INDUSTRIAL PROCESSES

Activity

1. Identifying some materials produced by industries in Uganda.

Product name	**Industry**
Clothes	Textile
Steel/iron bars	Steel and tube
Batteries	Electronic
Cement	Mining
Plastic equipment	Plastic
Fertilizers	Fertilizer industry
Soda and mineral water	Food/ beverage/ breweries

2. Complete the table by identifying industries with their corresponding products and classes.

Industry	**Product**	**Class of the industry**
Mining	Limestone, iron ore	Primary
Processing	Cars, drugs	Secondary
Service	Telecommunication	Tertiary

Common products from the industries of Uganda.

Industries consist of enterprises and organizations that produce or supply goods and services**.** The goods and services are important to the society as shown below.

Common product	**Use of the product**
Steel bars	Construction
Soda and mineral water	Human consumption
Cement	Construction
Fertilizers	Restoring soil fertility
Soaps and soap less detergents	For washing
Sanitizers	Killing micro organisms
Battery	Providing electric energy
Jelly	Human beautification

We are surrounded by rocks and minerals everywhere; on the ground we walk on, at the places of work, where we live and even the food we eat. There are several useful chemicals found in the rocks. These chemicals are obtained by the use of different chemical processes.

Most of the rocks are composed of naturally occurring inorganic solids that have a crystalline structure and a distinct chemical composition. These are known as **minerals.**

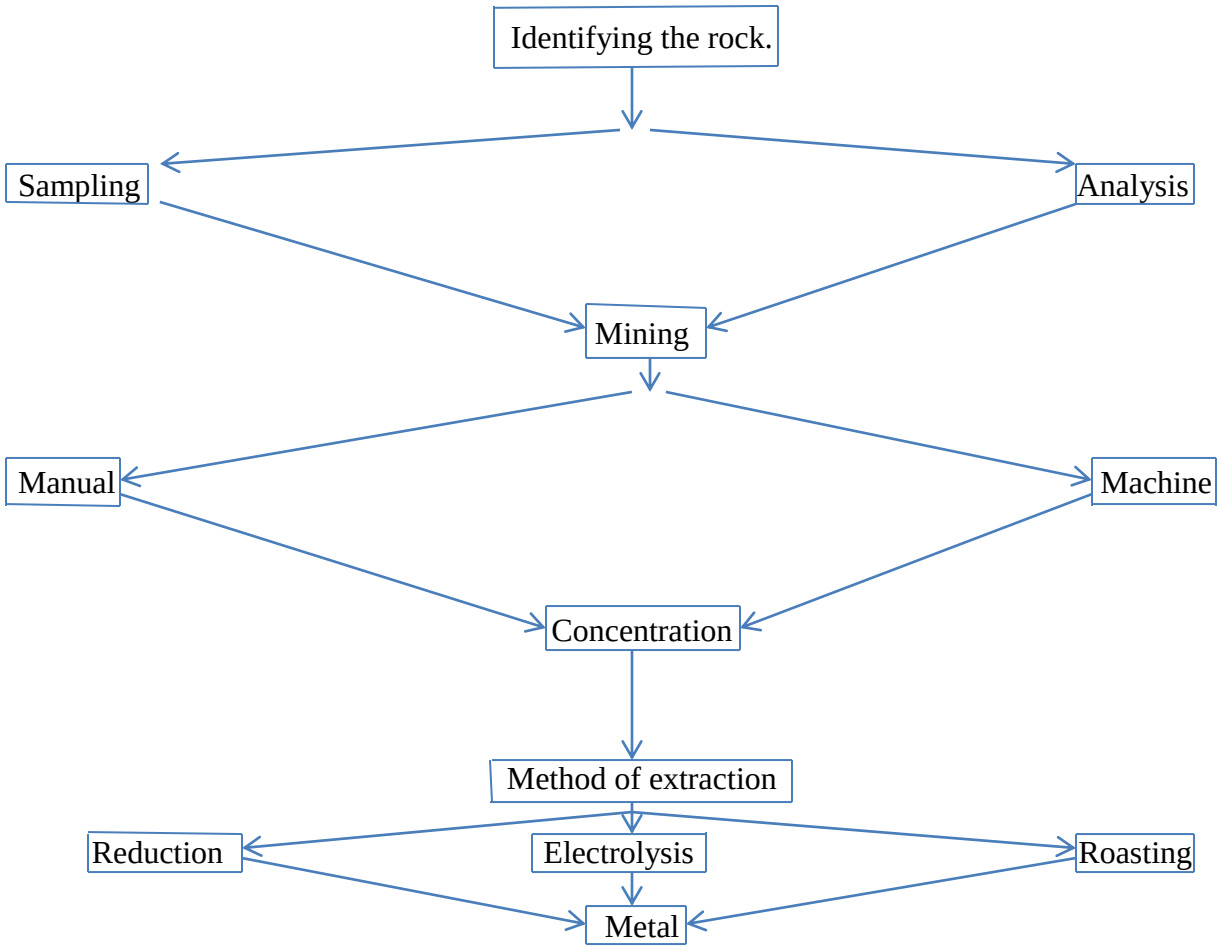
The table below shows some minerals, chemical formulae and their uses.

