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NATURAL AND MAN-INDUCED SOIL POLLUTION

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COLORADO 80840

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Department of English
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Soil pollution is a form of pollution that is not as readily apparent as that found in air and water but can be just as noxious. Soil pollution should be considered in any efforts to ameliorate the misuse of the environment. This report examines various forms of both naturally and humanly induced soil pollution.

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TABLE OF CONTENTS

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INTRODUCTION

Environmental pollution as understood by most people is a detrimental effect produced when natural systems are in some way altered. Environmental scientists, however, view pollution forms as "resources out of place," since they can be naturally occurring as well as man-induced phenomena.[1] The magnitude to which pollution becomes a serious problem depends upon the polluting agent and both short term and long term time factors. Nature has evolved checks and balances to rectify pollution situations and will eventually return a system to its original order provided man allows this to happen.

Air and water pollution problems produced by modern industrial societies are easily recognized, because their effects can be seen, smelled, tasted, and felt by nearly everyone who lives in a polluted environment. Soil contamination is a pollution form which is not so readily apparent as the other two forms, because it does not directly stimulate human senses. For this reason it often is overlooked as a serious physical hazard to human welfare, and information regarding this pollution form is not so readily available. This report will examine various expressions of soil pollution and will regard them as being either natural or man-induced forms.

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[1] A. R. Robinson, "Sediment, Our Greatest Pollutant?" Focus on Environmental Geology, Ronald Tank, ed. (New York: Oxford University Press, 1973), p. 186.

NATURAL SOIL POLLUTION

Natural soil pollution can occur in the following forms: air-borne and water laid sediment, soil radioactivity, selenium, condensation and precipitation nuclei, and chemical precipitates and evaporites. Since improper human management of soils can aggravate the naturally occurring polluting sources, these effects will be considered again under man-induced soil pollution. The pollutants listed and discussed in the following account represent the most common forms found in natural soil pollution.

Sediment

Sediment is considered by some to be the greatest soil and water pollutant.[2] It is more easily discernible in water systems. As a soil pollutant, however, it is much more difficult to ascertain whether sediment is a menace or a miracle. Floods, with their huge quantities of sediment load, have always blessed their flood-plains with renewed fertility--due to the way in which the sedimentation process takes place--and are an example of a check and balance system. When atypical, cataclysmic natural events occur, raw sediment is made readily available in its undersirable form. Such events include landslides and dam ruptures resulting from earthquakes, mudslides and avalanches, and volcanic eruptions. In areas where protective vegetal cover has been removed or does not

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[2] Ibid.

grow well, ordinary sheetwash and rilling take on exaggerated proportions when copious precipitation falls suddenly. These occurrences take place infrequently but have critical consequences when they directly affect urban concentrations, productive cropland, or alter drainage basins. Because sediment pollution in expanding urban areas is more obvious than in the other two situations, it becomes apparent that man has had much to do in aggravating this natural event. More attention, therefore, will be given to this problem later in this report.

Soil Radioactivity

Soil radioactivity is an interesting form of indigenous soil pollution. It is found everywhere, because soil minerals contain radioactive constituents which undergo continual decay, and in doing so, emit alpha, beta, and gamma rays in proportion to their decay rates. The radioactive atoms K^{40}, Rb^{87}, Th^{232}, U^{235}, and U^{238} are most abundant in common granites and shales due to their high concentrations of potassium feldspars ($KAlSi_3O_8$) and micas ($KAlC_4O_{10}(OH)_2$). Soils developed directly from these rock types are naturally more radioactive than soils derived from basalts (varying amounts of SiO_2, Al, and Ferromagnesium minerals), sandstones (basically SiO_2) and limestone ($CaCO_3$).[3]

[3] Arron Kaufman, "Radioactivity in Rocks," The Encyclopedia of Geochemistry and Environmental Science; Encyclopedia of Earth Sciences Series, Vol. IV A, edited by Rhodes W. Fairbridge (New York: Van Nostrand Reinhold Co., 1972), pp. 992-993.

Elevated radioactive counts have been noted in soils developed over mineral anomalies, ore bodies, and oil reservoirs, because each of these have formed in manners favorable to the concentration of radioactive minerals. Since mineralization in igneous rocks takes place late in magmatism, concentrations of trace minerals containing uraninite and thorite among more exotic metals appear in veins and pegmatities lacing earlier formed rocks.[4] Potash, a sedimentary carbonate of potassium, can contain as much as 63% potassium.[5] Uranium ores are produced when this element fills pore spaces or replaces organic material in sedimentary rocks.[6] When sedimentary rocks form in oceans, radioactive elements are often precipitated from seawater and thereby become constituents within the rocks.[7] Oil and natural gas reservoirs are frequently discovered because of this property. It is evident from the cited situations, therefore, that naturally enhanced radioactive soils are particularly useful to exploration geologists.[8] Soil pollution in this instance is not necessarily considered detrimental by those concerned.

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[4] Ibid., p. 993.

[5] Ibid.

[6] Ibid.

