EVIDENCE OF A NEED FOR FLUORINE IN OPTIMUM AMOUNTS FOR PLANT AND ANIMAL GROWTH, AND BONE AND TOOTH DEVELOPMENT, WITH THRESHOLDS FOR INJURY

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One of the major problems of dental research for the past three decades has involved phases of hypoplasia of different types. In 1913 the author published an illustrated report presenting an extended series of structural tooth defects, which seemed traceable directly to particular types of baby food. Black and McKay, in 1916, presented data relating to an endemic deformity of tooth structure chiefly expressed as "mottling" and "stain" which has come to be known as the "brown-stain mottled-enamel lesion." McKay's work through the succeeding years has emphasized the relation of this lesion to the water supply. Paleopathology, and medical and dental annals have been recording the existence of this disease. The recent studies of Churchill, Smith, and others have emphasized the probable relationship of this lesion to excess of F in the water. The widespread distribution of this lesion throughout large areas of many countries has emphasized the seriousness of the defect, and the probability that the causative factors will be found in soil conditions. The present studies have been carried forward to ascertain the method by which F acts when injurious effects are produced. The author's studies of blood chemical-changes, as associated with disturbances in mineral metabolism, have emphasized the sensitiveness of the human mechanism not only to shortage of essential minerals and vitamins, but also to toxic quantities of certain metallic and non-metalic substances. These have suggested the need for information on the influence of F on mineral metabolism, and on growth for both plants and animals.

Much of the F of the earth's crust occurs in apatite and other Ca-P compounds, being frequently associated with Ca and P. Since approximately one part in a thousand of the earth's crust is P and approximately an equal amount is F, there is no scarcity of either element in the igneous rocks from which soils were developed. There is about thirty times as much Ca as either F or P in the earth's crust. The problem of the chemical form and solubility of F, as compared with other elements, has much to do with its concentration and availability for serious effects. The various phosphate rocks that are used as fertilizers—primarily calcium phosphate—contain from 0.69 to 4.23 percent of F, which is about one-tenth the P content. The ratio of F to P_2O_5, as reported by Marshall, Jacob and Reynolds is an extended series of determinations, ranged from 0.06 to 1.32 for continental rocks; from 0.0178 to 0.085 for island deposits. The solubility of F is accordingly an important factor in determining the amount available in various waters and soils. Since igneous rocks are about equally rich in P and F, our problem clearly is not one of limited distribution of F. CaF, or fluorite, a common mineral, occurs in abundance in many districts, and is soluble to 37 parts per million of water. Other F salts, such as NaF, and sodium silico-fluoride (Na_2SiF_6) are also soluble—the former, 400 parts per ten thousand; the latter, 65 parts per ten thousand. F presumably has constantly been a factor in the environment of plant and animal life. Since living forms are the product of their environment, F has presumably had a part in vital phenomena. Its low solubility in the forms in which it occurs in igneous rocks suggests that it has not been present in high concentration in surface waters. These studies have accordingly been made to determine the effect of F on plant and animal growth; and on the levels at which it becomes toxic in the water bathing the plant roots, and when ingested by animals in water and food. Various types of plants have been grown in different nutrient fluids in which the concentration of F was varied up to 25 mg. per liter. F as NaF, added in progressive amounts to sprouting corn—when the plant is utilizing only the stored minerals of the kernel, while growing in distilled water—had a progressive stimulating effect up to 10 parts per million of the water; 20 parts, or more, were very toxic and produced only stunted growth with a bronzed appearance. When, however, Ca and P were added to the fluid, the toxic effect was very greatly reduced. The maximum concentration (37 parts per million) of CaF_2 (the common mineral fluorite) would, if present, prevent this cereal from sprouting; and if it occured in irrigation waters, would markedly depress plant growth. Surface drainage cannot readily become saturated. Water stored in soil and rocks as artesian water can more nearly do so, and has frequently been found to blight plant growth.

Studies have also been made of the effect on mineral metabolism when F is ingested by rats. In general several chemicals were depressed. The total iron of the blood of a control rat was at 50 mg. per 100 cc. (The succeeding numerical data for rat blood indicate mg. per 100 cc., when not given as percent.) When F was added as NaF (1 percent of the food), the iron content of the blood was 42.5 mg. The cell-Ca of the blood was reduced from 41.7 to 35. The inorganic P of the serum was reduced from 6.67 to 5.26; of the serum of 100 cc. of whole blood, from

3.89 to 3.42; in 100 cc. of blood cells, from 0.67 to 0.22; in the cells from 100 cc. of whole blood, from 0.28 to 0.08. The cell inorganic-P percent of the total-blood inorganic-P was reduced from 6.7 to 2.3. The inorganic P of whole blood, was reduced from 4.17 to 3.50; the Ca of whole blood, from 9.35 to 7.80. The Mg of blood rose from 2.63 to 3.50. The K of whole blood was reduced from 322 to 267. These data indicate that 1 percent of NaF (diet) caused general disturbance of mineral metabolism. They also suggest that ingestion of F, in amounts above the threshold of tolerance of the tissues, may be very depressing, and may materially influence mineral deposition in bones and teeth. Since, however, the teeth differ from the bones, in that a complete rebuilding process is not possible for the teeth through subsequent months and years, defects of the enamel would be permanent.

Field studies gave important data on waters and soils from many districts, including one in Northern Africa where the teeth of humans, and also those of camels, sheep, cows, goats, donkeys, and horses, are seriously affected. The waters from this district contain from 23 to 31 parts of F per ten million, determined by the Jacob and Reynolds method. The rocks from this district contained 5.38 percent of F, or 53,800 parts per million. This is the highest figure in our series, and higher than any found in the literature. Another series is related to the skeletal breakdown of a group of cattle on a western farm, where both the water and the soil contain excessive amounts of F. The blood of afflicted animals showed very marked depression of mineral constituents.