Mineral	**Chemical formula**	**Uses**
Silver	Ag	Making jewelry Making trophies Making electric wires Used in construction e.g roofing Making currency eg coins
Copper	Cu	Making electric wires. Making jewelry Used in construction eg roofing.
Graphite	C	Making pencil leads. Making lubricants. Making electrodes.
Iron pyrites (Iron disulphide)	FeS_2	Production of sulphur dioxide. Production of sulphuric acid Making of fertilizers due to its sulphur content.
Rock salt (Halite)	NaCl	Added to food to make it tasty. Used as preservative Used in water softening Making dry chemical fire extinguishers
Gypsum (plaster of Paris)- hydrated calcium sulphate	$CaSO_4.2H_20$	Manufacture of cement. Manufacture of plaster.
Haematite (Iron III oxide)	Fe_20_3	Making radiation shielding Production of iron and making steel and other iron products Making jewelry eg rings, nacklaces Making red pigments in paints, ceramics and cosmetics
Quartz (Silicon dioxide)	SiO_2	Making oscillators for watches, clocks, radios Glass manufacturing Used in construction
Calcite (Calcium carbonate)	$CaCO_3$	Used as building stones and in cement production Used in agriculture for soil treatment (neutralize acidic soils)

Dolomite(Calcium magnesium carbonate)	$CaMg(CO_3)_2$	Used as an ingredient in glass and ceramic production
Anhydrite	$CaSO_4$	Used as drying agent in plaster, paint and vanish.
Albite (Sodium feldspar)	$NaAlSi_30_8$	Used in the manufacture of glass and ceramics
Olivine (Magnesium Iron silicate)	$(Mg,Fe)_2Si0_4$	Added to blast furnaces to remove impurities and to form slag
Orthoclase (Potassium feldspar)	$KAlSi_30_8$	Manufacture of glass and ceramics. Used in production of cement and concrete.

Activity

Identifying the processes involved in obtaining useful chemicals from rocks.



Discussion questions

1. Why are sampling and analysis of the rock necessary before mining?

Sampling helps in obtaining the information necessary for the economic assessment of the ores.

Analysis gives information about the ore before massive mining can begin.

2. State 2 ways in which sampling can be done.

Hand sampling

Machine sampling

3. Compare manual and machine methods of mining.

Manual mining consumes time than machinery method

4. State 3 properties of rock which are considered before concentration of the rock is done.

Chemical composition of the ore

Conductivity if the ore

Solubility of the ore

Density of the ore

5. Outline 3 ways in which the rock is concentrated.

Froth flotation

Roasting

Gravity separation

6. Complete the table by identifying the examples of metals that can be extracted by each of the methods indicated.

Method of extraction	***Examples of metal extracted***
Electrolysis	*Sodium, potassium*
Chemical reduction	*Iron, aluminum*
Roasting	*Zinc , copper*
No extraction process	*Gold, silver*

EXTRACTION AND PURIFICATION OF METALS

An ore is a compound in which a metal is extracted. The table below shows metals and their principle ores.

