1.1 INTRODUCTION

“Water is elixir of Life”

Water is without doubt, the most abundant, the most accessible, and the most studied of all chemical compounds. Its omnipresence, its crucial importance for man’s survival and its ability to transform so readily from the liquid to the solid and gaseous states has ensured its prominence in man’s thinking from the earliest times. Water has many unusual chemical properties which make it a very important chemical for all life on this planet.

Water (dihydrogen monoxide) covers 70.9% of the Earth’s surface and is vital for all known forms of Life on earth. 96.3% of the planets water is found in oceans, 1.7% in ground water, 1.7% in glaciers and the ice caps of Antarctica and Greenland and a small fractions in other large water bodies and 0.001% in the air as vapour, clouds (formed of solid and liquid water particles suspended in air).

Only 2.5% is fresh water and 98.8% of that water is in ice and groundwater. Less than 0.3% of all fresh water is in rivers, lakes and the atmosphere and even smaller amount of the Earth’s freshwater (0.003%) is contained within biological bodies and manufactured products.

In the religion of ancient Mesopotamia, the oldest of whom we have written records (2000 BC). Nammu goddess of the primeval sea was The mother who gave birth to heaven and earth. She was also the mother of the god of water. Enki, one of the four controlling the major realms of the universe, in the Judaic-Christian tradition the spirit of God moved upon the face of the waters and creations proceeded via. A firmament in the midst of the waters to divide heaven from earth. Again, the flood figures prominently as it does in the legends of many other peoples, the obligatory washing practiced by Muslims before prayers are further manifestations of the deep ritual significance of water. According to Thales of Miletus (Greek Philosopher) it is
water that, in taking different forms, constitutes the earth atmosphere, sky, mountains, gods and men, beasts and birds, grass and trees and animals, down to worms, flies, and ants. All there are but different forms of water. Meditate on water. Aristotle considered water to be one of the four elements, alongside earth, air and fire.

Water is the basic primary need in the entire life cycle of plants and animals. The purity of water is important because it is directly related with human health and Ecosystems and is the basic requirement for the development of any region.

But presently it is being felt that around the world living beings as a whole and human population in particular, are faced with lack of access to adequate and safe water to meet their most basic needs. Water resources and related ecosystems that provide and sustain them, are today under threat from pollution, unsustainable use, land use changes, climatic changes and many other forces. The link between these threat and poverty is clear, for, it is the poor who are hit first and hardest [1].

Water, elixir of Life; is becoming more and more unfit and dearer to mankind due to mismanagement of water resources.

There are a large number of materials, including metals, non-metals, hydrocarbons, ions and various gases which pollute the atmosphere. Among all, the heavy metals are discharged by industries into air, water and soil [2]. They get into human food chain from the environment [3, 4]. These elements enter our biological system and disturb the biochemical processes, leading in some cases to fatal results[5].

Many of the sediments in our rivers, lakes and oceans have been contaminated by pollutants. Some of these pollutants are directly discharged by industrial plants and municipal sewage treatment plants others comes from polluted runoff in urban and small scale industries and workshop areas and some are the result of historical contamination [6,7]. Contaminated sediment can threaten creatures in the benthic environment exposing worms, crustaceans and insects to hazardous concentrations of
toxic sediments kill benthic organism, reducing the food available to larger animals such as fish [8]. Some contaminants in the sediments are taken up by benthic organism in a process called bioaccumulation [9]. When larger animals feed on these contaminated organism the toxins are taken into their bodies, moving up the food chain in increasing concentration in a process called as biomagnifications which affects the aquatic flora and fauna. The marine water or fresh water may accumulate hazardous level of toxic chemicals contaminated sediments that never always remains at the bottom of a water body. Anything that stirs up the water such as dredging, can resuspend sediments. Resuspension may mean that all of the animals in the water, and not just the bottom, dwelling organism, will be directly exposed to toxic contaminants[10].

The present work is centered to the Lake of Sagar and drinking water sources like dug wells, tube wells near and around Lake of Sagar city and automobile garages, denting-painting, workshops etc. Almost ¾ part of Sagar Lake is surrounded by roads and dwelling units like huts or houses. So the two most important sources of pollution are heavy traffic and domestic waste which are drained into lake directly. The traffic is always in action and gives their exhaust waste gases to the air and atmosphere of the lake and all these gases are settled by raining and sedimentation into the lake. Due to this the water sources like hand pumps, dug wells, domestic tube wells are also vulnerable to assimilate the pollutant into the water by capillary absorption [11]. The workers who works at the garages and other work shops like painting industries are also exposed to intake these heavy metals by inhalation or direct contact due to zero precaution while handling or working above optimum conditions[12]. So the water of lake and other drinking water sources, aquatic plants, aquatic animals, soil, worker of garages all are having the possibility of intaking heavy metals directly or indirectly[13, 14].
The list of toxic chemicals is very long. It is intriguing that even now there are many cases where one is not sure whether a particular chemical compound is toxic or not [15, 16, 17]. Some useful important chemicals are being controlled rigorously as their non-toxicity has not been proved [18]. There are valid confusions in respect of elements, where will the line be drawn between the essential limit and toxic limit and such sub-division (toxic essential) is artificial and can be misleading [19]. Many metals listed as environmental hazards are essential dietary trace elements required for normal growth and Pb, Hg, Mo, Ag, Te, Sn, Ti, W, U, Zn, Al, Sb, As, Ba, Be, Bi, Cd, Co, Ce the term concentration window to draw the arbitrary lines of demarcation[20].

(a) Essential at trace level for sustainance of life process.
(b) Deficient at lower level than (a) causing metabolic disorder.
(c) Toxic at higher level than (a) causing adverse effects.

Even well known toxic elements As, Pb and Cd are required in trace quantities for the growth of animals. The so-called biologically inert Al causes brain damage,
bone disease and anemia in patients subjected to hemodialysis using water containing 100 ÷ 1000 ppb of Al which is equally present in drinking water by Alum treatment [21, 22].

Toxic substances may be classified according to their functions and effects, such as mutagens, Carcinogens etc. or food, additives etc. or heavy metals [23]. Table 1.1 shows some toxic metals and their sources of occurrence and effects [24, 25].

