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Dharmendra Pratap SinghDepartment of Chemistry, S.V.
College, Aligarh, Uttar Pradesh,
India**Dr. Neerja Sharma**Department of Chemistry, S.V.
College, Aligarh, Uttar Pradesh,
India

Heavy metal pollutants in water and their detection techniques

Dharmendra Pratap Singh and Dr. Neerja Sharma

Abstract

Heavy metals contamination is one of the major problems in the world. The heavy metals like Mercury (Hg), Arsenic (As), Lead (Pb), Chromium (Cr), Cadmium (Cd), Nickel (Ni), Cobalt (Co) and Zinc (Zn) are considered to be highly toxic and highly hazardous. Heavy metals enter in the water through industrial discharge, metal painting, mining, and they reach the humans by food and drinking water and cause high blood pressure, liver and kidney damage, high risk of cancer of lung, skin. Hence detection and quantification of these heavy metals are very important for health care and prevention of serious diseases. This review is the general description of the occurrence of heavy metals and their detection in water. Atomic Absorption Spectrometry (AAS), X-ray fluorescence spectrometry and Biosensors are the most trending techniques for the detection of Mercury (Hg), Arsenic (As), Lead (Pb), Chromium (Cr), Cadmium (Cd), and Zinc (Zn) in water bodies. These methods provide strong reliability and best results of heavy metals.

Keywords: Heavy metals, detection techniques- AAS, x-ray fluorescence, biosensors

Introduction

Pollution is a global problem. It is a natural imbalance as you do not get clean air and clean water. The word "pollution" means anything that harms the environment and living things. The word "dirt" is derived from Latin. It means filth. Pollution refers to the combination of hazardous substances such as chemicals, industrial and domestic waste, radiation, noise, fumes, insecticides, fertilizers etc., that can be harmful to living people in any condition. So, we can say that pollution is because there are dangerous substances in our environment ^[1].

These harmful substances can be natural or artificial. Natural pollution is from volcano, SO₂ gas, CO gas, solid waste particles and other hazardous substances in the environment. On the other hand, pollution is caused by man-made. Some products are good for people but produce pollution. Smoking motors and heat coal to get electricity pollutes the air. Factories and industries produce waste, gases and sewages that pollute the soil, air and water.

Pollution is divided into many categories such as air pollution, water pollution, soil pollution, noise pollution, radiations and many other things ^[2].

The normal daily activity of humans affects the environment and causes global warming. Vehicles emit harmful gases (CO, CO₂, SO₂,) and waste products (non-combustible hydrocarbons and fuel) into the atmosphere. Sewage of home, fertilizer and pesticides in the fields affects water and land. It can also be noise, electromagnetic waves and other harmful radiation.

Types of Pollution

Water pollution

Water is essential for life. Everyone knows how important it is but water pollution is one of the biggest problems in our daily lives. Water pollution increases when toxic and hazardous substances are dissolved in water bodies such as lakes, rivers, seas and so on. Much toxic material pollutes the various water sources on which the life of all living things depends and is therefore a threat to life on earth and lowers water quality. Large amounts of pollutants such as garbage, chemicals reaching lakes, rivers, streams, groundwater and thus make clean water hazardous.

It is important to keep water safe and clean because even though we know that 70% of the earth is covered with water but only 25% of the water is fresh and used. Only 1% of usable water is readily available for our use.

Corresponding Author:**Dharmendra Pratap Singh**Department of Chemistry, S.V.
College, Aligarh, Uttar Pradesh,
India

We are advancing industry in our communities. Although these are important factors for the development of society, but these are identified as a major environmental danger. They emit a lot of toxic and harmful chemicals, gases and wastes in the environment. It can reach us through the earth, water, air.^[3] It is harmful to humans and other living being.

Industrial effluents are a major cause of water pollution. Other types of pollutants include organic waste, toxic chemicals, residues, small particles, gasoline, and radio equipment. 80% of diseases are born with water pollution. According to the WHO in various places drinking water is not available^[4].

There is a strong link in between water pollution and diseases in living beings. Many diseases are caused by drinking contaminated water^[5]. They reach every person^[6]. Due to contamination of water various diseases such as respiratory diseases, diarrhea, blue baby syndrome, cancer etc. These are most prevalent in rural and undeveloped areas. Dirty water can harm women during pregnancy. It affects the health of the newborn. Water pollution due to heavy metals causes hair loss, cirrhosis of the liver, neural disorder^[7]. Many diseases (diarrhea, cholera), bacterial infections (liver infection, jaundice, anorexia, fatigue) are born with contaminated water.