Metal	**Ores**	**Formula**
Sodium	Halite/ rock salt Cryolite	NaCl Na_3AlF_6
Potassium	Salt petre	KNO_3
Aluminum	Bauxite	$Al_2O_3.2H_2O$
Zinc	Calamine Zincite Zinc blend	$ZnCO_3$ ZnO ZnS
Iron	Spathic Haematite Magnetite Pyrite	$FeCO_3$ Fe_2O_3 Fe_3O_4 FeS_2
Copper	Copper pyrite(Copper iron sulpide) Malachite(Copper II carbonate hydroxide) Cuprite	$CuFeS_2$ $CuCO_3.Cu(OH)_2$ Cu_2O
Lead	Galena Cerussite Anglesite	PbS $PbCO_3$ $PbSO_4$
Silver	Silver glance (Argentite)	Ag_2S
Gold	Calaverite Sylvanite	$AuTe_2$ $(Au,Ag)Te_2$
Magnesium	Dolomite	$CaMg(CO_3)_2$

Methods of extracting metals from their respective ores.

The methods of extraction of their respective ores depend on their position in the reactivity series. There are 2 main methods of extracting

(a) **Electrolysis**

Used to extract highly reactive metals because they form very stable compounds eg Potassium, Calcium, Magnesium, and Aluminum. However, it's an expensive.

(b) **Reduction of the ores using carbon (coke) or carbon monoxide (CO).**

This is used for moderately reactive metals e.g Zinc, Iron, Tin, Lead and Copper.

Note. Hydrogen can also be used to reduce the oxides of metals. However the process is very expensive.

Extraction of copper.

Raw material

Copper pyrite

Silicon dioxide

Process of production

The ore is crushed into fine powder to increase its surface area. It's then mixed with water containing a frothing agent such as palm oil in a container.

Compressed air is blown into the mixture. The oil coated particles will float to the top of the tank while the rocky impurities such as silicon dioxide settle at the bottom of the tank.

The oil coated particles are skimmed off and dilute sulphuric acid is added to break the particles of the froth, filtered and dried.

Dried ore is roasted in air in a blast furnace to form copper I sulphide, Iron II oxide and sulphurdioxide gas.

$CuFeS_2\ (s) + O_2\ (g) \longrightarrow Cu_2S\ (s) + FeO\ (s) + SO_2\ (g)$

Silicon dioxide is added to the resultant mixture in the absence of air in the furnace to remove Iron II oxide and leaving copper I sulphide.

$FeO\ (s) + SiO_2\ (s) \longrightarrow FeSiO_3\ (l)$

Iron II silicate floats on the surface of the mixture where it is skimmed off.

Copper I sulphide is heated in controlled amount of air to form copper and sulphur dioxide gas.

$Cu_2S\ (s) + O_2\ (g) \longrightarrow Cu\ (s) + SO_2\ (g)$

Impure copper (blister copper) is purified by electrolysis where pure copper is used as a cathode while impure copper is used as the anode using copper II sulphate solution as the electrolyte.

At cathode, copper gains electrons to form copper metal

$Cu^{2+}\ (aq) + 2e \longrightarrow Cu\ (s)$

At anode, impure copper dissolves leading to the formation of copper II ions in the solution.

$Cu\ (s) \longrightarrow Cu^{2+}\ (aq) + 2e$

Side effects of the process and their mitigations.

Toxic fumes produced can be inhaled by workers leading to respiratory diseases like lung cancer, bronchitis and eventually suffocation and death.

This can be mitigated by putting on personal protective gears like face masks and ensuring proper ventilation in the workplace.

Sulphur dioxide produced as a by-product reacts with water forming acid rain that affects the walls of houses and aquatic animals as well as plants.

