

## EMERGING CONTAMINANTS IN AGRICULTURE AND THEIR IMPACTS ON ENVIRONMENT

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### ABSTRACT

"Environmental contaminant" is another name for pollution. Generally speaking it means any potentially undesirable substance (physical, chemical or biological) which at high concentrations is to have an adverse effect on the health of all living creatures. It usually refers to the introduction of toxic man-made substances produced by factories, such as DDT or toxaphene. Different kind of human activities also introduces toxic substances such as cadmium in high concentrations in ecosystems, which may have adverse effect on the environment. Industrial chemicals used worldwide enter into the upper atmosphere, spreads over a wide area and finally falls to the ground thereby polluting our homelands. Such pollutants may be found in soil, plants, air, water, sea animals, land animals, and birds. Agricultural pollution refers to the biotic and abiotic by-products of farming practices which causes environmental degradation and affects surrounding ecosystem. The pollution may come from a variety of sources, ranging from point source water pollution (from a single discharge point) to more diffuse, landscape-level causes, also known as non-point source pollution. Management practices play a crucial role in controlling impact of these pollutants. The types of contaminants measured in agriculture include: abiotic sources such as pesticides (including organochlorines), heavy metals (including radioactive elements), organic contaminants and biotic sources such as greenhouse gases from fecal waste, biopesticides, invasive species, and genetically modified organisms.

**Keywords:** Heavy metal, Pesticide, Persistent organic pollutant, Sewage sludge, Radionuclide, PPC.

### Introduction

The impact of potentially harmful chemicals in the environment that can affect the health of Humans and other organisms can be determined by considering the sources of these chemicals. These substances are typically referred to as contaminants, pollutants, or most aptly, environmental toxicants. The sources also provide clues to the transport and subsequent fate of these chemicals, including exposure pathways. There are generally two categories of environmental toxicants: naturally occurring and anthropogenic. Naturally occurring chemicals are those such as in poison ivy, poisonous mushrooms, and natural elements, such as mercury and arsenic. In particular, agricultural chemical inputs denote the different types of chemical applications in agricultural production, such as pesticides (including natural and biological pesticides), chemical fertilizers, veterinary drugs and feed additives, among others. Certain measures can be employed to avoid or limit exposures to these natural toxins. General avoidance, or identifying and cordoning off the source (if possible), represent prudent, immediate measures that can be taken. Remediation may be needed in some cases as well. Anthropogenic chemicals, conversely, are

those that human society or its industries create, use, and dispose. Some undergo transformation in the environment; generally, transformation is a detoxification process, but occasionally the transformation products are more harmful than what was initially released to the environment. A noteworthy example of this is the methylation of mercury by microorganisms to methyl mercury, which is significantly more toxic to humans than the parent compound. Unfortunately, it is difficult, and often not possible, to avoid incidental exposures to man-made chemicals without some form of regulatory action. Research suggests that the massive use of inorganic fertilizers world-wide is associated with the accumulation of contaminants, e.g. arsenic (As), cadmium (Cd), fluorine (F), lead (Pb) and mercury (Hg) in agricultural soils. In most developing countries, the pollution caused by agricultural chemicals is even more serious. Policy makers recognize that the excessive and unsystematic application of agrichemical inputs, pesticides and fertilizers in particular, is an obstacle to the development of sustainable agriculture, and poses a threat to the environment and humans alike. Several countries have enacted policies to regulate the usage volume and types of agricultural

chemicals thereby minimizing the evil impact of these harmful yet unavoidable substances that get released in the environment.

Agrichemicals particularly pesticides can enter the human body through inhalation, ingestion, or by dermal penetration through the skin. Pesticides may cause headaches, blurred vision, vomiting, abdominal pain, suppress the immune system, lead to blood and liver diseases, depression, asthma, and nerve damage. The issue with these effects is that they may appear until a while after being ingested so tracing the symptoms back to the pesticide can prove to be quite difficult. The easiest way to prevent the spread and abundance of agricultural pesticides is through education. If more farmers, especially in developing countries, knew about the risks of these pesticides, they would be more careful in the way that they use the pesticides and the protection that the sprayers wear. Another way is to adopt the Integrated Pesticide Management program which emphasizes non chemical and cultural pest control strategies such as removal of diseased plant parts, crop rotation that may disrupt the life cycle of pests, and biological control such as the use of insect predators. Particular attention needs to be paid to the developing world as their lower health status makes them more vulnerable to disease and they are usually dependent upon farming as their main source of income and economy.

### Abiotic sources

#### 1. Pesticides

Pesticides<sup>1-2</sup> and herbicides<sup>3</sup> are materials commonly practiced for eradicating insects, pests and other creatures pernicious to cultivated shrubs, trees, herbs, grasses *etc.* or that rattles manufacturing of crops. Soil contagion customarily occurs when pesticides and herbicides prevail and agglomerate in soils, which can amend microbial processes, escalate plant uptake of these toxic substances, and also have virulent effect on soil organisms. The extent to which these compounds prevail depend on their exclusive chemistry, which can influence adsorption kinetics and transit in the soil environment. Moreover, amalgamation of pesticides can also occur in animals after consumption of polluted pests and soil organisms. Furthermore, pesticides can also be

lethal to benign insects as well, such as pollinators, and to probable detractors of pests (i.e. insects that feed on or dependent on pests) compared to their direct effect on objective pests.

#### 1.1. Pesticide leaching

Pesticide leaching<sup>4</sup> is the mechanism where pesticides are blended with water and proceed wide into the numerous layers of the soil, conclusively polluting groundwater. The extent of leaching primarily depends on few components such as interrelationship to particular soil, pesticide quality, the rate of rainfall and irrigation. Most likely, leaching will take place due to higher water solubility of pesticide, granular structure of soil, occurrence of excessive watering immediately after pesticide employment and also due to less adsorption capability of pesticide to the soil. Leaching may notably emerge from treated farmlands, pesticide transfused spaces, pesticide utilization machinery washing areas, or dumping areas. Excessive concentration of nitrates in water can skeptically influence oxygen amounts for both human beings and aquatic systems.

#### 1.2. Organochlorines (OCs)

Organochlorine (OC)<sup>5-7</sup> pesticides are extensively used as synthetic pesticides all around the world. They are usually derived from chlorinated aromatic molecules or hydrocarbons, which have enormous utility in the chemical industry and in agriculture. These compounds are familiar for their tremendous lethality, passive deterioration and bioaggregation and can be used as pesticides, chemicals or industrial processes such as manufacturing plastics. They may be present either in old electrical transformers or may be generated from blazed garbages. Due to the high solubility in fats and oils, OCs are found in the fat of animals. OCs contribute to the contaminants of immense concern in the food chain. Industrial chemicals called **PCBs**, and the pesticides such as **toxaphene**, **DDT**, and **chlordan** are the most familiar OCs estimated in Arctic wildlife. Organochlorines are vapour producing compounds and can be borne by the air for far-reaching distances. Ultimately, they condense back and are accumulated on land or are diffused in water,

causing severe health risks to humans such as cancer and reduced immune systems. Some kind of deformities and irregularities developed in evolution and reproduction in fish-eating birds, which are present significantly in the food chain are often caused by organochlorines.