Causes of Water Pollution

i. Domestic Sewage

It is a major source of biological and microbial diseases. All the sewage of cities and towns has gone to water bodies which is the cause of various diseases in humans and animals. Domestic water pollution is pollution caused by household chores such as kitchens, toilets, laundry services, and soaps. Food spoilage, laundry wastes, garbage and other unused things that we easily pass through the ditch but this is our beginning to pollute the environment. Household sewage has a wide range of water pollution. Many types of products are used for the cleanliness of our homes. They add water pollution because they contain harmful chemicals. Most washing products and detergents contain phosphates that are used for easy cleaning, but these chemicals affect water bodies. Detergents can cause kidney and liver damage. Wastewater carries harmful microorganisms that are responsible for advancing disease in living organisms.

ii. Industrial Sewage

Industrial and industrial wastewaters are the main causes of water pollution^[8]. Most industries use water to make products that in value chemical processes. Such contaminated water goes into bodies of water such as canals, rivers, lakes etc. It affects people and the environment.

Sometimes contaminated water can have radioactive traces that cause cancer and birth defects. Industries produce water wastes after chemical production. That may contain heavy metals such as Lead (Pb), Mercury (Hg), Chromium (Cr) and other fertilizer companies producing large amounts of Ammonia. Iron plants produce cyanide. Some chemicals are used in industry to produce and manufacture new products. All chemical wastes reach to water bodies and make them harmful to humans and animals^[9].

iii. Chemical wastage in Agriculture

Fertilizers and pesticides are used to increase productivity. Most pesticides and fertilizers are misused in the fields and therefore cause increased water and soil pollution. DDT,

Aldrin, Malathion commonly used in agriculture without their proper knowledge^[3].

iv. Wastage of oil

Garbage oil reaches the water through leaks from the fuel tank and tanks that transport petrol, diesel, and other chemicals. As a result of the accident the oil came into contact with water and causes water pollution^[1,9].

v. Acid rain

Acid rain is also a major cause of water pollution when it falls to the ground. It reaches the bodies of water. This type of rainfall affects the pH level and pollutes the water^[9]. Acid rain is known as atmospheric acid which falls to the earth in the form of ice, rain, hail, dew, fog, mist, sleet, gas, smoke and aerosols. It is produced by heating coal, natural gas and oil and industrial chemical activities^[10]. The release of Sulfur dioxide (SO₂) and Nitrogen oxides (NO_x) significantly causes acid rain to react with water molecules in the air and to produce H₂SO₄ and HNO₃^[10].

Pharmacist M. Ducros in 1845 observed Acid rain for the first time^[11]. In 1872 the Inspector General and Royal Society of Alkali Robert Angus smith looked at the word "Acid Rain" in the article "Air and Rain: The Beginning of Chemical Climatology" and saw that (NH₄)₂CO₃ was in space over the agricultural region^[11].

vi. Use of Plastic

Plastic is useful in all sectors such as industry, housing, company, and stores. All products are packed in plastic. Most items are made of plastic because of their light weight and durability and strength.

Now plastic waste of the day is a major source of pollution. Plastic waste is often thrown into water directly. It stays in the water for many years^[5].

vii. Inorganic Wastage

Inorganic salts, iron compounds, cyanides, sulphates, nitrates present in water. Other toxic substances are heavy metals such as Hg, Pb, Zn, As, Sb, Se. These are known to pollute the water. These types of pollutants come from road dust, sewage, and industrial activities^[1].

Heavy Metals

Although heavy metals are not defined in terms of specific meanings, they have a higher atomic weight and a five times higher magnitude than water. Generally, some metals are found in the water when their presence rise and then toxicity increases in the water. The most toxic metals are Mercury (Hg), Arsenic (As), Lead (Pb), Chromium (Cr), Cadmium (Cd), Nickel (Ni), Cobalt (Co) and Zinc (Zn)^[12].

Some metals (Zn, Cu, Iron, etc.) are useful for humans and animals in the form of very small quantity. Other metals containing phosphates, nitrates, sulphates, and some of them are helpful in limited quantity^[13]. Excessive amounts of heavy metals are highly toxic and can cause skin cancer, lung diseases, urinary tract infections and other diseases^[14].

More than 50 substances are known to be heavy metals and 17 of these metals are considered to be highly toxic^[15]. Heavy metals are found in the crust of the earth and cannot be destroyed. In a small follow-up they reach the body through food, drinking water and air.

Table 1: Permissible values of heavy metals in water (by WHO) ^[15]

Entry	Heavy Metals	Value (Mg/L)
1	Arsenic (As)	0.01
2	Cadmium (Cd)	0.003
3	Copper (Cu)	2
4	Lead (Pb)	0.01
5	Mercury (Hg)	0.006
6	Nickel (Ni)	0.07
7	Uranium (U)	0.015

Some toxic metals are known as “trace metals”. These are categorized as Heavy metals have densities above 5g/cm³. Mercury (Hg), lead (Pb), copper (Cu), cadmium (Cd), zinc (Zn), nickel (Ni), arsenic (As) and antimony (Sb) are considered in this category ^[1].

