UNIT 3 MINERAL RESOURCES

Structure

3.0 Introduction
3.1 Objectives
3.2 Increasing Mineral Demand and Scarcity of Minerals
3.3 Mineral Deposits, Ores and Reserves
3.4 Types and Grouping of Mineral Resources
3.5 Mining: Introduction and Types
3.6 Mining Phases and Operations
3.7 Types of Waste Generated by the Different Mining Steps
3.8 Mining-Waste Management Methods
3.9 Impact of Mining on Environment
3.10 Mine Restoration
3.11 Let Us Sum Up
3.12 Key Words
3.13 References and Suggested Further Readings
3.14 Key to Check Your Progress

3.0 INTRODUCTION

Our life is accompanied by mineral resources at every step. Use of minerals by human beings has been so extensive since the very beginning of human civilization, that some major periods of pre history and history are named after minerals: the Stone Age, Bronze Age, and Iron Age. We currently live in the Iron Age, although some suggest that we have already entered the age of silicon, an important metal in the production of semiconductors, the mainstay of our current electronics. Mineral resources refer to material substances either composed of or extracted from minerals. They include ores, metals, gravel, sand, marble, granite, phosphate rock, and so on. These are usually inorganic compounds; although some deposits may be concentrated or accumulated by life-forms e.g. limestone (composed of the calcium carbonate shells of sea creatures). Minerals find a large number of ways in everyday use in domestic, agricultural, industrial and commercial sectors. Minerals have become essential in: (i) development of industrial plants and machinery (ii) generation of energy e.g. coal, lignite, uranium (iii) construction, housing, settlements etc. (iv) defense equipments e.g. weapons, armaments (v) transportation (vi) communication – telephone wires, cables, electronic devices (vii) medicinal system particularly in Ayurvedic system (viii) formation of alloys for various purpose (e.g. phosphorite) (ix) agriculture i.e. fertilizers, seed dressings and fungicides (e.g. zineb containing zinc, Maneb containing manganese, etc.) (x) jewellery e.g. gold, silver, platinum, diamond.

Mineral wealth as a natural asset can stimulate or enhance economic growth potential and social progress. The reserves of metals and the technical know-how to extract them have been the key elements in determining the economy and political power of nations. The world is facing serious and long term challenges
in the provision of mineral and energy resources. Although, no global shortages of non-fuel mineral resources are expected in the near future (According to United States Geological Survey’s Global Mineral Resource Assessment Project) a growing number and variety of obstacles have begun to restrict the availability of these resources. These complex issues comprise economic, technical, social, and environmental challenges.

### 3.1 OBJECTIVES

After reading this unit, you will be able to:

- discuss the pattern and causes of mineral demand;
- define the ecological, environmental and social impacts of mining;
- underline the importance of adopting a multipronged approach for mine restoration; and
- select the mineral resources in accordance with our strict sustainable development standards.

### 3.2 INCREASING MINERAL DEMAND AND SCARCITY OF MINERALS

Before the nineteenth century, global use of minerals was relatively insignificant compared to the abundance of mineral in geological deposits. Since the Industrial Revolution the associated demophoric (demographic plus technological) developments, however, has highly enhanced the rate of mineral resource use. This is evident from the fact that although the world’s population doubled, the mineral use has increased by a factor of 10 during 1750 and 1900. The mineral use at present is more than 13 times the amount used during 1900.

The demand for minerals is still extremely high, and will increase further with industrialization in developing countries, replacement of ageing infrastructures and introduction of new technologies. The life expectancy of a stock (how long a stock will last) is not linearly related to the increase in the stock i.e. a 10 to 100 fold increase in the stock does not mean that the stocks will last proportionately. In theoretical situation, assuming that future exploitation will continue at present rate and demand remains the same, the life expectancy of a stock can be linearly related to the increase in magnitude of the stock. In such situation the stock (reserve) is called as a **static reserve**. The demands generally increase exponentially due to increase in population and per capita consumption and the life expectancy of a reserve decreases exponentially. In such situation the reserve is called as **exponential reserve**. Exponential reserves are more realistic as they better reflect the real world pattern of demand. The demand for metals such as tin, zinc, copper and aluminum grows at about 1 to 4% per year. If we assume that demand increase by 3.5% per year, then annual demand will double approximately in every 20 years. A stock having a static reserve of 500 years may last only 83 years when the exponential rate of exploitation is taken into account. If the hypothetical 500 year static reserve is increased to 5000 years, the exponential reserve will increase from 83 years to only 147 years.