### 1.2.1. DDT, DDE and DDD

DDT (1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane)<sup>8-9</sup> is a synthesized chemical extensively applied to curb insects on agricultural crops in paddy fields and insects that transmit diseases like malaria and typhus. It does not appear commonly in the environment. DDT is an odorless and tasteless white crystalline solid. Because of its devastation to wildlife and the potential damage to human health, the application of DDT in many countries is now not being practiced, except for public health necessities. Because of exposure to high concentrations of DDT, various kind of symptoms including vomiting, tremors or shakiness, and seizures can develop in human. Effects on the liver and reproduction are also being observed in animal kept in laboratory. DDT is regarded as a potential human carcinogen. Two analogous synthetic compounds that occasionally toxicate DDT products are DDE<sup>9</sup> (1,1-dichloro-2,2-bis(chlorophenyl) ethylene) and DDD<sup>9</sup> (1,1-dichloro-2,2-bis(*p*-chlorophenyl) ethane). DDD was also used to kill pests, but its application has also been prohibited. One form of it has been used medically to treat cancer of the adrenal gland. Till date, no commercial use of DDE has been reported.

### Effects of DDT, DDE, and DDD on the environment

DDT typically is introduced to the environment when it is exploited as an insecticide. It remains in air for very short duration and 50% of it evaporates within 2 days. Nevertheless, it is almost water insoluble. DDT firmly adheres to soil particles and does not shift instantaneously to underground water. It remains in the soil for quite a long duration and 50% of it decomposes in the soil in 2-15 years. A few DDT gets dissipated from soil and surface water into the air and some of it are decomposed by sunlight or by microorganisms

in soil or surface water. DDT in soil usually undergoes disintegration to form DDE or DDD. Concentrations of DDT gets increased in plants and in the oily tissues of varied types of faunas.

### 1.2.2. Chlordane

Chlordane<sup>10</sup> is a representative of a class of synthetic compounds commonly termed as "chlorinated cyclodienes." It is applied as an insecticide, and notably as a termiticide, it is accessible in pure and technical grades. Pure chlordane is a syrupy, white, unaromatic liquid. It doesn't appear usually in the environment. It is a synthesised chemical that was treated as a pesticide in the United States from 1948 to 1988. Chlordane is a chemical compound and also component of an analogous pesticide mixture followed from synthesis of primarily three components- heptachlor, chlordane, and nonachlor. These profoundly chlorinated cyclodienes were distributed as organic toxic wastes precarious for human health. Industrial chlordane is not a sole chemical, on the other hand it is indeed a mixture of pure chlordane associated with numerous complimentary chemicals. It is a consolidated liquid whose color varies from colorless to warm and radiant colour. Chlordane has a moderate, annoying scent. A bit of its commercial names includes Octachlor and Velsicol 1068. Up to 1983, chlordane was utilized as a pesticide on crops like corn and citrus and on home lawns and gardens. In view of worry about catastrophe to the environment and casualty to human health, the Environmental Protection Agency (EPA) restricted all uses of chlordane in 1983 apart from regulating termites. In 1988, EPA prohibited all uses of chlordane.

### Environmental impacts of chlordane

Chlordane when applied as a pesticide on crops, on lawns and gardens, and to restraint termites penetrates into the soil. However, chlordane sticks completely to soil particles at the surface and is rarely enters groundwater. It can persist in the soil for more than 20 years. Greatest amount of chlordane departs soil by evaporation to the air. It decomposes very slowly. Chlordane doesn't get dissolved readily in water and deposits in the tissues of fish, birds, and mammals.

### 1.2.3. Chlorine

Chlorine<sup>11-12</sup> is a naturally occurring and exceedingly reactive gas. The name chlorine is extracted from word 'chloros' which means green, attributing to the color of the gas. The natural chemical element exists in the physical form of a green diatomic gas. Chlorine gas is two and one half times as heavy as air, has a profoundly disagreeable asphyxiate odor, and is terribly fatal. It acts as a powerful oxidizing, bleaching, and disinfecting agent in both liquid and solid form. This element is a component of the halogen family forming salts. It is obtained from chlorides through oxidation and electrolysis. Chlorine gas is greenish-yellow and reacts spontaneously with all other elements. The greatest consumers of chlorine are companies that manufacture ethylene dichloride and various chlorinated solvents, polyvinyl chloride (PVC) resins, chlorofluorocarbons, and propylene oxide. Chlorine is used in paper companies for bleaching, water and wastewater treatment plants for reducing water levels of microorganisms causing disease to humans. Due to release of chlorine to air, water, or land, chlorine exposure can take place in the workplace or in the environment. People using laundry bleach and swimming pool chemicals consisting of chlorine products usually are not exposed to chlorine itself. Chlorine is usually obtained solely in industrial settings. Chlorine is introduced in the body after breathing contaminated air or consuming contaminated food or water. Due to high reactivity, it does not persist in the body for long.

#### Effect of chlorine on the environment

Low concentration of chlorine generally affects the environment. In particular, it is especially adverse for organisms persisting in water bodies and in soil. After mixing with water it dissolves. Under specific conditions, it can leave from water and gets in air. Direct discharge of chlorine to the environment occur to air and to surface of water, where it reacts with other chemicals. In water, it reacts with inorganic substances to generate chloride salts and with organic substances to form chlorinated organic chemicals. In view of its reactivity, chlorine is not likely to do

movement through the ground and penetrates groundwater. Plants and animals are not likely to accumulate chlorine. Harmful effects of chlorine on the environment depend on chlorine content, the length and frequency of exposure and the condition of the environment at the time of exposure.

### 1.2.4. Aldrin/Dieldrin

Aldrin<sup>13</sup> is a component of the commonly named "classic organochlorines" (COC) family of pesticides. Pure aldrin is a white crystalline solid. In spite of its low solubility in water, it dissolves suitably in organic solvents, such as ketones and paraffins. Aldrin does not react with moderate acids or bases and is sufficiently stable in an environment having p<sup>H</sup> range 4-8. When exposed to temperatures above 200 °C, it becomes highly flammable. Aldrin gets transformed to dieldrin by plants and bacteria; which maintains the similar harmful effects and slow disintegrate of aldrin. Thus, aldrin and dieldrin are insecticides with analogous structures. Pure aldrin and dieldrin are white amorphous solids having a soft chemical odor. The few neat industrial powders have a tan color. Aldrin and dieldrin do not occur typically in the environment. Exposure to aldrin and dieldrin occurs usually after consumption of foods, such as root crops, fish, or seafood.