**TABLE 1.1: TOXIC METALS**

<table>
<thead>
<tr>
<th>Elements</th>
<th>Sources</th>
<th>Effects and Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>As</td>
<td>Mining by product, pesticides, chemical waste</td>
<td>Toxic possibility carcinogenic</td>
</tr>
<tr>
<td>Cd</td>
<td>Industrial discharge, mining waste, metal plating, water pieces</td>
<td>Replaces Ca biochemically, caused high blood pressure, kidney damage destruction of testicular tissue and RBCs, toxicity to aquatic biota.</td>
</tr>
<tr>
<td>Be</td>
<td>Coal, nuclear power and space industries</td>
<td>Acute and chronic toxicity possibility carcinogenic</td>
</tr>
<tr>
<td>B</td>
<td>Coal, detergent formulations, industrial wastes.</td>
<td>Acute and chronic toxicity, possibility carcinogenic</td>
</tr>
<tr>
<td>Cr</td>
<td>Metal plating cooling tower water additive (chromates)</td>
<td>Essential trace element, Carcinogenic</td>
</tr>
<tr>
<td>Cu</td>
<td>Metal plating, industrial and domestic waste Mining, mineral leaching</td>
<td>Essential trace elements, not very toxic to animals, toxic to plants and algae at moderate levels.</td>
</tr>
<tr>
<td>F</td>
<td>Natural geological sources, industrial waste, water additive.</td>
<td>Prevents tooth decay at about 1 mg/l causes molited teeth and bone damage.</td>
</tr>
<tr>
<td>Pb</td>
<td>Industry, mining, plumbing, coal, gasoline</td>
<td>Toxic anemia, kidney disease, nervous disorder wildlife destroyed.</td>
</tr>
<tr>
<td>Mn</td>
<td>Mining industrial waste, acid mine drainage, Microbial action on Manganese minerals at less potential energy</td>
<td>Relatively non toxic to animals, toxic to plants at higher levels, stains materials.</td>
</tr>
</tbody>
</table>
### Elements, Sources, Effects and Significance

<table>
<thead>
<tr>
<th>Elements</th>
<th>Sources</th>
<th>Effects and Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hg</td>
<td>Industrial waste, mining pesticides, coal</td>
<td>Highly toxic</td>
</tr>
<tr>
<td>Mo</td>
<td>Industrial waste, natural sources</td>
<td>Possibly toxic to animals, essential for plants.</td>
</tr>
<tr>
<td>Se</td>
<td>Natural geological sources, Sulphur, coal.</td>
<td>Essential at low levels but toxic at higher levels.</td>
</tr>
<tr>
<td>Zn</td>
<td>Industrial waste, metal plating, plumbing</td>
<td>Essential in many metallo enzymes, toxic to plants at higher levels.</td>
</tr>
</tbody>
</table>

All of above toxic heavy metals enters plants or animal body through water or food chain [26].

The quality of water is of vital concern for mankind since it is directly linked with human welfare. It is a matter of history that faecal pollution of drinking water caused water born diseases which wiped out entire populations of cities [27, 28].

Polyphosphate in detergents is the major sources of phosphate in water, serves as algal nutrients and is of much concern as Looter pollutant [29]. However, in an efficient sewage treatment plant, it is possible to remove phosphates from sewage containing organic waster as well as detergents [30].

### 1.2 SOURCES OF POLLUTION

[A] Natural source

The soil erosion in the most extensive pollutants of surface water, on the other hand bottom sediments are important sources of inorganic and organic matter in streams, fresh water estuaries and oceans so the sediments and suspended particles are also important repositories of trace metals like Cr, Cu, Mo, Ni, Co, and Mn.

Natural rain water contains many acidic organic and inorganic pollutants which may pollute the natural water bodies [31].
Urbanization

The increasing industrialization, urbanization developmental activities and consequent pollution of water has brought a veritable environmental crisis. The perusal of studies, carried out all over the world have revealed that millions of litres of sewage domestic waste industrial and agricultural effluents containing substance varying in characteristics from simple nutrients to highly toxic substance are being poured to the important sources of fresh water every day. The degree of pollution is quite evident by the presence of toxic contaminants like D.D.T., P.C.B. and many of the heavy metals in the water. The quality and quantity and magnitude of the degree of problem could be different and may vary from case to case [32].

Sources effects on ground water

The sewage from human habitations in one of the main sources of pollution. Domestic waste can severely contaminate ground water by introducing pathogenic bacteria, excessive quantity of nitrate, chloride and other pollutants. The other forms of excreta disposals are even more dangerous as the people often drain the effluents directly to the ground these effluents carry with them the pathogens which is the main cause for diseases such as dysentery, cholera, hepatitis, jaundice, polio, blue baby etc. During monsoon season, human faeces and other wastes are directly discharged into streams canal etc. Huge quantities of these untreated effluents exceed the natural purification capacity of that particular water resource for a very long way. Generally the pathogens are small enough to be filtered out of water while passing through the soil, but generally these pathogens get passage to enter into ground water.

Industrial sources

Many of the small scale industries discharge their untreated effluents directly to a water source or over the ground. Garages, automobile servicing centers etc. discharge organic and inorganic, chemicals while paint industries, manufactures and painters release a good quantity of toxic Cr, Pb, Cd metals.
Ni, Cu, Zn, Bi, Se, are common constituents of any electroplating industry. Small scale industries such as metal workshops, battery dealers etc. are involved in discharging numbers of harmful and toxic chemicals. Because of higher toxicity and quicker rate of traveling into the aquifer system the chlorinated solvents have been considered to be more dangerous than the others.

[E] Agricultural sources

Regular leaching of fertilizers, nitrate, phosphate, potassium, chloride, insecticides and pesticides is common in intensive cultivation of crops. Currently, number of pesticides are being used, and most of these are hazardous in nature. The dissolved salts in the irrigation water get deposited over the soil following evaporation of water. The addition of further excessive irrigation water leaches the salts form the soil and transfers these to underlying aquifer and ultimately to the ground water and making it unusable.

1.3 WATER QUALITY PARAMETERS AND STANDARDS

The water quality parameters for domestic water supply in the form of permissible limits, as laid down by US public health drinking water standards (USPH) and Indian Standard Institution (ISI) are represented in table 1.2 and World Health Organization (WHO) [33, 34, 35].

Table 1.2: Water quality parameters and standards

<table>
<thead>
<tr>
<th>(a) Substances affecting potability of water</th>
<th>USPH</th>
<th>WHO</th>
<th>ISI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total solids</td>
<td>-</td>
<td>1500</td>
<td>-</td>
</tr>
<tr>
<td>Colour (platinum cobalt scal)</td>
<td>Colourless</td>
<td>50 units</td>
<td>Colourless</td>
</tr>
<tr>
<td>Turbidity</td>
<td>-</td>
<td>25 units</td>
<td>-</td>
</tr>
<tr>
<td>Taste</td>
<td>Testless</td>
<td>Testless</td>
<td>Testless</td>
</tr>
<tr>
<td>Odour</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Iron</td>
<td>0.3</td>
<td>1.0</td>
<td>-</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.05</td>
<td>0.5</td>
<td>-</td>
</tr>
</tbody>
</table>
### Chapter 1