The bottom line is that on a global scale, the demand for mineral resources now are so great that even with a conservative or liberal estimate of remaining mineral
stocks, the known supplies of a number of minerals will be exhausted within a few decades. The effects of environmental degradation and associated pollution of mining activities may force us to curtail the exploitation of mineral deposits before they are exhausted. In other words, we need to emphasize the “three R’s” – reduce, reuse, and recycle as well as find substitutes for minerals in short supply (detailed in unit 4).

3.3 MINERAL DEPOSITS, ORES AND RESERVES

A mineral is a naturally occurring solid chemical substance that is formed through geological processes and that has a characteristic chemical composition, a highly ordered atomic structure, and specific physical properties. Minerals range in composition from pure elements and simple salts to very complex silicates with thousands of other forms. The study of minerals is called mineralogy. Mineral deposits are formed by natural geological processes. During the rock cycle, weathering may dissolve or physically remove certain elements and minerals, leaving behind a concentrated residue of the remaining minerals. Sedimentary processes can concentrate minerals through precipitation from a solution or by differential settling of grains in moving or still water. Certain minerals may selectively crystallize out of a hot, molten body of igneous rocks. During the formation of metamorphic rocks, elements may be mobilized in the rock, resulting in mineral changes and sometimes giving rise to economically useful mineral concentrations. The high temperatures associated with igneous and many metamorphic processes often result in hydrothermal processes (i.e. hot water dissolves, transports and subsequently reprecipitates and concentrates elements and minerals in deposits).

The abundance and distribution of minerals are very uneven. On a global scale a few elements (namely oxygen, silicon, aluminum, iron, calcium, sodium, magnesium, and potassium) are extremely abundant, making up over 99% of the Earth’s crust by weight. Some other elements like copper, tin etc. are very rare. Again, all mineral deposits are not usable and the supplies are practically exhaustible for both abundant and rare minerals. A mineral deposit becomes an ore deposit at certain point of time when the mining and processing of the mineral becomes techno economically feasible i.e. a mineral deposit of today may become an ore deposit on some day. Identified but unexploited ore deposits are called as reserves. Reserve estimates for a particular mineral will increase as new ore deposits come to existence, as the mining and processing technologies become more efficient and improved, or as price rises allows mining and processing of lower-grade deposits. Reserve estimates will decrease, as known deposits of a particular mineral are exhausted or if market prices fall, to discourage the mining of lower grade deposits.

At current consumption rates, the iron and aluminum in the Earth’s crust could last a million years and a hundred million years, respectively (without recycling). It seems virtually inexhaustible. But at the present rates of consumption, the proven ore deposits of iron and aluminum will last only for a few hundred to a couple of thousand years. Many substances are very rare. For instance, copper has an average concentration of only 55 to 63 parts per million (ppm) of the Earth’s crust, and tin only 2 ppm. There is an upper limit to the quantity of minerals that can be produced, even if energy supply is made unlimited. However, practically, our energy resources are limited. Taking world production,
consumption, and reserves into account, it has been estimated that our **virgin supplies of ores** for copper, tin, lead, zinc, and various other metals will be exhausted within a century.