#### Effect of aldrin and dieldrin to the environment

Aldrin disintegrates very calmly once emitted into the environment. It is very easily transferred through the air by dust particles. In the presence of oxidizing agents it combines with concentrated acids and phenols. UV radiation and bacteria transforms aldrin to dieldrin, hence we frequently find dieldrin in the environment. They are firmly attached to soil and gradually vaporizes to the air. Dieldrin decomposes gradually. Plants adsorb and reserve aldrin and dieldrin from the soil. Aldrin immediately transforms to dieldrin in plants and animals. Dieldrin is accumulated in the fat and escapes the body gradually. Intoxication with aldrin gives rise to effects like neurotoxicity. Studies have shown that aldrin activates the central nervous system (CNS),

which may lead to hyperexcitation and seizures.

### 1.2.5. Polychlorinated-dibenzo-*p*-dioxins and furans (PCDD/PCDFs)

Polychlorinated dibenzodioxins (PCDDs)<sup>14-16</sup> are a family of polyhalogenated organic compounds which are powerful hazardous waste from environmental point of view. They are generally referred to as dioxins, as each PCDD molecule constitutes a dibenzo-1,4-dioxin structural moiety, along with 1,4-dioxin as the basic central ring. They are formed as side products in the synthesis of chlorinated substances, combustion procedures and in straight chlorination reactions like chlorine bleaching of paper pulp. The utmost important sources of these contaminants are municipal waste and hospital incinerators, where combustion produces large number of chlorinated products. Another paramount source of these compounds is combustion of motor vehicle fuel as in some countries leaded fuel containing chlorine scavengers are still practiced.

### Effects of Polychlorinated-dibenzo-*p*-dioxins and furans (PCDD/PCDFs) on human health

Dioxins accumulation primarily occurs in fatty tissues since years, so even minute exposures may ultimately reach critical levels. Exposure to large doses of dioxins in humans can develop serious kind of perpetual acne, known as chloracne. Epidemiological studies give further evidence of formation of tumors due to high occupational or accidental levels of exposures to dioxins. Excess doses of dioxins may cause other harmful effects in humans such as developmental abnormalities in the enamel of children's teeth and central and nervous system pathology, thyroid disorders, damage to the immune systems, endometriosis, diabetes *etc.*

### 1.2.6. Hexachlorobenzene (HBC or HCBZ)

Hexachlorobenzene<sup>17</sup>, an organochloride is a fungicide earlier practiced as a seed treatment. It is a stable, white, crystalline chlorinated hydrocarbon. On heating, it decomposes and releases hazardous fumes of CO, CO<sub>2</sub>, HCl and other chlorinated compounds. Apart from its application as a fungicide, it is also used as

a chemical intermediate in the production of dyes, manufacture of organic chemicals, rubber and in preservation of wood. HCB is obtained as a side product in the synthesis of a innumerable chlorinated compounds, especially lower chlorinated benzenes, and in the synthesis of several pesticides. It is transmitted to the atmosphere in flue gases and fly charcoal formed at waste incineration facilities. Owing to its high lipophilicity and long-half-life in biota, HCB has a relatively high bioaccumulation potential. Other chlorobenzenes (tetra- and penta-substituted) are also comparatively lipophilic, semi-volatile, and persistent specifically in the abiotic environment. Lengthy oral exposure to this substance lead to a liver disease with correlated skin lesions. Hexachlorobenzene is fairly assumed to be a human carcinogen established on cooperation between thyroid, liver and kidney cancer and oral exposure in animals.

### 1.2.7. Chlorobornanes (CHBS)

The composite assimilation of chlorobornanes (CHBs) is generally referred to as toxaphene<sup>18</sup> which has been dissipated by atmospheric transfer at the same rate as DDT and PCBs. It is produced by the chlorination of bornane. It is composed of more than 300 compounds, which are substituted with 6 to 10 chlorines, having generally an average composition of C<sub>10</sub>H<sub>10</sub>Cl<sub>8</sub>. As a result of the low level of standards and occurrence along with other interrupting OCs like PCBs, DDTs, HCHs, investigation of this mixture is very problematic. Despite the fact that it is a major environmental pollutant, the levels and effects of toxaphene in the Arctic are not well analysed.

Toxaphene is an insecticidal mixture, which is comprised of mainly chlorinated bornanes (CHBs) with a marginal percentage of chlorinated camphenes. Even if CHB mixtures have been rigorously banned in many countries, but repeated release of it to the environment by volatilization from contaminated soils is still continued at a distressing rate in non-Arctic region where it is still use is being practiced. Primarily precipitation leads to its deposition in winter season while exchange of gas with open water competencies is mainly responsible for its accumulation in summer season. The food

chain can augment the effects of deposition in atmosphere, which can lead to high levels of CHBs in top predator fish in certain lakes. One of the major difficulties in analytical methods of measuring this complex mixture of compounds is quantitative estimation of CHBs for lakes or the Arctic ocean. It is proposed that extensive effort must be done to regulate its quality and a variety of analytical methods must be developed for measuring CHBs in microlevel. Toxaphene is one of the significant toxic substances uncovered in arctic biota. Literature study predicts that even low levels of toxaphene exposure may cause lethal effects on the liver, kidneys, lungs, and nervous system.

### 1.2.8. Hexachlorocyclohexane

Hexachlorocyclohexane (HCH)<sup>19</sup> does not arise normally in the environment, it is a synthesized chemical, a mixture of stereoisomers and is used as an insecticide. It occurs in eight chemical forms known as isomers. One of these isomers,  $\gamma$ -HCH, known as lindane is a white solid substance that vaporizes into the air as a colorless vapor with a marginally moldy odor. Lindane is used as an insecticide on fruit and vegetable crops in conjunction with greenhouse vegetables and tobacco and forest crops along with Christmas trees. It is still being utilized in ointments to cure head and body lice, and scabies. Nonetheless, its application is prohibited by the Environmental Protection Agency (EPA) and can be administered only by a certified applicator.

#### Effect of Hexachlorocyclohexane on air, water and soil

In air,  $\alpha$ -,  $\beta$ -,  $\gamma$ -, and  $\delta$ -HCH can exist as a vapor or adhered to tiny particles like soil or dust. Lindane can persist in the air for up to 17 weeks and migrate to large paths. Particles with associated HCH may be eliminated from the air by rain. In soil, sediments, and water, it is decomposed by algae, fungi, and bacteria to fewer toxic substances. HCH isomers are decomposed rapidly in water; lindane does not exist in water for more than 30 days. Lindane is not usually settled in drinking water. The period of duration that HCH isomers exist in soil is unknown. It can be stored in the fatty

tissue of fish. Heptachlor and Heptachlor Epoxide Heptachlor, a synthesized chemical is not found to appear naturally. Pure heptachlor is a white powder having the same odour as that of camphor. The low unadulterated category is tan. Various commercial names of it include Heptagran, Basaklor, Drinox, Soleptax, Termide, and Velsicol 104. In the past, heptachlor was applied enormously for wiping out insects in homes, buildings, and on food crops, particularly corn. Heptachlor epoxide is a white amorphous solid and is a decomposition product of heptachlor. The epoxide is expected to be present in higher amount in the environment than heptachlor.

