

NATURAL DUST AND ACID RAIN

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ABSTRACT

Atmospheric dust originates from three sources, terrestrial airborne matter, volcanic, and cosmic. Terrestrial natural dust makes up the main bulk reflecting the soil composition to 150 miles away. Soil erosion from flood plains, plowed fields and construction sites are the main source. Quartz, feldspar, the carbonates calcite and dolomite, and clay minerals are the components in decreasing order of frequency. Natural dust in the atmosphere interacts with rainwater converting the carbonates to benign gypsum ($\text{CaSO}_4 \cdot 2 \text{H}_2\text{O}$). Naturally leached soils produce less calcite than unweathered sediments on flood plains and construction sites, and in granitic and crystalline rocks less than in limestone areas.

Heavy industrialization associated with high emission of CO_2 and SO_2 on the one hand, and excess production of dust on the other appear to counteract man's interference with natural ecosystems in opposite direction.

Acid rain is made responsible for the acceleration of the natural decay of stone, for the accelerated leaching rate of soils and the change of growth rate of vegetation. Likens, Bormann and Johnson (1972) claim that the average pH of rainwater of the Rhine - Ruhr industrial area of West Germany has dropped from about pH=5 to less than pH=4 in the years between 1956 and 1966. The near exponential rate change of weathering of stone monuments for the Rhine-Ruhr area was documented by Winkler (1973) with time-lapse photos of Herten Castle in Westfalia, Germany (Fig. 1) carved from calcite-cemented Baumberg sandstone: one photo was taken in 1908, the second in 1968. Figure 2. shows the semi-quantitative plot for the Herten Castle since its construction in 1702; this curve is believed to be valid also for many other monuments in industrialized areas of the world (Fig. 3). Likens and Bormann (1974) ascribe the decrease of rainwater pH in the last 20 years in New England and other areas of the world to the

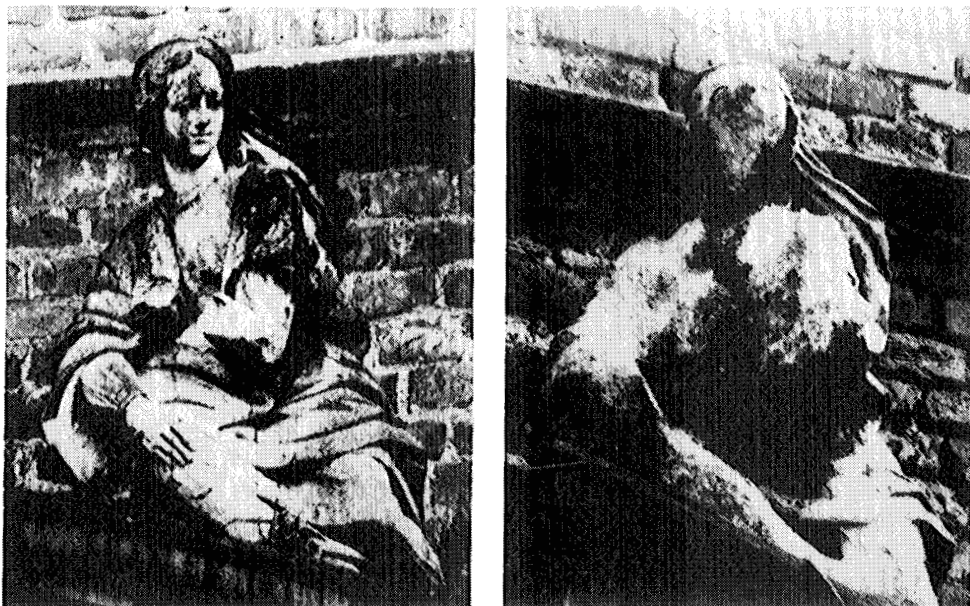


Figure 1. Time-lapse photos of statues at Herten Castle near Recklinghausen, Westfalia, Germany, built in 1702. The left side picture was taken in 1908, the right side picture 1969, showing almost complete destruction of the surface. Porous Baumberg sandstone is composed of mostly quartz grains which are cemented with soluble calcite. Photos and information were supplied by Mr. Schmidt-Thomsen, Landesdenkmalamt Westfalen-Lippe, Muenster, Germany.