Lead (Pb): Lead paint and dust are the primary source of lead exposure, especially in older homes. Leaded gasoline has caused lead contamination of soil near roadways and in urban areas. Drinking water is usually a smaller source of exposure to lead, but this varies greatly among homes, schools, and other buildings, and can add to other lead sources. Infants drinking formula can get half of their lead exposure from drinking water.

In a 1983 British Heart Card Study, BLLs of 7,378 men in 24 British cities were surveyed ^[16]. All men were divided into categories with a focus on lead in domestic water, water scarcity, and alcohol and tobacco use. The findings showed that when the first water pipeline drew 100 ppb at home, men's BLLs were 1.00 $\mu\text{mol} / \text{L}$, compared to 0.7 $\mu\text{mol} / \text{L}$ for men who had domestic tap water and contained undetectable earnings. Studies have recommended that lead in water be given more priority than in any other national campaign to reduce lead exposure.

In a follow-up study in Glasgow, Scotland, water-based lubricants and maternal BLLs from 1981 were compared to water and BLLs from 1993 ^[17]. In 1993, 17% of 1,812 households had daylight hours, the initial lead levels drawn from 1 L of water were pp10 ppb, compared with 49% of the 131 households enrolled in the 1981 study. Maternal BLLs decreased by 31% over the same period (11.9 $\mu\text{g} / \text{dL}$ in 1981 vs. 3.7 $\mu\text{g} / \text{dL}$ in 1993). Despite these declines, the study reported that even reduced levels of lead in tap water are likely to pose a risk to bottle-fed babies. Adults absorb 35 to 50% of lead in drinking water and the rate of absorption of children can be greater than 50%. Sucking on the front has led to things like age and body shape. In the human body, a large percentage of lead is transferred to the kidneys, followed by the liver and other soft tissues such as the heart and brain, however, bone marrow represents a large part of the body. The nervous system is responsible for the increased risk of lead poisoning. Headaches, attention spam, irritability, memory loss and dizziness are the first symptoms of the consequences of exposure to lead in the central nervous system.

Lead is present in tap water to some degree not only because of its decline in natural resources, but also in plumbing systems where pipelines, solder, fittings or home service connections contain lead. Polyvinyl chloride (PVC) pipes also contain lead compounds that can be extracted from them and lead to high concentrations of drinking water.

The amount of lead dissolved in the pipeline system depends on a number of factors, including the presence of chloride and dissolved oxygen, pH, temperature, softness, and duration. Acidic water is a very high polar solvent ^[18].

Although lead can be drawn from lead pipes indefinitely, lead leaks from commercial joints and copper taps appear to decrease with time ^[19]. Connections sold in newly built homes with a copper pipe can produce enough lead (210-390 $\mu\text{g} / \text{l}$) to create intoxication in children.

Lead levels in drinking water can be reduced by means of corrosion control measures such as lime addition and pH adjustment in the distribution system from <7 to 8-9. ^[20].

Lead can also be extracted from the installation of lead carbonate pipes in lead pipes and metal pipes from old thick pipes that have collected lead from lead sources such as pipelines and utility connections, or water no longer working as plumb solvent. In 1988, it was estimated that the 5 $\mu\text{g} / \text{l}$ earning rate exceeded only 1.1% of public water supply systems in the USA ^[21].

A recent review of lead levels in drinking water in the USA found that geometric means 2.8 $\mu\text{g} / \text{l}$. The median level of lead in drinking water samples collected from five Canadian cities was 2.0 $\mu\text{g} / \text{l}$. A study conducted in Ontario (Canada) found that the average lead intake in water actually consumed during a one-week sample was between 1.1–30.7 $\mu\text{g} / \text{l}$, at a rate of 4.8 $\mu\text{g} / \text{l}$ ^[22].

In the United Kingdom from 1975 to 1976, there was no lead in drinking water in two-thirds of households, but levels were above 50 $\mu\text{g} / \text{l}$ in 10% of households in England and 33% in Scotland ^[33]. In Glasgow (Scotland), where water is known as plumb solvent, concentration leading to about 40% of samples exceeds 100 $\mu\text{g} / \text{l}$ ^[23]. If the concentration of 5 $\mu\text{g} / \text{l}$ in drinking water is taken into account, the total amount of lead from this source can be calculated from 3.8 $\mu\text{g} / \text{day}$ infants up to 10 μ / day per adult.

Arsenic (As): Arsenic is a natural component of the earth's crust and is widely distributed throughout the ecosystem in air, water, and land. It is highly toxic in its inanimate form. Humans are exposed to high levels of inorganic arsenic by drinking contaminated water, using contaminated water for food preparation and irrigation for food crops, industrial processes, eating contaminated food and smoking. Prolonged exposure to inorganic arsenic, especially with drinking water and food, can lead to chronic arsenic poisoning. Skin ulcers and skin cancer are the most visible results.