### 3.4 TYPES AND GROUPING OF MINERAL RESOURCES

Mineral deposits are diverse in nature and composition, reflecting their origins. Minerals can be divided into different categories such as metallic, nonmetallic, precious and energy minerals. **Metallic minerals** include iron, aluminum, copper, zinc, lead, gold, tin, chromium and so on. **Metallic minerals** can be ferrous (iron and related metals such as chromium, manganese, nickel, and molybdenum, which are commonly alloyed with iron) or nonferrous (gold, copper, silver, etc.). **Nonmetallic minerals** can similarly be divided into **structural materials**, such as building stone, sand, gravel, and other components of cement and concrete, and **industrial materials**, such as fertilizer components (phosphorus and potassium), salts, sulfur, other nonmetals used in manufacturing, asbestos, abrasive minerals (such as emery, or corundum, and industrial diamonds), and so on. The third category is **precious minerals** such as gemstones and semiprecious minerals that serve no pragmatic function and are purely of ornamental and aesthetic value. Finally, uranium and fossil fuels (coal, oil and natural gas) are sometimes regarded as a fourth category called **energy minerals**.

Due to the unequal distribution of mineral deposits around the world and the depletion of once existing deposits, many countries have small or nonexistent reserves of certain important minerals. Certain minerals which are necessary for the production of essential goods are classified as **critical minerals**. A **strategic mineral** is a critical mineral, that a particular country or countries must import from areas that are potentially unstable politically, militarily, or socially. Problems in these areas could disrupt the supplies of such minerals. Critical minerals may or may not always have substitutes and sometimes the substitutes are rarer than the critical minerals themselves.

In order to have a better understanding of the mineral deposits for effective exploration, they are subdivided into different categories. The classification can be done based on a number of criteria, such as minerals or metals contained, the shape or size of the deposit, host rocks (the rocks which enclose or contain the deposit) or the genesis of the deposit (the geological processes which combined to form the deposit). Based on the major anion group present, a list of minerals is given below and is in approximate order of their abundance in the Earth’s crust. The list follows the Dana classification system.

**a)** **Silicate class:** The largest group of minerals by far is the silicates. These are composed largely of silicon and oxygen, with some parts of aluminum, magnesium, iron, and calcium. Most rocks are ~95% silicates. Examples of some important silicate rocks are feldspars, quartz, olivines, pyroxenes, amphiboles, garnets, and micas.

**b)** **Carbonate class:** The major anion here is carbonate (CO\(_3\))\(^2⁻\). This includes minerals of calcium carbonate (calcite and aragonite), magnesium/calcium carbonate (dolomite) and iron-carbonate (siderite). Carbonates are commonly found in marine settings when the carbonate containing dead organisms settle
and accumulate on the sea floor. They are also found as evaporite deposits (e.g. the Great Salt Lake, Utah) and also in karst regions, where the dissolution and reprecipitation of carbonates leads to the formation of caves, stalactites and stalagmites. The carbonate class also includes the nitrate and borate minerals.

e) **Sulfate class:** Sulfate minerals (anion as $\text{SO}_4^{2-}$) are commonly formed in evaporitic settings. Both sulfates and halides are formed at the water-sediment interface by slow evaporation of highly saline waters. They also occur in hydrothermal vein systems as gangue minerals along with sulfide ores. Secondary oxidation product of original sulfide minerals also comes under this class. Common sulfate minerals are anhydrite (calcium sulfate), celestine (strontium sulfate), barite (barium sulfate), and gypsum (hydrated calcium sulfate). The sulfate class also includes the chromate, molybdate, selenate, sulfite, tellurate, and tungstate minerals.

d) **Halide class:** Halides, like sulfates, are commonly found in evaporite settings such as salt lakes and landlocked seas such as the Dead Sea and Great Salt Lake. It includes the fluoride, chloride, bromide and iodide minerals. This class mainly represents the natural salts such as fluorite (calcium fluoride), halite (sodium chloride), sylvite (potassium chloride), and sal ammoniac (ammonium chloride).