#### Effect of heptachlor and heptachlor epoxide on the environment

In comparison to heptachlor, heptachlor epoxide gets dissolved more readily in water. They are very firmly attached to soil particles and evaporate steadily to air. Heptachlor epoxide can persist in the soil and water for hundreds of years. Animals are primarily responsible for conversion of heptachlor to the epoxide. Plants generally pick up heptachlor from the soil. Concentration of heptachlor increases in the tissues of fish and cattle.

### 1.2.10. Polychlorinated Biphenyls (PCBs)

PCBs are a cluster of industrial synthetics which resembles each other with uniform structural moiety. Generally, they are oily liquids or solids, without having any odour or taste and is not found to appear naturally. One of the most popular trade name of a commercial PCB mixture is Aroclor. PCBs don't ignite readily and are thermally very stable mixtures. In the past, they were frequently treated as coolants, insulating materials, old microscope oil, hydraulic fluids and lubricants in electrical equipment such as transformers and capacitors. As levels in the environment increased, the potential for harmful effects increased. Pre-1977 products may still contain PCBs.

#### Environmental effect of PCBs

PCBs penetrate in air as solid or liquid aerosols or vapor and can persist in air for more than 10 days. In air, they can migrate through wind up to long distances. They transport from air to

soil and water in the form of snow or rain. Despite the fact that it does not dissolve readily in water, they are attached strongly to soil particles. They generally take many years for decomposition in soil and are stored in the bodies of fish and seafood.<sup>20</sup>

## 2. Heavy metals

In general, any metallic element with comparably high densities, atomic weights, or atomic numbers are known as heavy metals. They are natural components of the Earth's crust and thus cannot be downgraded or damaged.

The major contributors of heavy metals like lead, cadmium, arsenic, mercury *etc.*<sup>21-22</sup> into agricultural systems are fertilizers, organic wastes such as manures, and industrial wastes. Sometimes, farming processes like irrigation, contributes to accumulation of selenium (Se) in the soil. This can lead to high selenium concentrations in downstream water reservoirs, causing serious threat to wildlife, livestock, and humans. Some heavy metals such as iron, cobalt, and zinc are either essential nutrients, or relatively harmless such as ruthenium, silver, and indium, but large concentration of these metals can be very toxic. Other heavy metals, such as cadmium, mercury, and lead, are highly poisonous. Significant sources of heavy metal poisoning include mining, tailings, industrial wastes, agricultural runoff, occupational exposure, paints and treated timber. Moreover, the formation of reservoirs can also cause mercury to be released from flooded areas. Metals have a tendency to deposit in specific parts of the body. For example, lead deposits in the bones, mercury and cadmium accumulate in kidney and liver, and the derivative of mercury known as methylmercury deposits uniformly through the body.

### 2.1. Fertilizers

A fertilizer<sup>23</sup>, produced from either natural or industrial material, is applied to soils or to plant tissues for providing one or more plant minerals essential for the development and growth of plants. Most frequently used fertilizers usually contain the three major macronutrients in different proportions such as Nitrogen (N) for stimulating leaf growth,

Phosphorus (P) for augmentation of roots, flowers, seeds, fruit and Potassium (K) mainly for robust stem growth, transportation of water in plants, growth of flowering and fruiting. The nitrogen (N) and phosphorus (P) utilized for agricultural land (via synthetic fertilizers, composts, manures, biosolids, *etc.*) can provide beneficial plant nutrients. However, excess concentration of N and P can have unfavorable environmental consequences. Only a small fraction of the nitrogen-based fertilizers is transformed to produce plant matter. The residue is left either in the soil or lost as runoff. Excessive rate of usage of nitrogen-containing fertilizers provided by both synthetic fertilizers (as highly soluble nitrate) and organic sources such as manures (whose organic N is mineralized to nitrate by soil microorganisms) blended with the increased water-solubility of nitrate can bring about increased runoff into surface water as well as leaching into groundwater, hence causing groundwater pollution. The excessive use of nitrogen-containing synthetic or natural fertilizers is notably damaging, as much of the nitrogen that is not taken up by plants is converted into nitrate which is readily leached. Nitrate concentrations higher than 10 mg/L (10 ppm) in groundwater can give rise to "blue baby syndrome" (acquired methemoglobinemia). The nutrients, mainly nitrates, in fertilizers can lead to problems for natural habitats and for human health if they are washed off soil into water courses or leached through soil into groundwater. eutrophication can occur in downstream area because of excess nutrient supply from these same fertilizer sources including P, leading to anoxic areas called dead zones. Furthermore, the mistreatment of fertilizers can cause air pollution in the form of ammonia.

#### 2.1.1. Cadmium

Cadmium<sup>24-25</sup> is a natural element found in the earth's crust with no taste or odour. Cadmium (Cd) is a soft, malleable, bluish white metal found in zinc ores, and to a lower concentration, in the cadmium mineral greenockite. It is typically found as a mineral blended with other elements such as oxygen, chlorine, or sulfur to form cadmium oxide, cadmium chloride, cadmium sulfate and

cadmium sulfide respectively. All soils and rocks, including coal and mineral fertilizers, are found to possess cadmium. Industrially used cadmium is extracted during the preparation of other metals like zinc, lead, and copper. Cadmium has multiple uses as it does not undergo corrosion readily. This element is primarily applied in batteries, pigments, metal coatings, and plastics. The concentration of cadmium in phosphorus-containing fertilizers changes significantly and can be problematical. Regular usage of high-cadmium fertilizer can contaminate soil and plants. Producers of phosphorus-containing fertilizers now select phosphate rock based on the cadmium content.

### **Effects of cadmium on human health and environment**

Cadmium is introduced to air from various sources such as mining, industry, coal combustion, household wastes and Cd particles can migrate to large distances before finally gets contaminated with the ground or water. It penetrates water and soil from waste disposal and spills at toxic waste locations and thereby attached firmly to soil particles. In general, cadmium is water insoluble and non-flammable metal, whereas its amorphous form undergo combustion and generates copious amount of toxic fumes. Cadmium and its compounds are very hazardous in nature and exposure to this metal can cause cancer and may have a harmful effect on cardiovascular, renal, gastrointestinal, neurological, reproductive, and respiratory systems.

#### **2.1.2. Lead**

Lead<sup>25</sup> is a weighty metal as it has higher density than other commonly available metals. Lead in its pure form display a bright, silvery appearance with a blue tinge which gets tainted on contact with moist air. Lead is highly dense, malleable, ductile, and highly corrosion resistant. It has no characteristic taste or odor. Lead is present in all segments of our environment and has numerous uses. It is most commonly used in the production of batteries, in ammunition, metal products (solder and pipes), roofing, and devices to shield x-rays. Due to health concerns, lead from sources like gasoline, paints and ceramic products,

caulking, and pipe solder has been significantly prohibited since last few years.

