The Geosphere and Geochemistry :

The **geosphere**, or solid earth, is that part of the earth upon which humans live and from which they extract most of their food, minerals, and fuels . Two atmospheric pollutant phenomena—excess carbon dioxide and acid rain have the potential to cause major changes in the geosphere. Too much carbon dioxide in the atmosphere may cause global heating ("greenhouse effect"), which could significantly alter rainfall patterns and turn currently productive areas of the earth into desert regions.
The low pH characteristic of acid rain can bring about drastic changes in the solubility and oxidation-reduction rates of minerals. Erosion caused by intensive cultivation of land is washing away vast quantities of topsoil from fertile farmlands each year . In some areas of industrialized countries, the geosphere has been the dumping ground for toxic chemicals.
The interface between the geosphere and the atmosphere at earth's surface is very important to the environment. Human activities on the earth's surface may affect climate . One of the greater impacts of humans upon the geosphere is the creation of desert areas through abuse of land with marginal amounts of rainfall. This process, called **desertification**, is manifested by declining groundwater tables, salinization of topsoil and water, reduction of surface waters, unnaturally high soil erosion, and desolation of native vegetation.
The most important part of the geosphere for life on earth is soil. It is the medium upon which plants grow, and virtually all terrestrial organisms depend upon it for their existence. The productivity of soil is strongly affected by environmental conditions and pollutants.
The earth is divided into layers, including the solid iron-rich inner core, molten outer core, mantle, and crust. Environmental chemistry is most concerned with the **lithosphere**, which consists of the outer mantle and the **crust**. The latter is the earth's outer skin that is accessible to humans. It is extremely thin compared to the diameter of the earth, ranging from 5 to 40 km thick. Most of the solid earth crust consists of rocks. Rocks are composed of minerals, where a **mineral** is a naturally-occurring inorganic solid with a definite internal crystal structure and chemical composition. A **rock** is a solid, cohesive mass of pure mineral or an aggregate of two or more minerals.

Structure of Minerals:

The combination of two characteristics is unique to a particular mineral . These characteristics are a defined chemical composition , and a specific crystal structure. The **crystal structure** of a mineral refers to the way in which the atoms are arranged relative to each other. It cannot be determined from the appearance of visible crystals of the mineral, but requires structural methods such as X-ray structure determination. Different minerals may have the same chemical composition, or they may have the same crystal structure, but may not be identical for truly different minerals. Table (1) show the Major Mineral Groups in the Earth's Crust.

Table(1):Major Mineral Groups in the Earth's Crust

Mineral group	Examples	Formula
Silicates	Quartz	SiO_2
	Olivine	$(Mg , Fe)_2SiO_4$
	Potassium feldspar	$KAlSi_3O_8$
Oxides	Corundum	Al_2O_3
	Magnetite	Fe_3O_4
Carbonates	Calcite	$CaCO_3$
	Dolomite	$CaCO_3.MgCO_3$
Sulfides	Pyrite	FeS_2
	Galena	PbS
Sulfates	Gypsum	$CaSO_4.2H_2O$
Halides	Halite	NaCl
	Fluorite	CaF_2
Native elements	Copper	Cu
	Sulfur	S

Surface Processes :

Surface geological features are formed by upward movement of materials from earth’s crust. With exposure to water, oxygen, freeze-thaw cycles, organisms, and other influences on the surface, surface features are subject to two processes that largely determine the landscape—weathering and erosion. Weathering consists of the physical and chemical breakdown of rock and erosion is the removal and movement of weathered products by the action of wind, liquid water, and ice . Weathering and erosion work together in that one augments the other in breaking down rock and moving the products. Weathered products removed by erosion are eventually deposited as sediments and may undergo diagenesis and lithification to form sedimentary rocks.

Environmental Effects of Mining and Mineral Extraction

Although surface mining is most often considered for its environmental effects, subsurface mining may also have a number of effects, some of which are not immediately apparent and may be delayed for decades. Underground mines have a tendency to collapse leading to severe subsidence. Mining disturbs groundwater aquifers. Water seeping through mines and mine tailings may become polluted . One of the more common and damaging effects of mining on water occurs when pyrite, FeS , commonly associated with coal, is exposed to air and becomes oxidized to sulfuric acid by bacterial action to produce acid mine water . Some of the more damaging environmental effects of mining are the result of the processing of mined

materials. Usually, ore is only part, often a small part, of the material that must be excavated. Various beneficiation processes are employed to separate the useful fraction of ore, leaving a residue of tailings. A number of adverse effects can result from environmental exposure of tailings. For example, residues left from the beneficiation of coal are often enriched in pyrite, FeS, which is oxidized microbiologically and chemically to produce damaging acidic drainage (acid mine water).
Uranium ore tailings unwisely used as fill material have contaminated buildings with radioactive radon gas.

Nutrients in soil:

Nutrients are stored in soil on "exchange sites" of the organic and clay components. Calcium, magnesium, ammonium, potassium and the vast majority of the micronutrients are present as cations under most soil pH . The cation exchange capacity of soils is an important measure of its ability to store these nutrients and provide them to growing plants as needed. Organic substances (humic and fulvic acids, humus) contain exchange sights because of the presence of carboxylic acids. An organic component is an essential ingredient of all healthy soils.

The carboxylic acids exchange protons in soil in the same manner that protons are exchanged in aqueous solution . Soil pH is therefore an important parameter, which affects the ability of a soil sample to exchange cations and the ease with which nutrients move through the soil. Ideally, a soil sample should have a pH near 6.5 to provide for optimum nutrient storage capacity and ease of movement to the plant roots. Phosphorous is present in soil as orthophosphate (PO_4^{3-}). The two forms of phosphate that are present in soil under most conditions, HPO_4^{2-} and $H_2PO_4^{-}$, are anions. Phosphate complexes of most metals have very low solubility , and phosphate is therefore relatively immobile in soil.