e) **Oxide class:** The oxide class includes the oxide and the hydroxide minerals. This class is extremely important as in addition to valuable metals they also provide the best record of changes in the Earth’s magnetic field. They commonly occur as precipitates close to the Earth’s surface, oxidation products of other minerals in the near surface weathering zone, and as accessory minerals in igneous rocks of the crust and mantle. Example of common oxides are hematite (iron oxide), magnetite (iron oxide), chromite (iron chromium oxide), spinel (magnesium aluminium oxide — a common component of the mantle), limonite (iron titanium oxide), rutile (titanium dioxide), and ice (hydrogen oxide).

f) **Sulfide class:** Common sulfides include pyrite (iron sulfide — commonly known as fool’s gold), chalcopyrite (copper iron sulfide), pentlandite (nickel iron sulfide), and galena (lead sulfide). The sulfide class also includes the selenides, the tellurides, the arsenides, the antimonides, the bismuthinides, and the sulfosalts (sulfur and a second anion such as arsenic).

g) **Phosphate class:** It includes any mineral with a tetrahedral unit $(\text{AO}_4)^{3-}$ where A can be phosphorus, antimony, arsenic or vanadium. By far the most common phosphate is apatite which is an important biological mineral found in teeth and bones of many animals. The phosphate class includes the phosphate, arsenate, vanadate, and antimonate minerals.

h) **Element class:** This group covers native metals and intermetallic elements (gold, silver, copper), semi-metals and non-metals (antimony, bismuth, graphite, sulfur), natural alloys, such as electrum (a natural alloy of gold and silver), phosphides, silicides, nitrides and carbides (which are usually only found naturally in a few rare meteorites).
i) **Organic class:** This class includes biogenic substances getting concentrated or transformed by geological processes. Various oxalates, mellitates, citrates, cyanates, acetates, formates, hydrocarbons and other miscellaneous species constitute this class. Examples include whewellite, moolooite, mellite, fichtelite, carpathite, evenkite and abelsonite.

Strunz classification is also very similar where the scheme divides minerals into nine classes, which are further divided into divisions, families and groups according to chemical composition and crystal structure. i) elements ii) sulfides and sulfosalts iii) halides iv) oxides and hydroxides v) carbonates, nitrates and borates vi) sulfates, chromates, molybdates and tungstates vii) phosphates, arsenates and vanadates viii) silicates ix) organic compounds.

**Check Your Progress 1**

**Note:**

a) Use the space given below for your answer.

b) Compare your answers with those given at the end of the unit.

1) What factors are responsible for scarcity of mineral resources? Differentiate between exponential reserves and static reserves.

2) Classify different types of mineral resources.

---

**3.5 MINING: INTRODUCTION AND TYPES**

The term mining refers to the process of taking out minerals or their ores from the earth. Some minerals can be mined more easily as they are found at the earth’s surface, while others lie far beneath the surface and can be obtained by digging deep underground. There are two types of mining A) surface mining B) sub-surface mining.
A) **Surface mining** is adopted when mineral deposits occur at or near the surface of the earth (<300m). Depending upon the type of ore and its place of occurrence surface mining can be done by ways such as open pit mining, dredging or strip mining. In **open pit mining** the minerals are extracted out by removing the materials that cover the deposits. This process forms open pits in the mining site. The minerals like iron, limestone, copper, sand stone, marble etc. are obtained by this method. **Dredging** is the method in which chained buckets and drag lines are used to scrap out the minerals from under water mineral deposits. Finally, in the method of **strip mining** the ores are stripped off by using bulldozers, power shovels and stripping wheels. Phosphate rocks are removed by this method. Strip mining is economical till the stripping ratio (ratio of over burden to quantity of ore recoverable) is low.

B) **Sub-surface mining** is used when the mineral deposit lies deep beneath the earth’s surface. In this method, big tunnels are dug in the earth surface to extract out ores from the horizontal ore bodies. The ore extraction capacities of these methods are generally much lower than for surface quarries as well as the quantity of waste produced per unit of ore mined. The ground area of this type of underground mine is considerably smaller than for surface quarrying, except for subhorizontal layers. They are associated with a different kind of mechanical risks (subsurface collapse, structural weakness around shafts and other inclines).