### **Environmental concerns of lead and related human hazards**

Lead does not decompose on its own, its compounds are disintegrated by sunlight, air, and water.

Industry waste or fossil fuel combustion waste releases high concentration of lead in air, where it can stay for about 10 days. Maximum proportion of lead in soil accumulates from particles tumbling from air, from landfills and leaded paint. Lead gets adsorbed to soil particles and does not migrate from soil to underground or drinking water except for soft nature of water. It stays in soil and water for long duration. Numerous kind of adverse effects of lead on human health can be observed such as disruption of the biosynthesis of haemoglobin, anaemia and also of the nervous system, increase in blood pressure, damage of kidney and brain, miscarriages and subtle abortions, downturned man fertility, decreasing learning capabilities of children and disruptions in children behavioral such as aggression, impulsive behavior and hyperactivity.

#### **2.1.3. Mercury**

Mercury is a rare metal and occurs in nature having several varieties. The metallic mercury is a lustrous, silver-white liquid without having any fragrance. On heating, it changes to a colorless, odorless gas. Mercury reacts with other elements, such as chlorine, sulfur, or oxygen, to produce inorganic mercury compounds. Most of its compounds are white amorphous solids or crystals. Mercury also binds with carbon to form organic mercury compounds like methyl mercury, formed primarily by microscopic organisms in the water and soil. Metallic mercury is used to produce chlorine gas and caustic soda in chemical industry and also in thermometers, barometers, manometers, sphygmomanometers, float valves, mercury switches, mercury relays, fluorescent lamps and other devices, dental fillings, and batteries. Mercury salts are used in skin-lightening creams and as antiseptic creams and ointments.



## Mercury and the environment

Volcanic eruptions and other geological processes generate about 50% of the mercury which penetrates the environment every year and the other 50% is generated by mankind. Mercury is introduced in the air from various sources like mining ore deposits, burning coals and from manufacturing plants wastes. It infiltrates the water or soil from sources such as natural deposits, disposal of wastes, and the use of mercury-containing fungicides. Methyl mercury is formed in water and soil by microorganisms like bacteria and gets deposited in the tissues of fish and other organisms. The high concentration of this toxic metal poses a particular threat to the developing brains of young and unborn children. Its doses increase in tissues as we move up the food chain.

### 2.1.4. Arsenic

Arsenic<sup>25</sup> is a natural semi-metallic chemical that is found all over the world in groundwater at very low levels. It usually forms inorganic arsenic compounds with oxygen, chlorine, and sulfur. In plants and animals, it reacts with carbon and hydrogen to form odorless and tasteless organic arsenic compounds. Organic arsenic is comparatively less harmful as compared to inorganic arsenic. Arsenic is used industrially as an alloying agent, as well as in the processing of glass, pigments, textiles, paper, metal adhesives, wood preservatives and ammunition. Arsenic is also used in the hide tanning process and, to a limited extent, in pesticides, feed additives and pharmaceuticals. Ores of copper and lead possess minute quantities of arsenic.

### Global effect of arsenic

In spite of less rate of evaporation, most of the arsenic compounds are soluble in water. It enters air first and then from air to the ground, when contaminated materials undergo combustion. It doesn't decompose easily, but can transform from one form to another. Organic arsenic gets concentrated in the tissues of fish and shellfish, but majority of the arsenic found in fish is non-toxic in nature. Nonetheless, inorganic arsenic compounds are highly toxic and worldwide contamination of drinking water occurs due to these

compounds. The early symptoms of short-term exposure to high levels of inorganic arsenic (for example, through drinking-water and food) are generally observed in the skin, and include pigmentation changes, skin lesions and hard patches on the palms and soles of the feet (hyperkeratosis). But long-term exposure to it may also cause cancers of the skin, bladder and lungs.

### 2.1.5. Fluoride

Synthetically produced fluoride<sup>26</sup> is also found naturally in soil, water, phosphate rocks and foods. Therefore, the use of phosphate fertilizers all over the space has increased concentrations of fluoride in soil. It has been found that contamination of food from fertilizer is not of concern as plants accumulate less fluoride from the soil. But the matter of concern is the probability of fluoride toxicity to livestock that consume contaminated soils. Currently, effects of fluoride on soil microorganisms and on human health, particularly problems with bones, teeth, and neurological development are also a matter of increasing concern.

### 2.1.6. Radionuclides

Radionuclides<sup>27</sup> either occur naturally or are artificially produced in nuclear reactors, cyclotrons, particle accelerators or radionuclide generators. The radioactive content of the fertilizers varies considerably and depends both on their concentrations in the parent mineral and on the fertilizer production process. Variety of activities such as atmospheric testing of nuclear weapons, nuclear waste dumping, and incidents such as the 1986 Chernobyl nuclear accident mainly contributes to the release of radionuclides to the environment. Cesium is the man-made radionuclide that is commonly found in the north. Polonium is the most frequently found radionuclide in nature. Uranium is a radionuclide that can be found in nature at an elevated amount due to uranium mining.

The highest concentrations and risks of radionuclides in the Arctic are attributed to natural radionuclides, mainly <sup>210</sup>Po (Polonium), <sup>210</sup>Pb (Lead), <sup>228</sup>Th (Thorium), and <sup>232</sup>Th. Among the anthropogenic sources-based radionuclides, <sup>137</sup>Cs (Cesium)

contributes mainly to hazard issue but it represents merely 2% to 3% of the total doses and is derived from land-mammal consumption.

Various anthropogenic radionuclides which are of paramount interest and concern in the Arctic environment are:

**<sup>137</sup>Cesium (Cs):** This Cs isotope is produced when nuclear fission of uranium and plutonium fuels takes place. Due to worldwide increase of radioactive waste generated from atmospheric weapons testing and nuclear power production, Cs is highly abundant in the environment with long half-life of 30 years. It is universally treated in industry as closed gamma source for determination of thickness of materials and in medicine as a airtight source for therapeutics and as a tracer substance.

**<sup>90</sup>Sr:** Strontium possesses 6 radioisotopes which are emitted directly from fission products of uranium. Among these radioisotopes, <sup>90</sup>Sr is the considered to be the most important due to its long radiation half-life of 29 years. In medicine, cutaneous lesions which are a few millimeters in depth can be treated by <sup>90</sup>Sr. In industry, it is used in thickness gauges as a compact heat source for static dust elimination by air ionization procedure and also as thermoelectric source in instruments which require long-lived, independent power source. It is highly abundant in the environment because of global fallout from testing of atmospheric weapons, thereby accumulating in bones and teeth.