Nitrogen, phosphorous and potassium are used in large quantities by all growing organisms. Since they are typically present in soil at the percentage level, they are call **macronutrients**. Deficiency of any of these three elements reduces plant growth and lowers crop production. Fertilizers are substances used to replenish these essential nutrients. Synthetic chemicals are often used for this purpose, but manure and compost work just as well (some people think they are better), and permit organic wastes to be put to good use. The macronutrients are used by plants (and animals) to build amino acids and proteins. Phosphate forms the backbone of DNA and is used to store energy in chemical bonds.

Table (2) The Macronutrients in soil

Element	**Symbol**	**Chemical Form in Soil**
Calcium	Ca	Ca^{2+}
Carbon	C	HCO_3^-, CO_3^{2-}
Hydrogen	H	H^+
Magnesium	Mg	Mg^{2+}
Nitrogen	N	NO_3^-, NH_4^+
Oxygen	O	HO^-
Phosphorous	P	H_2PO^{4-}, HPO_4^{2-}
Potassium	K	K^+
Sodium	Na	Na^+

Micronutrients are classified as "essential" and "non-essential." An essential plant nutrient is one that is required for life, whereas a non-essential plant nutrient (present in soil a very low levels) will increase crop yield--but its absence will not cause the organism to die.

Table (3): The essential micronutrients

Element	**Symbol**	**Chemical Form in Soil**
Boron	B	H_3BO_3
Chlorine	Cl	Cl^-
Copper	Cu	Cu^{2+}
Iron	Fe	Fe^{2+}, Fe^{3+}
Manganese	Mn	Mn^{2+}
Molybdenum	Mo	MoO_4^{2-}
Sulfur	S	SO_4^{2-}
Zinc	Zn	Zn^{2+}

Table (4):The non-essential micronutrients

Element	**Symbol**	**Chemical Form in Soil**
Aluminum	Al	Al^{3+}, $Al(OH)_2^{+}$
Cadmium	Cd	Cd^{2+}
Cobalt	Co	Co^{2+}
Lead	Pb	Pb^{2+}
Mercury	Hg	Hg^{2+}
Nickel	Ni	Ni^{2+}
Selenium	Se	SeO_4^{2-}
Silicon	Si	SiO_2

Essential micronutrients are elements used at trace levels in enzymes to assist with special body processes. Some examples where essential micronutrients are required include oxygen transport by hemoglobin and electron transport in cell metabolism. The role of non-essential micronutrients is not well understood and is an area of on-going research.

Pesticides and Chemical Wastes in Soil :

Pesticides are used in all forms of agriculture to control unwanted insects and plants. Paris green, a form of arsenic, was used to control the potato beetle until the advent of modern synthetic pesticides that have been used since the 1950s. Fields that were treated with Paris green fifty years ago still contain unacceptable levels of arsenic, since the arsenic cannot be degraded into another substance and the only natural removal mechanism is leaching . Chlorinated hydrocarbons became popular as broad-spectrum pesticides after World War II, the most widely used being DDT (dichlorodiphenyltrichloroethane). Other pesticides that are classified as chlorinated hydrocarbons include: Methoxychlor, Dieldrin, Endrin, Chlordane, Aldrin, Endrin, Heptachlor, Toxaphene and Lindane . These substances do not last as long as non-degradable substances like arsenic, but they do have unacceptably long half-lives in the soil. The very long time needed to degrade chlorinated hydrocarbons, and the fact that they are concentrated in the food chain, led to legislation banning their use in the United States and Europe. Unfortunately, these compounds are still in common use in underdeveloped countries. Modern pesticides have half-lives of weeks or days, and if used properly, do not build up in soil like their predecessors.

In years past it was common practice to deposit industrial wastes in landfills of simply bury containers of waste chemical in the soil. This material is not easily degraded and has the potential to pollute the groundwater. Once in the soil, these substances can enter the food chain by being incorporated into plant tissue, which is eaten by livestock. The most infamous example of such a case occurred in Michigan, where dairy cattle were exposed to PCBs. PCB contaminated milk was consumed by people who drank the milk and the cattle had to be destroyed.

Lead can be a problem when lead washes off buildings that have been painted with lead based paint (common with old buildings). Lead additives to gasoline caused significant increases to lead soil levels near major highways. Legislation to remove the lead additives stopped this source of lead, but the legacy of lead based gasoline will remain in the soils near major metropolitan thorofares for years to come. In years past, lead and copper smelters caused significant environmental degradation with fallout from the smelting process. Restrictions on environmental emissions have done much to correct this problem, but the soil near most smelters is still contaminated. In most cases, the only mechanism for cleanup of these areas is the natural leaching process.

General Questions:

Q1:/ What is the **desertification process?** And how it is manifested ?

Q2:/ Of the following , the one that is not a manifestation of desertification is

(a) declining groundwater tables , (b) salinization of topsoil and water, (c) production of deposits of MnO_2 and $Fe_2O_3 \cdot H_2O$ from anaerobic processes, (d) reduction of surface waters, (e) unnaturally high soil erosion.

Q3:/ ((Weathering and erosion work together to determine the landscape)) . Describe how they work ?

Q4:/ Micronutrients are classified as "essential" and "non-essential." What is the differences between these two groups?

Q5:/ Write short essay about the environmental effects of mining and mineral extraction .

Q6:/ ((Soil pH is an important parameter for nutrients in soil)) . Discuss how the pH effects the nutrients in soil .

Q7:/ What are the main chlorinated hydrocarbons " as pesticides " that found in the agricultural soils .