This can be mitigated by using scrubbers to capture sulphur dioxide and using it for production of sulphuric acid.

Social benefits of the process

Employment opportunities, income earning and improved standards of living.

Increased government revenue to the government from taxes charged on the industries, leading development of infrastructures like roads, hospitals, schools hence better standards of living.

Extraction of aluminum

Raw material

Bauxite

Sodium hydroxide.

Process of production

Bauxite is ground into powder to increase the surface area and heated to convert any Iron II oxide impurity present into Iron III oxide and also to remove water of crystallization.

The powder is then boiled with ho concentrated sodium hydroxide solution that dissolves the amphoteric aluminum oxide and acidic silicon dioxide to form sodium aluminate and sodium silicate in the container.

$Al_2O_3\,(s) + 2\,NaOH\,(aq) \longrightarrow NaAlO_2\,(aq) + H_2O\,(l)$

$NaOH\,(aq) + SiO_2\,(s) \longrightarrow NaSiO_3\,(aq) + H_2O\,(l)$

The un dissolved basic Iron III oxide is filtered off. Carbon dioxide is bubbled through the filtrate to precipitate aluminum hydroxide leaving the silicate ions in the solution.

$NaAlO_2\,(aq) + CO_2\,(g) \longrightarrow Al(OH)_3\,(aq) + Na_2CO_3\,(aq)$

Aluminum hydroxide produced is then washed several times, dried and heated strongly to produce anhydrous aluminum.

$Al(OH)_3\,(s) \longrightarrow Al_2O_3\,(s) + 3H_2O\,(l)$

Aluminum oxide is dissolved in cryolite to lower its melting point to $800^{o}c$.

Electrolysis of molten aluminum oxide occurs using graphite electrode in an Iron bath lined with graphite (carbon)

At cathode, a grey solid is formed.

Al^{3+} (aq) + 3e $\longrightarrow$ Al (s)

At anode, a colorless gas that relights a glowing splint is formed.

$2O^{2-}$ (aq) $\longrightarrow$ O_2 (g) + 4e

Aluminium is collected at the bottom of the cell because aluminum has a higher density that the electrolyte.

Side effects of the process and their mitigations.

Burns from contact with hot surfaces and chemical spills leading to injuries to the workers. This can be mitigated by wearing personal protective equipment like gloves.

Social benefits of the process.

Employment opportunities, income earning and improved standards of living.

Source of government revenue, hence improved infrastructure using the revenue like roads, hospitals, and schools thus improved standards of living.

Extraction of Iron

Raw material

Haematite

Coke

Limestone.

Process of production.

The raw materials such as heamatite, coke and limestone are introduced into the blast furnace.

Hot air is blown into the furnace at the bottom which comes into contact with red hot coke producing carbon dioxide.

C (s) + O_2 (g) $\longrightarrow$ CO_2 (s)

Higher up the furnace, oxygen is not enough, the rising carbon dioxide reacts with more coke forming carbon monoxide.

CO_2 (g) + C(s) $\longrightarrow$ CO (g)

The carbon monoxide gas produced reduces heamatite (Iron III oxide) to molten Iron.

Fe_2O_3 (s) + 3CO (g) $\rightleftharpoons$ 2Fe (s) + $3CO_2$ (g)

Limestone is decomposed by heat to form calcium oxide and carbon dioxide.

$CaCO_3$ (s) $\longrightarrow$ CaO (s) + CO_2 (s)

Calcium oxide formed reacts with the main impurity in Iron, silicon dioxide to form calcium silicate, a slag which floats on the top of the molten Iron and is tapped off.

The pig Iron is then removed from the bottom of the furnace. It is purified by passing air through molten Iron to remove non molten metal impurities.

Side effects of the process and their mitigations.

Poisonous fumes produced from the plant leading to respiratory diseases when inhaled hence death.it can be mitigated by wearing personal protective gears like face masks.

Excessive noise from the plant causing hearing impairment. This can be mitigated by wearing personal protective gears.