Some radionuclide in measured doses still exist in temperate and arctic ecosystems. In northern ecosystems, high concentrations of the long-lived fission products (<sup>137</sup>Cs (half-life 30.2 years) and <sup>90</sup>Sr) are present even now due to its slower turnover rates in a cold and dry climatic condition. The 1986 Chernobyl accident transmitted supplementary <sup>137</sup>Cs into the atmosphere. They are also conveyed by ocean currents from industrialized countries of Europe.

**<sup>131</sup>I:** Nuclear weapons tests and nuclear reactors generates large number of fissionable products such as radioactive iodines, specifically, <sup>131</sup>I, <sup>132</sup>I, and <sup>129</sup>I. After being released to the atmosphere, radioactive iodine may again condense back to land via precipitation, thus contaminating vegetation

and ultimately, the food supply. Radioiodine is very vital because of its judicious application in treatment of the thyroid.

**<sup>239</sup>Pu:** Plutonium is a human-made radioactive element which is utilized as fuel in nuclear reactors and also in explosive preparation in nuclear weapons. <sup>239</sup>Pu has a half-life of 24,390 years. Nuclear weapons testing programs have so far deposited globally more than 5,000 kilograms of plutonium, mostly as insoluble oxide particles, into the stratosphere.

**<sup>222</sup>Rn:** Radon is synthesized by the radioactive decay of radium, a universal element in rock and soil, which again is produced from the radioactive decay of uranium. Radon gas percolates from soil into buildings mainly through sump holes, dirt floors, floor drains, cinder-block walls, and cracks in bases and concrete floors. It can agglomerate remarkably, when captured indoors.

**Tritium (<sup>3</sup>H<sub>1</sub>):** Tritium is the radioactive isotope of hydrogen atom with a nucleus containing one proton and two neutrons. Tritiated water (<sup>3</sup>H<sub>2</sub>O) is the most typical form of tritium, which has a radiation half-life of 12.5 years. It is produced when heavy water (<sup>2</sup>H<sub>2</sub>O) absorbs neutrons during the mechanism of fission at moderate level in a nuclear reactor. Tritiated water can also be produced in the atmosphere due to the release of tritium gas from nuclear reactors. Till date, the maximum amount of the tritium deposited in the environment is due to atmospheric nuclear weapons tests which were conducted prior to 1963.

**<sup>238</sup>U:** Naturally occurring uranium consists of <sup>238</sup>U (99.27%), <sup>235</sup>U (0.72%), and <sup>234</sup>U (0.0054%).

<sup>235</sup>U is extracted from natural uranium and is used in nuclear reactors or nuclear weapons. The uranium left after complete eradication of <sup>235</sup>U is referred to as "depleted uranium," which remains to be a source of harmful radiation as well as a potential chemical hazard. High doses of uranium have been traced in well water in different parts of Canada.

### 2.1.7. Other metals

Fertilizers rich in zinc are commonly recycled from wastes of steel industry due to their beneficial effect for plant growth, resulting in

the emission of harmful and toxic metals such as aluminium, chromium, mercury, lead, arsenic and nickel to the environment.<sup>28</sup> Despite the fact that these probable harmful impurities can be eliminated but due to their high cost, it is very often ignored. Highly pure water-soluble fertilizers containing blue dyes practiced around households, such as Miracle-Gro are extensively available in larger packages at undoubtedly less price than retail quantities and are used in the plant nursery business. There are also some cost-effective retail granular garden fertilizers prepared with high purity ingredients.

### 2.1.7.1. Aluminum

Aluminum is the most abundant element, found in combined form with other elements such as minerals and rocks in the earth's crust. It is silver-white in colour and is light, durable and functional metal. Aluminium is extensively been practiced at an optimum level in the three major industries such as transportation, packaging, and construction. It is also used in cooking utensils, containers, appliances, and building materials. Aluminium is phenomenal due its low density and its ability to prevent corrosion through passivation process. Hence, it is widely used in different forms including aluminum nitrate, aluminum oxide, aluminum hydroxide (used in antacids), aluminum chlorohydrate (used in deodorants), and aluminum sulfate (used to treat drinking water). It is also used in paints and fireworks, and to produce glass, rubber, and ceramics.

#### **Environmental impact of aluminium:**

Huge concentrations of aluminium are found near mining sites; tiny amounts of aluminium are transmitted to the environment at the coal-fired power plants. Acidic precipitation is the primary natural factor to assemble aluminium from natural sources. But the leading factor of presence of aluminium in salt and freshwater are the industrial processes that also discharge aluminium into air. It gets attached to particles in the air and depending on the water quality, aluminium can dissolve in lakes, streams, and rivers. It can be absorbed from soil by some plants. In water, aluminium behaves as a harmful agent on gill-breathing animals like fish by causing loss of plasma-

and hemolymph ions resulting in failure of osmoregulation. In human, harmful effect of aluminium is less compared to heavy metals. Most aluminium consumed will be excreted from the body via urine. In the body, aluminium is accumulated in bone, brain, liver, and kidney. Aluminium, even if rarely, can cause vitamin D-resistant osteomalacia, erythropoietin-resistant microcytic anemia, and alterations in central nervous system. People with kidney problems are especially at a risk and adequately high doses can cause anemia. Since aluminium is excreted by kidneys, so their function may be affected by toxic amounts of aluminium. Chronic ingestion of hydrated aluminium silicates (for excess gastric acidity control) may result in aluminium binding to intestinal contents and increased removal of other metals, such as iron or zinc.

### 2.1.7.2. Chromium

Chromium is a naturally occurring element found in rocks, soil, plants, animals, and in volcanic dust and gases. Chromium exist in mainly three chromium (0), chromium (III), and chromium (VI). Chromium (III) compounds are highly stable and occur naturally, in the environment. Chromium (0) does not occur naturally and chromium (VI) occurs very rarely. It is a grey, lustrous, hard and brittle transition metal without having any taste or odor. Chromium (III) is an essential nutrient in our diet. Our bodies need only a very small amount of Chromium (III) whereas other forms of chromium are not so needed. Chromium is used for manufacturing steel and other alloys, bricks in furnaces, and dyes and pigments, and for chrome plating, leather tanning, and wood preserving. Chromium is blended with steel to make it hard and to make stainless steel. Other chromium-steel alloys are used to form armor plate, safes, ball bearings and cutting tools *etc.*

#### **Effects of chromium on our environment**

Chromium is released into air, water and soil through both natural processes and human activities such as manufacturing, disposal of products or chemicals containing chromium, or burning of fossil fuels. Chromium particles settle from air in less than 10 days and attaches

strongly to soil particles. Maximum amount of chromium sticks to dirt particles that fall to the bottom, finally moving from soil to groundwater and only a little amount of it dissolves in water. Chromium although, not known to deposit in the bodies of fish, can however destroy the gills of fish that swim near the point of discharge. In animals chromium can cause respiratory problems, a lower ability to fight disease, birth defects, infertility and tumor formation. Shortage of chromium (III) in human beings may cause heart diseases, disruptions of metabolisms and diabetes. However, the intake of excess amount of it can cause various health effects such as skin rashes *etc.* Chromium (VI) is dangerous typically for people who used to work in the steel and textile industry. People who have tobacco smoking tendency also have a higher chance of exposure to chromium. Chromium (VI) is also known to cause various health effects. When it is used as a compound in leather products, it can cause allergic reactions, such as skin rash, nose irritations and nosebleeds. Other health problems caused by it are ulcers, respiratory problems, weakened immune systems, kidney and liver damage, lung cancer *etc.*

