Soil and Soil Pollution

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Abstract: ***Agriculture is mainly dependent on the soil and the climate. The soil covers portions of the surface of the earth. It is an intimate mixture of organic and inorganic materials, water and air. Loose powdery soils usually support crop growth. They have originated from disintegration and decomposition of rocks at the surface of the earth by the action atmospheric agents like heat, water, carbon dioxide, nitrogen oxides, Sulphur dioxide etc. Rocks are the original components of the earth's crust. So a thorough knowledge of rocks and the earth's crust is essential for understanding the origin of different soil and the causes of variation of properties of different soils. The nature of the earth's crust varies from place to place in India and abroad. The crust is the outermost layer of the earth.***

1. Introduction

1.1 Soil: Its Formation, Constituents and Properties

Soil is the complex biogeochemical material which forms at the interface between the earth's crust and the atmosphere and differs markedly in physical, chemical and biological properties from the underlying weathering rock from which it has developed. Soil comprises a matrix of mineral particles and organic material, often bound together as aggregates and populated by a wide range of micro-organisms, soil animals and plant roots. The spaces between particles and aggregates form a system of pores which are filled with soil solution and gases. Since soil acts as a sink for contaminants and also a filter for water infiltrating to the water table, its physical, chemical and biological properties are highly relevant to considerations of contaminated land and its reclamation.

1.2 Soil Constituents

1.2.1 Soil Minerals

The soil clay fraction <2 μm in diameter and is formed mainly of clay minerals with some small particles of other minerals. Clay minerals are secondary minerals which have formed from the weathering products of primary minerals. Clay minerals are sheer silicates formed from two basic components: a silica sheet of Si-O tetrahedral and a gibbsite sheet comprising AI- OH octahedral. Isomorphism substitution of either AL^{3+} for Si^{4+}, or Mg^{2+} for Al^{3+} in the structural sheets of some clay minerals gives raise to excess kaolinite their cat ion absorptive capacity which is independent of the soil pH. The four commonly occurring types of clay minerals are:

Kaolinite : A highly stable 1:1 (silica : gibbsite) mineral, which is nonswelling with a relatively small surface area (5-100m^2 g^{-1}) and a low adsorptive capacity (cat ion exchange capacity [CEC] 2-20mol_c kg^{-1}).

Smectiites: 2:1 (silica:gibbsite) minerals which swell on wetting and shrink on drying, they have large surface area (700-800m^2g^{-1}) due to the access of soil solution to all lamellae surfaces which, together with isomorphism substitution, contributes to their relatively high absorptive capacity (CEC80- 120mol_ckg^{-1})

Lllite: A 2: 1 clay like the Smectites with a lower absorptive and swelling/shrinking capacity and properties intermediate between kaolinite and Smectites (Surface area 100-150c mol_c Kg^{-1} and CEC of 10-40c mol_c kg^{-1}).

Vermiculite: A 2:1 mineral with a very high degree of isomorphism substitution of Mg2+ for AI3+ in the gibbsite sheet giving it a high CEC (100-150c mol_ckg^{-1}) with an intermediate surface area (300-500m^2 g^{-1}).

1.3 Soil Properties

1.3.1 Soil Permeability

The voids between soil particles and aggregates from a continuous system of pores within the soil profile. Pores with a diameter greater than 30 μm tend to drain under gravity and are normally filled with air in dry weather, Pores smaller than 30 μm tend to retain water against gravity and much of this may be available to plant roots, Soluble contaminants infiltrating the soil profile will be subject to both interial drainage within the profile, diffusion between regions of different solute concentration and in most cases, adsorption onto the organo-mineral colloidal complex. In addition to the inter-particle pores, warm burrows, root channels, desiccation cracks, or excavations will lead to more rapid movement of contaminants down the profile, either in solution, or absorbed on soil particles.