**Introduction**

<table>
<thead>
<tr>
<th></th>
<th>USPH</th>
<th>WHO</th>
<th>ISI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>1.0</td>
<td>1.5</td>
<td>-</td>
</tr>
<tr>
<td>Zinc</td>
<td>5.5</td>
<td>15</td>
<td>-</td>
</tr>
<tr>
<td>Calcium</td>
<td>100</td>
<td>200</td>
<td>-</td>
</tr>
<tr>
<td>Magnesium</td>
<td>30</td>
<td>150</td>
<td>-</td>
</tr>
<tr>
<td>Chlorine</td>
<td>0.1</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Sulphate</td>
<td>250</td>
<td>400</td>
<td>1000</td>
</tr>
<tr>
<td>Magnesium+Sodium sulphate</td>
<td>-</td>
<td>1000</td>
<td>-</td>
</tr>
<tr>
<td>Phenolic compounds</td>
<td>0.001</td>
<td>0.002</td>
<td>0.005</td>
</tr>
<tr>
<td>Alkyl benzene sulphonates</td>
<td>-</td>
<td>Surfactants</td>
<td>-</td>
</tr>
<tr>
<td>COD</td>
<td>4.0</td>
<td>10</td>
<td>-</td>
</tr>
</tbody>
</table>

#### (b) Toxic metals

<table>
<thead>
<tr>
<th></th>
<th>USPH</th>
<th>WHO</th>
<th>ISI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead</td>
<td>0.05</td>
<td>0.1</td>
<td>-</td>
</tr>
<tr>
<td>Arsenic</td>
<td>0.05</td>
<td>0.05</td>
<td>0.02</td>
</tr>
<tr>
<td>Barium</td>
<td>1.0</td>
<td>0.1</td>
<td>-</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.01</td>
<td>0.01</td>
<td>-</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Selenium</td>
<td>0.01</td>
<td>5 μg/l</td>
<td>0.05</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.001</td>
<td>1 μg/l</td>
<td>0.05</td>
</tr>
<tr>
<td>Silver</td>
<td>0.05</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Uranium</td>
<td>5.0</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

#### (c) Substances affecting health

<table>
<thead>
<tr>
<th></th>
<th>USPH</th>
<th>WHO</th>
<th>ISI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluoride</td>
<td>1.5</td>
<td>1.5</td>
<td>3.0</td>
</tr>
<tr>
<td>Nitrate</td>
<td>40</td>
<td>45</td>
<td>-</td>
</tr>
<tr>
<td>BOD</td>
<td>5.0</td>
<td>6.0</td>
<td>-</td>
</tr>
</tbody>
</table>

#### (d) Inorganic chemicals

<table>
<thead>
<tr>
<th></th>
<th>USPH</th>
<th>WHO</th>
<th>ISI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia</td>
<td>0.5</td>
<td>0.5</td>
<td>-</td>
</tr>
<tr>
<td>pH</td>
<td>6.0-8.5</td>
<td>6.5-9.2</td>
<td>6.0-9.0</td>
</tr>
<tr>
<td>Specific conductance</td>
<td>300 μ moh cm⁻¹</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Dissolved oxygen (DO)</td>
<td>4.0-6.0</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

#### (e) Radiological requirements

<table>
<thead>
<tr>
<th></th>
<th>USPH</th>
<th>WHO</th>
<th>ISI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strontium-90</td>
<td>-</td>
<td>30 μμc/l</td>
<td>-</td>
</tr>
<tr>
<td>Radium-226</td>
<td>3 pc/l</td>
<td>10 μμc/l</td>
<td>-</td>
</tr>
<tr>
<td>Gross beta</td>
<td>1000 pc/l</td>
<td>1000 μμc/l</td>
<td>-</td>
</tr>
</tbody>
</table>

*Where units are not written the unit is ppm (mg/l) except pH*
1.4 PHYSIOCHEMICAL PARAMETERS OF WATER

(A) Hydrogen Ion Concentration (pH)

It is the measure of the relative acidity or alkalinity and represents the negative logarithm of the concentration of free hydrogen ion in a solution [36].

\[ \text{pH} = - \log_{10} [\text{H}^+] \]

(B) Alkalinity

In most natural waters bicarbonates and some times carbonates are present in appreciable amounts. Their salts get hydrolyzed in solution and produce hydroxyl ions consequently raising the pH.

\[ \text{M}^+ + \text{HCO}_3^- + \text{H}_2\text{O} = \text{M}^+ + \text{H}_2\text{CO}_3^- + \text{OH}^- \]

Principle:

It is determined by titration of the sample with a standard solution of strong acid. Alkalinity due to hydroxide and carbonate is determined to the first end point (pH 8.3) using phenolphthalein indicator and bicarbonate alkalinity is determined to the second end point (pH 4.3) using methyl orange indicator.

(B) Total Hardness

The hardness of water indicates water quality in terms of Mg\(^{2+}\) and Ca\(^{2+}\), expressed as CaCO\(_3\). The analysis is done by complexometric titration.

(D) Chloride

High chloride content in water bodies harms metallic pipes as well as agricultural crops. Waste water has higher chloride content than the raw water. It is determined by titration with AgNO\(_3\) using K\(_2\)CrO\(_4\) as an indicator.

1.5 Biochemical Parameters:

(A) Dissolved oxygen (DO)

Dissolved oxygen levels in natural as well as waste waters depend on physical, chemical and biological activities of the water body. The analysis of dissolved oxygen
is very important in water pollution control as well as waste water control. Two methods are used, the Winkler or Iodometric method involving Magnous sulphate and Sodium acid with Sodium thiosulphite and the other method is electrometric method.

(B) **Biochemical oxygen demand (BOD)**

The degree of microbially-mediated O₂ consumption in water is known as the biochemical oxygen demand. This parameter is commonly measured by the quality of O₂ utilized by suitable aquatic micro-organism during 5-day period.

\[
[\text{CH}_2\text{O}]_n + \text{O}_2 \xrightarrow{\text{Micro-organism}} n\text{CO}_2 + n\text{H}_2\text{O}
\]

The selection of micro-organism (seedling) is crucial and the results are obviously not reproducible. Sample is deficient in micro-organism the dilution water needs seedling. The standard seed material is settled domestic waste water which has been stored for 24-36 hours at 20°C.

(c) **Chemical Oxygen Demand (COD)**

Although BOD test indicates the amount of total organic matter, there are so many drawbacks. To compensate them Chemical Oxygen Demand (COD) test is carried out. It is an index of the total organic content of water oxygen demanding substances in water.

COD may, therefore, be defined as the amount of oxygen by organic matter in a sample of water for its oxidation by a strong chemical oxidizing agen such as K₂Cr₂O₇. It is expressed as ppm of oxygen taken from a K₂Cr₂O₇ solution in two hours.

\[
3[\text{CH}_2\text{O}] + 16\text{H}^+ + 2\text{Cr}_2\text{O}_7^{2-} \rightarrow 4\text{Cr}^{3+} + 3\text{CO}_2 + 11\text{H}_2\text{O}
\]

The amount of untreated Cr₂ O₇⁻ is then determined by titration with a standard Mohr's salt solution.
Ag$_2$SO$_4$ catalyses the oxidation of straight chain aliphatic compounds, aromatic hydrocarbons and pyridine, HgSO$_4$ ties up Cl$^-$ as soluble complex and prevents its interferences.