The greatest threat to public health from arsenic comes from contaminated groundwater. It is present at high levels of groundwater in many countries, including Argentina, Bangladesh, Chile, China, India, Mexico, and the United States of America. Drinking water, contaminated plants and food prepared with contaminated water are sources of exposure.

Fish, mussels, meat, poultry, dairy products and grains can also be sources of arsenic, although exposure to these foods is generally very low compared to exposure to contaminated groundwater. In marine animals, arsenic is found mainly in its non-toxic form.

Arsenic is used in industry as an alloying agent, as well as in the processing of glass, pork, textiles, paper, metal attachments, wood preservatives and ammunition. Arsenic is also used in skin rejuvenation and, to a lesser extent, in pesticides, supplements and medications.

People who smoke cigarettes can also be exposed to the natural arsenic content in tobacco because tobacco plants can absorb the arsenic naturally present in the soil. Also, in the past, the potential for high levels of arsenic exposure was high when tobacco plants were treated with lead pesticides.

The International Agency for Research on Cancer (IARC) classified arsenic and arsenic compounds as carcinogenic in humans, and also said that arsenic in drinking water can cause cancer in humans. Other adverse health effects that may be associated with long-term intake of rare arsenic include progressive effects, diabetes, lung disease and heart disease. Arsenic caused by myocardial infarction, in particular, can be an important cause of obesity. In China (Taiwan province), arsenic exposure has been linked to "Blackfoot disease", a serious vascular disease that leads to decay. The disease has never been seen in other parts of the world, however, and malnutrition may be contributing to its development.

Arsenic has also been linked to the adverse effects of pregnancy and infant mortality, with impacts on the health of children, and uterus exposure in early childhood has been linked to an increase in adult mortality due to multiple cancers, lung disease, heart disease, and kidney failure. Numerous studies have shown the negative effects of arsenic exposure on improving cognition, cognition, and memory [24].

Zinc (Zn): Zinc occurs naturally in air, water and soil, but zinc levels increase exponentially, due to the addition of zinc by human activities. Most of the zinc can be absorbed during industrial activities, such as excavation, coal and waste disposal and metal processing. Some soils are highly polluted by zinc, and these are found in areas where zinc must be converted or purified, or sewage from industrial areas should be used as fertilizer.

Zinc is the 23rd most abundant element in the Earth's crust. The main ore is zinc blende, also known as sphalerite. Other important zinc ores are wurtzite, smithsonite and hemimorphite. The main zinc mining areas are Canada, Russia, Australia, the USA and Peru. Land production exceeds 7 million tons per year and commercial deposits exceed 100 million tons. More than 30% of the global zinc requirement is met with reuse.

Although people can handle very high concentrations of zinc, too much zinc can still cause serious health problems, such as stomach aches, skin irritation, vomiting, nausea and anemia. High levels of zinc can damage the pancreas and disrupt protein metabolism and cause arteriosclerosis. Excessive exposure to zinc chloride can cause respiratory disturbances. Zinc can be dangerous for unborn babies and newborns. Once their mothers have absorbed a high concentration of zinc the babies can be exposed to it through the blood or milk of the mother.

Mercury (Hg): Mercury is the most dangerous metal in human health and the environment. It has high toxicity, tension, and bio- tendency to accumulate in the human body. Mercury is on the first list of 129 chemical products manufactured by USEPA. Mercury metal tracks are found in chloro-alkaline plants, thermometers, barometers, fluorescent light. Organic mercury species are generally more toxic than non-organic species. It is possible that inorganic mercury is naturally converted to organic mercury.

Therefore, it is important to control the inorganic mercury leaching from the mercury-containing waste. Improper waste disposal during early industrialization led to mercury

pollution in the soil. Natural sources of mercury emissions are volcanic emissions, forest fires, and emissions from polluted water and land systems. Mercury is also found in coal and oil fires, solid medical waste, and mercury production. In the United States, an estimated 97% of anthropogenic mercury emissions come from both fire and industrial sources [25].

In medicine, in addition to the aforementioned use of mercury as a remedy for syphilis, mercury compounds have also been used as diuretics [calomel (Hg_2Cl_2)], and mercury amalgam is still used to fill teeth in many countries.

The effect of mercury toxicity on the CNS includes depression, fear, irritability, hallucinations, concentration, memory failure, hand tremors, headache, lips, tongue, jaw and eyelids, weight loss, sedation and constant fever, drowsiness, headaches, insomnia, and weakness. Consistent with the effect of the nervous system, mercury should provide a different cause for other abnormal sensory systems and vision loss, relapses, optic neuropathy, hearing loss, combined sense of smell, and abnormal sensation of touch [26].