### 2.1.7.3. Nickel

Nickel is the 24<sup>th</sup> most abundant mineral in the earth's crust. It is a naturally-occurring, hard, ductile, silvery white metal with a slight golden tinge and can be found in all types of soils. Nickel can undergo slow aerial oxidation at room temperature and is considered corrosion-resistant. It combines readily with other metals to form solid mixtures known as alloys. The most common nickel alloy is nickel-iron, used in making stainless steel. Other nickel alloys are used to manufacture coins, jewelry, plumbing and heating equipment, gas-turbine engines, and electrodes. Nickel also combines with chlorine, sulfur, and oxygen to form odourless or tasteless compounds having a characteristic green color with high water solubility. Nickel compounds are used for nickel plating, to color ceramics, and to make some batteries. They also act as catalysts to increase the rate of chemical reactions.

### Nickel and the environment

Nickel is found naturally in both food and water, and may be augmented by man-made pollution. Nickel from smoke sticks to small dust particles in the air and settles to the ground or is washed from the air by rain or snow. More than a month is required to eliminate nickel particles from the air. It may seep into groundwater in acidic soils. Nickel changes its form although it does not undergo decomposition. It doesn't store in the bodies of fish but may be stored in plants and land animals. In the workplace, people can be exposed to nickel by inhalation, ingestion, and contact with skin or eye. Nickel is not a cumulative poison, but higher doses or chronic inhalation exposure may be toxic or even carcinogenic. It may cause allergies often marked by itchy, red skin.

### 3. Organic contaminants

Herbicides, pesticides, plant and animal tissues which normally do detrimental effects on the environment are termed as organic contaminants. These types of contaminants basically comprise of dye, humic substances, phenolic compounds, petroleum, surfactants, pesticides, and pharmaceuticals and are powerful pollutants in wastewaters. These contaminants are compounds basically comprised of carbon, hydrogen, and other potential elements. The existence of organic contaminants in water normally produce hazardous chemicals during disinfection. Humic substances such as humic acid, fulvic acid, or humin, which generates from the decomposition of organic matter and pharmaceuticals such as antibiotics, are ample in farm wastewaters and these should be eliminated before release. Organic contaminants dissolve and accumulate in organic phases of animals and plants. However, the quantities of these contaminants in the environment depends on the bioaccumulation process. Bioaccumulation is the overall result of all uptake and loss processes, such as respiratory and dietary uptake, and loss by egestion, passive diffusion, metabolism, transfer to offspring and growth. When organisms absorb these contaminants, the bioaccumulation of the same significantly varies based on the organism's capability to customize the absorbed contaminant mixture.

Interestingly, some contaminants are preserved whereas water soluble or degradable ones are disposed of the body, ending up with no overall accumulation.

### 3.1. Sewage sludge

Sewage sludge<sup>29</sup> is the surplus semi-solid substance, that is produced as a by-product during sewage analysis of industrial or municipal wastewater and is not only fundamental settled organic and inorganic solids from the sewage, phosphorus precipitates, but also the biomass produced during aerobic, anoxic, and/or anaerobic degradation procedure. The sludge basically constitutes inorganic and organic process additives, which again comprises of 40-80% by dry weight, based on the extent and type of sludge treatment procedure. In domestic sewage, the organic part generates from human faecal material while certain industries can also contribute significantly to the organic loading. The organic component of sludge is a mixture of fats, proteins, carbohydrates, lignin, amino acids, sugars, celluloses, humic material, and fatty acids. Live and dead micro-organisms are composed of a remarkably high proportion of the organic material and provide a large surface area having greater number of active sites for sorption of lipophilic organic contaminants in the sludge. The properties of sludge depends on various factors such as origin (i.e., domestic, industrial, and mixed) and treatment

type. It differs in its physical (processability and handlability), chemical (presence of nutrients and contaminants), and biological parameters (microbial activity and presence of pathogens). Application of post-treatment of the sewage sludge such as anaerobic digestion or aerobic composting can have a drastic effect on residual contaminant levels in case of their biodegradability. Over the years, the presence of more than 300 various diverse types of organic contaminants such as monocyclic aromatics, alkyl and aromatic amines/imines, organotin compounds, aliphatic hydrocarbons, carbonyls, haloethers, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), polychlorinated dibenzo-para-dioxins and furans (PCDD/PCDF), pesticides and polymers of various types and surfactants within sewage sludge has been detected by several EU countries. Concentrations of these compounds ranges from the pg/kg to g/kg interval. Accumulation into the sludge from wastewater depends mainly upon sorption, degradation and volatilization. For most compounds, their presence in sludge will be influenced primarily by the presence of potential sources within the catchment of the wastewater treatment plant. Details of the concentration range of the main organic contaminants detected in sewage sludge are represented in **Table 1**.

**Table 1:** Summary of the properties, occurrence and transfer of the principal organic contaminants in sewage sludge<sup>30</sup>

Compound group	Physico-chemical properties	Concentration range in sludge (ds)	Degradation	Plant uptake
Polycyclic aromatic hydrocarbons (PAH)	limited water solubility, volatile to lipophilic	1-10mg/kg	Weeks to 10 years, strongly adsorbed by soil organic matter	Very poor, foliar absorption and root retention
Phthalate acid esters	generally lipophilic, hydrophobic and non-volatile	1-100mg/kg	Rapid, half life < 50 days	root retention and translocated
Linear alkylbenzenesulphonate (LAS)	amphiphilic	50-15000mg/kg	Very rapid	Minimal
Alkyl phenols (NPE)	lipophilic	100-300mg/kg	Rapid < 10 days	Minimal, root retention
Polychlorinated biphenyls (PCB)	low water solubility, highly lipophilic and semivolatile	1-20mg/kg	Very persistent, half life several years, strongly adsorbed by	root retention, foliar absorption, minimal root uptake and translocation

			soil matter	
Polychlorinated dibenzo- <i>p</i> -dioxins and furans (PCDD/F)	low water solubility, highly lipophilic and semivolatile	<few µg/kg	Very persistent, half life several years, strongly adsorbed by soil organic matter	root retention, foliar absorption, minimal root uptake and translocation
Organochlorine pesticides	lipophilic to hydrophilic, some volatile	few mg/kg	Slow, half life>1 year, loss by volatilization	root retention, translocation not important, foliar absorption
Monocyclic aromatics	water soluble and volatile	<1-20mg/kg	Rapid	Limited owing to low persistent, rapidly metabolized
Chlorobenzenes	water soluble/volatile to lipophilic	<0.1-50mg/kg	Lower MW compounds lost by volatilization, higher MW compounds persistent	Possible via roots and foliage, may be metabolized
Short-chained halogenated aliphatics	water soluble and volatile	<5mg/kg	Generally rapid loss by volatilization	foliar absorption and possible translocation
Aromatic and alkyl amines	water soluble and low volatility	<1mg/kg	Slow	Possible
Phenols	lipophilic and high water solubility	<5mg/kg	rapid	Possible via roots and foliage

