1. INTRODUCTION

One of the results of development in the world is the problem of the pollution. The problem of water pollution began from the earliest time, with the expanding industries, discharging their waste water in neighboring streams which become unfit as a surface of industrial water supply.

The purpose here is to present a concise account of the application of ion exchange to separating the components of waste water with particle emphasis on industrial waste water.

1.1. Pollution

Many important process involving chemicals, some of which have given rise to significant environmental problems, have involved transfer of chemical form on reservoir or compartment to another [1].

1.1.1. Type of pollution

1.1.1.1. Air pollution

In the present in the air particles, smoke and gases are rise concentrate than normally [2-4].Pollution of atmospheric appear in many sources and in variety way [5].

a- Continuous release, in a dilute form, of toxic or corrosive gases (gases which give corrosive solution on contact with water such as SO_X and NO_X).

b- Intermitted and normally infrequent release, in a more concentrated form, of toxic or corrosive gas.

c- Foul-smelling gases which may be harmful only nuisance such as hydrogen sulphide, hydrogen fluoride and silicon tetrafluoride.

d- Gases which are not harmful to man in the concentration encounter but which are harmful to vegetation.

e- Dust which may be toxic, or an irritant, or just nuisance such as cement, phosphate and fertilizers dust.

f- Smuts including contamination ones.

g- Sprays including aerosols.

h- Polluted rain is considered to be the most serious disadvantage of industrialization all over world.

1.1.1.2. Soil pollution

Trace elements such as lead, mercury, cadmium, zinc, cobalt and chromium originating from various source may finally reach surface soil. These metals are concentrated in the plant tissues and then transferred across the food chains into human beings. Contamination of soil occurs mainly in industrial regions and within center of large settlements where vehicles and municipal wastes are the most important source of trace metals. In Toyma, in Japan, the citizens had suffered from strange disease that made them enable to move and very short. It had been discovered that cadmium, found in wastes of zinc melting industry, was thrown into rivers, transferred into the soil and then into the rice plant, the principal food for Japanese, was the cause of this disease. In addition to aerial sources of trace pollutants, fertilizers, sewage derived materials have been added to the trace element pool in soil [6].

1.1.1.3. Radioactive pollution

Radioactive isotopes are used in industry , agriculture, medicine and research work to gather with the activities related the nuclear fuel cycles generate active wastes. Wastes which generally contain atom that undergo radioactive decay and emits radiation are referred to be as radioactive wastes [7]. In medicine nuclear applications include diagnostic and therapeutic procedures (^{99m}Tc, ^{60}Co) [8]. In research work and similar activates which need release of radwaste to the environmental (^{65}Zn, ^{74}As, ^{115}Cd), in addition to the uranium fission products. Hence, nuclear reactors radwaste solutions may contain a variety corrosion and fission product radioisotopes. They appear in different concentrations and ionic forms, depending on the kind and size of the fuel element leak and the chemical composition of radwaste solution. Dominating radioactive corrosion products include ^{53}Cr, ^{54}Mn, ^{59}Fe, ^{58,60}Co, ^{65}Zn and ^{124}Sb. The dominating fission products are mainly ^{90}Sr, ^{131}I and ^{134,137}Cs. The presence of some of these ions may effect chromatographic behaviour of each other in decontamination processes. Finally, short lived radwaste generated in industry, medicine and research is stored at the place of origin until its activity falls to back ground level, after which it is considered as nonradioactive waste [9,10].

1.1.1.4. Water pollution

Throughout history, the quality of drinking water has been a factor determining human welfare. Fecal pollution of drinking water has frequently caused waterborne diseases that have decimated the populations of whole cities. Unwholesome polluted by natural sources has caused great hardship for people forced to drink it or used it for irrigation. Today there are still occasional epidemics of bacterial and viral diseases caused by infections agents carried in drinking water-ominously, a major out break of deadly cholera in Peru in 1991, the first in the Western Hemisphere in this century. However, waterborne diseases have in general been well controlled, and drinking water in technologically advanced countries in the 1980 is remarkably free of the disease-causing agents that ware very common water contaminants only a few decades earlier. Currently, waterborne toxic chemicals pose the greatest thereat to the safety of water supplies in industrialized nations. This is particularly true of ground water in the U.S. rivers, lakes, and streams. In some areas, the quality of groundwater is subject to a number of chemicals threats. There are many possible sources of chemicals contamination. These include wastes from industrial chemical production, metal plating operations, and pesticide runoff from agricultural lands. Some specific pollutants include industrial chemical such as chlorinated hydrocarbons; heavy metal including cadmium, lead, and mercury, saline water, bacteria, particularly coliforms, and general municipal and industrial wastes. Since World War II there has been a tremendous growth in the manufacture and use of synthetic chemicals. Many of the chemicals have contaminated water supplies. Two examples are insecticide and herbicide runoff from agricultural land, and industrial discharge into surface waters. Most serious, though, is the threat to ground water from waste chemical dumps and landfills, storage lagoons, treating ponds, and other facilities. It is clear that water pollution should be a concern every citizen. Understanding the sources, interactions, and effects of water pollutions is essential for controlling pollutants in an environmentally safe and economically acceptable manner. Above all, an understanding of water pollution and its control depends upon a basic knowledge of aquatic environmental chemistry. That is why these text covers the basics of aquatic chemistry prior to discussing pollution. Water pollution may be studied much more effectively with a sound background in the basic properties of water, aquatic microbial reactions, sediment-water interactions and other factors involved with the reactions, transport and effect of this pollutants [11]. The present of in concentration higher than normal in natural water ways (lake, streams, rivers, and oceans) of dissolver or suspended foreign material such as silt, chemicals, fecal matter, metallic elements, organic material, or nutrients [5], [12-15]. It is convenient to divide them into classes, as follows:-

1.1.1.4.1. Excreta and organic industrial waste

If the organic constituent are excessive even after the treated or untreated waste water is diluted by discharge into a body of water, the biochemical oxygen demand of the stabilizing organisms may deplete the available oxygen content of water producing pollution. The effluent from sewage plants, food processing, paper making, malting and distillation process, all contribute to the biochemical oxygen demand mad on natural water. The biochemical oxygen demand (B.O.D.) should be reduced to 20 mg/L., and suspend solids (S.S) to 30 mg/L. before discharge a body of water. (B.O.D. is a measure of the amount of oxygen which well be used in the biological decomposition of the organic matter present in the influent).

1.1.1.4.2. Infection agents

Arising mainly from excreta, pathogenic bacteria must be prevented from contaminating potable water. Coliform organisms which can be detected and estimated may be used to monitor water system. It should be noted that a negative test does not mean that the water is virus-free.

