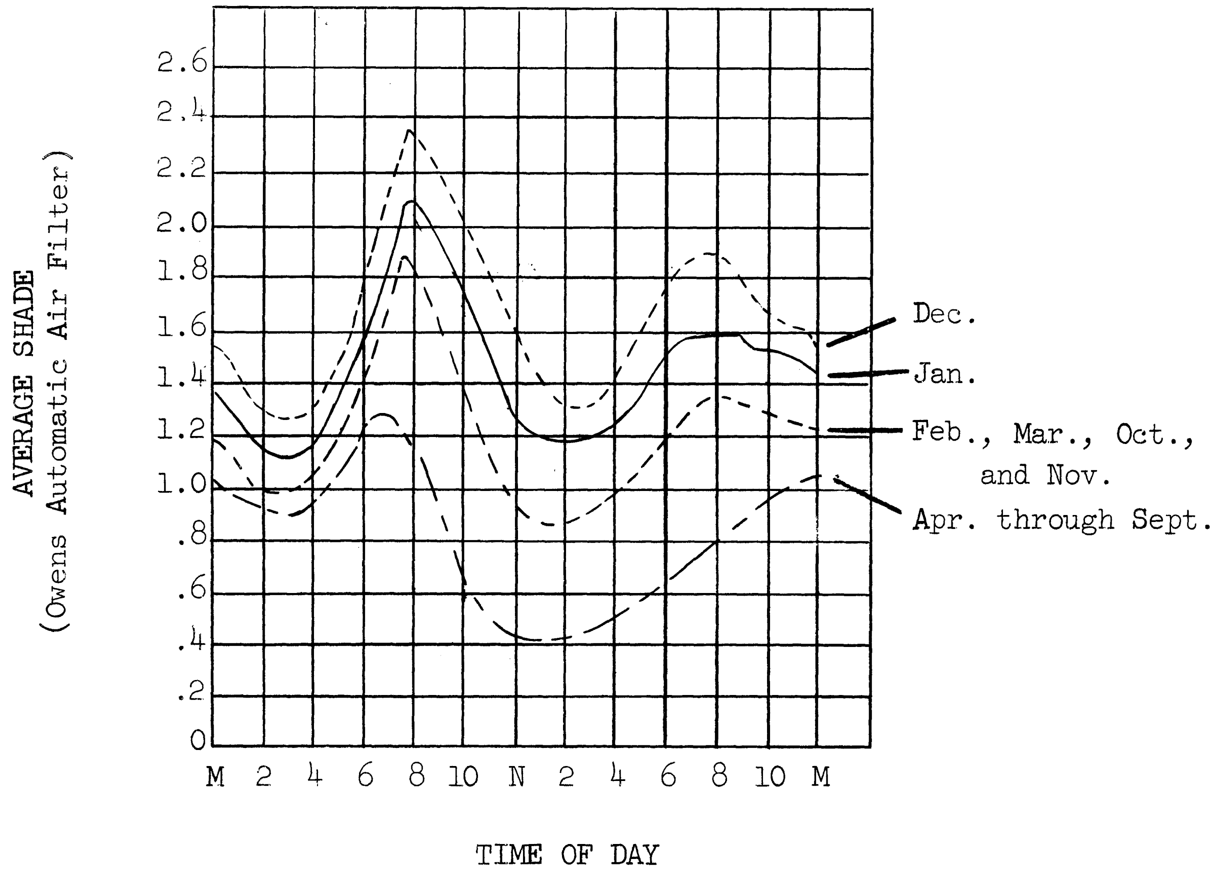
The dustfall distribution in cities is a valuable indication of the amount of fly ash and dust deposited from stack emissions. Most of the particles collected in this manner are larger than 20-40 microns in size. An example of the monthly dustfall for a number of cities is shown in the following table [5].

Mean Dustfall for Various Cities
(tons/square mile/month)

City	Year	Monthly Mean
Chicago	1947	61.2 tons
Cincinnati	1946	34.0 "
Detroit	1953	72.1 "
Los Angeles	1948	33.3 "
New York	1953	67.5 "
Pittsburgh	1951	45.7 "
Rochester	1942	26.4 "
Toronto	--	54.2 "

The variation in concentration is closely related to meteorological conditions and human habits. Observations in many cities indicate a daily cycle with a diurnal rhythm, one maximum occuring in the morning from about 8-9 o'clock and the other in the late afternoon or evening. This diurnal variation reflects the influence of solar heating and cooling, turbulence and other factors. The average diurnal and annual variation in particulate contaminants in American cities is illustrated in the following graph [6].

Sources of dust are quite numerous and can be attributed to many activities. All combustion processes produce contaminants to some extent, regardless of the nature of the fuel. The combustion of coal in pulverized form is recognized as one of the chief sources of fine dust in the air. While devices have been installed in many power plants that will remove 95 percent of the fine ash, these are not sufficient to prevent air pollution. Considerable industrial dust of sub-micron size is produced by the metal industry, blast furnaces, open-hearths, foundries and smelters. In large cities household furnaces and domestic incinerators



disperse several hundred tons of dust each day. Some of the dust that arises from city streets contains particles of rubber supposedly eroded from automobile tires. Many natural aerosols such as fogs, spores, pollens, volcanic dusts and dust dispersed from arid regions persist in the cities as well as in the country [7].