Social benefits of the process

Employment opportunities as the residents get salaries hence improved standards of living.

Slag is used as a fertilizer hence improving crop yields and earning of income by farmers hence improving their standards of living.

Nitrates as fertilizers in food production and their production from nitrogen in the air.

Nitrogen as the main constituent of sir is essential for living organisms. Plants require nitrogen to grow. Animals obtain nitrogen by feeding on plants.

However, nitrogen gas must first be converted to nitrates that can be used by plants and animals as source of nitrogen.

Question

What name is given to the process by which nitrogen is converted into its compounds?

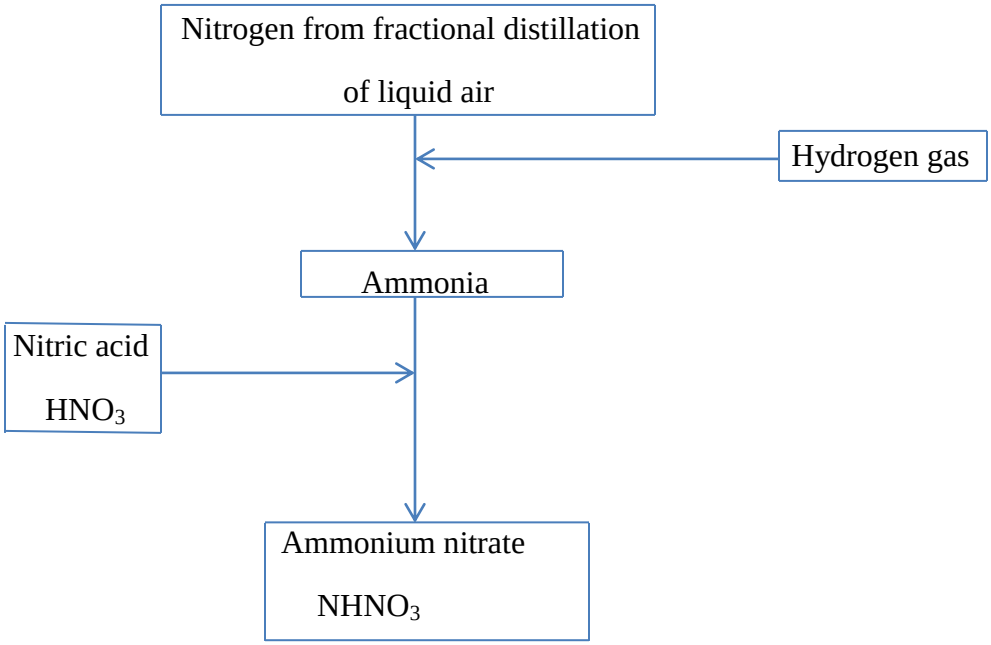
Nitrification

Nitrogen has two major uses.

Used in the manufacture of ammonia

Used in the manufacture of fertilizers.

The flow chart below shows how nitrates are obtained from nitrogen.



Ammonia

Ammonia naturally occurs in many parts of the environment, such as in soils, air and vegetation. It's an essential compound of nitrogen and hydrogen. Ammonia however can be prepared in the lab.

Lab preparation of ammonia

The apparatus is set up as shown in the fig 11.3. The flask has to be slanted to prevent water produced by the reaction from running into the hot flask where it causes the glass to crack.

A mixture of calcium hydroxide and ammonium chloride is first grounded thoroughly. It is then placed in the flask and heated, producing ammonia which is collected by downward displacement of air since it is less dense than air. The gas is dried by calcium oxide.

$$Ca(OH)_2\,(aq) + 2NH_4Cl\,(aq) \longrightarrow CaCl_2\,(aq) + 2H_2O\,(l) + 2NH_3\,(g)$$

Instead of calcium hydroxide, sodium hydroxide or potassium hydroxide may be used, in each case; the flask would be placed in the vertical position and heated.