### 3.6 MINING PHASES AND OPERATIONS

The operations carried out on a mine site to exploit and upgrade a deposit can be divided into three main steps:

- **Preparatory or development operations** providing access to the deposit: the scale of these clearance (or stripping) operations in the case of an open-pit mine and for drilling drifts, shafts or inclines for an underground mine, vary considerably according to the characteristics of the deposit. Opencast pits generally produce about ten times more waste on average than underground mines, which are more selective.

- **Ore extraction operations** (or workings), and crushing or preliminary sorting operations to optimise the transport and grade of crude ore before its transfer to the processing unit.

- **Ore processing** (in many cases for metallic mines) set of operations generally grouped in a specialized unit (called concentrator) used to separate the mineral phases containing the useful substances from the waste gangue. The product of the plant, enriched with useful materials, is called the “concentrate”. In most cases, the concentrate is the marketable product.

Mines of so called high assay substances (iron, manganese, bauxite) are rarely found associated with ore processing units on site. In these cases, the ore is exported without processing to distant sites where its metallurgical conversion is more advantageous, particularly in terms of energy. Note also that methods of chemical or sometimes biological processing of the ores are also used in mine sites, in addition to physical and physicochemical methods (gravity separation and flotation). This applies in particular to gold ones (cyaniding), more recently
to copper and nickel oxide ores (heat leaching or autoclave), and even more recently, to copper and cobalt sulphide ores (bioleaching). In some exceptional cases, no physical or chemical process is applicable. A smelter must accordingly be installed nearby and, in these conditions, forms part of the mine (nickel saprolite).

3.7 TYPES OF WASTE GENERATED BY THE DIFFERENT MINING STEPS

Each of the ore mining and processing steps can generate mining waste. This waste generally has different physical and chemical properties, resulting in different potential environmental impacts. The respective volumes of waste produced essentially depend on the type of deposit and the technological alternatives used for mining and for ore processing; stripping of the deposits in strip mined quarries is often one of the steps producing the most waste during ore extraction operations. The chemical composition of the waste varies considerably according to the substance mined and the nature of the geological formation containing the deposit. It is interesting to note that in the most part, these wastes are saleable products, which will be sold if local market conditions are favourable. In addition, both coarse and fine residues are routinely required for site restoration and landscaping.

The main types of mining waste in addition to topsoil and overburden are classified into two categories: waste rock’ (mine rock piles) and Tailings (processing waste). Two further types of “waste” because of the need of their environmental management are: temporary stockpiles of ore and slags.

a) Waste rock

Waste rock is the unused extraction product that is generally stored indefinitely in a landfill site which, for economic reasons associated with transport costs, is located in the immediate vicinity of the main mining centre. The quantity of mining waste that can be stored at a mining centre varies considerably and mainly depends on the selectivity of the mining method. As a rule, opencast pits and quarries generate much more mining waste than that of underground mine. The main type of waste rock is generated by surface (or barren rock) stripping to expose the shallow ore. This is a rock that is weathered to varying degrees, although increasingly fresh with depth and showing the geological characteristics of the local surrounding material. Its composition is similar to the rocks of the sector. The largest (in tonnage) quantity of barren rock comes from stripping for opencast mines. In underground mines, these barren rocks are generated by the passages (shafts, crosscuts).

b) Tailings (processing waste)

At a mine, an ore mill normally abuts on the extraction centre to produce the first marketable products (metallic concentrates, sorted ore, and ingots). The technological processes are very different according to the type of substance mined, and the modernity of the technologies employed (flotation, leaching, and biotechnology). Mill waste is generally referred to as tailings, or releases or effluents. For a given mineral, it will have different physicochemical properties according to the conditions in which it has been generated. Its
volume and variety has increased to match raw material demand, combined with the proliferation of upgrading methods and their degrees of sophistication. It is found in solid, liquid and gaseous form as:

- Aqueous solutions from cyaniding.
- Slurries of finely ground particles that have undergone one or more types of physical or chemical treatment, and which contain one or more industrial additives (that have participated in the conversion process) (xanthates, miscellaneous salts, starch, etc.). These tailings are normally dumped in a sort of lagoon or settling basin within an embankment at the exit of the mill.
- Atmospheric releases from sulphide roasting contribute to air pollution.