Cadmium (Cd): Cadmium and cadmium compounds, compared to other heavy metals, are soluble in water. So they also go a long way in e.g. soil, is generally not available and do not like to be collected. Cadmium is readily available through many organisms, especially microorganisms and molecules where bio-concentration factors are arranged in thousands of sequences. Soil invertebrates are also high in cadmium. Most organisms exhibit low to less than 100 levels of torture. In animals, cadmium is concentrated in the internal organs rather than in the muscles or fat. It is usually higher in the kidneys than in the liver, and higher in the liver than in the muscles. Cadmium levels usually increase with age.

Cadmium is toxic to many types of microorganisms as shown by laboratory tests. However, the presence of a corpse, a high concentration of dissolved salt or organic matter in test vessels all minimizes the toxic effect. The main effect is growth and repetition. The least affected organisms in the soil are fungi; some species are removed after exposure to cadmium in the soil. There is a selection of antimicrobials after low metal exposure to the soil.

Cadmium is often used in a variety of industrial applications. Major industrial applications of cadmium include the production of alloys, pigments, and batteries [24]. Although the use of cadmium in batteries has shown significant growth in recent years, its commercial use has declined in developed countries in response to environmental concerns.

In the United States, for example, the daily intake of cadmium is about $0.4\mu\text{g} / \text{kg} / \text{day}$, less than half the recommended EPA oral dose for the U.S. This decline has been linked to the introduction of stricter contaminants from plate installation activities and, more recently, to the introduction of common restrictions on cadmium consumption in certain countries. In addition, a diet rich in cadmium can significantly increase cadmium concentration in the human body. Examples are liver, mushrooms, shellfish, mussels, cocoa powder, and dry sea. The main circulatory system is the circulatory system, and the blood vessels are considered the main organs of cadmium toxins.

Table 2: Sources of heavy metal pollutants in water

S. No.	Heavy Metal	Sources
1	Hg	chlor- alkali, Batteries, Paint and dyes, paper and pulp, Motor vehicles, explosives, Pharmaceuticals, mining and metallurgy, pesticides
2	Pb	Batteries, Chlor-Alkali, Paints and dyes, Petroleum refining, Fertilizers, Motor vehicles, Explosives, Pesticides,
3	Zn	Electroplating, chlor- alkali, petroleum refining, fertilizers, motor vehicles, mining, and metallurgy
4	Cd	Batteries, chlor- alkali, paints and dyes, petroleum refining, fertilizers, mining, motor vehicles
5	As	Pharmaceuticals, mining and metallurgy, explosives, pesticides

Table 3: The MCL standards established by US Environmental Protection Agency (USEPA) and diseases due to heavy metals [1].

S. No.	Heavy Metals	Diseases
1	Arsenic	Liver disease, Skin manifestations, visceral cancers, vascular disease, blood diseases, lungs diseases
2	Cadmium	Kidney damage, renal disorder, lungs diseases, human carcinogen, blood diseases, lungs diseases
3	Chromium	Headache, diarrhea, nausea, vomiting, carcinogenic
4	Copper	Liver damage, Wilson disease, insomnia
5	Nickel	Dermatitis, nausea, chronic asthma, coughing, human carcinogen
6	Zinc	Depression, lethargy, neurological signs and increased thirst
7	Lead	Damage the fetal brain, blood diseases, diseases of the kidneys, circulatory system, and nervous system
8	Mercury	Rheumatoid arthritis, liver, kidneys, circulatory system and nervous system, blood and lung disease

Detection techniques of heavy metals in water

It is a very big problem of the presence of toxic heavy metal and many harmful pollutants in water. It is very difficult task to set the limit for environment. Fe, Zn, Cu, Co, Cr, Mn and Ni are heavy metals which trace amount is required for biological aspects, but their higher amount can be toxic. Other heavy metals are truly toxic in any amount. These toxic metals are Pb, Hg, Cd and As. Their toxicity is very big problem for worldwide in the environment [23].

When we detect heavy metals in water, water sample is taken from various fields as surface water, different depth water, bottom water of the lakes, rivers and many water sources. There are many analytical techniques to detect the toxic heavy metals. These techniques are given below:

1. Atomic Absorption Spectroscopy (AAS)
2. X-ray fluorescence spectrometry
3. Biosensors

Besides these some other techniques are also developing. Each technique has some unique features, advantage or disadvantage

1. Atomic Absorption Spectroscopy (AAS)

Atomic Absorption Spectrometry (AAS) is a standard analytical process for detecting heavy metals and metalloids from environmental samples. This method is very sensitive to measuring down to one billion parts of a gram sample. In AAS, an element specifically absorbs light wavelength and corresponds to the energy needed to propagate electrons from one energy level to another high energy level.