[7] K. C. Jackson, Textbook of Lithology (New York: McGraw-Hill Book Co., 1970), p. 183.

[8] Louis Azzaria, Mercury in Soil and Air as a Guide to Mineralization in Four Areas of Quebec (Mineral Deposits Service: Government of Quebec, Minister of Natural Resources, 1973), p. 1.

Two other radioactive elements, Sr^{90} and Cs^{137}, are worth noting, although they normally are not found in deleterious amounts in soils. Serious contamination of soils due to these elements comes about only when soils are exposed to sources containing these elements in harmful levels, such as nuclear fallout or uranium mine tailings. Sr^{90}, because it is chemically similar to calcium,[9] can enter the food chain through ion exchange when plants are growing and taking on soil nutrients. Natural restraints against this happening usually remedy this problem especially when ample calcium is available, since calcium is the preferred soil nutrient of plants.[10] Although Cs^{137} can behave like potassium, the natural danger from soil contamination by this element is slight, because it usually is bound electrostatically to clay colloids in the soil.[11] Like Sr^{90}, then, it becomes a problem only when man acts as an interferring agent.

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[9]William H. Nebergall, Frederic C. Schmidt, and Henry F. Holtzclaw, College Chemistry with Qualitative Analysis, 4th edition (Lexington, Mass.: D. C. Heath and Co., 1972), pp. 864-865.

[10]Warren H. Adams, C. W. Christenson, and Eric B. Fowler, "Relationship of Soil, Plant, and Radionuclide," Radioactive Fallout, Soils, Plants, Foods, Man, Eric B. Fowler, ed. (Amsterdam: Elsevier Publishing Co., 1965), p. 50.

[11]Rankama Kalervo, Progress in Isotope Geology (New York: Interscience Publishers, 1963), p. 116.

Selenium

Selenium is a regional but serious type of soil pollution. It causes an animal infirmity called "alkali disease" and is commonplace in the western Great Plains. This troublesome element is found in elevated concentrations in soils derived from the Pierre shale and Niobrara formations of Cretaceous age.[12] Although the geologic reasons why selenium should be found in appreciable amounts only in these formations of the abundant Cretaceous Great Plains rocks is not known, the chemical explanation of how selenium in the form of selenite is deposited in marine formations can be deduced. Selenium in dissolved form enters the oceans from land waters and readily precipitates into an insoluable ferric compound if colloidal ferric hydroxide is present in the sea water.[13] After diastrophism elevates the rocks above sea level, weathering agents erode the selenium bearing rocks and break them down to soil forming materials (Figure 1). The selenium remains chemically bound in the soil particles and would remain harmless if it were not for certain types of plants, called "converter plants," which assimilate selenium and alter it to a soluble form. The soluble selenium is then redistributed to the soil as humus when the converter plant dies. It is now in a form easily incorporated by other plants, particularly

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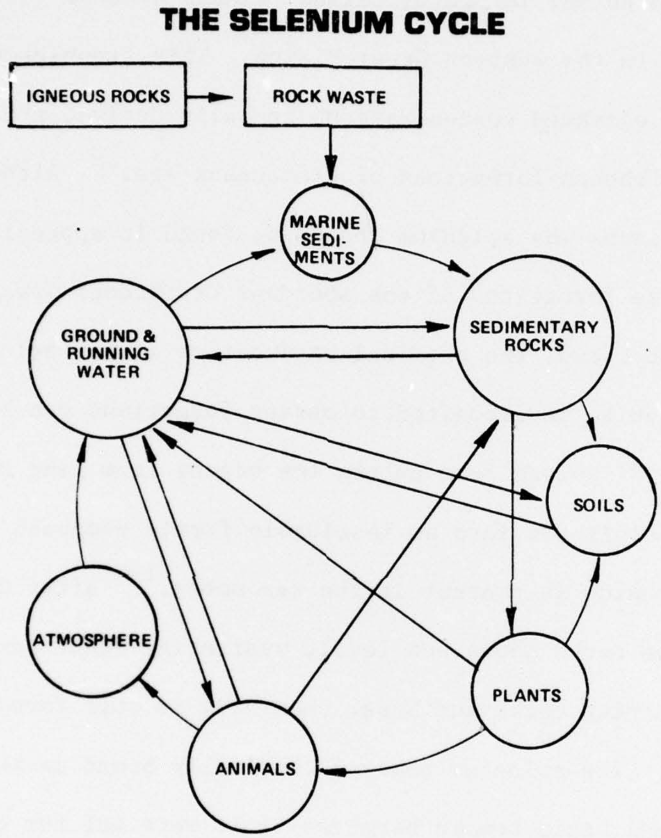
[12]Alvin L. Moxon, Oscar E. Olson, and Walter V. Searight, "Selenium in Rocks, Soils, and Plants," Tech. Bull. No. 2, Agricultural Experiment Station, South Dakota State College of Agriculture and Mechanical Arts, Brookings, S.D., 1939, p. 15.

[13]Ibid.