1.3.2 Soil Chemical Properties Soil pH:

The pH of the soil is the most important physico-chemical parameter affecting plant growth and the behavior of contaminants in soils. The soil pH is a measurement of the concentration of H^+ ions in the soil solution present in the pores of a soil which is in equilibrium with the negatively charged surfaces of the soil particles. Unless stated otherwise soil pH values are usually measures in distilled water but the use of dilute electrolytes (e.g. $CaCl_2$) more closely reflects the field situation.

Soil pHs are normally within the range 4-8.5 although the extreme range found over the world is pH2-10.5. In general, soils in humid regions tend to have pHs between 5 and 7 and those in arid regions 7 and 9. Ion temperate regions, such as UK, the optimum pH for arable soils are 6.5 and 6.0 for grassland. Soil PHs can be raised by limiting with $CaCo_3$.

In general, bacteria do not tolerate very acid conditions and so soils in which the microbial degradation of organic pollutants is desirable should be maintained at a pH of between 6 and 8. The mobility and bioavailability of most divalent metals are greatest under acid conditions and therefore liming is a way of reducing their bioavailability (expect for the MoO_4^{-2} anion which is most available at high pH).

1.4 Sources of Soil Contaminants

Soil receive contaminants from a wide range of sources, including:

1) Atmospheric fallout from:

- Fossil fuel combustion (Oxides and acid radicals of S and N);
- Pb, Co2, etc. from automobile exhausts:
- Metal smelting operations (As, Cd, Cu, Cr, Ni,,Pb, Sb,TI and Zn):
- Chemical industries (Organic micro pollutants, Hg);
- Waste disposal by incineration (TCDDs, TCDFs);
- Radioisotopes from reactor accidents (e.g. Wind scale, UK, 1957 and Chernobyl, USSR, 1986) and atmospheric testing of nuclear weapons"
- Large fires (e.g. soot, PAHs, etc. from burning oil wells).

2) Agricultural Chemicals:

- Herbicides (e.g.2, 4-D,2,4,5-T containing TCDD, B and As compounds);
- Insecticides (chlorinated hydrocarbons, e.g.DDT,BHC);
- Fungicides (Cu, Zn, Hg and Organic molecules).
- Acaricides (e.g " Tar Oil");
- Fertilizers (e.g. and U impurities in phosphates);

3) Waste Disposal (intentional/ unintentional input to soil);

- Farm manures (As and Cu in Pig and poultry manures);
- Sewage sludge's (rich in heavy metals and organic pollutants PAHs and PCBs, etc.);
- Composts from domestic wastes (metals, etc.);
- Mine wastes (coal mines – SO4, etc, metalliferous mines Cd, Cu, Pb , Zn, Ba, U, etc,);
- Seepage of leach ate from landfills.
- Ash from fossil fuel combustion, incinerators, bonfires and accidental fires;
- Burial of diseased livestock on farmland.

4) Incidental Accumulation of contaminants;

- Corrosion of metal in contact with soil (e.g. Zn from galvanized metal, Cu and Pb from roofing, scrap yards, etc,);
- Wood preservatives from fencing (PCP, Creosote, as and CU);
- Leakage from underground storage tanks (Petrol, chlorinated solvents);
- Warfare (organic pollutants from fuels, smoke and fires, metals from munitions and vehicles);
- Sports and leisure activities (Pb from gunshot and fishing weights, Pb, Cd, Ni and Hg from discarded batteries, hydro-carbon from split petrol and lubricating oil)

A more comprehensive list of the most common contaminating uses of land includes: waste disposal sites, gas works oil and petroleum refineries and petrol stations, electricity generating stations, iron and steel works, non-ferrous metals processing, metal products fabrication and metal finishing, chemical works, glass-making and ceramics, textile plants, leather tanning works, timber and timber products treatment works, manufacture of integrated circuits and semiconductors, food processing, sewage works, asbestos works, docks and railway land, paper and printing works, heavy engineering installation, installations, processing radioactive materials, and burial of diseased farm livestock.