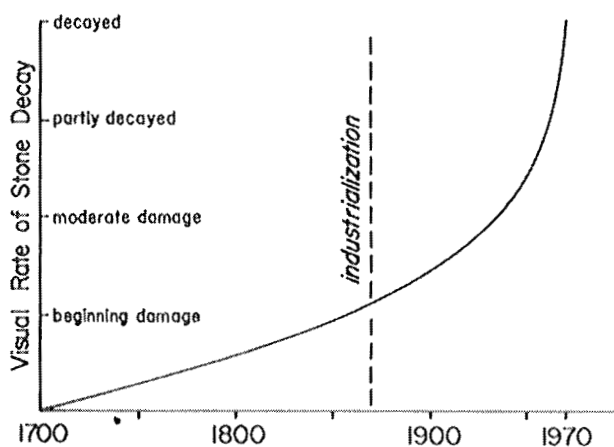


Figure 2. Graphic presentation of approximate weathering rate for picture set of statue at Herten Castle, Westfalia, Germany, illustrated in Figure 1.



Figure 3. Rapid decay towards total destruction of relief on tympanon of parish church in Opherdicke, near Unna, Westfalia. Destruction was severe in 1893, after 600 years of exposure, but catastrophic within the last 80 years. The rate of weathering of Figure 2. appears to apply here too. Stone is Soest Greensandstone with 65% calcite. Photos and information were supplied by Mr. Schmidt-Thomsen, Landesdenkmalamt Westfalia-Lippe, Germany.

increased use of fuel oil and natural gas, also to the reduction of neutralizing alkalic reacting soot by mandatory industrial dust precipitators. The presence and the interaction of natural airborne dust is not mentioned. Winkler (1973) gives three components for natural dust:

1. Windblown dust, from dry river beds, flood plains and beaches, but also from plowed fields and construction sites lacking a protective vegetative cover. Quartz, carbonates, feldspars, and clay minerals are the most important mineral components.

2. Volcanic dust: The explosive eruption of volcanoes has sent dust into the upper atmosphere, essentially as silica glass, where it has travelled for several years before it could settle back to the earth's surface.

3. Extraterrestrial dust or cosmic dust is found in marine sediments of most geological ages as small pellets of iron and silicate glass. Their chemically inactive character and the minute

quantities present make their effect insignificant.

The following table summarizes natural dust, its mineral content and relative reactivity with air pollutants:

COMPOSITION OF NATURAL DUST

Mineral Composition: Approx. Reactivity:

1. Terrestrial Dust, the most essential component of windblown silt:
 - a) dust from carbonate rocks (limestone, dolomite):
 - agricultural soils... clay, quartz little reactive
 - flood plains calcite, some clay .. calcite most reactive
 - construction sites ... calcite, clay calcite most reactive
 - b) dust from crystalline rocks (granite, gneiss, slate, etc.):
 - agricultural soils ... quartz, clay little reactive
 - flood plains quartz, clay, silicates.. little reactive
 - construction sites ... quartz, clay, silicates.. little reactive
 - c) dust from glacial till (moraines):
 - agricultural soils ... quartz, clay, (silicates).. little reactive
 - flood plains quartz, clay, calcite... reactive (calcite)
 - construction sites ... quartz, clay, calcite... reactive (calcite)
 - d) dust from glacial outwash (sand and gravel):
 - agricultural soils ... quartz, silicates, (calcite). reactive
 - flood plains quartz, silicates, calcite.. reactive
 - construction sites ... quartz, silicates, calcite.. reactive
2. Volcanic Dust: glassy silicates; about one tenths of terrestrial dust:
 - quartz, silicates... very little reactive
3. Cosmic Dust: glassy silicate and glassy metallic; amount is minimal:
 - no reaction expected

Quartz, the carbonate minerals calcite and dolomite, the feldspars, ferro-magnesian silicates and various clay minerals are the mineral components of importance. Calcite in dust readily reacts with the acids in the rainwater despite its brief contact between the cloud base and the surface of the terrain. The slow sinking velocity of silt-sized particles in still air ranges from 1 mm to 1 cm per second (fig. 4); calcite has thus enough time to react with the acids in the

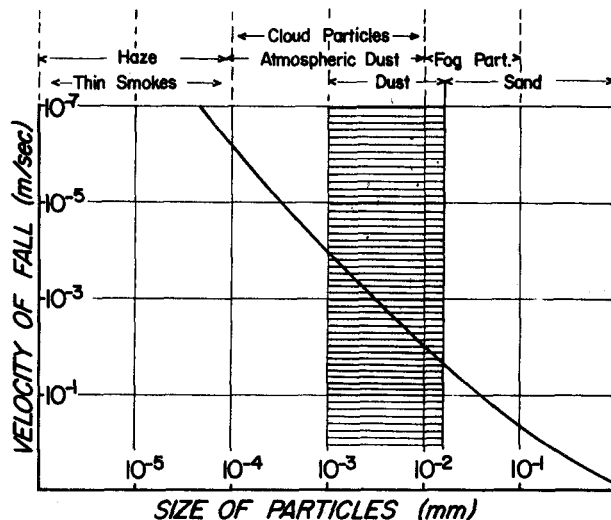


Figure 4. Sinking velocities of particles in still air. The size of natural dust is marked.