Figure 1



Marine sediments acts as a trap or reservoir for selenium in the form of a colloidal ferric hydroxide; selenite is rapidly removed from solution as an insoluble ferric compound. Diastrophism and erosion then bring it back to the surface.

Source: Alvin L. Moxon, Oscar E. Olson, and Walter V. Searight. Selenium in Rocks, Soils, and Plants. Agricultural Experiment Station, South Dakota State College of Agriculture and Mechanical Arts. Brookings, S.C., 1939, p. 79.

grasses. Selenium is not eliminated by animals foraging on the contaminated grasses, because it becomes a part of the animals' muscle tissues and is also contained within the protein content of milk produced by the cows. The physical effect of this element upon human consumers of these two food products is not known, but it has been the subject of some recent interest.[14]

Condensation and Precipitation Nuclei

Condensation and precipitation nuclei constitute a fourth type of soil pollution. Favorable temperatures conditions will cause water vapor to condense to water droplets (or sublimate to ice crystals) upon contact with a suitable nucleus. Usually the nucleus is a dust particle, salt crystal, pollen spore, or hygroscopic smoke particulate. Over a period of many years, certain soil characteristics can develop related to a particular nucleus ever present in the atmosphere over a specific area which becomes, then, a part of that area's particular environment. Specific examples are areas located near ocean coasts, active volcanic regions, and regions peripheral to deserts and semi-arid lands. In these regions hygroscopic nuclei are abundant, and their source is constant. Winds transport these particles to atmospheric levels where meteorological transformations take place and send them back

[14] I. G. Simmons, The Ecology of Natural Resources (New York: John Wiley and Sons, Halsted Press, 1974), p. 303.

to earth as a nucleus. It is interesting to note that raindrops developed around salt spray crystals have the same chemical composition as sea water but are very much diluted.[15]

The chemical composition of raindrops also becomes important in the development of clays, a parent material of soils. Carbon dioxide, dissolved salts, and oxygen enter the ground through raindrop infiltration and becomes stored in groundwater. Groundwater in turn leads to the development of all soil-forming processes.[16] In this way raindrop constituents play a major role in determining the type of soil-forming process that will come about. Persistent variations in any one or all of the constituents listed will determine which process will dominate and which soil will then be developed.

Chemical Precipitates and Evaporites

Chemical precipitates and evaporites form another group of natural soil pollutants. Salt brines accumulate in tidal marshes and leave crusty deposits on soil surfaces when the water content evaporates. If the need for arable land becomes acute, these soils can be made highly productive with a great deal of effort and technology. The Dutch have demonstrated this fact by their seven

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[15] Robert J. Foster, Physical Geology (Columbus, Ohio: Charles E. Merrill Publishing Co., 1971), p. 101.

[16] Charles B. Hunt, Geology of Soils (San Francisco: W. H. Freeman and Co., 1972), pp. 275-277.

centuries of land reclamation from the deltaic marshes of the Rhine, the Maas, and the Scheldt Rivers and their distributaries.[17]

Alkali deposits despoil a great deal of our western soils especially in the arid southwestern states. These deposits develop when groundwater carrying in solution carbonate and sulfate forms of alkaline earth metals (compounds of calcium strontium, barium, and magnesium) perculates upward through capillary action to the earth's surface.[18] Upon reaching the land-air interface, the water is evaporated leaving minerals behind in crystallized form. In humid areas these salts would be carried away by runoff, but in arid lands, they remain on the surface forming expansive accumulations much of which has considerable resource value. More often, however, the deposits are really small and cause productivity and grazing problems.

The leaching process also contributes to soil pollution through a method called calcification. Calcification operates much like the evaporation process but in the opposite direction. In this instance surface water perculates downward through the soil dissolving mineral salts along its way. The mineral calcite is exceedingly vulnerable to leaching and will form a precipitate called caliche at the capillary fringe of the soil (Figure 2).