Through the years, **solid waste** has evolved in line with technological progress, from multi centimetre grain size with a still high content of the desired element (i.e. low tonnage and hence low exchange surface areas to micron grain size with very low chemical contents (i.e. high tonnage and high waste). The release mesh varies from one ore deposit to another, depending not only on the level of technology but also on the geological and mineralogical characteristics.

c) **Ore stockpiles Ore stockpiles**

Ore stockpiles are intermediate storage of products and may not be considered as waste and are normally temporary dumps of lean ore at the mine site, depending on the cut-off content, which may vary with time. This management requires maintenance on the mine site for a period sometimes longer than a decade. Selectivity of materials corresponds to ores of lower grade than the limit assay. These ores with content lower than the limit content at the time of storage can be used later with advancement in technology or market. It can also be used as a raw material for preparing some other product.

d) **Slags**

The burning or smelting of ores of Fe, Cu, Sn etc. to remove sulphides produces slags as the waste. These oxidised products are found either accumulated near the mine, if smelting was conducted nearby, or often stacked in heaps near the smelter. Ash produced by cleaning furnaces or smoke stacks is frequently associated with them.

### 3.8 MINING WASTE MANAGEMENT METHODS

By order of importance, the disposal of tailings is generally done by:

- Terrestrial impoundment (tailings ponds),
- Underground backfilling,
- Deep water disposal (lakes and sea),
- Recycling.

a) **Terrestrial impoundment**

Terrestrial deposition is the predominant method for tailings disposal. It concerns fine waste and slurries such as mill tailings. The principle of tailings
Energy and Mineral Resources
dams (or ponds) is to dispose of the tailings in an accessible condition that
allows their future reprocessing (once improved technology or a significant
increase price makes it profitable). Actually, the vast majority of tailings
facilities are design as permanent disposal facilities. Tailings are often
transported to the impoundment via pipelines.

b) Underground backfilling

The backfilling of mines is possible only for ore deposits which do not have
any contact with an aquifer. Such an operation is usually costly and will be
carried out for stability and safety reasons.

c) Deep water disposal

The disposal of tailings and solid waste directly into bodies of water although
sometimes was used in past operations, is rapidly becoming unauthorised as
a standard practice due to the significant pollution effects, it can have on the
receiving waters and the possible subsequent impacts on the livelihoods of
the local communities. This method requires specific conditions and specific
impact assessments. An appropriately designed underwater disposal of
sulphidic tailings is an ideal solution from an environmental point of view
in the short term with control of the level of water.

d) Recycling

Coarse mining waste and especially barren rock is sometimes considered as
materials for roads, building foundations or cement factories, depending on
its geotechnical and geochemical characteristics. Recycling is not classified
as disposal. If a market will emerge later, the rock stored temporarily can be
sold as aggregate when environmental specifications are met. With new
techniques, the tailings can be reprocessed.

3.9 IMPACT OF MINING ON ENVIRONMENT

Although mining provides a variety of socio-economic benefits, from the
exploration to the closing stage, it has serious impacts on ecosystem, biodiversity,
environment, health and socio-cultural systems. These impacts come through
the value chain activities like prospecting, exploration, site development, ore
extraction, mineral dressing, smelting, refining/metallurgy, transportation and
post mining activities. The sector is resource intensive in turn generating massive
amount of solid and liquid wastes of high concentrations, and sometimes toxic
substances. If not well handled, its environmental and social costs can be massive.
In general, degradation arising from mining includes air pollution; surface and
ground water pollution; land, agriculture and forest degradation; sound pollution;
as well as socio-cultural problems such as health, rehabilitation, conflicts,
inequality, alcoholism, drug abuse, prostitution and other social unrests. All these
have negative implications for various livelihoods and sustainable development
and therefore, require urgent attention.