Ammonium sulphate may be used instead of ammonium chloride

The usual drying agents such as conc. Sulphuric acid and anhydrous calcium chloride are not used because ammonia reacts with them to form ammonium sulphate and tetra ammine calcium chloride respectively.

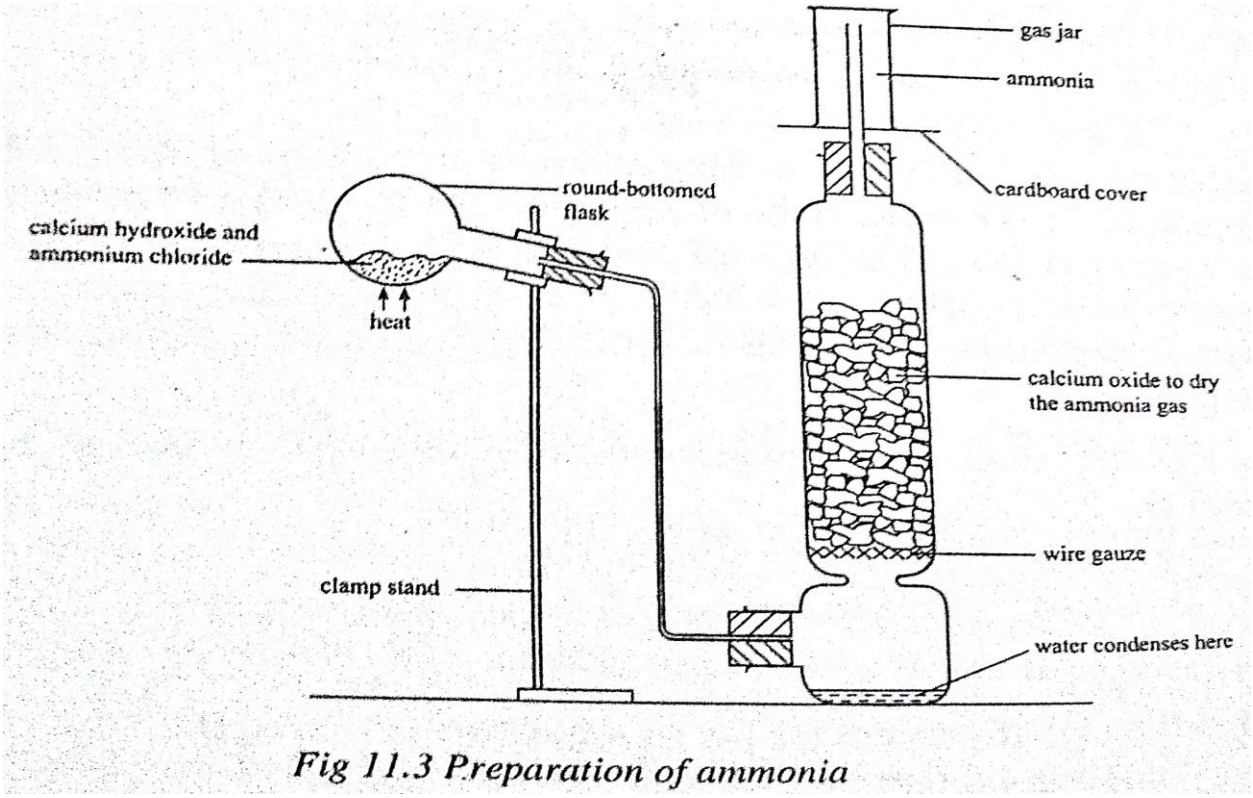


Fig 11.3 Preparation of ammonia

Ammonia is converted into a variety of fertilizers such as potassium nitrate, ammonium nitrate, ammonium sulphate, diammonium phosphate. These fertilizers are known as **inorganic fertilizers**.

There are various fertilizers; however some are better than others depending on their nitrogen composition. Consider the fertilizers given in the table below.