### 1.6 IMPACT OF TOXIC CHEMICAL ON ENZYMES

Generally heavy metals like Hg$^{2+}$, Pb$^{2+}$, Cd$^{2+}$, Zn$^{2+}$, As$^{3+}$ act as enzyme inhibitors because these metals have the tendency for sulphur containing ligands like $\cdot$SH and $\cdot$S-CH$_3$ in cysteine and methionine\[37\].

\[
\text{Enzyme} + 2\text{Hg}^{2+} \rightarrow \text{Enzyme} + \text{Hg} + 2\text{H}^+ 
\]

Since metalloenzyme contains metal when one metal ion of a metalloenzyme is replaced by other foreign toxic metal ion of similar size and charge thus. Zn$^{2+}$ in some metallo-enzyme is substituted by Cd$^{2+}$ which leads to cadmium toxicity.

#### (A) Biochemical effects of lead

Lead is more abundant than other heavy metals. Lead is removed from the atmosphere by wet and dry deposition process. As a result, street dust and roadside, soils and roadside water sources become enriched with Pb.

![Fig. 1.2: Daily lead balance for a city resident](image)

Department of Chemistry, Dr. H.S. Gour University, Sagar (M.P.) 12
Pb interference heme synthesis, which leads to hematological damage. Pb inhibits more than one key enzymes involved in the overall process of heme synthesis whereby the metabolic intermediates accumulate. An important phase of heme synthesis is the conversion of delta aminolevulinic acid to prophobilinogen.

\[
\text{HO}_2\text{C} - \text{CH}_2 - \text{CH}_2 - \text{C} - \text{CO}_2\text{H} \quad \text{NH}_2
\]

**Delta aminolevulinic acid**

[ALA dehydrase : Cytoplasm]

\[
\text{HO}_2\text{C} - \text{C} - \text{CH}_2 - \text{C}_2\text{H}_4\text{CO}_2\text{H} \quad \text{H}_2\text{N} - \text{C} - \text{N} - \text{C} - \text{H} \quad \text{H}_2\text{N}
\]

**Prophobilinogen**

Lead inhibits the ALA-dehydrase enzyme (I) so that it can not proceed further to form (II) prophobilinogen. This causes the disruption of the synthesis of haemoglobin as well as other respiratory pigments cytochromes. Finally Pb does not permit utilization of O\textsubscript{2} and glucose for life sustaining energy production. This can be detected in the blood of about 0.3 ppm. At higher levels of Pb in the blood (more than 0.8 ppm) there will be symptoms of anemia due to the deficiency of hemoglobin. Elevated Pb levels (more than 0.5-0.8 ppm) in the blood cause kidney dysfunctions and finally brain damage [38].

Due to the chemical analogy to Pb\textsuperscript{2+} and Ca\textsuperscript{2+} bones act as repositories for Pb accumulated by the body. Subsequently, this Pb may be remobilized along with phosphates from the bones which exert a toxic effect when transported to soft tissues.

(B) **Biochemical effect of cadmium**

Cd occurs in nature in association with zinc minerals. Growing plants acquire Zn and they also take up and concentrate Cd with the same biochemical setup. The outbreak of Cd poisoning occurred in Japan in the form of Ñťai Ñťaiô or Ñ“ouch Ñ“ouchô
disease. Many people suffered in Japan in the form this disease in which their bones became fragile. At high level Cd cause Kidney problem anemia and bone marrow disorders.

The major portion of Cd ingested into kidney and excreted. But a small fraction is found with body protein, metallothionerin, present in the kidneys, while the rest is stored in the body and gradually accumulate with age. If excessive amounts of Cd$^{2+}$ are ingested, it replaces Zn$^{2+}$ at key enzymatic sites, causing metabolic disorders [39].

(C) **Biochemical effects of Arsenic**

Most of insecticides and fungicides and herbicides have Arsenic As(III) is most toxic among all its compounds it attacks on --SH of an enzyme.

\[
\text{Enzyme} + \text{As}^{3+} \rightarrow \text{Enzyme} \text{As}^{3+} + 2\text{OH}^{-}
\]

The cellular energy generating enzymes in citric acid cycles are adversely affected by As. The inhibitory action is based on inactivation of pyruvate dehydrogenase by complexation with As(III) whereby the generation of ATP prevented.

In excessive amounts Arsenic causes gastrointestinal damage and cardiac damage chronic doses can cause vascular disorders such as black foot disease. Arsenic and its compounds are reported to be mutagenic and teratogenicity in nature. The toxicity, availability and environmental mobility of Arsenic are very much independent on their chemical forms [40].
(D) **Biochemical effects of copper**

Copper is one of the most indispensable elements for normal Metabolism in man and most animals. It is essential element of numerous key metalloenzymes which are critical in melanin formation and crosslinking of collagen and elastin. It plays a vital role in hemopoiesis maintenance of vascular and skeleton integrity and function of nervous system. Copper may be stored in the liver and released as required in the form of ceruloplasmin. Its excess amounts are toxic. Excessive accumulation of copper in tissues occurs in Wilson’s disease [41].

(E) **Biochemical effect of selenium**

Elemental selenium is not rapid oxidized and is slowly available to plant from soils. Selenous acid (H$_2$SeO$_3$) and its salts are the major water soluble Se species. H$_2$SeO$_3$ is very mobile in the aqueous environment and readily available to plants. SeO$_4^{2-}$ is fairly strong oxidizing agent and readily reducible to SeO$_3^{2-}$ under most environmental conditions [42].

(F) **Biochemical effects of Chromium**

Chromium is essential nutrient for plant and animal metabolism (glucose metabolism, amino and nucleic acid synthesis). However, when accumulated at high levels, it can generate serious trouble and diseases (nausea, skin ulceration, lung, cancer) and as the concentration reaches 0.1 mg/gm or 100 ppm body weight, it can become lethal Chromium (VI) is the most toxic form for bacteria, plants and animals.

Steel works, chromeplating, lather tanning industries produce high chromium waste. Understanding the behaviour of Cr in natural aquatic system is, therefore, of major concern [43].

1.7 **SOME WATER BORNE DISEASES**

[A] **Liver Diseases**

Disturbance of water and electrolyte balance are among the more significant and troublesome complication of liver disease. These are due in part of impairment of
liver function and in part to the effect of liver, on the kidneys and other organs. Among the blood analysis which are of clinical importance under these conditions are those for plasma proteins, serum sodium and serum potassium. Iron levels may also be altered in liver disease being elevated in hepatitis and in hemochromatosis in the latter condition the iron binding capacity of the serum may be at the saturation level as compared with 14 to 69 percent of capacity in cirrhosis and 28 to 59 percent of capacity in normal individual [44]. In diseases of liver, total protein may be decreased since albumin is chiefly synthesized in liver and any disease condition of liver, leads to decrease in albumin consequently resulting in hypoproteinemia. In chronic gastrointestinal disease there is interference with protein digestia and absorption leading to hypoproteinemia. Hyperprotenemia occurs in chock dehydration. Increased level of BUN is seen in vomiting diarrhea and water depletion, serum alkaline phosphate increase in liver diseases [45].