1.1.1.4.3. Plant nutrients

This arise from two main source : sewage which subjected to tertiary treatment, and agricultural land drainage. The build of these nutrients in water system is called eutrophication the nutrients lead to a rapid increase in algae, normally seen as blue-green algae on the surface, and because of their high consumption of oxygen from the water, the body of water ceases to be able to support animal life.

1.1.1.4.4. Organic pesticides

In the early part of the century, with the all sample chemicals, mainly inorganic salts, it was possible to keep people is fed on small diversified farms where labour was plentiful and cheap, cultural practices blocked the build-up of pests. There followed arrange of organo-chloro compounds, organo-phosphate, and other broad-spectrum poisons- (referred to as DDT general) these were supposed to usher in a new era of industrialized agricultures to solve pest problems for ever. The environment was saturated with the persistent poisons, pests developed resistance to them, and many other food chains with serious results. The use of this type of pesticide are the hormones (narrow-spectrum biochemical) and biochemical controls (parasites) which aim to pinpoint control without poisoning the ecosystem.

1.1.1.4.5. Waste mineral and chemicals

Heaps of mineral waste or chemical waste can be leached by rain or oxidized by air to harmful solutions and air borne release. Many different chemicals have been discharged into water ways and done immense damage. Toxics may alter the biological activity of streams. Changes in pH due to releases of acids or alkalis may kill off the animal life To combat the effects, upper and lower pH limits may be set for discharges, and upper limits have been set for many toxics including heavy metals, cyanide phenols [16,17].

1.1.1.4.6. Oil

Oil pollution of the sea has steadily increase with the increased used oil . The recent major disaster, the explosion of the tanker Betelgeuse in Bantry Bay. Fire in January 1979 which resulted in the loss of 51 lives, and the wrecking of Amacocadiz on the coast of Brittany, which the loss, on a highly sensitive coasts of 220.000 tons of light arabian crude oil, have combined to bring the attention of the media of the world such vulnerable containers, while the oil well below-ant in the Golf of Mexico emphasized the problems of under sea wells[18,19].

1.1.1.4.7. Radioactive liquid waste

Radioactive waste is defined as the material that need to be disposed of from power plants, laboratories, and other places that work with radioactive materials. The various process used in the nuclear fuel cycle and in the application of radionuclides in research, medicine and industry generate a range of low-and intermediate-level liquid waste streams [20,21].

1.2. Toxicity and Chemistry of Some Heavy Metals

1.2.1. Toxicity of heavy metals

Heavy metals such as mercury, lead, zinc, and ... etc. Play an important role in human life. Table (1) shows occurrence and significance of trace elements in natural wastes and effect him on human body [22].

1.2.2. Chemistry of some heavy metal

1.2.2.1. Copper

Copper mainly occurs in the oxidation states (I) and (II) and it an element known and used from ancient times (Bronze Age). Its minerals and compounds are widely abundant on the earth's crust as sulphides, arsenides, chlorides and carbonates, and it is still used in alloys such as brass (Cu-Zn) and bronze (Cu-Sn). The metal is oxidized in moist air forming a green coating of carbonate. It's thermal and electrical conductives are well know and utilized domestically and industrially. Copper is a constituent of O_2-transporting pigment and redox enzymes, and hence is essential to life. However, in large quantities it is toxic to plants and invertebrates but less so to mammals. Pollution by copper is centered upon areas of industrial used and agricultural applications [23].

Table (1) The occurrence and significance of trace elements in natural wastes and effect him on human bod

Element	*Source*	*Effect and significance*	*U.S.Public Health Service Limit, mg/liter[25]*	*Occurrence: % of Samples, highest and mean concentrations (μg/liter)2 [24]*
Arsenic	**Mining by-product, pesticides, chemical waste**	**Toxic, possibly carcinogenic**	**0.05**	**5.5% (above 5 μg/L),336, 64**
Beryllium	**Coal, nuclear power and space industries**	**Acute and chronic toxicity, possibly carcinogenic**	**Not given**	**Not given**
Boron	**Coal, detergent formulation, industrial wastes**	**Toxic to some plants**	**1.0**	**98% (above 1 μg/L), 5000, 101**
Cadmium	**Industrial discharge, mining waste, metal plating, water pipes**	**Replaces zinc biochemically, causes high blood pressure and kidney damage, destroys testicular tissue to aquatic biota**	**0.01**	**2.5%, not given, 9.5**
Chromium	**Metal plating, cooling-tower water additive (chromate), normally found as Cr(VI) in polluted water**	**Essential trace elements (glucose tolerance factor), possibly carcinogenic as Cr(VI)**	**0.05**	**2405%, 112, 9.7**

Table (1) Continuous

Copper	**Metal plating, industrial and domestic wastes, mining, mineral leaching**	**Essential trace element, not very toxic to animals, toxic to plants and algae at moderate levels**	**1.0**	**74.4%, 280, 15**
Fluorine (fluoride ion)	**Natural geological sources, industrial waste, water additive**	**Prevents tooth decay at about 1 mg/L, causes mottle teeth and bon damage at around 5 mg/L in water**	**0.8-1.7 depending on temperature**	**Not given**
Iodine (iodide)	**Industrial waste, natural brines, seawater intrusion**	**Prevents goiter**	**Not given**	**Rate in fresh water**
Iron	**Corroded metal, industrial water, acid mine drainage, with iron minerals**	**Essential nutrient (component of hemoglobin) not very toxic, damage materials (bathroom fixtures and closing)**	**0.05**	**75.6%, 4600, 52**
Lead	**Industry, mining, plumbing, coal, gasoline**	**Toxicity (anemia, kidney disease, nervous system), wildlife destruction**	**0.05**	**19.3% (above 2 µg/L), 140, 23**
Manganese	**Mining, industrial waste, acid mine drainage, microbial action on manganese minerals at low pE**	**Relatively nontoxic to animals, toxic to plants at higher levels, stains materials (bathroom fixtures and closing)**	**0.05**	**51.4% (above0.3 µg/L), 3230,58**

Table (1) Continuous

Mercury	**industrial waste, mining, pesticides coal**	**Acute and chronic toxicity**	**Not given**	**Not given**
Molybdenum	**Industrial waste, natural sources, cooling-tower water additive**	**Possibly toxic to animals, essential for plants**	**Not given**	**32.7 (above 2 µg/L), 5400, 120**
Selenium	**Natural geological sources, sulfur, coal**	**Essential at low levels, causes "alkali disease" and "blind staggers" in cattle, possibly carcinogenic**	**0.01**	**Not given**
Silver	**Natural geological sources, mining, electroplating, film-processing wastes, disinfect ion water**	**Causes blue-grey discoloration of skin, mucous membranes, eyes**	**0.05**	**6.6% (above 0.1µg/L), 38, 2.6**
Zinc	**Industrial waste, metal plating, plumbing**	**Essential element in many metalloenzymes, aids wound healing, toxic to plants at higher levels; major component of sewage sludge, limiting land disposal of sludge**	**5.0**	**76.5% (above 2 µg/L), 1180, 64**

1.2.2.2. Zinc

Zinc in the group 12 metals have an ns^2 configuration of outer electron and although they contain d and f electrons, these are not involved in bonding. Hence their chemical behavior and properties position them with the s- and p- block electrons. They all form compounds in their II oxidation state. It may be used in fertilizers for some zinc-deficient soils because some known pathological conditions are associated with dietary deficiencies in zinc [26].