Physical Properties of Dust

Dust particles are very small and most air contaminants do not even approach the upper limit of 100 micron definition. A dust cloud of 10,000,000 particles per cubic foot can just be observed in good illumination. The following list is a comparison in microns of particle sizes compared with known objects [3].

Comparison of Particle Sizes

Item	Size
Raindrop	1000 microns
Head of common pin	1500 "
Hair thickness	75 "
Smallest particle visible to naked eye	35 "
Average industrial dust	10 "
Paint pigment	5 "
Soot particle	1 "
Tobacco smoke	0.2 "

The physical properties of aerosols (dusts) have been the subject of much research. These findings will be reviewed briefly:

1. Increased concentrations of aerosols can reduce visibility and even obscure objects from complete vision. The reduction of visibility is not due to a blocking action but is due to the phenomenon of scattering of light.

2. The mass of individual particles of an aerosol is extremely small; likewise, the momentum of the particles in an air stream is likewise very small. Consequently the particles tend to follow the streamlines of the gas and flow around an obstacle. For this reason, the disposition of small particles may take place with very low efficiency.

3. Concentrated aerosols exhibit the interesting property of coagulation in which the particles are brought together and coalesce. It has been shown that the rate of coagulation is proportional to the square of the concentration and almost independent of the particle size.

4. Small particles suspended in a gas possess some of the properties of molecules. Owing to the impact of molecules of air, dust particles are in continuous movement, even in quiet atmospheres.

5. Another characteristic property of dust particles is the ability to take on an electrical charge by collision with ions. Once having become charged, the particles are attracted to a pole of the opposite charge.

It is frequently stated that small particles settle in the air at their terminal velocity which is given by the law of Stokes. This must be interpreted correctly. It is impossible to calculate the distance which small dust particles will be carried by wind simply by estimating the time that it takes for them to fall in still air from the top of the stack. Aerosol particles are carried with the wind and are subject to eddy turbulence. The percentage of the particles that settle through a stagnant air layer onto a surface depends on mass and size, but the actual free fall of heavier particulates will bring them to the ground only slightly faster than those of the small particles or gases. Fairly accurate estimates can be made of the behavior of gas and aerosol clouds under normal meteorological conditions [7].

Physiological Effects of Dusts

Aside from specific chemical or bacteriological effects, aerosols of solid particulates which penetrate the respiratory passages often result in pulmonary conditions. Most forms are manifested merely by pigmentation, with no effect on the function of the lungs. Two kinds of dust, however, produce definite pulmonary disease, namely, silica and asbestos. Silicosis is an industrial disease caused by inhaling large quantities of finely divided silica. The action is not due to mechanical irritations, but is physio-chemical and can be modified by the presence of other minerals. The disease often results in tuberculosis. The result of the inhalation of asbestos is more of a mechanical irritation resulting in disruption of the blood capillaries in the lungs, thus leading to cardiac changes.

With these diseases the duration and continuity of exposure are of importance, as well as the concentration of the aerosol, with daily exposure over many years, about 1 mg of dust per cubic meter of air is a safe level. Consequently, the diseases are more of the occupational type than of general public concern [7]. The American Conference of Governmental Industrial Hygienists in 1955 published a rather complete listing of threshold limits (upper limits of safety) [9].

Interesting studies have been made on the penetration of small aerosol particles into the lungs. The nasal passages are excellent filters, and few particles above 10 microns will pass. The penetration increases rapidly below five microns diameter. Below one micron, the retention of the small particles in the lungs begins to fall off so that the net quantity retained becomes less for very small particles [7].

Mechanical Dust Control

There are four basic methods for removing industrial dust from the air. They are filtration, electrical precipitation, wet methods, and dynamic precipitation.

1. Filters are the oldest of the many ways of removing dust from the air. Efficient dust filters can also remove air-borne bacteria, molds and spores, but in general they are used to remove dusts of a nuisance nature. Filters consist of porous medium, through which dust-laden air is made to pass, the suspended particles being impinged or enmeshed by the filter medium.

2. Electrical precipitation is especially effective against fine particles. The dust laden air is directed through an electrostatic field with voltages which average 12,000 volts (in ventilation units). The rate of air flow passed through the precipitator is not much greater than that used with commercial air filters, but a higher efficiency is obtained.

3. The wet methods of air cleaning consist of sprays or curtains through which air is made to pass. Earlier methods made use of the spray chambers but newer designs consist of relatively porous filters over which water is made to flow. Such washers are most effective against nuisance dusts and, if there is no recirculation of water, odor difficulties are not as common as with the older spray chambers. The efficiency of the collector is very high but their largest application is in the control of dust explosions from powdered aluminum or magnesium.