SGOT increases in hepatic necrosis, CCl₄ poisoning, arsenic poisoning and fatty degeneration results in May liver diseases.

In addition to the main forms of cirrhosis, namely portal, post necrotic and biliary, there is a miscellaneous group of condition in which fibrosis may be associated with disturbance of liver architecture. Brief consideration will be given to the following conditions.

(a) Hemachromatosis and hemosiderosis

(b) Hepatolenticular degeneration

(c) Schistosomal cirrhosis

(d) Sickle cellanemia cirrhosis

(e) The cirrhosis of hereditary disorders of metabolism.

[B] Cholera

This is a highly contagious disease (water born and food born), caused by the bacteria, *Vibrio cholera*. Typical symptoms are diarrhea with rice water stool,
vomiting, rapid dehydration muscular cramps and anuria. In severe case, acute renal failure is possible.

The bacteriology of cholera is complicated. *Vibrio eltor* replaced the classical *V. cholrea* by the end of 1965. Most of the *Eltor vibrios* isolated were found to belong to the serotype Ogawa. *V. cholerae* is a gram-negative, comma shaped actively motile organism. The *Eltor vibrioes* resemble the true cholera vibrioes morphologically serologically and also biochemically.

**Table 1.3: Essential macro elements in human body**

<table>
<thead>
<tr>
<th>Elements in human body</th>
<th>Normal concentration in plasma (mg/L)</th>
<th>Cholera stool (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium</td>
<td>140</td>
<td>120-130</td>
</tr>
<tr>
<td>Potassium</td>
<td>5</td>
<td>15-25</td>
</tr>
<tr>
<td>Chloride</td>
<td>100</td>
<td>120</td>
</tr>
<tr>
<td>Bicarbonates</td>
<td>22-30</td>
<td>45</td>
</tr>
</tbody>
</table>

[C] **Diarrhoea**

It is also a water borne disease which is caused by the presence of protozoa, *Amoebic colitis*, Infusoria (*E. coli*), mercury and arsenic in water which results in constitutional disorders like diabetes, Addison’s disease and dehydration as a result the concentration of Na, K, Mg in blood goes down to a very low value. However there is an increase of blood sugar of patients, cadmium nitrate poisoning of blood are also some of the causes of diarrhoea.

[D] **Amoebiasis**

This is a water-borne disease, defined by WHO as the condition of harbouring *Entamoeba histolytica* with or without clinical manifestation. It has world-wide distribution. The disease is characterized by liquid stools with mucous and blood.

Man gets the infection through food chair (Cut fruits, salads, vegetables, contaminated drinking water, cold drink etc.).
Liver abscess is a common complication of amoebic dysentery. It may also result in gastric trouble cirrhosis of liver addition disease, blood disease like leukemia and also diabetes mellitus, some other symptoms of the disease are vomiting and diarrhoea, as a result, loss of Na, K, Mg and increase in blood sugar is observed. Increase pulse rate decreased blood foressure albuminuria are some of the symptoms.

**Jaundice**

It is also water borne disease, characterizing by increase of bile pigments in body fluids and tissues. It is associated with increase of bilirubin in blood, the serum cholesterol value is raised, excessive break down of R.B.Cs is observed and W.B.C. Count is low in hepato-cellular jaundice.

**Hepatitis**

The concentration of esterified cholesterol and the percentage of the total cholesterol are lowered in Hepatitis. Due to this liver is most affected, resulting lowering of serum albumin level.

Though hypertension, diabetes and heart disease which are quite prevalent among common people, may not be directly related to environmental pollution but as a result of uptake of polluted water, the normal functioning of different organs in the body may be effected and that may result in disease mentioned below, a brief description of these diseases is as under.

**Diabetes**

When insulin is introduced into the blood the content of blood sugar decreases the decrease varying with the amount of insulin entering with the amount of insulin entering the blood. Thus, hyperglycemia is observed in diabetes which results in the passage of sugar into the urine i.e., glycosuria, can be stopped. When insulin is injected an increase in the synthesis of glycogen and in the oxidation of carbohydrates in observed. Insulin the hormone of the island tissue is a protein with a molecular weight of 12000.
Hypertension and Heart Disease

During complete physical and mental rest the normal value of the systolic blood pressure in a human being (20-40 years old) may be taken as 100-125 mm Hg, the diastolic pressure 60-70 mm Hg with pulse pressure of 35-55. The value of the blood pressure may vary with a number of factors given below.

(i) Effect of changes in cardiac activity on arterial blood pressure.
(ii) Effect of changes in the arteriolar resistance on arterial blood pressure.
(iii) Effect of changes in the amount of blood on the blood pressure.
(iv) Effect of size of the lumen of capillaries and veins on arterial blood pressure.
(v) Effect of the viscosity of the blood on blood pressure.

The pressure be continuously below or above normal condition is called respectively hypo- or hypertension.

The most common cause of death is failure of the heart. This may be sudden or slow. Arterial hypertension is one of the rise of cholesterol proteins etc. which caused increased blood coagulability and hence a tendency to the deposition of thrombin. Due to increased viscosity of the blood its friction against the walls of a vessel is increased and consequently, greater is the resistance offered to its flow in the vessels, as a result the arterial blood pressure is raised [47].

So it is the matter of fact that hypertension and most of the heart diseases are related to each other, and the main role for above cause is blood.

The composition of blood is effected by the intake of different inorganic and organic substances viz., toxic metals, such as lead, sodium, cadmium, calcium, nitrates, oils, fats, sugar etc., as a result human being may suffer from hypertension, heart diseases, liver diseases, kidney diseases etc.

1.8 OCCUPATIONAL HAZARDS

Workers in mines, factories, commercial firms, forestry and agriculture are exposed to risks high to low; which are called the occupational hazards. According to
the United Nations, some 2 Lakh workers die each year throughout the world due to accident and occupational diseases. Another 10 millions suffer from non-fatal injuries. Some common occupational diseases are discussed given below [46].

[A] **Deadly Dust**

The worst occupational diseases are caused by dust. These are broadly termed as lung diseases (pneumoconiosis) and their effect depends on the nature of dust, its fineness, concentration, period of exposure and the victim’s health.

[B] **Silicosis**

It originates from dust containing free silica or silicon dioxide. It was first reported in 1947 in India in the Kolar Gold mines and then found to occur in various other mines and industries like coal, mica, silver, lead, zinc and manganese mines and pottery and ceramics, sand blasting, metal grinding, building construction, rock mining, iron and steel industry and other.