1.2.2.3. Cadmium

Cadmium in the group 12 metals have an ns^2 configuration of outer electron, and, although they contain d and f electrons, these are not involved in bonding. They all form compounds in their II oxidation state. It pollution originates from smelters, incineration of plastics and its pigments, fossil, fuels, electroplating, metallurgical processes ...etc. Recently, use on land of swage sludge with a high concentration of metals, including cadmium, as fertilizers has caused concentration cadmium is generally highly available to plants although availability depends on the composition and presence of complexing agents in the soil [26].

1.2.2.4. Nickel

Nickel can be found in nature in combination with sulphur, arsenic and antimony ores (e.g. pentlandite($(Ni, Fe)_9S_8$; millerite NiS) but is mined economically only in few areas of the world. Following periodic trends it exists at the low stable oxidation state of (II) with coordination numbers of 4, 5 or 6 with diverse and complex stereochemistries. The metal is relatively unreactive towards water, air or fluorides, hence it is used, by electroplating, for protection of other metals. It is relatively toxic to most plants but much less to mammals, and it may pollute areas locally where it is mined or worked [23].

1.3. Different Tools Used for the Management of Waste Water

The processes available for treatment of liquid wastes fall generally into three main categories; chemical precipitation, evaporation and ion exchange. Other processes are being used but not extensively [27].

1.3.1. Chemical precipitation

Chemical precipitation methods based on the coagulation-flocculation-separation principle are mostly used for the treatment of liquid effluents from research establishments, and also reprocessing plants. Most radionuclide and heavy metals can be precipitated, co-precipitated and adsorbed by insoluble compounds, e.g. hydroxides, carbonates, phosphates, ferrocyanides and antimonates, and also removed from solution. However, the separation is never complete for several reasons, and the decontamination factors achieved can be relatively low

[28], so chemical treatment is usually used only for low-and intermediate-level liquid waste treatment.

1.3.2. Evaporation

Evaporation is probably the best technique for wastes having relatively high salt content and for nitric acid containing effluent, i.e. having high electric conductivity, a relatively low volume and needing high operating costs and high decontamination factors. Because of its relatively high operating casts and high decontamination efficiency, evaporation is preferably confined to the treatment of intermediate and high-level radioactive liquid wastes. Although can be considered a fairly simple operation which has been successfully applied in the conventional chemical industry for many years its application in the treatment of radioactive waste can give rise to many problem such as corrosion, scaling, or foaming. All of those problems should be considered as potential limitations of the evaporation process [29].

1.3.3. Ion exchange

Ion exchange is generally understood to mean the exchange of ions of like sign between a solution and a solid highly insoluble body in contact with [30]. The solid (ion exchanger) must, of course, contain ions of its own, and for the exchange to proceed sufficiently rapidly and extensively to be of practical value, the solid most have an open, permeable molecular structure so that ions and solvent molecules can move freely in and out. Many substances, both natural(e.g. Zeolite) and artificial, have ion exchanging properties, but for analytical work synthetic organic ion exchanger (resin) are chiefly of interest, although some inorganic materials, e.g. zirconium phosphate and ammonium 12-molybdo-phosphates, also, possess useful ion exchange capabilities and have specialized applications.

1.3.3.1. Type of ion exchange materials

1.3.3.1.1. natural ion exchange materials

Many types of natural materials are used as ion exchangers. These materials are not produced from any artificial process. Good results and high uptake obtained by using the natural exchangers.

1.3.3.1.1.1. Zeolite

Generally, zeolites consist of three dimensional aluminosilicate framework containing inside their cavities metal ions and water molecules. Zeolite has a chemical formula $M_{2n}OAl_2O_3X\ SiO_2.4H_2O$. Where M is cation of valency n, X is the number of SiO_2 molecules ranging from (1-1000), and 4 is the number of water molecules. ***Breck*** [31] in such general formula the water contents have different values according to the type of zeolite analcine with the formula $Na_{16}[Al_{16}Si_{31}O_{96}]\ 6H_2O$ has 18% water content while faujasite $Na_{12}Ca_{12}Mg_{11}[Al_{58}Si_{134}O_{384}]\ 235H_2O$ has 50% water content ***Jacobs*** [32] mentioned that the substitution of silicon ions by isomorphous aluminum creats a negative charge on the zeolite aluminosilicate framwork. The charge is compensates by positive ions inside the framwork. The mobility of these positive ions in matrix cavities devotes to replace them by other cations present in contact, which makes zeolite used as ion exchanger. Zeolite shows a high thermal, radiation oxidation and reduction stability.

1.3.3.1.1.2. Nile rose plant (Water Hyacinth)

Water hyacinth plant is an aquatic floriplant contain violet flower. Mohammed Ali bring it from India to Egypt to give the floriated shape for the Nile river. This plant grow only on the surface of the soft water and has scientific name called *Echornia speciosa*. Removal of cadmium from waste water by water hyacinth has been investigated by ***Rai*** [33]. The growth of the plant was inhibited at cadmium concentration 2 mg/L. Cadmium was found to accumulate in the top as well as in the roots of the plants. The uptake was enhanced with time of exposure and between 5 th and 16 th days, the enhancement was more significant. Kinetics and mechanism of uptake were also studied. The value of the natural accumulation factor was found to be significant. Also, in out work we used powder of the dry hyacinth plant in the removal of some heavy metals such as, lead, cadmium and zinc from the waste water.

1.3.3.1.1.3. Animal bone (animal tricalcium phsphate)

Bone is essentially composed of phosphorus and calcium, where the chemical composition of bone is tricalcium phosphate [$Ca_3(PO_4)_2$] in addition to fluoride. It also contain trace elements such as magnesium, sodium and iron. Bone consider a good source of phosphorus where it was used in the manufacture of high grade phosphoric acid and phosphate fertilizer. It is also used in the manufacture of sugar. Treated bone at 600°C can be used for the as natural exchanger to remove heavy metals such as lead, cadmium and zinc from the waste [34].