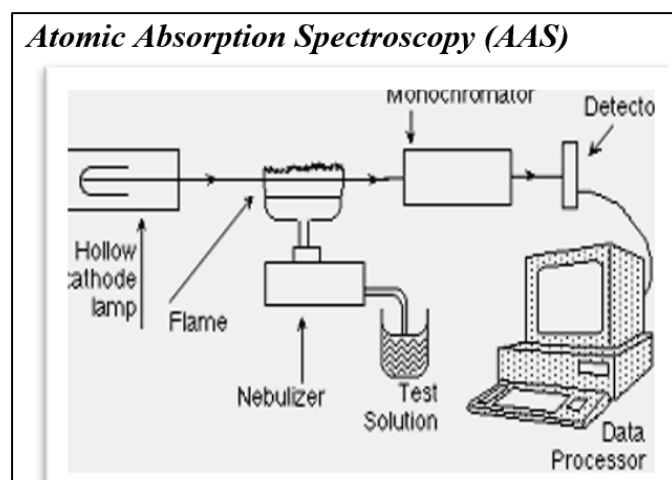
The AAS method is more efficient, faster, and cost-effective to monitor the levels of heavy metals [cadmium (Cd), lead (Pb) and arsenic (As)] in water [20]. It is very reliable and easy to use and can analyze and measure the concentration of heavy metals in the sample. CSIRO scientist Alan Walsh in 1954 developed the first Atomic Absorption Spectroscope. This method basically uses the principle that free atoms (gas) produced by an atomizer can absorb radiation from time to time. It measures the absorption of atoms of the earth's state in the form of a gas. Atoms absorb ultraviolet or visible light and make changes in high levels of electrical activity. The analysis filter is determined from the absorption value. Concentration rates are usually determined from the app's

curve after measuring the instrument by known concentration levels.

The metal content of water and mud samples was developed by Flame Atomic Absorption Spectrometry (FAAS) [30] or Graphite Furnace Atomic Absorption Spectrometry (GFAAS). According to the Environment Minister's Regulation [31], a sample containing heavy metals (lead, cadmium, mercury, nickel, zinc, copper and chromium) is determined after digestion using strong acids. The analysis can be performed with atomic absorption spectrometry (AAS) or spectroscopy of plasma atomic emission spectroscopy (ICP-AES).

The Atomic Absorption Spectrophotometer was used to detect heavy metals (Zn, Cu, Fe, Mn, Co, Pb, Cd and Ni) in water and fish (Mugil Cephalus) off the coast of Poompuhar (off the southeast coast of India) before and after the Tsunami.

Light Source: Empty cathode lamps are the most common radiation source in AAS. It contains a Tungsten anode and a blank cylindrical cathode made of a cut element. This is sealed in a glass tube filled with inert gas (neon and argon). Each item has its own unique lamp that should be used for that analysis.

**Fig 1:** Atomic Absorption Spectroscopy (AAS)

Nebulizer: It absorbs liquid samples at a controlled rate and creates a good aerosol spray to be introduced into the flame. It

mixes aerosol with petrol and oxidant well to be introduced into the flame.

Atomizer: Atomizer analyzes the elements that need to be in the atomic state. Atomization is the division of particles into individual molecules and the splitting of the molecules into atoms. This is done by exposing the analyst to high temperatures in the flame or in the graphite furnace. There are two types of Flame atomizer. In this atomizer to create flame we need to mix liquid gas and petrol. In most cases flame air, acetylene flame or nitrous oxide acetylene flame. Liquid or soluble samples are widely used with a flame atomizer and other graphite tube atomizer. It uses a graphite furnace to heat the sample and these samples are placed in a small tube made of combustible graphite to burn and produce analysis. Graphite tubes are heated using high current electricity.

Monochromator: It is the most important component in the AA Spectrometer. A mono-chromator is used to select specific wavelengths that absorb a sample, and to emit additional wavelengths. The choice of a particular light allows for the determination of the selected element in front of others.

Detector: A lamp selected by a monochromator is directed to a detector which is usually a photomultiplier tube, whose function is to convert a light signal into an electrical signal equal to the intensity of light. The electric signal drive is completed by the signal amplifier. The signal can be displayed or read continuously in the print data channel in the requested format.

Calibration Curve: A measurement curve is used to determine the unknown focus of an object in a solution. The metal is measured using several known concentration solutions. The absorption of each known solution is measured and adjusted for the measuring curve for the v/s absorption curve. Sample solution is applied to the tool and the absorption of the substance in this solution is measured. The unknown concentration of an object is calculated from the measuring curve.

Applications: This spectroscopy is used to detect heavy metals (lead, mercury, calcium, magnesium). It is used in the areas as environmental Studies, drinking water, seawater, soil, food industry and pharmaceutical industry.

2. X-ray fluorescence spectrometry

X-ray fluorescence (XRF) spectrometer is an x-ray tool used for general, non-corrosive processing of stones, minerals, and liquids. It works on wavelength-dispersive spectroscopic terms such as electron microprobe (EPMA). However, XRF is generally not able to process small-scale that are exactly the same as the EPMA function (2-5 microns), so it is commonly used for the analysis of large quantities of material [27]. The relative ease and low cost of sample preparation, and the stability and ease of use of x-ray spectrometers make this one of the most widely used methods for analyzing large and sequential objects in rocks, minerals, and rope.