The mining, processing and disposal of minerals have many negative effects on
environment. The main harms caused by mining are as follows:

i) It results in formation of derelict land or mine spoil due to removal of top
soil from the mining area to get access to the deposit disturbs and damages
the land causing defacing the landscape.
ii) It causes ground subsidence, which results in tilting of buildings, cracks in house, buckling of roads, bending of rail tracks and leaking of gas from cracked pipelines leading to serious disasters.

iii) It disturbs the natural hydrological process and also pollutes ground water as well as surface water. Sometimes radioactive substances like uranium also contaminate the water bodies through mine wastes.

iv) Extraction and processing of ores emits enormous quantities of air pollutants such as suspended particulate matter (SPM, soot, metal particles etc.).

v) Miners often suffer from serious respiratory and skin diseases like asbestosis, silicosis, blacklung disease etc., due to constant exposure to the suspended particulate matter and toxic substances.

3.10 MINE RESTORATION

It is the process of creating functional ecosystems (or sometimes industrial or municipal land) from mined land so that the wastes and pollutants no longer available to enter into any ecosystem. It includes material placement, stabilizing, capping, regarding, placing cover soils, revegetation, and maintenance. Rehabilitation management is an ongoing process.

Waste dumps are contoured to flattened and stabilize them against erosion. Sulfide containing ore are usually covered with a layer of clay to prevent its oxidation by rain or air to sulfuric acid. Open pit are backfilled and covered with topsoil, and plantation is promoted to help consolidation of the material. Fencing is often done to prevent access. Tailings dams are left to evaporate, and then covered with waste rock, clay and soil etc. followed by plantation to enhance stabilization. Rehabilitation in case of underground mines is relatively easier and less costly due to higher grade of the ore and lower volumes of waste rock and tailings. In some situations, stopes are backfilled with concrete slurry using waste, so that minimal waste is left at surface. Often in gold mines, rehabilitation is performed by scavenger operations which treat the soil within the plant area for spilled gold using modified placer mining gravity collection plants.

A holistic strategy for restoration of mine spoil must essentially include the following: (i) mechanism to store fertile top soil layer for use in post mining restoration operation, (ii) ensuring least disturbance and protection of the remaining parts of the affected ecosystems, (iii) rainwater harvesting, (iv) assisted soil remediation through addition of pond bed silt and sediment as well as earthworm, (v) assistance to available persistent rootstock, if any, (vi) attracting seed dispersers, (vii) direct seeding, (viii) vegetative cutting, and (ix) plantations, preferably a mixed native vegetation (x) use of microbial population for bioremediation and supplement the easy establishment of vegetation (xi) treatment to adjacent farmlands and streams affected by mining operations, and, (xii) preventive measures to mine induced groundwater pollution. Different market mechanisms could be applied to incorporate the costs of such activities. Policy measures and incentive should also be devised for taking care of such affirmative initiatives and market forces. As far as possible the cultural resources such as local knowledge and skills should be appreciated in addressing the challenge of mine spoil restoration.
A primary succession of vegetation in the mining areas could be catalyzed by natural regeneration of native forest species originating from remnant forests and ancient trees in the vicinity. In combination with direct seeding, it can increase the likelihood of restoration success. The natural process of succession is enhanced by the variety of fauna supported by the remnant vegetation, that help in seed dispersal in the adjacent areas. Sediments of aquatic systems like lakes, ponds, tanks act not only as a rich source of nutrients but also as a seed bank for a variety of grasses, herbs, shrubs and trees. This also stimulates microbial activity and improves the chemical and physical properties of the reclaimed soil. In peripheral dump areas root stocks can be supported to regenerate through a combination of rainwater harvesting. Direct seeding using a mixture of native species has proven to be cost-effective and ecologically viable restoration method. The seed mixture must be carefully selected based on physical and chemical properties of mine spoil as well as ecological, economic and social criteria. The composition includes framework species across taxa, herbs, shrubs and trees, early and late successional species, as well as a few keystone species to accelerate the restoration of a functional ecosystem. Framework species are a minimum number of indigenous species having the potential to accelerate biodiversity recovery and enhance natural regeneration to create a self sustaining forest ecosystem from a single plantation event. Similarly, keystone species are species which play a critical role in maintaining the structure of an ecological community, affecting many other organisms in an ecosystem and helping to determine the types and numbers of various other species in the community. Direct sowing methods in combination with minimal soil work, provides a large base for choice of species, and ensures high biodiversity per unit area and can also be combined with natural regeneration.