1.3.3.1.2. Synthetic ion exchange materials

1.3.3.1.2.1. Inorganic ion exchange

This is mainly because of their greater power to resistance chemical attack, radiated and temperature. Synthetic inorganic ion exchangers can be divided into :

1- Insoluble salts of polyvalent metals, e.g. titanium phosphate, zirconium phosphate.

2- Hydrated metal oxide, e.g. hydrous titanium oxides.

3- Insoluble salts of heteropolyacids, e.g. ammonium molybdophosphate.

4- Insoluble salts of cyano-complexes, e.g. ferrocyanide and cobalt cyanide.

5- Synthetic zeolite, e.g. the permutites which are used in water softening.

These materials can behave as selective sorbents and ion exchangers and it must be conditioned before use in an effort to overcome their limited resistance to acids and alkali's and limited mechanical stability.

1.3.3.1.2.1.1. Properties of synthetic inorganic ion exchanger

Generally, the primary condition of an ion-exchange process is the stoichiometry. It is an established fact [35]. However, inorganic ion exchangers are not very good in this regard because they show an adsorption phenomena in addition to normal ion-exchange process on their surface. An attempts have been made to study this aspect by ***Gill et. al.*** [36].The plots of log K_d vs. pH for stannic ferrocyanide and zirconium ferrocyanide are linear but the slopes do not really correspond to the valence of the ion exchanged. However the slopes for monovalent approximate to unity. The deviation in behavior for the uptake of bivalent and tetravalent ions may due to the prominence of mechanism other than ion exchange; like precipitation, surface adsorption or simultaneous adsorption of anions. In the case of ceric antimonate, titanium antimonate [37] and ceric tungestate the slopes are very close to 1, 2 and 3 for the sorption of Cs^+, Hg^{2+} and Ti^{3+}, respectively. This suggests that for all practical purpose, the exchange on these ion exchangers is stoichiometrric in nature and obeys the low of mass action. A large number of insoluble salt formed from multivalent metals and polybasic acids have been investigated as inorganic ion exchangers. Although most of the work deals with studies on zirconium phosphate, other phosphates, arsenates, antimonates, tungestates, molybdate and hydrous oxides have been also studies as potential ion exchangers. Among the antimonate of quadrevalent elements which form an equally promising series, tin [38,39], titanium [40,41] and zirconium [42,43] antimonates have already been investigated by earlies works.

1.3.3.1.2.2. Organic resins

In general organic resins (synthetic or natural) have advantages over other ion-exchange metals and they have a wide application in the treatment of waste water effluents. In the treatment of radwaste solution, there are some limitations, have limitation, some of which are limited radiation stability can be disadvantage when treating intermediate-level effluent for the removal of high-energy beta, gamma emitters such as cobalt and cesium, and for the same reasons the presence of alpha emitters may be a problem [44].

1.3.3.1.2.2.1. Properties of organic resins

a- Stability of organic resins

Organic resins is widely used for water treatment, so that the publish heed data refer mainly to the interactions between organic resins and the relatively pure waters used for production of dematerialized or softened water. Waste waters are much more harmful to resins, and the effect of the components of waste water on organic resins may be categorized as chemical and physical. Chemical degradation is caused by oxidation, reaction of the resin with organic materials present in the water, or thermal instability. These effects lead to chemical changes in the structure of the resin. Hence problems with the stability of organic resins which occur only occasionally in water treatment can be quite common when ion exchange is used for effluent treatment. Understanding the factors affecting the stability of resins is therefore most important for the successful application of this technique in effluent treatment [45].

b- Chemical stability

There are two main group of organic resins:

1- Those formed by polycondensation or step-growth polymerization

2- Those formed by free radical or chain-growth polymerization

The first group includes the oldes synthetic resins known, those based on phenol-formaldehyde polymers, which are also among the least stable. Resins made by chain-growth polymerization are mostly based on polystyrene and to a lesser/extent on acrylamide, acrylic acid. All these latter structure are crosslinked with divinyl benzene (DVB). Deterioration of the resin can a rise from chemical changes in the matrix and/or in the active groups. Generally chemical stability of synthetic ion-exchanger plays an important role in their analytical applications. Exchangers which have a high solubility in water, as well as in acidic media, may not be very useful for separation studies. It is, therefore, advisable to have a rough guide of the solubility of an ion exchanger [46] made an effort in this direction.

c- Thermal stability

These is a significant difference in the thermal stability of cation and anion-exchange resins, where the cation exchangers containing sulphoric acid groups are thermally stable. In the acid or H^+ form their stability is determined by the carbon-sulphur bond. The thermal stability of the ammonium form of a gel poly(acrylic acid) resin has been studied in a polishing application for boiler feed supply, in cleaning high and low-pressure heater drains at 49-65°C and 149-177°C respectively[47,48]. Although there were some problems at higher temperatures, the weak acid resin proved to be more stable than a conventional strong acid resin. But anion exchangers are far less resistance to heat than cation exchangers. Poly styrene-derived strong base resins in the base or OH^- form can withstand temperatures of up to only 40°C. Above these temperature their decomposition approximately follows the Hofmann degradation mechanism [49]. Finally, Table (2) gives a general comparison of inorganic and organic ion exchangers and identifies in a quantitative fashion their particular characterization [35].

Table (2): General comparison of inorganic with organic ion exchangers.

Function	*Organic resins*	*Inorganic absorbers*	*Comment*
Thermal stability	Fair-poor	Good	Inorganic have an advantage particularly for storage/disposal
Chemical stability	Fair-poor	Good	Inorganic are safer with strong nitric acid for elution, although some inorganic may dissolve.
Radiation stability	Fair-poor	Good	High temperature and the present of oxygen reduced the stability of organic in particular.
Exchange capacity	High	Low-high	The best inorganic, such as hydrous titanium oxide, or zirconium phosphate, can complete with organic. For cesium zeolites can be batter than organic.
Selectivity	Available	Available	Can be improved by using suitable ionic form of exchanger or by choice of eluting agents.
Regeneration	Good	Uncertain	Evidence rather than inorganic normally favored for permanent absorption.
Mechanical strength	Good	Variable	Inorganic may be brittle or soft also may break down physically outside a certain pH range.
Cost	High	Low-high	More common inorganic are cheaper than organic, but other could be costly to prepare.
Immobilization	Good	Good	Inorganic are compatible with/or convertible to stable inorganic structure; organic with bitumen cement or polymers or might be incinerated.
Handling	Good	Fair-variable	Organic available as tough spheres, ideal for handling and transfer; inorganic generally as angular particles and may be more friable.