1.5 Characteristics of some major groups of soil contaminants

1.5.1 Heavy Metals

The range of heavy metal concentrations found in sewage sludges (μm g^{-1} in dry matter): Ag (<960), As(<30), Cd(< 3410), Cr (<40600), Cu (50-8000), Hg (<55),Min(60-3900),Mo (<40), Ni(5300), PB(29-3600) Sb (<34), Se (<10), Sn (40-700),V (20-400), Zn(91-49000)[10] Organic Contaminants:

There are more than 20.000 organic contaminants known already and this number will increase as analytical methods are further refined and more studies made of materials containing wide ranges of organic pollutants, such as industrial wastes, sewage sludge's and landfill leaches.

Pesticides can be soil contaminants as a result of persistence after use on crops, run-off from treated land, accidental spillages or pesticides manufacture. Although there are over ten thousand commercial pesticides formulations of around 450 compounds in use, they can be classified under relatively few groups of molecules. These compounds are used because of their inherent toxicity towards specific pests but there is a risk of the toxic properties affecting soil organisms, other beneficial plants and animals and humans. This can occur by uptake through plants, through the food chain, or in contaminated drinking water which the pesticide, or its toxic decomposition product, reached either by leaching or in run- off.

Three main groups of insecticides are currently used in agriculture organochlorines, organophosphates and carbonates. The organochlorines have been widely used for up to 50 years and are the most persistent of all groups of pesticides. The persistence decreases in the order: DDT > dieldrin > lindane (BHC) > heptachlor > aldrin with half - lives of eleven years of DDT down to four years for aldrin. Organophosphates are highly toxic to humans and other mammals but are less persistent in the soil than organchlorines (six month half-lives for parathion, daizinon and demeton). Carbamates are used to control a wide range of pets including molluscs, fungi and insects but have a similar persistence to organophosphates. Aidicarb (or "Temix") is a highly toxic caramate that is used both as an insecticide and nematicide on potato and sugar beet crops. It is readily oxidized in the soil but, its oxidation products are also highly toxic and readily leached and can cause ecological and human health problems. Some examples of the molecular structures of pesticides and other organic contaminants are shown in Fig. 8.2.

There are six major groups of compounds used as herbicides:

Phenoxyacetic acids, toludines, triazines, phenylureas, bipyrodyls and glycines. The most important phenoxyacetic acid are 2,4-D and 2,4,5-T which have a persistence of up to eight months but are of particular environmental significance because they can be contaminated with dioxins (TCDDs). “Agent orange” the defoliant used by the US forces in Vietnam comprised a mixture of 2, 4-D and 2, 4, 5-T and caused wide spread contamination of soils by dioxin. The toluidines and triazines are fairly strongly absorbed and have a persistence of up to twelve months although atrazine contamination of ground waters is a serious problem in many intensive arable farming areas. The phenylureas tend to be fairly soluble and are rapidly leached. In contrast, the bipyridyls such as paraquat and diquat are cationic and strongly absorbed on soil colloids Kd values of < $4{,}2x\ 10^4$ on montmorillonite) and are therefore very persistent, Fungicides comprise amour diverse group of compounds including inorganic, such as copper and mercury compounds, and a wide range of organic compounds.

1.6 Pesticide Pollution

The following types of pesticides are commonly used:

Chlorinated hydrocarbons (e.g. DDT, Aldrin, Dieldrin, Lindane, BHC, etc)

a) Carbonate compounds (e.g. Carbonyl o, Sevin, Zectrion etc,)
b) Orango-Phosphorous compounds (e.g., Mwthly or ethyl parathion, melathion, guthion etc,)
c) Inorganic Compounds (e.g.As_2C_3, PbO_2, $NiCl_2$, $CuSO_4$, etc,)
d) Miscellaneous compounds (e.g. Organic mercurials 2, 4d; 2, 4, 5T etc.)