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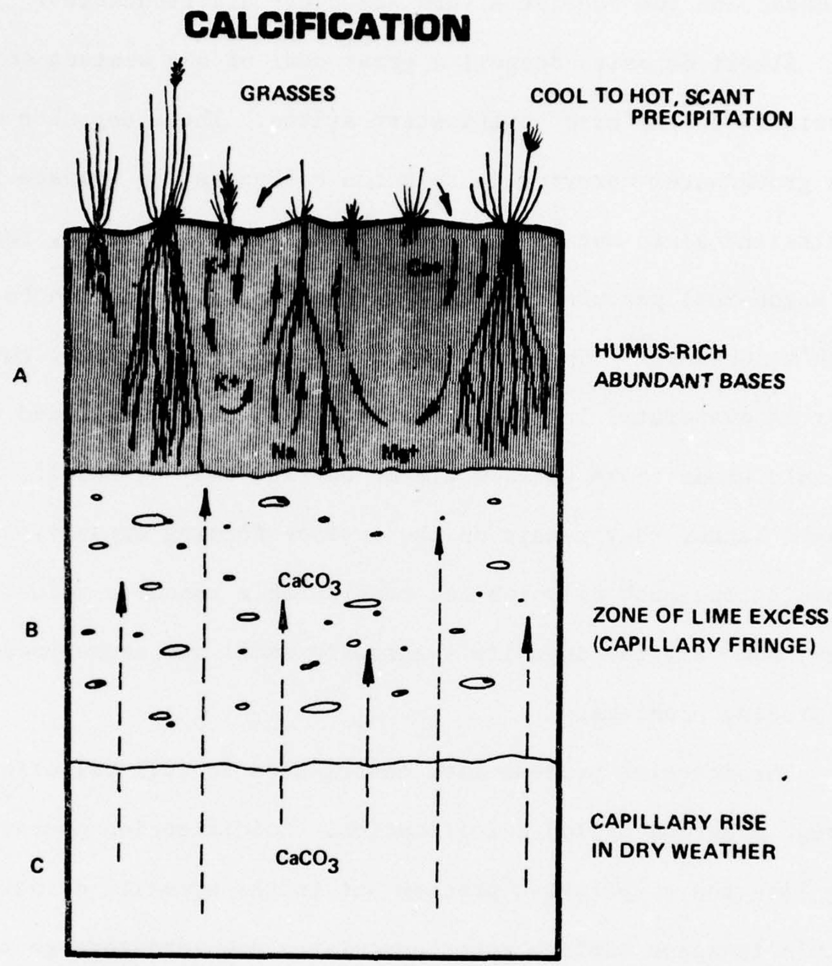
[17] Jesse H. Wheeler, Jr., J. Trenton Kostbade, and Richard S. Thoman, Regional Geography of the World (New York: Holt, Rinehart, and Winston, Inc., 1975), p. 193.

[18] John R. Lewis, College Chemistry (New York: Barnes and Knoble, 1971), p. 254.

Figure 2



Calcification occurs in dry continental climates. Basic minerals calcium, magnesium, potassium, sodium are not leached out and remain in the soil until vegetation returns them to the soil surface. Calcium carbonate is brought upward to the B horizon by capillary water during dry periods where it is precipitated as nodules, slabs, or dense stony layers.

Source: Arthur N. Strahler. Physical Geography. 4th Edition. John Wiley and Sons, Inc. New York, 1975, p. 301.

Usually this material accumulates in the subsoil, but it can be found in appreciable amounts as tiny nodules in the topsoil. The resultant soil is called a pedocal (pedon for soil, cal for calcite) and develops most favorably in semiarid grass and brush lands.[19] The detrimental effects of calcification is related to a "hardpan" of mineral deposits at the capillary fringe. An impervious layer of caliche forms at this level making downward perculation of water impossible after it reaches this hardpan. Recharge of groundwater reservoirs is thereby inhibited. In drought years when ground reservoirs are considerably lower, plants suffer a great amount of stress or die, because their roots cannot reach groundwater.

MAN-INDUCED SOIL POLLUTION

Man has always been a polluting agent, but it has only been recently that he has given much consideration to what he has done to foul his habitat. Indeed, it has been naively argued by many that until the Industrial Revolution, his effect had been subdued by nature's infallible check system.[20] Until he had greater technological knowledge, it is argued that man could not pollute at a rate commensurate with irreversible degradation. This argument, however, overlooks the fact that early man used fire and grazed

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[19] Foster, p. 107.

[20] G. W. Dimbleby, "The Impact of Early Man on his Environment," Population and Pollution, edited by Peter R. Cox and John Peel, (London: Academic Press, 1972), p. 7.

animals in his agricultural activities.[21] These two simple but remarkable technological developments are known today to be extremely detrimental to land surfaces and ecological systems when not properly controlled. Yet, many people regard the Industrial Revolution as the onset of technological pollution. During that time man gave little thought to the control of his new skills, because he was unaware of pollution's long-term effects. Today, with a more sophisticated outlook and more stringent laws aimed at protecting the environment, man has taken steps toward correcting past as well as continuing errors.

In considering soil pollution from human activities, the following forms represent areas of greatest concern: sediment, septic treatment effluent, smoke stack emissions, radioactive pollution, insecticides, herbicides, and fertilizers, road salts and hydrocarbon particulates from vehicle exhaust, and spoil bank and mine tailing deposits.

Sediment

Sediment becomes a man-induced soil pollutant when the ground has been disturbed and exposed to erosional agents, particularly running water and wind, which carry it away and deposit it on top of soil surfaces. Outstanding and timeless generators of accelerated sediment production include urban land development, highway and

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[21] Ibid., p. 8.

railroad construction, and improper agricultural and forestry practices. Because all involve removal of massive amounts of vegetative cover, they leave the exposed soil vulnerable to erosive agents which can quickly eradicate centuries of delicate ecological balancing.