1.4. Treatment of Waste Water Using Inorganic and Organic Materials

1.4.1. Treatment of waste water using inorganic ion exchanges

a- Titanium phosphate

Various methods have been described for the preparation of titanium phosphate (TiP) ion exchangers, leading to formation of amorphous, granular amorphous [50] and crystalline [51,52] products. The composition of the amorphous materials varies between P/Ti rations of 0.6 and 2.0 and different empirical formula such as $\{(TiO)_{0.535}(HPO_4)_{0.369}(OH)_{1.77}\}.1.11H_2O$ [50], $TiH_2(PO_4)_2.4H_2O$ and $Ti(PO_4)_4$ [50] have been proposed for these materials. High exchange capacity has been found (~7.5 meq./g) [50] and is not appreciably affected by calcinations [53,54]. The exchanger can be easily regenerated [50] and exhibits a high selectivity towards Cs^+ [50]. Selectivity series for alkali metal cations reported by various authors [55] differ substantially, probably owing to different products being used.

b- Cerium phosphate

When a solution phosphoric acid is mixed with a solution containing a Ce(IV) salt a precipitate of cerium phosphate is formed, the composition, degree of crytallinity and structure of which are strongly dependent on experimental conditions such as precipitation medium, temperature, digestion time, PO_4/Ce ratio in solution, rate and order of mixing, stirring etc. The products obtained may be divided into four groups; amorphous, microcrystalline, fibrous crystalline and crystalline cerium phosphote-sulphate. The composition of the amorphous materials varies, with PO_4/Ce ratios between 1.03 and 1.95 [56,57]. For some products an empirical formula $Ce_3(OH)_8(H_2PO_4)$ has been postulated [58]. If The precipitation is carried out in sulphoric acid media, the PO_4/Ce ratio decreases and the product contains 2-6% of sulphate [56]. The maximum exchange capacity of 2.9 meq./g[59] is totally lost on heating the exchanger to 200°C [59]. The selectivity series for alkali metal cations follows the order of hydrate ionic radii, i.e., $Cs^+ > Rb^+ > K^+ > Na^+ > Li^+$ [58-60]. Standard enthalpy changes have been determined for the Li-H, Na-H and K-H exchanges (+3.6, +3.1, -0.63 KJ/mol),respectively [58].

c- Zirconium arsenate

Zirconium arsenate (ZrAs) is prepared either as an amorphous substance by mixing zirconium salt solutions with arsenic acid [55] or as a crystalline material by refluxing the amorphous zirconium arsenate with H_3AsO_4 for a prolonged period [61]. The Na^+-H^+, Ti^+-H^+ and Ba^{2+}-H^+ exchange processes have been found to be irreversible[55], owing to the structural rearrangement when going from or to a possible precipitation of barium arsenate within the exchanger. Amorphous zirconium arsenate has been reported as a suitable material for concentrating cesium from a mixture containing multivalent and alkali metal ions [55].

d- Cerium arsenate

Cerium arsenate (CeAs) is prepared by mixing a solution of cerium sulphate in sulphoric acid with arsenic acid and fluxing. A crystalline product of composition $Ce(HAsO_4)_2.2H_2O$ is obtained, which loses one molecule of water at 60°C and the second at 110°C. A total exchange of Li^+ and Na^+ for H^+ has been achieved, which was not the case with larger cations. The exchange isotherms show good reversibility for the Li^+-H^+ exchange, probably owing to crystal structure of the starting and back-exchange H^+ forms being the same. However, small and remarkable hystereses were found for the total Na^+-H^+ and K^+-H^+ half-exchange [62].

e- Titanium molybdate

Titanium molybdate (TiMo) is prepared by mixing $Ti(SO_4)_2$ or $TiCl_4$ solutions with an acidic solution of sodium molybdate. Amorphous products with Mo/Ti ratio ranging from 0.5 to 2.0 have exchange capacity between 0.8 and 1.6 meq./g. The capacity is substantially by heating the exchanger to 200°C. High selectivity of this exchanger towards Pb^{2+}, Ba^{2+}, Ti^+ and K^+ has been found and numerous separations such as Zn^{2+}-Pb^{2+}-Ti^+, Bi^{3+}-Pb^{2+}-Ti^+, Na^+-Rb^+, K^+-Cs^+, Ba^{2+}-Ca^{2+} and Na^+-Cs^+ have been achieved [63,64].

f- Thorium molybdate

Thorium molybdate (ThMo) is prepared by mixing $Th(No_3)_4$ and Na_2MoO_4 solutions. Various conditions of preparation lead to formation of different products. This exchanger is readily dissolved in mineral acids and on heating to 100°C its capacity (~0.57 meq./g) is lost. Total adsorption of Fe^{3+}, Zr^{4+} and Pb^{2+} has been observed and Co^{2+}-Fe^{3+}, Zn^{2+}-Fe^{3+} and Cu^{2+}- Fe^{3+} separations have achieved with this exchanger [65].

g- Titanium tungstate

Titanium tungstate (TiW) is prepared by mixing $TiO(SO_4)_2$ or $TiCl_4$ solutions with Na_2WO_4 [66].The amorphous material is highly stable towards mineral acids [66]. The exchange capacities vary between 0.42 and 0.76 meq./g depending upon the exchanger composition, and are higher for bivalent than univalent cations. Higher selectivity towered Ca^{2+} than other alkaline earth metal cations has been found, permitting the separation of Ca^{2+} from Sr^{2+}, Mg^{2+} and Ba^{2+} [64-66].

h- Zirconium tellurate

Zirconium tellurate (ZrTe) is prepared by refluxing $ZrOCl_2$ and $NaTeO_4$ solution in 1 M hydrochloric acid and its composition corresponds to the formula $Zr(H_2TeO_6).4H2O$. Four molecules of water are lost on heating to 100-500°C, and condensation to $Zr(TeO_5).H_2O$ was occurred at 650-700°C [67].

i- Silico-titanate

El-Naggar et. al. [68] was synthesize silicon-titanate as a action exchanger and the study the removal of some toxic hazardous elements such as Cs^+, Na^+, Co^{2+} and Eu^{3+} ions on Silicon-titanate. Silicon-titanate was also synthesized by dropwise addition of 0.6M sodium metasilicate to 0.6M solution of Ti prepared by dissolving titanium tetrachloride and yielding Si/Ti molar ratio equal to unity. The experiments were carred out in a shaker with thermostated water bath at 60°C. Characterization of SiTi using X-ray patterns, infrared and thermal analysis techniques was carried out. Divalent cations such as Ni^{2+}, Cd^{2+}, Zn^{2+} and Cu^{2+} in the pH range 2 to 8 have been exchanged with the exchangeable active site of the exchangers using a batch technique[69].