Principle

The XRF method is based on basic principles commonly used in many other methods, including interactions between electron and x-ray beams and samples, including X-ray

spectroscopy (SEM - EDS), X-ray diffraction (XRD), and wavelength spectroscopy (microprobe WDS).

Major analysis and tracking of geological objects by x-ray fluorescence is done by the behavior of atoms in contact with radiation. When objects are excited with high intensity, small wavelength rays (e.g., X-rays), can be ionized [28]. When radiation is enough to release a strongly entrenched inner electron, the atom becomes unstable, and the outer electron replaces the missing inner electron. When this happens, the energy is released due to a decrease in the binding force of the internal orbital electron compared to the outer one. The emitted radiation is less powerful than the main X-ray events and is called fluorescent radiation. Because the photon energy emitted is a factor in the change between.

Certain electron orbitals in an object, luminous X-rays can be used to determine the quantity of material present in a sample.

Instrumentation

X-ray analysis of large objects and tracking of earth's objects by XRF is done by the behavior of atoms in contact with X-radiation. The XRF spectrometer works because when a sample is illuminated by a powerful X-ray beam, known as a spectrum, some energy is dispersed, but some are also absorbed into the sample in a chemical-dependent manner. The X-ray event is produced from the Rh target, although W, Mo, Cr and others can be used, depending on the application. When this primary X-ray light illuminates the sample, it is said to be happy. The excited sample also emits X-rays and wavelength of the atomic species present in the sample. How did this happen? The atoms in the sample absorb the X-ray energy by releasing ionizing, releasing electrons from low-energy levels (usually K and L). The emitted electrons are replaced by electrons from the outer, higher energy orbital. When this happens, the energy is released due to a decrease in the binding force of the internal orbital electron compared to the outer one. This release of energy is in the form of the release of X-ray signals that indicate the type of atoms present. If the sample has a wide range of elements present, as is the case with most minerals and rocks, the use of a Wavelength Dispersive Spectrometer such as that in the EPMA allows the separation of complex X-ray scales to the length of each element. Various types of detectors (gas flow equilibrium and scintillation) are used to measure the strength of the output beam. The flow counter is usually used to measure the average length (> 0.15 nm) standard X-ray X-rays from simpler materials than Zn. The scintillation detector is often used to analyze short wavelengths in the X-ray spectrum (K spectra of element from Nb to I; L spectra of Th and U). X-rays of intermediate wavelength (K spectra produced from Zn to Zr and L spectra from Ba and abnormal earth objects) are usually measured using both devices simultaneously. The maximum energy measured by these machines is equal to the quantity of material in the sample. The exact value of each item is determined by comparing the mineral or rock levels of their known composition from previous analyzes by other techniques.

Applications

X-Ray fluorescence is used in a variety of applications, including

- research in igneous, sedimentary, and metamorphic petrology
- soil research
- mining (e.g., ore distance measurement)
- cement production

- production of clay and glass
- iron ore (e.g., quality control)
- environmental studies (e.g., particle analysis of air filters)
- petroleum industry (e.g., sulphur content of crude oil and petroleum products)
- field analysis in geological and environmental studies (using portable, hand-held XRF spectrometers)

X-Ray fluorescence is well-suited for inclusive research

- Chemical analysis of bulk material (Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, P) rock and sediment
- Chemical analysis of consecutive material mass (mass > 1 ppm; Ba, Ce, Co, Cr, Cu, Ga, La, Nb, Ni, Rb, Sc, Sr, Rh, U, V, Y, Zr, Zn) in soil and water to find trace elements usually in the order of a few parts per million ^[29].

X-ray fluorescence is limited to the analysis of comparatively large samples, usually > 1 gram

- items that can be prepared in powder form and made equally well
- building materials with similar construction standards, which are well accessible
- substances containing a high quantity of substances where absorption and fluorescence effects are well understood

In most cases of stone, metal and minerals, the sample is ground into a fine powder. At this point it can be directly analyzed, especially in the case of tracking object analysis. However, a much wider range for the bulk of the various substances, especially iron, as well as the wide range of grains in the powder sample, makes measuring equals and standards very difficult. For this reason, it is common to mix a powder sample with a chemical flux and then use a furnace or gas furnace to heat the powder sample. Melting creates a homogeneous glass that can be analyzed and calculated the size of the material (now refined).

Strength

X-Ray fluorescence is well-suited for research that includes: Chemical analysis of bulk material (Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, P) in samples
Chemical analysis of the following mass (> 1 ppm; Ba, Ce, Co, Cr, Cu, Ga, La, Nb, Ni, Rb, Sc, Sr, Rh, U, V, Y, Zr, Zn) in sediments

Limitations

In theory the XRF has the ability to detect X-ray output in almost all objects, depending on the length of the scale and the frequency of the x-rays.