Urban areas are more prolific contributors to sediment yield than are unurbanized areas. More impervious surfaces exist in urban locations even though sediment sources there are often small and widely scattered compared to unprotected soil in unurbanized regions.[22] Calculations deriving comparisons between the two places show that in land undergoing municiple expansion between 1,000 to more than 100,000 tons per square mile per year are removed whereas unurbanized regions yield on the average between 200 to 500 tons per square mile per year.[23]

Since the cost of sediment control is great, it is often excluded in proposed developmental projects. Not only that, it must also involve protecting areas beyond actual construction sites which many developers do not feel is their obligation.[24] The

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[22]Brian J.L. Berry and Frank E. Horton, Urban Environmental Management Planning for Pollution Control (Englewood Cliffs, N.J.: Prentice Hall, 1974), p. 64.

[23]Ibid., p. 74.

[24]Pamphlet, U.S. EPA Office of Water Problems, Rural Water Section, "Control of Sediments Resulting from Highway Construction and Land Development," U.S. Government Printing Office, September 1971, p. 45.

following information from the U.S. Environmental Protection Agency regarding the consequences of highway construction effectively summarizes the problems of cost and sediment yield.

> One inch of precipitation at a velocity of nineteen miles per hour and falling on one acre of exposed soil weighs one hundred tons and provides all the kinetic energy necessary to initiate erosion. Kinetic energy is drastically reduced when vegetation is left on the land.
>
> Over one billion tons of sediment reach American rivers per year. Ten percent of this comes from highway construction or land development.
>
> Currently, four thousand acres of land per day are undergoing development in some form.
>
> Sediment yields from one acre of developing land may exceed twenty to forty thousand times that obtained from adjacent farmland or undeveloped woodland.
>
> The cost for erosion and sediment control on a highway which has an average construction cost of one million dollars per mile is estimated by construction engineers to be between ten and fifteen thousand dollars per mile.
>
> The cost for control in housing developments is given to be forty dollars per lot by engineers and geologists but as high as one hundred dollars per lot by developers.
>
> The cost of engineering, surveying, reconstruction, and removal of deposited materials from, say, a municipal water system including reservoirs can run as high as four million dollars which does not include the increased cost of filtration and purification at the water treatment plant itself as the result of sedimentation. It should also be noted that this is only a temporary remedy as the likelihood of incurring the same problems again is very high especially in rapidly urbanizing areas and in dryland areas.[25]

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[25] Ibid., pp. 5-11.

Although running water is the most important agent of sediment transportation and deposition, wind should also be mentioned. During the dust bowl days of the thirties and early fifties, tons of airborne particles, including fine-grained topsoil were transported from millions of acres of exposed agricultural land in the south and midwest to the entire northeast portion of the United States.[26] Often the slightly heavier particles were redeposited as dunes on nearby areas when they became stabilized around bushes, trees, and in the lee of fences and low-lying buildings. In other places topsoil which had not blown was buried by the coarser, less fertile subsoil making for useless plots of agricultural land for many years. Today in the seventies, drought driven wind is once again threatening to remove exposed topsoil in the manner it did previously. It is interesting to note that overgrazing and fire have again contributed much in rendering the ground vulnerable to blowing even though soil conservation technology is more available now than ever before. Blowing in urban developments also remains a serious problem that is generally approached mildly. Ordinances against negligence on the part of developers to prevent blowing and water erosion are enforced only when official complaints are registered.

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[26] Ruben Parson, Conserving American Resources (Englewood Cliffs, N.J.: Prentice-Hall, Inc.,), p. 252.

Septic Treatment Effluent

Septic tank and cesspool effluent is a widespread source of soil pollution in modern societies. It is estimated that at present one fourth of the American population uses some method of waste disposal involving leaching and soil absorption.[27] These systems are generally located in rural or outlying suburban districts and many times do not operate effectively due to difficulties involving soil factors. Permeability varies with soil conditions and clogging often results in putrid consequences for the soil, the groundwater, and the resident whose drains back up with effluent.

It is the function of a septic treatment system to condition sewage so that it can percolate into the subsoil. Anerobic bacteria biologically decompose the solids which are then partially removed from the tank by water. The water flows into a seepage pit, seepage bed, or seepage trench where the soil absorbs the effluent at a rate relative to the permeability of the soil (Figure 3). It is at this point where septic treatment problems usually begin. If the effluent drains too rapidly through the soil, it can reach wells or surface water supplies and contaminate them.[28]