j- Silico-antimonate

Silico-antimonate (SiSb) [69-71] was synthesized by dropwise addition of 0.6M sodium metasilicate to 0.6M solution of Sb prepared by dissolving antimony metal in aqua regia and yielding Si/Sb molar ratio equal to unity. The experiments were carred out in a shaker with thermostated water bath at 60°C. Characterization of SiSb using X-ray patterns, infrared and thermal analysis techniques was carried out. Divalent cations such as Ni^{2+}, Cd^{2+}, Zn^{2+} and Cu^{2+} in the pH range 2 to 8 have been exchanged with the exchangeable active site of the exchangers using a batch technique. From the results obtained, the equilibrium capacities and distribution coefficient values were calculated indicating high selectivity values for Ni^{2+}, Cd^{2+}, Zn^{2+} and Cu^{2+} ions in silico-antimonate compared to other antimonates. Also SiSb show high chemical stability in H_2O, nitric and hydrochloric acids. All these results support the stability of the prepared materials for the removal of the toxic metals concerned from waste waters.

k- Zirconium titanate

Zirconium titanate ion exchanger was prepared [72] by dropwise addition of zirconium chloride (0.5M) to titanium tetrachloride (0.5M) dissolved in 4M HCl with molar raio Zr/Ti equal to 1.18. Diffusion behaviour of Cs^+, Zn^{2+} and Eu^{3+} ion exchanger on zirconium titanate (ZrTi) were studied under particle diffusion conditions and the limited batch technique . The values of the diffusion coefficients, activation energy and the entropy of activation were calculated and compared with those obtained for other inorganic and organic resins. The value of the obtained effective diffusion coefficient were found to increase in the order $Cs^+ > Zn^{2+} > Eu^{3+}$. The activation energy was found to decrease with decreases in the entropy of the activation of the system [72].

l- Iron(III) titanate

Iron(III) titanium was prepared [73] by addition of (0.5M) ferric nitrate solution to (0.5M) titanium tetrachloride (dissolved in 4M HCl) with molar raio equal to unity. The process was carried out in thermostated water bath at 70°C with constant stirring. The data obtained proposed that the chemical formula of iron(III) titanate may be written either as $Fe_{1.3}(TiO_4).\ 2H_2O$ or $Fe(TiO_4)_{0.76}.1.5H_2O$. The surface area values of unloaded and loaded iron(III) titanate with Cs^+, Co^{2+} and Eu^{3+} ions were measured using BET-technique. The selectivity sequence for sorption of Cs^+, Co^{2+} and Eu^{3+} ions on iron(III) titanate was found to be; $Co^{2+} > Eu^{3+} > Cs^+$. The leach rate values of Cs^+, Co^{2+} and Eu^{3+} ions from iron(III) titanate heated to 1000°C different leachants were determinated and shows lower values compared to those obtained from unheated iron(III) titanate (dried at 50°C) which elucidate the suitability of iron(III) titanate in fixation of Cs^+, Co^{2+} and Eu^{3+} ions by thermal treatment up to 1000°C [73]

1.4.2. Treatment of waste water using organic resins

1.4.2.1. Acrylic acid polymers {P(AA)}

Acrylic acid polymers are very useful in the treatment of environmental waste, radioactive waste and industrial wastes. Conversion polymerization of acrylic acid (AA) is increased with increasing temperature and is decreased with radiation dose rate at a given temperature [74]. This behaviour as well as the change in the molecular weights of the polyacrylic acid p(AA) were explained to be due to the termination of growing chain radicals occluded in the precipitated polymer primary radical. Many authors, studied the synthesis and characterization of acrylic acid (AA) polymerization by gamma-radiation developed of actinide ions interacting with in aqueous solution [75-77]. They found that the carboxylic acid functional groups can be interacted with metal ions in solution and the hydrogen ions of carboxylic groups can be exchanged by metal ions.

1.4.2.2.Acrylamide polymers {P(AM)}

The polyacrylamide P(AM) was prepared by gamma radiation-initiated polymerization of the corresponding monomer solution. The prepared polymers were assessed for used in the adsorption of some radionuclides that might be present in radioactive waste effluents. It was found that the polymer efficiency for cobalt-60 was affected by the composition of the ionization of polymer. Also, the polymer efficiency was increased by increasing the pH-value and polymer concentration [78-79].Polyacrylamide P(AM) is one of the most widely used flocculent. It has shown a high efficiency for coagulation of acidic, basic and neutral inorganic and organic impurities from water. In this respect, it is non toxic and when used for its re-used in industrial processes. Thus, reducing the consumption of water and accordingly improves the economy of the processes. Furthermore, the polyacrylamide P(AM) is employed in clarification of potable water and solidification of sewage sludges. Polyacrylamide P(AM) finds wide applications, in many finds, e.g. water treatment edible and potable products clarification, mineral processing and removing of harmful inorganic residues from industrial waste water. This allows recycling water in industrial processes and so serves greatly in the consumption of water in industry [80-82].

1.4.2.3. Acrylamide polymeric resins and it's polymeric impregnated

Template polymerization technique polymeric resins [83-86] such as poly(acrylamide-acrylic acid) P(AM-AA), poly(acrylamide-acrylic acid-diallylamine hydrochloric) $[P(AM\text{-}AA\text{-}DAA)^{+}Cl^{-}]$ and poly(acrylamide-acrylic acid-diallylethyl-amine hydrochloride) $[P(AM\text{-}AA\text{-}DAEA)^{+}Cl^{-}]$ were prepared by gamma radiation initiated template polymerization of acrylic acid on acrylamide polymers poly(amino-amine) resin was prepared by gamma radiation in the presence of polyacrylamide [87]. When the template polymerization of acrylic acid on acrylamide was carried out in the presence of zirconium oxychloride to produce resin complexed with zirconium metal. The obtained resin was impregnated with zirconium phosphate by treating the obtained resin with phosphoric acid to form poly(acrylamide-acrylic acid)-zirconium phosphate [88]. Poly(acrylamide-zircinium phosphate) P(AM)-ZrP was used by may authors [89-91], for separation of radioactive isotopes of ^{137}Cs, ^{90}S, and ^{60}Co from radioactive liquid waste. The higher radiation stability of polyacrylamide and poly acrylic acid may be due to both materials being crosslinked on irradiation. The effect of radiation on ion-exchange of the high polymeric resins may be lead to crosslinkings or degradation changes in physico-chemical properties. Some carboxylic exchangers based on copolymers of acrylamide and acrylic acid are more resistant to radiation than most carboxylic cation exchangers. Structural of polyacrylamide become crosslinked on irradiation, while polymethylacrylic acid are intensively degraded [92,93].