Some of the adverse effects of pesticides are given below:

1) Some arsenic pesticides may render the soil permanently infertile.
2) Pesticide residues in soil may be taken up by plants and cause phytoxicity. They may enter the aquatic environmental and enter the food chain.
3) Pesticides such as, endrin, dieldrin, DDT, heptachlor etc, may seep through the soil and contaminate ground water and surface water. They may eventually contaminate drinking water supplies.
4) Fruit, vegetables, rice, wheat, barley, maize etc. are known to contain considerable quantities of toxic pesticide residuce such as of DDT, BHO and other organochloro pesticides.
5) Polychlorinated biphenyls PCB) having half-life periods of about 2 years in soil are among the most hazardous soil pollutants. They may accumulate in soil and plants and when they eventually enter the animals or human body, they may cause severe health disorders including eye damage, skin problems, nervous disorder, foetus deformities and liver or stomach cancer.
6) Irrigated water from pesticide contaminated soils may evaporate and spread the toxic pesticide vapours in the atmosphere.
7) DDT can enter the food chain and accumulate in human fats and may lead to disorders such as impotency.
8) Persistent pesticides can damage human tissues and interfere with the normal metabolic activities by disturbing enzymatic functioning.
9) Chlorinated pesticides and herbicides are hazardous soil pollutants which can affect the soil texture and damage the ecosystem.
10) Herbicides such as dioxin may cause congenital birth defects in offsprings.
11) Hunting birds feeding on grains contaminated with DDT are threatened of extinction.
12) Organophosphate pesticides may cause muscular disabilities, tremors and dizziness.
13) Excessive use of synthetic pesticides may lead to defoliation of forests and adverse effect on fauna and flora.
14) Farm animals drinking stagnant water in fields sprayed by pesticides developed toxic symptoms and some mortalities ware reported.
15) Farmers and farm workers are particularly prone to pesticide poisoning because of greater exposure while handling and spraying.
16) Accidental spillages and leakages in pesticide manufacturing industries cause disastrous effects on the people residing in nearby areas due to pollution of air, water and soil. The Bhopal tragedy on 3rd December 1964 as a lingering example.
17) Contaminated soils may act as potential carriers of pathogenic bacteria and other dangerous organisms which may endanger human health.
18) Volatile pesticide may cause pollution of air in the surrounding areas.

1.7 Control of Soil Pollution

The Following measures may be adopted to control soil pollution.

1) Treat sewage before land disposal.
2) Understand soil, water and plant relationship and protect the nature cycle of fixation.
3) Preserve and protect top fertile soil. Control soil erosion by proper the plantation measures.
4) Prevent entry of leachates into soil by providing proper polythene sheet and liner in landfill.
5) Use carefully the fertilizers and pesticides in optimal dose.
6) Rotate the crop patterns to allow the soil replenish the nutrients.
7) Plough or mix the soil to improve aeration, porosity and permeability.
8) Cultivate grass and grow papaya on polluted wastelands.

References

[1] Abbott, M.B., Bathurst, J.C., Cunge, J.A., O'Connell, P.E. and Rasmussen, J. 1986. An introduction to the European Hydrological System - Système Hydrologique Européen "SHE". *J. Hydrol.* **87**: 45-77.

[2] Barg, U.C. 1992. *Guidelines for the promotion of environmental management of coastal aquaculture development.* FAO Fisheries Technical Paper 328. FAO, Rome.

[3] Calamari, D. and Barg, U. 1993. Hazard assessment of agricultural chemicals by simple simulation models. In: *Prevention of Water Pollution by Agriculture and Related Activities.* Proceedings of the FAO Expert Consultation, Santiago, Chile, 20-23 Oct. 1992. Water Report 1. FAO, Rome. pp. 207-222.
[4] Janus, L.L. and Vollenweider, R.A. 1981. *The OECD Cooperative Programme on Eutrophication: Summary Report - Canadian Contribution.* Inland Waters Directorate Scientific Series No. 131, Environment Canada, Burlington, Ontario, Canada.