XRF analysis cannot differentiate between object configurations, so these analyze are performed regularly with other instruments (see TIMS and SIMS).

XRF analysis cannot separate ions of the same substance in different valence regions, so this analysis of rocks and minerals is performed by techniques such as liquid chemical analysis or Mossbauer spectroscopy.

3. Biosensors

The term "biosensor" refers to a powerful and innovative analytical tool that encompasses a wide range of organisms such as drug detection, diagnostics, biomedicine, food safety and performance, environmental monitoring, safety and security. The first biosensor developed by Clark and Lyons (1962) to measure glucose in biological samples used the

electrochemical method of obtaining oxygen or hydrogen peroxide using weak glucose oxidase electrodes. Since then, significant advances in technology and the use of biosensors have been made in new ways, including electrochemistry, nanotechnology in bioelectronics ^[31]. Given the significant advances in this field of biosensors, various technologies have been adopted to develop biosensors ^[32]. With an emphasis on research tools demonstrating how biosensor performance has evolved from classical electrochemical to optical / visual, polymer, silica, glass and nanomaterials to improve editing, sensitivity and selection limits. Interestingly, microbes and bioluminescence also contribute significantly to label-based biosensors, while biosensors do not have labels that affect the use of transistor devices or capacitors and nonmaterial ^[34]. It provides a basis for understanding technological advances in the equipment used, including biosensors, biologists and high-tech devices designed for scientists and portable or limited non-commercial devices ^[30]. Finally, current research methods, future challenges and limitations in the field are highlighted. The current review is divided into different sections describing two technological technologies followed by different types of biosensor devices of electrochemical, optical / visual, polymer, silica, glass and nonmaterial ^[35]. These devices are designed for specific purposes and an overview of all this will provide readers with comprehensive data on biosensor devices and their applications.

Types of Biosensors

The different types of biosensors are classified based on the sensor device as well as the biological material that is discussed below.

1. Electrochemical Biosensor
2. Physical Biosensor
3. Piezoelectric Biosensors
4. Thermometric Biosensor
5. Optical Biosensor
6. Resonant Biosensors
7. Thermal Detection Biosensor
8. Wearable Biosensors
9. Enzyme Biosensor
10. DNA Biosensor
11. Immunosensors
12. Magnetic Biosensors

Biosensors Applications

Biosensor devices include organic and physiochemical detector and the main function of this device are to detect analytics. Therefore, the use of biosensors is still varied. These devices are active in the medical, food, marine industry as they provide better sensitivity and stability compared to conventional techniques ^[33]. In recent years, these sensors have become quite popular, and they work in various fields mentioned below-

- Common healthcare checking
- Metabolites Measurement
- Screening for sickness
- Insulin treatment
- Clinical psychotherapy & diagnosis of disease
- In Military
- Agricultural, and Veterinary applications
- Detection of Crime
- Medical Diagnosis
- Monitoring of Environmental Field
- Quality Control
- Process Control in Industries

- Processing & monitoring in Industrial
- Ecological pollution control
- Industrial & Environmental Applications
- Study & Interaction of Biomolecules
- Development of Drug

Biosensors have unique property to be used in heavy metal detection in polluted water. They used for this purpose based in the type of biologically active element antibody-based biosensors used to detect Cd^{2+} , Pb^{2+} and Hg^{2+} ions [36, 37]. Antibody has a binding affinity towards these metal EDTA complex. Phosphate based fluorescence biosensors were developed by Kulkarni *et al.* [38] to detect Hg^{2+} , Cr^{2+} , Cu^{2+} . Protein based biosensors can detect Cd^{2+} , Cu^{2+} , Hg^{2+} , Pb^{2+} and Zn^{2+} [39]. These biosensors are emerging techniques for water quality monitoring.

Conclusion

Water pollution is a global problem because the various Heavy metals [Lead (Pb), Cadmium (Cd), Zinc (Zn), Arsenic (As) and Mercury (Hg)] pollute water. The toxicity of these heavy metals depends on their chemical nature. The various techniques used for the detection of Lead (Pb), Cadmium (Cd), Zinc (Zn), Arsenic (As) and Mercury (Hg) in water samples should be very selective and very reliable. Nowadays the most popular and trending analytical techniques for detecting Lead (Pb), Cadmium (Cd), Nickel (Ni), Copper (Cu), Zinc (Zn), Arsenic (As) and Mercury (Hg) have been described in this review.

There are many different ways to get these heavy metals detected with their advantages and disadvantages. However, further research efforts are needed for the development of effective, fast, accurate and efficient systems for Lead (Pb), Cadmium (Cd), Zinc (Zn), Arsenic (As) and Mercury (Hg) detection. Atomic Absorption Spectrometry (AAS), Biosensors and X-ray Fluorescence Spectrometry are very useful in their detection of water samples.

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