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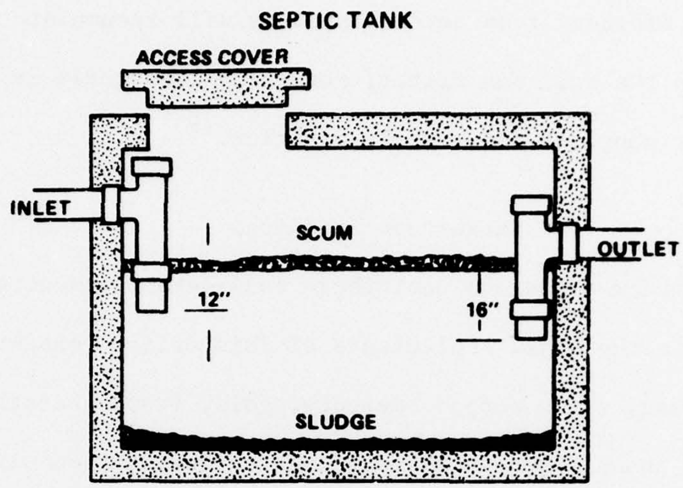
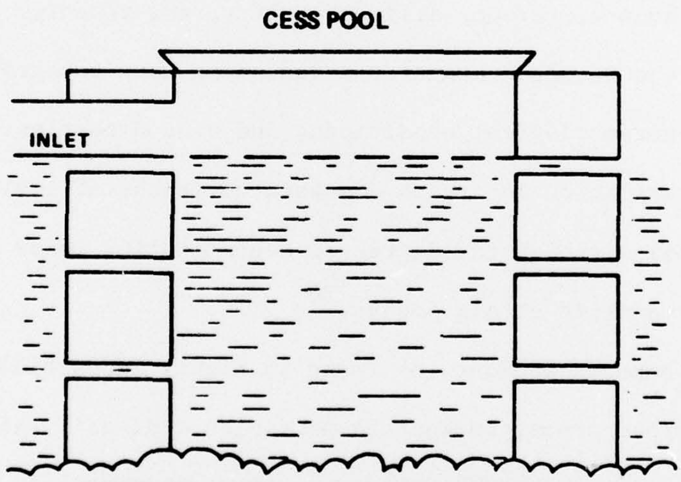
[27] John M. Cain and M. T. Beatty, "Disposal of Septic Tank Effluent in Soils," Focus on Environmental Geology, edited by Ronald Tank (New York: Oxford University Press, 1973), p. 433.

[28] Ibid., p. 434.

Figure 3





Source: Modified from "The Roebic Story; Life in a Septic Tank or Cesspool," North Haven, Conn.: Roebic Laboratories, n.d. Pamphlet.

An associated problem arises when septic tanks or cesspools are placed too close together even when the soils are efficiently permeable. Effluent from several systems will accumulate more rapidly than the soil can filter, resulting frequently in contaminated water supplies for a whole district.[29]

Smokestack Emissions

Smokestack emissions contribute considerable quantities of pollutants to the soil. Pollutants of this origin consist of such metals as lead, zinc, copper, mercury, gold, iron, and others which enter the atmosphere as particulates during processing. Nonmetallic particles are also broadcast by smokestacks and include calcium carbonate, carbon, silicon, sulfur, and arsenic. Such pollutants can become concentrated depending upon topography, persistent meteorological conditions, and wind direction. Concentrated contamination can reach downward to depths of twelve inches into the soil although the degree of contamination loses significance below a depth of six inches.[30]

With some exceptions, as found in highly industrialized or intensely mined areas, smokestack particles ordinarily affect only those areas near the stack. However, they can circulate upward

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[29] Ibid., p. 439.

[30] F. C. Canney, "Geochemical Study of Soil Contamination in the Coeur D'Alene District, Shoshone County, Idaho," <u>Mining Engineering</u>, 1959, 11:205-210.

and act as condensation nuclei creating smoggy conditions. Through precipitation the particles can also be deposited in varying amounts upon structures, vehicles, streets, vegetation, soils--indeed, the whole landscape. More studies are needed to determine the detrimental effects that emissions have upon soils, but it is already known that this source of soil pollution exists in various parts of the country and in degrees commensurate with other environmental factors of those areas.

Radioactive Pollution

Radioactive fallout is an alarming pollutant, because it has global ramifications when circulated in the atmosphere. Although water and air pollution from other causes are now far more imminently detrimental to human well being, radioactive fallout is the most frightening to most people. This results from perceptions which have formed as a result of the 1945 atom bomb detonations over Japan and the subsequent nuclear weapons development and testing which followed. This problem has been greatly alleviated through international cooperation, although there have been some cases where violations of agreements have taken place.

Radioactive soil pollution also exists around industries engaged in activities which utilize radioactive elements in their operations or products. Such companies come under close scrutiny when questionable radioactivity-related events occur and affect persons or regions near the plant.

What is radioactive fallout and how does it biologically effect man over a long period of time? Fallout mainly consists of fission products from the nuclear fuels U^{235} and Pu^{239}. Two thirds of the fission products have very short half lives, but Sr^{90} and Cs^{137} found in the remaining third are two elements which have very long half lives and therefore contribute most to fallout contamination.[31] Since Cs^{137} and Sr^{90} are radioactive members of their respective chemical families, they behave chemically like their harmless yet important chemical relatives, K and Ca.[32] Both Sr^{90} and Cs^{137} are easily absorbed into the soil where they can act, in small amounts, as plant nutrients. The greatest danger to man, then, comes about when these radioactive nutrients enter the food chain by assimilation into the plant and becomes either directly ingested by humans or indirectly through milk, milk products, and meat from cattle which have eaten contaminated plants and grasses. Once in the human body Cs^{137} alters to Cs^{144} which behaves like Ca and enters the bones where it will accumulate over a long period of time leading eventually to possible bone cancer. Sr^{90} under the same conditions and behaving like K will enter the body's tissues

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[31] R. M. Aleksakhin, Radioactive Contamination of Soil and Plants, Academy of Science of the USSR, Moscow, 1963, published for the U.S. Atomic Energy Commission and the National Science Foundation, Washington, D.C., by the Israel Program for Scientific Translations, Jerusalem, 1965, p. 7.