[C] **Asbestosis**

Asbestosis is the Greek expression for ‘unquenchable’. Because of its versatility it resists heat and moisture it is largely used in home construction, insulation of buildings and ships and also in car brake linings. The finest fibers, invisible to the naked eye, are the most dangerous as they find ready access to our respiratory tract, line the air tubes accumulate in the lungs.

The silica dust (from asbestos fibers) deposits in the lungs causes pulmonary fibrosis leading to respiratory problems and death in sever cases; it causes cancer of the air tubes and gastrointestinal tract.

[D] **Byssinosis**

Some 2 million textile and cotton mill workers are victims of byssinosis. Cotton emits lot of dust in various stage of its processing. The disease strickes sometimes 10 years after exposure. It progresses step by step, starting from temporary sickness of sneezing and coughing to permanent breathlessness which shortens life spam.
[E] **Pneumoconiosis**

It is commonly associated with mines and known as the source of “black lungs”. Coalmine workers who are exposed to coal dust lose their capacity to work hard and succumb to the disease which leads to tuberculosis and death.

[F] **Hygiene**

Hygiene is defined as the science of health that includes all factors which contribute to healthy living. The purpose of hygiene is to allow man to live in healthy relationship with his environment.

1.9 **INSTRUMENTATION**

The modern method of analysis have reached to a sufficiently advance level, so as to cope up satisfactorily with virtually all tasks viz., sensitivity, selectivity, convenience, precision and determination rate etc. Especially with regards to the trace determination of metals/organic compounds in a sample obtained from natural origin. The key problem is still accuracy i.e. a sufficiently low risk of systematic errors as a consequence of contamination and losses during the stages of analytical procedures. During the last two or three decades AAS, AES, XEA and NAA have exerted predominance, in the trace analysis of metals relevant to ecotoxicology as well as samples obtained from biological, environmental and natural origin.

Spot test is the oldest technique for the determination of trace inorganic element. This technique has required a least amount of the sample and gave the significant result that the expecting elements are present or not. This technique involves spot test plate or may be sometime filter paper with highly concentrated water samples [48].

The present thesis involves three major techniques for sensitive authenticity and convenience of the work.

I. Laboratory method or Spectrophotometric determination

II. Atomic Absorption Spectrophotometer

III. Electrochemical or Volta metric determination
1.9.1 LABORATORY METHOD OR SPECTROPHOTOMETRIC DETERMINATION

1.9.1.1 Spectrophotometry

An optical spectrophotometer and its name imply, is really two instrumenting in one cabinet- a spectrometer and a photometer.

An optical spectrometer is an instrument possessing an optical system which can produce dispersion of incident electromagnetic radiation and which measurements can be made of the quantity of transmitted radiation at selected wavelength of the spectral range. A photometer is a device for measuring the intensity of transmitted radiation or a function of this quantity when combined in the spectrophotometer the spectrometer and photometer are employed conjointly to produce a signal. Corresponding to the difference between the transmitted radiation of a reference material and that of a sample at selected wavelength the visible spectrophotometer deals in the range of 400-760 nm [49].

1.9.1.2 Theory of Spectrophotometry

When light (monochromatic or heterogeneous) falls upon a homogeneous medium a portion of the incident light is reflected, a portion is absorbed within the medium and the remainder is transmitted [50].

1.9.1.3 Theory of Spectrophotometry and Colorimetry

When light (monochromatic or heterogeneous) falls upon a homogeneous medium, a portion of the incident light is reflected, a portion is absorbed within the medium, and the remainder is transmitted. If the intensity of the incident light is expressed by $I_0$ that of the absorbed light by $I_a$ that of the transmitted light by $I_t$ and that of the reflected light by $I_r$, then:

$$I_0 = I_a + I_t + I_r$$
For air-glass interfaces consequent upon the use of glass cells, it may be stated that about 4 per cent of the incident light is reflected. $I_r$ is usually eliminated by the use of a control, such as a comparison cell, hence:

$$I_0 = I_a + I_t \quad (1)$$

**Lambert's law:** This law states that when monochromatic light passes through a transparent medium the rate of decrease in intensity with the thickness of the medium is proportional to the intensity of the light. This is equivalent to stating that the intensity of the emitted light decreases exponentially as the thickness of the absorbing medium increases arithmetically, or that any layer of given thickness of the medium absorbs the same fraction of the light incident upon it. We may express the law by the differential equation:

$$-\frac{dI}{dl} = kI \quad (2)$$

Where $I$ is the intensity of the incident light of wavelength $\lambda$, $l$ is the thickness of the medium, and $k$ is a proportionality factor. Integrating (2) and putting $I = I_0$ when $I = 0$, we obtain:

$$\ln \frac{I_0}{I_t} = kl \quad (3)$$

Or, stated in other terms,

$$I_t = I_0 \cdot e^{-kl} \quad (3)$$

Where $I_0$ is the intensity of the incident light falling upon an absorbing medium of thickness $l$, $I_t$ is the intensity of the transmitted light, and $k$ is a constant for the wavelength and the absorbing medium used. By changing from natural to common logarithms we obtain:

$$I_t = I_0 \cdot 10^{-0.4343kl} = I_0 \cdot 10^{-Kl} \quad (4)$$

Where $K = k/2.3026$ and is usually termed the absorption coefficient. The absorption coefficient is generally defined as the reciprocal of the thickness (1cm)
required reducing the light to \( \frac{1}{10} \) of its intensity. This follows from equation (4), since:

\[
\frac{I_t}{I_0} = 0.1 = 10^{-KI} \text{ or } KI = 1 \text{ and } K = \frac{1}{I}
\]

The ratio \( \frac{I_t}{I_0} \) is the fraction of the incident light transmitted by a thickness \( l \) of the medium and is termed the transmittance \( T \). Its reciprocal \( \frac{I_t}{I_0} \) is the opacity and the absorbance \( A \) of the medium (formerly called the optical density \( D \) or extinction \( E \)) is given by:

\[
A = \log \frac{I_0}{I_t}
\]

(5)

Thus a medium with absorbance \( I \) for a given wavelength transmits 10 percent of the incident light at the wavelength in question.

**Beer's law:**

In quantitative analysis however, mainly concerned with solutions. Beer studied the effect of concentration of the coloured constituent in solution upon the light transmission or absorption. He found the same relation between transmission and concentration as Lambert had discovered between transmission and thickness of the layer \{equation (3)\}, i.e., the intensity of a beam of monochromatic light decreases exponentially as the concentration of the absorbing substance increases arithmetically. This may be written in the form:

\[
I_t = I_0 \cdot e^{-k'c}
\]

\[
= I_0 \cdot 10^{-0.4343k'c} = I_0 \cdot 10^{-k'c}
\]

(6)

where \( c \) is the concentration, and \( k' \) and \( K' \) are constants. Combining (4) and (5), we have:

\[
I_t = I_0 \cdot 10^{-acl}
\]

(7)

or

\[
\log \frac{I_0}{I_t} = acl
\]

(8)

**Deviation from Beer's law:**

Beer's law will generally hold over a wide range of concentration if the structure of the coloured ion or of the coloured nonelectrolyte in the dissolved state does not change with concentration. Small amounts of electrolytes, which do
not react chemically with the coloured components, do not usually affect the light absorption; large amounts of electrolytes may result in a shift of the maximum absorption, and may also change the value of the extinction coefficient. Discrepancies are usually found when the coloured solute ionises, dissociates, or associates in solution, since the nature of the species in solution will vary with the concentration. The law does not hold when the coloured solute forms complexes, the composition of which depends upon the concentration.