1.4.3. Mechanism of the template polymerization technique

For a template polymerization initiated by an initiator [94,95] suggested the following mechanism for the initiation reaction.

$$I \longrightarrow 2R^{\cdot}$$

$$R^{\cdot} + M \longrightarrow RM^{\cdot}$$

Where, I is an initiator-initiated polymerization in the presence of an added template (T), the initiation reaction can be written according to Chapiro's suggestion as follows.

$$R \longrightarrow 2R^{\cdot}$$

$$T \longrightarrow 2T^{\cdot} \text{ or } T^{\cdot} + R^{\cdot} \ (R^{\cdot} \text{ small radical})$$

Where R is a monomer or solvent and T is the added template polymer for a template polymerization system in which the monomer preferentially interacts with the template polymer[96] challandtan suggested the following mechanism

$$M + T \xrightleftharpoons{KL} M.\,T \text{ adsorption equilibrium of monomer}$$

$$R_{M\cdot n} + T \xrightarrow{KC} R\,M'_{T,n} \textit{ complexation of radical}$$

$$P + T \xrightarrow{KC} P_{T,n} \textit{ complexation of polymer}$$

Fractions step, associated with the template

$$R\,M'_{T,n} + M \xrightarrow{KP,T} R\,M'_{T,n+1} \textit{ template propagation}$$

$$R\,M'_{T,n} + RM' \xrightarrow{KP,T} R\,M'_{T,n+m} \textit{ termination}$$

$$R\,M'_{T,n} + R\,M'_{n} \xrightarrow{Kt,\ Tn} P_{n+m} \textit{ Cross termination}$$

1.4.4. Factors affecting the sorption process

1.4.4.1. Swelling

When an ion-exchange resin becomes wet, it absorbs water and increases in volume. This phenomenon is called (swelling) and it is a reversible process. The degree to which swelling occurs is controlled by the osmotic pressure in the resin and the strain to which the elastic polymeric network is submitted [97].

Swelling equilibrium depends on the tendency of the polar and ionic constituents of the resin to surround themselves with polar solvent, and thus to expand the matrix [98]. The fixed functional groups and any mobile ion can form a solvation shell. The interior of the resin exchanger is a highly concentrated solution of ions and has a tendency to dilute itself by taking additional solvent. This effect would appear as an osmotic pressure difference between the interior of the resin and the external solution [97]. Neighboring fixed ionic groups repel each other electrostatically leading to stretching the chains of the matrix. All of this factors can govern the swelling characteristics of resins. Polar solvent are as a rule, better swelling agent than nonpolar solvents since they interact more strongly with the ions and polar groups in the resin. Highly crosslinking resins have a reduced ability to swell, the greater number of links makes the network more rigid. The greater the affinity of the groups for the polar solvent, the more strongly the resin swells. Resins may swell more strongly when their functional groups are completely ionized [99].

1.4.4.2. Degree of swelling

The degree of swelling of the resin was calculated by swelling a known weight of the dry resin overnight in excess water, the degree of swelling is calculated by using the following formula:

$$\text{Degree of swelling} = (WS - W) / W$$

Where, WS and W are weight of resin after and before swelling respectively [100].

1.4.4.3. Capacity

The total capacity of resin indicates the quantity of exchangeable ions per unit weight of dry resin or per unit value of wet resin. It constitutes the upper limit of the quantity substance that can be sorbed on the resin in separations where one ion is sorbed completely and the other is eluted. The total capacity is usually determined by titration, spectrophotometrically and radiometrically for radioactive isotopes. The capacity of the resin in meq/g was calculated using the following equation [101].

Capacity = (% uptake/100). C_o. V/m. Z. meq./g

Where, C_0 is the concentration of the solution. (M/L)

V is the solution volume. (ml)

m is the weight of solid. (g)

Z is the valency of the cation.

The accepted way of characterizing the capacity of an ion-exchanger is by giving the number of inorganic groups contained in the specific amount of the dry material. The characteristic constant contained in this way is usually called the weight capacity and is expressed in millequivalents per gram dry resin [102].

1.4.4.4. Temperature

The influence of temperature on tracer level separations [103], the increase in temperature causes an increase in the diffusion coefficient in the resin as well as in the solution. Therefore, more coefficient separations are generally obtained. However in most cases, temperature has rather small effect on the separation coefficient. On the other hand, the increase in temperature decrease the viscosity of the aqueous phase giving rise to an increase in the flow rate.

1.4.4.5. Particle size and porosity

Resins prepared by condensation are usually taken the form of irregularly formed particles, while these prepared by polymerization can be obtained as spherical beads. The diameter of the beads is important for the time necessary for the separation. This is because smaller the particles, the easier is the equilibrium between the resin and solution occurs. However, small particles limit the flow rate. The pore diameter of polymerization resins is the order 10A°. In case of large ions where particle diffusion is the rate controlling step, resins with large pore diameter posses better kinetic properties [104].

1.4.4.6. Effect of pH

At Higher pH values the amide groups are unprotonated while the carboxylate groups [105], and quaternary ammonium groups [106], it are ionized. Alternatively, the interaction can occur between these cations of the solution and the active groups of the polymer chains for floc formation.

1.4.4.7. Selectivity

The reactivity of metal ions in solution may be related to the following:

a- Electronic configuration of the ion.

b- Ionic radii of metal ion.

c- Electronegativity of the anion.

d- Solubility of metal salt in water.

e- Number of water molecules associated with the metal salt.

f- Position on hard-soft acid bases scale of metal ion and the ligands.

It has been shown that different ions are absorbed with different strengths in the ion-exchange resins. Multivalent ions are strongly absorbed from dilute solutions than ions of lower valences. The absorption strength increase with decrease diameter of the hydrated ion. In the case of strongly acidic cation exchange resins, weakly acidic ion-exchange resins absorb hydrogen ions most strongly and a slight excess of hydrogen ions in the solution can displace all other cations from the resin. Weakly acidic resins are particularly selective for multivalent metal ions and bivalent ions and bivalent ions such as Cu^{2+}, Co^{2+}, Ni^{2+}, Pb^{2+}, Zn^{2+} and Cd^{2+} [107,108]. In the strongly basic exchange resin the valence of the ion and the diameter of the hydrated ion play an important role similar to those of the strongly acidic resins. The affinity of ions is determinated on medium strongly and weakly basic resins is determinated by valency, diameter of the hydrated ion and the strength of the acid corresponding to the anion and structure of ions [98].