[32] Kalervo, p. 439.

and can produce various cancerous tumors throughout the body.[33] Figure 4 illustrates the routing of fallout through the soil to man.

Aleksakhin distinguishes radioactive fallout as three types depending upon the intensity and altitude of detonated explosions and atmospheric conditions.[34]

> Local fallout occurs immediately because the fireball reaches the ground.
>
> Tropospheric fallout results from kiloton explosions and travels long distances, but since it is hygroscopic and is removed from the atmosphere through precipitation or fog, it usually lasts as a hazard only between twenty to thirty days.
>
> Stratospheric fallout, produced by megaton bombs, has the longest lasting and most global effect. It travels quickly in the troposphere where about ninety percent of the particles are removed and settle on the earth's soils and in its waters.

Radioactive particles released by nuclear detonation include I^{131}, Ba^{140}, Sr^{90}, Cs^{137}, Pu^{239}, and Kr^{85}.[35] Of the harmful particles, Sr^{90} and Cs^{137} are deposited by precipitation in water-soluble form, whereas any Pu^{239} which is not expended by the explosion is deposited primarily in a non-soluble form.[36] The

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[33] Aleksakhin, p. 18.

[34] Ibid., p. 14.

[35] J. Calvin Giddings, Chemistry, Man, and Environmental Change, An Integrated Approach (San Francisco: Canfield Press, 1973), p. 429.

[36] Aleksakhin, p. 14.

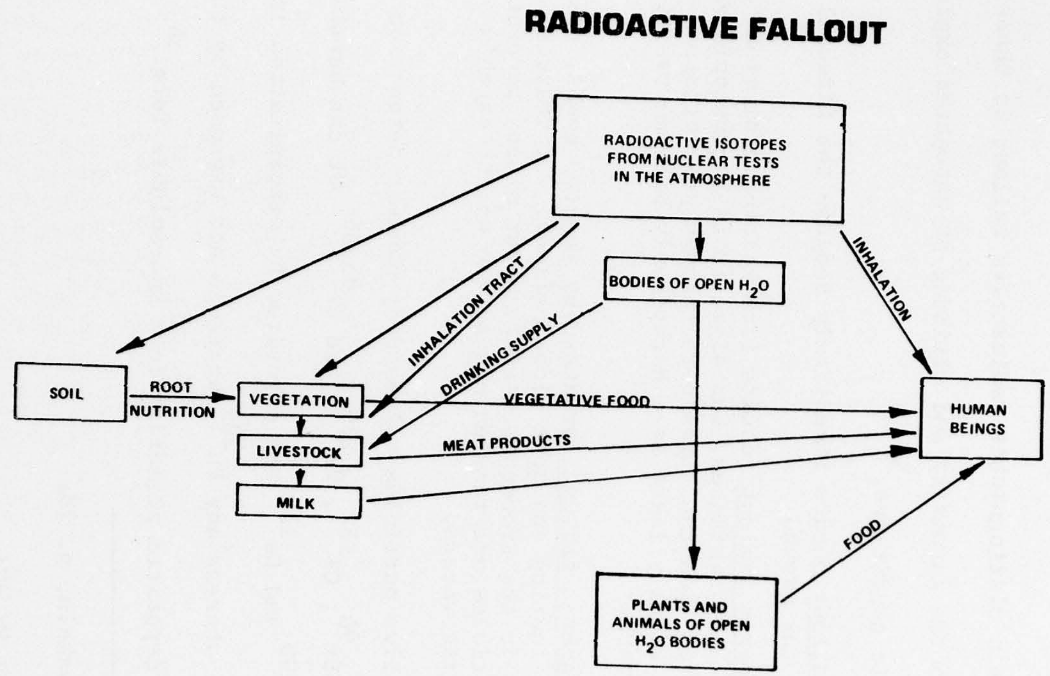

Figure 4. Schematic diagram showing the effect of radioactive fallout upon the biosphere and humans.

Source: R. M. Aleksakhin. "Radioactive Contamination of Soil and Plants." Academy of Science of the USSR. Moscow, 1963. Published for the U.S. Atomic Energy Commission and the NSF. Jerusalem, 1965, p. 9.

others are essentially so short-lived that they cannot be considered effective soil polluters. After Sr^{90} and Cs^{137} enter the soil from fallout, some of these radionuclides become partially bound to soil colloids and will not exchange ions with neutral salts; therefore, they will not be taken up by plants.[37] Those particles that are soluble and are not bound to the soil will exchange ions readily with harmless plant nutrients and contaminate the plant.[38] If, however, Ca and K, the harmless plant nutrients, are abundant in the soil, exchange with the radioactive elements will not take place since plants will discriminate against these elements so long as Ca and K are plentiful.[39]

From this discussion it can be seen that the mechanical composition of soils is very important in determining the extent of radioactive contamination due to fallout. Generally, accumulations are greater on coarse, sandy soils than on heavier clayey soils or on soils high in humic or calcium content. Other biological migratory effects, however, are greatly inhibited due to stable

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[37] Berry and Horton, p. 64.