air whereby high relative humidity can accelerate the reaction. The sulfate ion is not eliminated from rain but converts from sulfurous or sulfuric acid to relatively harmless gypsum, CaSO_4 . The sulfate ion tied up in gypsum is not noxious to man. Waters rich in sulfate, however, are known to have severely attacked alkalic cement and concrete. The presence of water-soluble gypsum appears to explain the frequent high calcium content of rainwaters. Sumi et al. (1959) describe gypsum as the chief water-soluble component in the atmosphere of almost all industrialized areas.

The mineral quartz is inert and non-reactive; clay crystals, however, can absorb ingredients and hold them tightly on their crystal surfaces which may help to neutralize some acid components in the air temporarily until they can be released again to the soil. Feldspars and the ferro-magnesian silicates react with the tiny H^+ cation in acid rain producing less acid conditions of the rain when tied up during the weathering process. The time of interaction in the atmosphere appears to be sufficient for the reaction.

The mineral composition of natural dusts depends primarily upon

the area of origin, as well as whether the dust is derived from deeply weathered agricultural soils, from fresh or weathered glacial drift materials, or from flood plains and construction sites. Despite local accumulations of windblown debris of considerable magnitude in the geological past, the rate of dust deposition is believed to have possibly tripled since man has started agricultural activity and construction by scarring the protective sod cover of the American plains. Davitaya (1969) has noticed considerable increase of dust in the firn of the remote mountains of the Caucasus caused by both natural and human recent events, like the eruption of Mt. Krakatoa in 1883, and others. Yaalon and Ganor (1973) discuss in detail dust transport from desert floors, dry flood plains and valley trains of glacial outwash. Dust can be lifted upward from bare ground to a height of 1500 to 2000 m, when turbulent surface winds prevail, common near high-pressure fronts. Theoretically, wind does not lift silt-sized particles off the ground as shown in Figure 5., as the dead air layer affects the

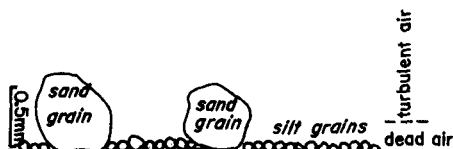


Figure 5. Sand and Silt grains, schematized. Silt grains within the dead air layer are not readily picked up by wind.

silt size. Splashing and bouncing impacts only can mobilize the grains. Soil aggregates smaller than 0.84 mm diameter are subject to wind erosion with a non-linear increase with decreasing grain sizes, whereby air friction can break up the soil grains. Grain diameters larger than 20 μm settle to the ground relatively fast. The plowing and tilling of dry fields, the activity of road graders and soil moving devices on major construction sites stir up clouds of dust eliminating the need for strong air turbulence at the ground surface level. The dust production is also increased by over-grazing and traffic by cattle, like in the Sahel drought belt of Africa today. No reliable data are available for man's participation of natural dust in the air.

Likens and Bormann (1974) report acid rainwaters at near $\text{pH} = 4$ in New England which were also recorded at Geneva and Ithaca, New York; the acidity has increased since about 20 years ago and is believed to have been associated with the increase of natural gas and oil consumption, but also with the compulsory installation of particle-removing devices from flue gasses. The extrapolation of acidity of rain into the near future may raise the question whether or not man's interference in possibly two opposite directions can re-establish

original pre-interference conditions in the acidity of rainwaters: high acidity of the rainwater by air pollution on the one hand and higher production of neutralizing natural dust and soot on the other. The question is thus arising why abnormal acidity arises only in some places. e.g. in New England though the sulfates and other acid ingredients from industrial sources are spreading about equally through atmospheric dispersion throughout the industrial part of the United States. This writer believes that the dense and continuous forest cover of the New England states produces much less natural dust than the agricultural prairie states (Fig. 6); in addition, the area is