Examples of rehabilitation success of mine spoils in arid regions in India notes the use of a combination of rainwater harvesting, soil amendments and plant establishment methods using trees, shrubs and grasses. Such an approach is also socially acceptable as it enhances productivity of the systems and availability of products to people. Along with direct seeding, planting of large vegetative cuttings, and wherever possible, assistance to persistent root stock has provided effective results in Rajasthan.

**Check Your Progress 2**

**Note:**

a) Use the space given below for your answer.

b) Compare your answers with those given at the end of the unit.

1) Write a note on types of mining and operations.

........................................................................................................................................................................
........................................................................................................................................................................
........................................................................................................................................................................
........................................................................................................................................................................
........................................................................................................................................................................
........................................................................................................................................................................
........................................................................................................................................................................
........................................................................................................................................................................
2) Describe in brief on types of waste generated during mining and their management.

3) Enumerate various environmental impacts related to mining.

4) Enumerate different strategies for restoration of mines.

3.11 LET US SUM UP

- Mineral resources refer to material substances either composed of or extracted from minerals.
- Minerals can be divided into different categories such as metallic, non-metallic, precious and energy minerals.
- The term mining refers to the process of taking out minerals or their ores from the earth. Some minerals can be mined more easily as they are found at the earth’s surface, while others lie far beneath the surface and can be obtained by digging deep underground.
- Although mining provides a variety of socio-economic benefits, from the exploration to the closing stage, it has serious impacts on ecosystem, biodiversity, environment, health and socio-cultural systems.
- Examples of rehabilitation success of mine spoils in arid regions in India notes the use of a combination of rainwater harvesting, soil amendments and plant establishment methods using trees, shrubs and grasses.
3.12 KEY WORDS

Mineral : A mineral is an element or chemical compound that is normally crystalline and that has been formed as a result of geological processes.

Critical Mineral : These are minerals whose use is necessary for the production of essential goods.

Hydrothermal process : Any process associated with igneous activity involving the action of very hot waters.

Ore deposit : A mineral deposit at a certain place and time that can be sourced economically.

Mineral Reserves : These are the identified ore deposits that are yet to be exploited.

Tailings : These are the materials left over after the process of separating the valuable fraction from the uneconomic fraction of an ore.

3.13 REFERENCES AND SUGGESTED FURTHER READINGS


3.14 KEY TO CHECK YOUR PROGRESS

Check Your Progress 1

1) Your answer must include the following points:
   • Industrial revolution
   • Increased human needs

2) Your answer must include the following points:
   • On the basis of their electric conductivity and use
   • On the basis of major anion group present

Check Your Progress 2

1) Your answer must include the following points:
   • Depending on place of occurrence and excavation
   • Preparatory operations and Ore extraction operations
   • Ore processing
2) Your answer must include the following points:
   • Waste rocks, Tailings and Ore stockpiles
   • Terrestrial impoundments
   • Underground backfilling
   • Deep water disposal and recycling

3) Your answer must include the following points:
   • Land degradation
   • Air, water, soil and sound pollution
   • Health aspects

4) Your answer must include the following points:
   • Backfilling and plantation
   • Ecosystem perspective
   • Holistic strategy