1.5. Literature Survey

Qdias et. al. [109] studied that removal of heavy metals from waste water by membrane processes. The application of reserve osmosis (RO) and nanofiltration (NF) technologies for the treatment of waste water containing copper and cadmium ions to reduce fresh water consumption and environmental degradation was investigated. Synthetic waste water samples containing Cu^{+2} and Cd^{+2} ions at various concentrations were prepared and subjected to treatment by RO and NF in the laboratory. The results showed that high removal efficiency of the heavy metals could be achieved by RO process (98% and 99% for copper and cadmium, respectively). NF, however, was capable of removing more than 90% of the copper ions existing in the feed water. The effectiveness of RO and NF membranes in treating waste water containing more than one heavy metal was also investigated.

The removal of heavy metals from waste waters by natural and Na-exchanged bentonites investigated that by ***Alvarez et. al.*** [110]. Batch sorption studied of Cr^{+3}, Ni^{+2}, Zn^{+2}, Cu^{+2}, Cd^{+2} were conducted on Ca-bentonite to determine their retention capacities for this metal cations commonly present in the waste water of galvanic industries. The Langmuir model was found to describe the sorption process well, offering maximum sorption capacities of 44.4 mg Cr/g, 6.32 mg Ni/g, 5.75 mg Zn/g, 7.72 mg Cu/g 7.28 mg Cd/g on Ca-bentonite and 49.8 mg Cr/g, 24.2 mg Ni/g,23.1 mg Zn/g, 30.0 mg Cu/g, 26.2 mg Cd/g on Na-bentonite. The used of Na-bentonite in the purification of waste water from Ni, Cr and acid-Zn electroplating process was an effective treatment in small-scale and in semi-industrial-scale tests.

Yang et. al. [111] determinated that removal and recovery of heavy metals from waste waters by supported liquid membranes. The removal and recovery of Cu, Cr and Zn from plating rinse waste water using supported liquid membranes (SLM). SLMs with specific organic extractants as the liquid membrane carriers in series are able to remove and concentrate heavy metals with very high purity, which is promising for recycling of heavy metals in the electroplating industry.

Hequet et. al. [112] proved that removal of Cu^{+2} and Zn^{+2} in aqueous solutions by sorption onto mixed fly ash. However, fly ash is shown to be efficient in the removal of heavy metallic ions in the aqueous phase. The objectives of this work were to study the removal of Cu^{+2} and Zn^{+2} in water by sorption onto fly ash and fly ash mixture. The stability of the resulting cake was also approached in terms of leaching capability. Experimental design methodology was used in order to identify influential parameters and to evaluate their interactions. Temperature, fly ash to ion concentration ratio, and ash quality were particularly studied. Different ashes and a fly ash mixture were investigated. They each have alkaline reaction with water to a different extent, and this allows the control of the pH determined.

Removal of lead, cadmium and zinc from aqueous solutions by precipitation with sodium di-(n-octyl) phosphate, discussed that by ***Esalah et. al.*** [113]. Cadmium, zinc and mixture of lead, cadmium and zinc were precipitated in the form of PbL sub 2 sub (sub s sub), CdL sub 2 sub (sub s sub), and ZnL sub 2 sub (sub s sub). Lowering the pH of the feed solution reduced the removal of the metals as some of the phosphinate precipitated in the acid form as HL sub (sub s sub). The removal of lead, cadmium and zinc, from a solution containing three metals gave a selectivity in the order Zn greater than Pb greater than Cd. Predications of an equilibrium-constant model, using measured solubility products of the precipitates and literature values of stability constants, gave metal removals, loss of precipitating agent, and equilibrium pH in good agreement with measured values.

The new integrated processes combining adsorption, membrane separation and flotation for heavy metal removal from waste water his study by ***Mavrov et. al.*** [114]. The process was divided into the following three stage: firstly, heavy metal bonding by a bonding agent, secondly, waste water or a hybrid process combining flotation for highly contaminated waste water, and thirdly, bonding agent regeneration. In this studied, prepared that zeolite loaded with metal was presented.

Huang et. al. [115] founded that adsorbing colloid flotation with polyaluminum chloride, a powerful technique for removing heavy metals from waste water but it is not much used for waste water treatment because its separation efficiency is very poor for solutions with high concentrations of electrolyte. They had demonstrated that this drawback could be eliminated by using polyaluminum chloride (PAC) as a coagulant. Adsorbing colloid flotation with polyaluminum chloride was also tested for the removal of heavy metals from the waste waters of a tannery and of an electroplating factory.

The nonlinear wave propagation theory (III) removing heavy metals from waste water by ion-exchange process. It was studied that by ***Chern et. al.*** [116]. Batch experimental tests using IRC-718 cationic resin were conducted to obtained the ion exchange equilibria of H/Cu and H/Ni systems, and column tests were conducted to obtain the breakthrough and regeneration curves under various operating conditions. The batch experimental results show that the affinity sequence is Cu greater than the H greater than Ni. The column experimental results show that IRC-718 in H-form is effective for moving cupper from synthetic waste water but not effective for nickel removal. For a cupper-rich feed solution, the ion-exchange wave was a noncharpening wave and its regeneration wave was a self-sharpening one. For a copper/nickel mixture feed, nickel gradually appears in the effluent, and a plateau of concentration higher than the feed one is identified. Simple equations based on the nonlinear wave propagation theory had been developed to predict the breakthrough and regeneration curves, and the predicated results are quite comparable with the experimental data.

Ion exchange extraction of heavy metals from waste water sludge discussed by ***Al-Enezi et. al.*** [117] The ion exchange process had been increasingly used for the removal of heavy metals or the recovery of precious metals. It is a versatile separation process with the potential for broad applications in the water and waste water treatment field. This article summarizes the result obtained from a laboratory study on the removal of heavy metals from municipal waste water. Data on heavy metal content of the waste water and sludge samples collected from the plant are presented. The results obtained from laboratory experiments using a commercially available ion exchange resin to remove heavy metals from sludge were discussed. A technique was developed to solubilize such heavy metals from the sludge for subsequent treated by the ion exchange process. The results showed high efficiency of extraction, almost 99,9%, of heavy metals in the concentration rang found in waste water effluents and sludge.

Comparison of ion-exchange resins and biosorbents for the removal of heavy metals from plating factory waste water discussed that by ***Brower et. al.*** [118]. Three process waste water steams, acid/alkali, chromate and cyanide were tested at their original pH and near neutral pH. Neurospora crassa gene expressed in the periplasmic space (NCP) was most efficient in removing the heavy metals from waste waters at near natural pH. When the sorbents were tested for removal of part per billion levels of Cd, NCP demonstrated the highst percent removal.