Fertilizer	Chemical formula
Ammonium nitrate	NH_4NO_3
Potassium nitrate	KNO_3
Urea	NH_2CONH_2

(a) Calculate the molar mass of each of the fertilizer in the table below. (C=12, K=39, H=1, N=14, O=16)

(b) Calculate the percentage composition of nitrogen in each of the fertilizer.

(c) Write the fertilizers in descending order with respect to their percentage composition of nitrogen.

(d) Identify the best fertilizer out if the 3 fertilizers. Give a reason for your answer.

Preparing ammonium nitrate

Raw material

Nitrogen

Hydrogen

Process of production

Nitrogen gas from fractional distillation of liquid air is reacted with hydrogen in the ration of 1:3 respectively to form ammonia gas by Haber process. The reaction requires a temperature of 450-500^{o}c and a pressure of 200 atmospheres and finely divided Iron catalyst.

N_2 (g) + $3H_2$ (g) $\rightleftharpoons$ $2NH_3$ (g)

Ammonia produced is heated in excess oxygen in presence of platinum catalyst forming nitrogen monoxide and water all in the tank.

$4NH_3$ (g) + $5O_2$ (g) $\longrightarrow$ 4NO (g) + 6 H_2O (l)

Nitrogen monoxide is cooled and then oxidized further by oxygen to form nitrogen dioxide.

2NO(g) + O_2 (g) $\longrightarrow$ $2NO_2$ (g)

Nitrogen dioxide is dissolved in water in presence of oxygen to form nitric acid.

$4NO_2$ (g) + $2H_2O$ (l) + O_2 (g) $\longrightarrow$ $4HNO_3$ (l)

Nitric acid formed is reacted with Ammonia gas to form ammonium nitrate.

Side effects of the process and their mitigations.

Some fertilizers when dissolved in water, from acidic solutions that alter the soil PH hence low crop production. This can be mitigated by use of alternative fertilizes like organic manure.

Run off of these fertilizers into water bodies increase algae blooms cutting off the supply of oxygen leading to suffocation of aquatic animals eventually death. This can be mitigated by use of alternative fertilizers like organic manure.

Social benefits of the process.

Source of employment opportunities a residents get salaries hence improved standards of living

High levels of nutrient supplied to crops leading to improved crop production and income earnings from the yields hence better standards of living.

Types of fertilizers.

There are majorly 2 types of fertilizers ie;

1. Natural fertilizers.

These are obtained from plants and animal wastes eg manure. They are referred to as organic manure.

2. Synthetic fertilizers.

These are fertilizers manufactured artificially. They contain one or more elements required by plants for proper growth eg ammonium nitrate, potassium nitrate, ammonium sulphate.

Comparison between natural and synthetic fertilizers.

Natural fertilizers	Synthetic fertilizers
Derived from plants and animal remains	Derived from mineral acids and other inorganic compounds
Contain less amounts of NPK	Contain more amounts of NPK
Add organic matter to the soil.	Don't add organic matter to the soil
Slow in their action	Faster in their action
Less likely to cause damage to the leaves and roots.	Can easily cause damage to the leaves and roots

Manufacture of cement

Raw materials.

Clay

Limestone

Gypsum

Procedures

Crush a mixture of limestone and clay into a fine powder.

The fine powder is then mixed with water and allowed to flow in a rotating drum in which it is strongly heated to about 1500^{o}c.

Calcium oxide reacts with aluminum and silicon to form lumps of calcium aluminate and calcium silicate. The lumps are crushed to form cement as fine powder.

Gypsum is added during the grinding to moderate the reaction between cement and water.

Cement is packed in bags ready for use.

Side effects of the process and their mitigations

Production of dust during crushing that leads to respiratory problems like bronchitis or asthma. This can be mitigated by putting on personal protective gears like face masks.

Production of too much noise during crushing of limestone that leads to hearing impairment after exposure for a long period of time. This can be mitigated by using personal protective gears like ear plugs

Cement contains alkaline substances that cause skin and eye irritation and severe burns on prolonged exposure. This can be mitigated by providing workers with protective gloves, goggles and clothing.