1.9.2 ATOMIC ABSORPTION SPECTROPHOTOMETRY (ASS)

This is a popular method for the determination of metals in environmental samples. It was introduced by Dr. A. Walsh of Australia in 1955 and it represented a revolutionary development in trace metal analysis. The principle is illustrated in Fig. 1.3 (A-D) [51].
In Fig. 1.3(A), Fraunhoffer dark lines arise from the absorption of sunlight from the photosphere of the sun, by the atoms in the gaseous outer layer of the sun. In (B), the light from a tungsten lamp, directed through the flame of a Bunsen burner, is dispersed by a spectrograph and portrayed as a continuous spectrum. In (C), a small amount of NaCl on a platinum wire is introduced into the flame while the light source is turned off. The characteristic yellow D-line of Na 5893 Å is seen in the spectrum. Now, the lamp is turned on and the experiment repeated (D). A dark line is observed at 5893Å, i.e., exactly at the position as in (C).

Atomic absorption spectrophotometry is based on the measurement of the decrease in light intensity from a source (hollow cathode lamp) when it passes through a vapor layer of the atoms of the analytic element. The hollow cathode lamp produces intense electromagnetic radiation with a wavelength exactly the same as that absorbed by the atoms, leading to high selectivity.

### 1.9.2.1 Preparation of Sample Solution

For the application of flame spectroscopic methods the sample must be prepared in the form of a suitable solution unless it is already presented in this form; exceptionally, solid samples can be handled directly in some of the non-flame techniques [52].

Aqueous solutions may sometimes be analyzed directly without any pre-treatment, but it is a matter of chance that the given solution should contain the correct amount of material to give a satisfactory absorbance reading. If the existing concentration of the element to be determined is too high then the solution must be diluted quantitatively by before commencing the absorption measurement. Conversely, if the concentration of the metal in the test solution is too low, then a concentration procedure must be carried out.

Solutions in organic solvents may with certain reservations, be used directly provided that the viscosity of the solution is not very different from that of
an aqueous solution. The important consideration is that the solvent should not lead to any disturbance of the flame: an extreme example of this is to carbon tetrachloride which may extinguish an air-acetylene flame.

### 1.9.2.2 Preparation of Standard Solutions

In flame spectrophotometric measurements we are concerned with solutions having very small concentrations of the element to be determined the followed that the standard solutions which will be required for the analyses also contain very small concentrations of the relevant elements, and it is rare practicable compare prepare the standard solutions by weighing out directly the required reference substance. The usual practice therefore is to prepare stock solutions which contain about 1000 µg cm\(^{-3}\) of the required element, and then the working standard solutions are prepared by suitable dilution of the stock solutions. Solutions was contain less than 10 µg cm\(^{-3}\) are often found to deteriorate on standard owing 10 adsorption of the solution on to the walls of glass vessels. Consequently, standard solutions in which the solute concentration is of this order should not be stored for more than 1 to 2 days.

The stock solutions are ideally prepared from the pure metal or item the pure metal oxide by dissolution in a suitable acid solution: the solids used must of course be of the highest purity, e.g., the Johnson Matthey 'Specure' range of reagent. In many cases however it is prepared by dissolution of a suitable metallic salt in de-ionized water provided that the salt satisfies the normal requirements of a primary standard.

### 1.9.3 VOLTAMETRIC METHOD:

The fundamental features of Volta metric methods combine inherently high accuracy with extra ordinary detection sensitivity good precision and ability of oligo determination. Voltametry requires considerably low cost instrumentation on
its operation and maintenance. These features have made voltammetry an important method to analyse various metals and organic compounds in substances of natural environmental and biological origin. The voltametric methods originate from a simple electro chemical trace method, Polarography introduced by J. Meyrovski in 1922. It essentially involves electrolysis at a microelectrode leading to a reduction of a metal ion (electro active species) or its oxidation to ionic species [53].

\[ M^+ + ne = M \]  \hspace{1cm} \text{(1)}

\[ \text{Cd}^{2+} + 2e^- = \text{Cd} \]

With gradual increase of potential \( E \), the resulting current response is measured around its respective redox potential \( E^0 \). The resulting current potential plot Fig. 1.4 is the polarogram.

**Fig. 1.4: A Typical polarogram**

A typical polarogram is shown and description of various term are given below:
Migration current
Residual current
Diffusion current
Limiting current
Kinetic and catalytic current
Half wave potential

**(A) MIGRATION CURRENT**

Migration current is a consequence of electric attraction between the electrode and oppositely charged ions.

Heyrovsky (1934) showed that the whole effect of migration current as it is denoted can be eliminated simply by adding indifferent electrolyte to the solution in a concentration so large that its ions, carry almost all the current such as electrolytes is known as supporting or base electrolyte.

**(B) RESIDUAL OR CONDENSER CURRENT**

Residual Current is the sum of a small faradaic current ($i_f$) from the reduction of traces of impurities and a charging condenser current ($i_c$) hence.

Residual current = $i_f + i_c$

**(C) DIFFUSION CURRENT**

The electrostatic force of attraction on the reducible ions is nullified by an excess of supporting electrolyte present in the solution. This is because of the fact that the ions of the added salt carry practically all the current and the potential gradient is compressed or shortened to a region so very close to the electrode surface that it is no longer operative to attract electro reducible ions. Under such conditions, the limiting current is called diffusion current.

The value of diffusion current at its limiting value using a dropping mercury electrode is given by Ilkovic equation.
\[ i_d = 607 \, n \, D^{1/2} \, C^{2/3} \, t^{1/6} \] 

where, 
- \( i_d \) = diffusion current in \( \mu A \)
- \( n \) = number of Faraday of electricity required per mole of the electrode reaction.
- \( D \) = diffusion coefficient of ions in \( cm^2 \, sec^{-1} \)
- \( C \) = concentration of electroactive species in mM/1
- \( m \) = rate of flow of mercury from the dropping electrode capillary in mg sec\(^{-1}\)
- \( t \) = drop time in seconds. Usually measured at the half wave potential.
- 607 = a combination of numerical constants.

The Ilkovic equation points out two facts of great importance:

i) The observed diffusion current is directly proportional to the concentration of electroactive material. This fact forms the basis of quantitative polarographic analysis.

ii) The diffusion current is proportional to the product \( m^{2/3} \, t^{1/6} \). The latter is important because it permits results with different capillaries under otherwise identical conditions to be compared. The diffusion current is simply the ratio of \( m^{2/3} \, t^{1/6} \) values.