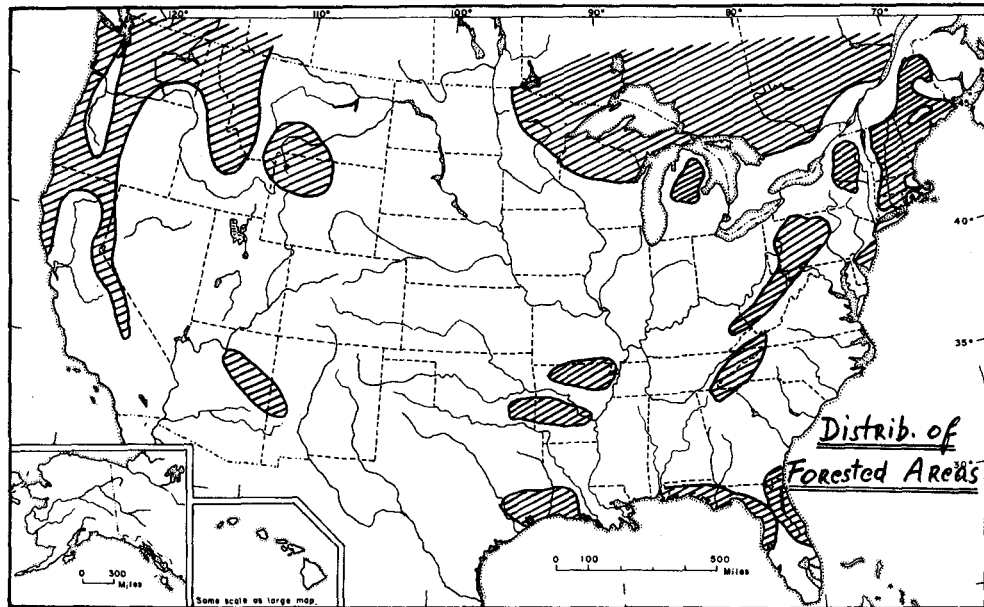


Figure 6. Distribution of forested areas of the United States.

almost entirely underlain by igneous and metamorphic rocks which do not produce acid-neutralizing calcite. Figure 7. shows the distribution of major areas with crystalline rocks exposed at the surface. A tentative range of about 240km (150 miles) from carbonate areas should be allowed, necessary to supply the major bulk of carbonate dust. This author is also convinced that the degree of calcite leaching of the upper soil layer has a strong bearing on the supply of calcite to the dust.

It is difficult to evaluate the true neutralizing strength of both natural and industrial dusts. A closer investigation could give directives where precipitators for industrial dust removal should be employed in order to avoid damage by acid rain in the future. Thus the requirements for future installations of industrial scrubbers should be based upon regional, geological-ecological considerations if

we want to eliminate further damage by acid rains to the environment, and finally to man himself.

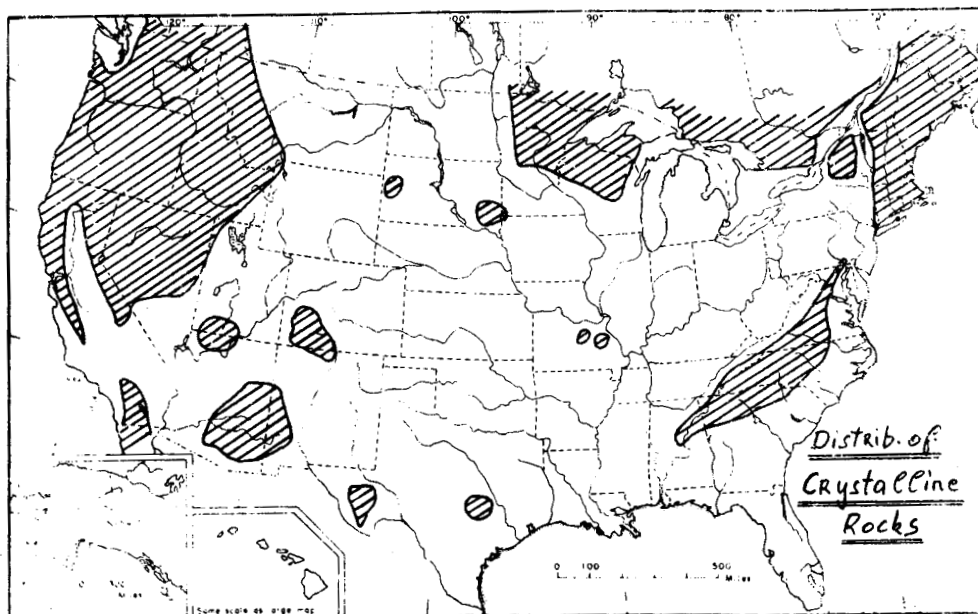


Figure 7. Distribution of non-calcareous crystalline rocks of the United States.

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