Carbon dioxide emissions during cement production leading to greenhouse effect end eventually global warming. This can be mitigated by using renewable energy sources like biomass, solar and wind to replace fossil fuels.

Social benefits

Employment opportunities, salary earning and improved standards of living.

Source of government revenue as the industry pay tax leading to improved infrastructure like roads hence improved standards of living.

Manufacture of chlorine and sodium hydroxide using mercury cathode cell

Raw materials

Concentrated sodium chloride solution (brine)

Mercury cathode

Graphite

Production process

Chlorine and sodium hydroxide are manufactured by electrolysis of concentrated sodium chloride solution using graphite anode and mercury cathode cell.

At anode, chloride ions and hydroxide ions migrate to the anode and the chloride ions are discharged to form chlorine gas.

$2Cl^-(aq) \longrightarrow Cl_2(g) + 2e$

At cathode, sodium ions and hydrogen ions migrate to the cathode and sodium ions are discharged to form sodium metal.

$Na^+(aq) + e \longrightarrow Na\ (s)$

Sodium mixes with mercury to form sodium amalgam.

$Na(s) + Hg(s) \longrightarrow NaHg\ (s)$

Sodium amalgam reacts with water forming sodium hydroxide , mercury and hydrogen gas.

$NaHg\ (s) + H_2O\ (l) \longrightarrow NaOH\ (aq) + Hg(s) + H_2(g)$

Side effects of the process and mitigations.

Suffocation due to the release of other gases like hydrogen. This can be proper use of personal protective equipment like gas masks.

Exposure to high concentration of chlorine leading to respiratory problems, eye irritation and skin burns resulting to injuries, suffocation and death. This can be mitigated by proper use of personal protective gears like gas masks, protective clothing and goggles.

Social benefits of the process.

Manufacturing plant is the source of government revenue leading to the development of infrastructure like roads, hospitals, schools hence improved standards of living.

Source of employment opportunities to the residents, salary earning and improved standards of living.

Chlorine is used in the manufacture of weed killers which when applied in our gardens will improve crop yields hence income earning and improved standards of living.

Sodium hydroxide is used in the manufacture of soaps that is use in homes to improve on hygiene and style of living.

Chlorine is used in the manufacture of bullet proof vests worn by soldiers and police officers hence their protecting lives.

Manufacture of sulphuric acid.

Raw materials

Sulphur dioxide gas

Oxygen gas.

Process of production

Sulphurdioxide free from impurities is heated with dry pure oxygen at a temperature of 450-500^{o}c and a pressure of about 1-3 atmospheres in presence of vanadium (v) oxide catalyst to form sulphur trioxide. The reaction occurs in the combustion cylinder.

$SO_2\ (g) + O_2\ (g) \rightleftharpoons SO_3\ (g)$

Sulphur trioxide is dissolved in little water to form oleum.

$SO_3\ (g) + H_2SO_4\ (l) \longrightarrow H_2S_2O_4\ (l)$

Oleum is diluted carefully with moderate amount of water to form 98% concentrated sulphuric acid.

$H_2S_2O_4\ (l) + H_2O\ (l) \longrightarrow H_2SO_4\ (l)$

Side effects of the process and their mitigations.

Toxic fumes and gases like sulphur dioxide and sulpur trioxide from the process which when inhaled may cause chronic respiratory issues and irritation of the throat and nasal passages. This can be mitigated by proper use of personal protective equipment like gas masks.

Acid spills on the surfaces leading to accidents like burns resulting to severe injuries as the acid is very dangerous. This can be mitigated by proper use of personal protective gears like acid resistant gloves, aprons and boots.

Accidental leaks or emissions of sulphur dioxide and sulphur trioxide can harm the environment leading to green house and eventually global warming since they are greenhouse gases. This can be mitigated by installing scrubbers to capture the gases before they are released into the atmosphere.

Social benefits of the process.

Employment opportunities to the residents, salary earning and improved standards of living

Manufacture of fertilizers hence improved farm yields thus improved style of living.

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