The diffusion current \( i_d \) depends upon several factors such as:

- Temperature
- Viscosity of the medium
- The composition of base electrolyte
- Dimension of the capillary
- The molecular or ionic state of electro-active species
- Pressure of the dropping mercury electrode.

The Ilkovic equation has been modified by Lingane and Loveridge (1950) they suggested a correction and the corrected equation is:
\( i_d = 607 \, nD^{1/2} \, Cm^{2/3} \, t^{1/6} \left[ 1 + A \frac{D^{1/2} \, t^{1/6}}{m^{1/3}} \right] \)

(D) KINETIC CURRENT

The current is a result of slow reaction processes occurring between absorbed ions at the surface of the mercury dropping electrode prior to electron exchange. This phenomenon has been found in organic fields especially with carboxylic radicals.

(E) HALF WAVE POTENTIAL

The potential corresponding to the mid point of the diffusion current wave is known as the half wave potential and may be defined as Ï€The potential at the point of inflection of the current voltage curve i.e. polarographic waveñ. This is the essential basis of qualitative polarographic analysis.

The significance of half wave potential can be best understood by considering the behaviour of redox system:

\[ \text{Ox} + n\text{e}^- = \text{Red} \]

\[ \text{(3)} \]

For such system the electrochemical equilibrium may be represented mathematically as:

\[ E = E^0 + \frac{0.0591}{n} \log \frac{[\text{Ox}]}{[\text{Red}]} \]

\[ \text{(4)} \]

The half wave potential is related to the standard oxidation potential by equation:

\[ E_{1/2} = E^0 + \frac{RT}{nF} \log \frac{[\text{Ox}]}{[\text{Red}]} \]

\[ \text{(5)} \]

Where (Ox) and (Red) are the activity coefficients of appropriate oxidizing and reducing species respectively. This equation shows that half wave potential depends only on the value of standard potential of the electrode and the ratio of diffusion coefficients of metal atom in the amalgam and metal ion in the solution for a redox system.
\[ E = E^0 + \frac{0.0591}{n} \log \left( \frac{i_d - i}{i} \right) \] .... (6)

From this equation it is obvious that when \( i = i_{d/2} \) then

\[ E = E^0 \] the standard electrode potential and it is the half wave potential of electro active species under study.

Thus equation (6) may be written as:

\[ E = E_{1/2} + \frac{0.0591}{n} \log \left( \frac{i_d - i}{i} \right) \] é (7)

from equation (7) is followed that if

\[ \log \left( \frac{i_d - i}{i} \right) \] is plotted against

Corresponding potential \( E \) of the microelectrode a straight line should be obtained, with a slope value of \((0.0591/n)\) for reversibly redox system and its intercept to the potential axis is half wave potential \((E_{1/2})\).

1.9.4 ADVANCED POLAROGRAPHIC METHODS

The development of advanced polarographic method with improved sensitivities viz. sampled, do polarography, normal pulse polarography (NPP) and differential pulse polarography (DPP) are included in advanced polarographic methods. A brief introduction to BPP, DPP, and Cyclic voltammetry is discussed here.

1.9.4.1 Normal Pulse Polarography

The normal pulse polarography preserves entirely the sensitivity improvement achieved in test polarography by discrimination against the charging current. In addition the pulse method gains enhanced sensitivity through the increased faradaic currents, by comparison to those observed in test or conventional polarography, sensitivity limits are usually between \(10^{-6}\) to \(10^{-7}\) M. varying voltage pulse are superimposed on a constant base voltage \((E_b)\) for most of
the life of each mercury drop from the d. me. After a fixed waiting period $T$ measured, form the birth of the drop a square wave voltage pulse of about 40 ms duration is applied. At the instant when voltage pulse is applied. The charging current is very large but is decays rather rapidly.

1.9.4.2 Differential pulse polarography (DPP)

Two measuring periods and used. One immediately preceding the pulse, the other very near end of the pulse. The overall response plotted is the difference in the current ($\Delta i$) as a function of potential as a result peak shaped polarograms, also known as differential pulse polarogram are superimposed on a slowly increasing linear voltage ramp (Fig. 1.5).

Two measuring periods are used. One immediately preceding the pulse, the other very near the end of the pulse. The overall response plotted is the difference in the current ($\Delta i$) as a function of potential as a result peak shaped polarograms, also known as differential pulse polarogram are observed. Its sensitivity limits are usually $10^{-7}$ to $10^{-9}$ M (Fig. 1.6).

![Fig. 1.5: Sampling scheme for differential pulse polarography](image-url)
1.10. AIMS AND SCOPES OF THE PRESENT WORK

In the modern era man finds himself exposed to an environment, containing many different pollutants these pollutants contaminate the water, air and all our surroundings. There is a definite permissible limit of different organic and inorganic substances in water which a man can tolerate in the form of domestic water supplies for drinking water.

The permissible limits for surface water are 3 to 5 times higher that is the general requirement for recreation and aesthetic (rowing, navigation) aquatic life fish, wild life and irrigation etc. wide variation from the values given in the Table 1.2 is encountered under a variety of physiological, pathological and environmental condition etc. water in taken by a normal person is largely a matter of individual choice or habit. Normally an individual is in water equilibrium i.e. water gain equal to water loss by all source.

The quality of water is of vital concern for mankind since it is directly linked with human welfare.
It is a matter of history that faces pollution of drinking water caused by water borne diseases such as infective hepatitis, poliomyelitis cholera, diarrhea, typhoid and dysentery.

Water quality characteristics of aquatic environments arise from a multitude of physical, chemical and biological interactions. The balance in the aquatic ecosystem is upset by human activities, resulting in pollution, which is harmful for human health.

The determination of water quality parameters like, pH, DO, BOD, COD etc. and levels of metals and organic substances in water samples is an important analytical task to judge the quality of water sample and its usefulness for public health. It is also known that various diseases cause abnormalities in the composition of biological fluids, particularly blood and urine of the patient by way of increase or decrease of the concentration of its constituent or through appearance of new compounds in them [54].

The present study has been conducted in Sagar city, keeping in view its suitability relating human health and also that no regular data or study is available regarding over all status of drinking/lake water and exposed human for their health purpose. The objective is to create a serious attention to the different water sources like dug wells, tube wells, domestic water supply (from corporation) etc. in and around Sagar city of M.P. and also analysis of these samples for their metal traces content. The above analysis has enabled the author to speak of the quality of water samples and their impact on human health.

Analysis of blood samples obtained from patients suffering from different diseases mainly heart disease, diabetes hypertension, kidney problem and memory problem has also been done for the diagnostic purposes. Advanced analytical methods viz. Atomic absorption spectrophotometer (AAS), UV-vis spectrophotometer and differential pulse polarography (DPP) have been used for the above purpose.
1.11 REFERENCES


Chapter-1

Introduction


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