4. Dynamic separators are widely used in industry and combine, in a single unit, a fan and collector. These devices are basically fans with blades and housing so designed that the dust is caused to move into a separate compartment near the top of the blade while air passes through an air scroll. The general efficiency is very good but not as complete as in the wet method.

The future of air cleaning will probably hinge more on the further development of electrostatic precipitation than any other device in use at the present time. The principle involved and its applications contain all the attributes much desired in dust control systems. The method is highly efficient, more so for fine dust and bacteria than any other known means, and possesses very low resistance to the flow of air. Some details in design and operation remain to be perfected, but thus far it is safe to state that electrostatic precipitation affords the only available means of obtaining air practically particle-free [6].

Catalogs of the "American Air Filter Company" lists and illustrates industrial equipment of the above mentioned design principles [10].

Meteorological Factors in Dust Control

For a given source of industrial dust, severity of air pollution is determined largely by the weather. Even though the total discharge of contaminants to the atmosphere in a given area remains constant from day to day, the degree of air pollution will vary widely. The observation that smoke dissipated much more quickly on some days than on others is the direct result of differences in weather. Quantitative means for evaluating these weather parameters are necessary to ensure satisfactory and economically optimum solutions to atmosphere pollution problems. To assure the most economical solution, the cost of increased collection efficiency or process alteration must be weighed against the cost of increased stack height or meteorological control of emission rates.

The more important applications of meteorology to the control of industrial dusts is summarized as follows:

1. Determination of Allowable Emission Rates

   Concentrations of particulate contaminants downwind from a source of constant discharge will vary with weather conditions. Consequently, a knowledge of regional climatology is necessary in order to define the frequency of different levels of contamination. Knowing this frequency and the allowable level of pollution caused by the particular substance in question, the required reduction in emission is determined.

2. Stack Design

   The application of dispersion theory and a knowledge of local weather conditions are necessary to determine the required stack height for a given emission. Meteorology and aerodynamics can be used in the design of stack nozzles, in the determination of optimum stack velocities and stack-gas temperatures, and in the determination of stack location relative to plant structures and topography.

3. Planning and Interpreting Air Pollution Surveys

   The results of an air polutions survey lose much of their value unless they are correlated with weather conditions at the time of the survey. The location of atmospheric samplers and sampling technique should be based on a thorough consideration of meteorological factors. By proper consideration of weather factors in survey planning and the collection of adequate weather data during the survey, the value of the information obtained is greatly increased. The time period required for the survey is also kept to a minimum.

4. <u>Plant-site Selection</u>

Water, transportation, raw materials, and markets have long been important factors and are given appreciable study in the comparison and selection of plant sites. Due to varying climate, downwind populated areas, and other local factors, the atmosphere in different locations differs in its ability to receive industrial dusts and waste without causing a nuisance, and for this reason, climatology also has become an important factor in site selection.

5. <u>Meteorological Control</u>

An industrial operation may be such that the discharge of a potential atmospheric pollutant can be restricted to periods of weather favorable for dispersion. When weather conditions are unfavorable, production is cut back and discharge of the offending material is reduced. Under extremely unfavorable conditions, the emission of some materials may be stopped. To be successful, such a program requires accurate forecasting and flexibility of plant operation.

During the period of the day when gustiness and lapse rate are increasing, the air is in a state of instability because of disturbances of mechanical and thermal origin. The capacity of the atmosphere for dilution and dispersion of contaminants is then at its highest. At sunset and during the night, the contaminants over large cities and industrial areas tend to collect in the inversion layer, extending from several hundred to a thousand feet or more above ground level.

In cloudy, overcast weather, the gustiness or turbulence is fairly uniform both day and night. The extent of dispersion of atmospheric pollution will then depend mainly on the wind velocity and topographical features of the terrain. During periods of low wind velocity or calms in such weather, the level of contaminants increases. At last a balance is reached which depends upon the scale of industrial and domestic activities and the ease with which airborne pollutants can be dispersed downwind and crosswind under the cloud layer. Under inversion conditions the ceiling may be much lower and higher concentrations of pollutants will be built up, giving rise to serious conditions if the inversion period is prolonged over several days duration.

It is therefore apparent that meteorological factors, when favorable for dispersion, will result in the rapid mixing and dilution to harmless proportions of relatively large quantities of gaseous and dust waste products. A minimum of control measures will suffice during periods of high turbulence in clear weather. Such controls, to keep a city atmosphere reasonably clean, include the use of proper combustion equipment to prevent release of smoke, the collection of dust and fly ash of particle size greater than 10-20 microns by means which are available without excessive costs, and the elimination of acid gases such as sulfur dioxide, oxides of nitrogen, hydrogen sulfide, and by-products from refinery, chemical, and metallurgical operations by means of stacks of sufficient height for proper dispersal. For the greater part of the year, such simple measures would be effective over many industrial areas [5].

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