[38] Howard Roberts and Ronald G. Menzel, "Availability of Exchangeable and Non-Exchangeable Strontium 90 to Plants," <u>Radioactive Fallout, Soils, Plants, Foods, Man</u>, edited by Eric B. Fowler (Amsterdam: Elsevier Publishing Co., 1965), p. 21.

[39] Warren H. Adams, C. W. Christenson, and Eric B. Fowler, "Relationship of Soil, Plant, and Radionuclide," <u>Radioactive Fallout, Soils, Plants, Foods, Man</u>, edited by Eric B. Fowler (Amsterdam: Elsevier Publishing Co., 1965), pp. 50-51.

retention of many of the fission fragments by soil colloids through ion exchange, adsorption, and by chemical precipitation. Ion exchange takes place in water soluble radioactive particles including Sr^{90} and Cs^{137}. The colloidal fraction of radioisotopes are retained in adsorption and through chemical precipitation. Alkaline soils may form hydroxides, basic carbonates, and radioisotopes of rare earths.[40]

In dry lands fallout particles settle out as "dry" precipitation in various ways. The most common way occurs as "dust" particles carried down to the earth's surface by gravity. Sometimes they enter plants directly from the atmosphere through a process called "biltuation" which occurs when winds hit plants.[41] They can enter both plants and soils at night as the result of earthward atmospheric diffusion of water vapor. In the United States, Nevada and New Mexico have experienced this form of soil pollution resulting from fallout produced by surface detonations of nuclear weapons. The effects of this contamination may remain in the soils of these two states for thousands of years.[42]

Other Pollutants

Other man-induced soil pollutants include certain insecticides, herbicides, fertilizers, road salts, hydrocarbon particulates, and

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[40] Aleksakhin, pp. 46-54.

[41] Ibid., pp. 17-19.

[42] Ibid.

spoil bank and mine tailings. Leaching is a natural process which can carry residue from any of the pollutants listed and deposit it at varying depths in soils. In the leaching process, water percu- lates down through soils carrying particles in suspended or dis- solved form. If leaching takes place through deposits left by man, such as those above, harmful minerals can then accumulate in soil layers and subsequently enter the food chain. Sprays and powders from insecticides, herbicides, and fertilizers are very susceptible to leaching as well as acting as condensation nuclei for frost, dew, fog, or precipitation. Some fertilizers containing nitrates literally become poisons when altered to nitrites by microbial action in soils or later in human (infant) intestinal tracts.[43] It is well known that the use of DDT, formerly an extremely effective pesticide, has been outlawed because of its noxious effects upon living things. Road salts, applied in winter, become soil constituents in summer because of their soluble nature. Hydro- carbons kill vegetation along roads and streets, deteriorate soil quality limiting renewed growth, and are carried away along with silts by storm runoff to become problems elsewhere. Last, spoil banks and mine tailings often contain lead, mercury, uranium, and sulphur which makes for "derelict land" of no use to anyone.[44]

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[43] Barry Commoner, "Threats to the Integrity of the Nitrogen Cycle: Nitrogen Compounds in Soil, Water, Atmosphere, and Precipi- tation," Global Effects of Environmental Pollution, edited by S. Fred Singer (New York: Springer-Verlag New York Inc., 1970), p. 85.

[44] Simmons, p. 294.

SUMMARY

Many soil pollutants have been discussed, and each merits its own separate investigation. However, the purpose of this paper has been to compile information on the various forms. Generally, soil pollutants are classified as natural or man-induced depending upon the greater perpetrator. Normally, most of the pollutants discussed are already found in the natural environment and are part of the natural scheme of things. When man works inadvertantly and accelerates their effects, they become environmental hazards. Soil pollutants of both classes have been linked directly to human and animal diseases. These sources include selenium, Sr^{90}, and $Cs^{137 \text{ or } 144}$ from radioactive fallout, and septic treatment effluent. Smokestack emissions, pesticides, fertilizers, mine despoliation, and the effects of highway usage are direct man-induced offenders of environmental quality.

All effects of natural soil pollution cannot be thought of as being harmful. Ore bodies and petroleum sources are many times located by anomalous soil constituents or increased radioactivity. Others are so natural that one finds it difficult to defend the stand that they are actually pollutants. Thus, it becomes questionable that certain condensation nuclei, alkali flats, salt marshes, and natural radioactive decay should be included in the connotative definition as adverse pollutants rather than "resources out of place."

This report has examined ways in which soil pollution

originates. What can or should be accomplished to alleviate this form of pollution remains as enigmatical as the problems of air and water pollution.

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