### 3.2. Biosolids

Different types of treated sewage sludges that can be practiced as soil conditioner are known as biosolids.<sup>31</sup> The application of biosolids to agricultural soils is established as a benign agricultural process as it affords needful nutrients and organic matter which will be helpful for augmenting soil properties. Even though biosolids can provide a waste management pathway for sewage sludge but they are still considered as a disposal site for industrial and domestic chemicals that are segregated in solids during treatment of wastewater. It is already established about the existence of measurable concentrations of dioxins and pharmaceuticals in biosolids which has led to serious concerns about accumulation of dioxins and an array of emerging contaminants in soil. Although the occurrence of these contaminants in environment is typically less, but even then, toxicologists, epidemiologists, and risk assessment experts have proposed that the optimum levels of these contaminants can have adverse environmental consequences on a large scale. A combination of traditional physical, biological, and chemical processes involved in wastewater treatment for

removing solids, modern organic matter such as persistent organic pollutants, brominated flame retardants, fluorinated compounds (PFCS), or pharmaceuticals from the wastewater is not satisfactory. Hence some supplementary post treatments methods like thermal drying and composting are being implemented at a faster rate for the enhancement of sludge properties. Nonetheless, total purification of biosolids is quite difficult to accomplish, hence biosolids intended for land application may contain pathogens, heavy metals, persistent organic pollutants (POPs), and other “emerging contaminants” (ECs) consisting of veterinary medicines, nanomaterials, paints and coatings, pharmaceuticals and personal care products (PPCPs). The main spotlight of human/environmental worry has shifted from the “traditional” contaminants such as metals, dioxins, PCBs, and pesticides to PPCPs that penetrates the environment mainly through domestic routes, and finally ends up in biosolid. Although very less concentrations of these contaminants exist in the environment, but majority of these contaminants are found to have critical toxicological effect, especially as components of complex mixtures. The main

concern regarding the existence of organic contaminants in sludge is its ability to access into the human food chain by absorption into edible portions of crop plants. The increased level of human and other terrestrial organism's (birds, invertebrates, and livestock) exposure to organic pollutants and PPCPs occurs generally through the diet and the consumption of contaminated crop plants.

### 3.2.1. Persistent Organic Pollutants (POPs)

The POPs<sup>32</sup> are organic compounds that can resist photolytic, biological, and chemical degradation to a greater extent. Poor water solubility, large lipid solubility, long half-life in soils, sediments, air, or biota makes them highly potential agents for bioaccumulation. Large lipophilicity leads to the substance bio-settling from the surrounding medium into the organism coupled with environmental endurance and a protection to biological degradation. Due to this property, bio amplification of POPs occurs through the food chain. A major group of POPs is comprised of the halogenated hydrocarbons and organochlorines including industrial products like PCBs, PCDD, PCDD/Fs, and 15 pesticides. Among the POPs, dioxins (polychlorinated dibenzo-*p*-dioxins, PCDDs) and furans (polychlorinated dibenzofurans, PCDFs) are recognized as the most harmful chemical species. Different environmental processes such as oxidation, hydrolysis, and photolysis have no effect on the decomposition and conversion of POPs. The POPs have very optimum effect in polar regions, but may have significant effect in other parts of the world. Hence, the overall accumulation of POPs in the polar regions is very prominent. The transport of POPs to plants is significant due to strong absorption of these substances on soil and are hardly moved into plant roots or carried into plant tissues present above the ground. Although in small amounts, Many plant species such as lettuce, tomato, rice, maize, and soybean have the ability to absorb small amount of POPs through their roots. People and animals are exposed to carcinogenic POPs primarily through their diet, occupationally, or while growing in the womb, leading to developmental defects, breast cancer, endocrine disruption within the reproductive

system, the central nervous system, or the immune system, chronic illnesses, and death.

### 3.2.2. Pharmaceuticals and Personal Care Products (PPCPs)

Any kind of product used by individuals for personal health, cosmetic reasons, or practiced in agriculture to increase growth or health of livestock are known as pharmaceuticals and personal care products. Hence, a broad range of chemical substances including prescription and over-the-counter therapeutic drugs, veterinary drugs, fragrances, and cosmetics come under the periphery of the phrase PPCP. Unlike pharmaceuticals, personal care products are released to the environment after routine use during showering and bathing. PPCPs are likely to be present in treated wastewater sources including river, lakes, streams, and groundwater, used for drinking as well as agricultural purposes.<sup>33</sup> The extensively studied pharmaceutical groups include nonsteroidal anti-inflammatory drugs (NSAIDs), antibiotics, beta-blockers, antiepileptic drugs, blood lipid-lowering agents, antidepressants, hormones, antihistamines, and personal care products include triclosan and triclocarban. The study is based on the volume of prescriptions/use, extent of toxicity, and supporting proof for its presence in the environment. The frequently detected pharmaceutical groups in biosolids include anti-biotics, the NSAID, diclofenac, the anti-epileptic drug, carbamazepine and the blood lipid-lowering agent, gemfibrozil along with the personal care products triclosan and triclocarban. Although the up-take of PPCPs by plants is a well-known fact but the knowledge is limited to a few compounds or plants. Compounds with strong absorption and resistance to degradation persist in surface soils for long periods and have the potential to subsequently be up-taken by plants, and exhibit bio accumulative and endocrine disturbing activity.

### Biotic sources

#### 4. Greenhouse gases from fecal waste

Feces are type of biomass that can be transformed into energy by means of a range of mechanisms. Thermal and biochemical are the

two fundamental ways in which feces can be transformed to energy. Thermal processes involve the transmission of heat to the manure and subsequent conversion of biomass to chemical form by various mechanisms such as combustion, pyrolysis, gasification. Combustion of large number of carbon and hydrogen bonds present in the feces releases large amount of energy. Gasification process involves conversion of solid waste into a gaseous product, which readily undergo combustion and turned into energy. Biochemical process is generally practiced for wet waste, whereby anaerobic digestion by enzymes in bacteria take place, eventually decomposing the natural waste and producing biogas, a mixture of methane and carbon dioxide, which in turn can be transformed to energy.

Since last few year, emissions from livestock were found to be higher than that of the transportation sector. Through photosynthesis, the livestock feces are absorbed by plant and through respiration enter in the atmosphere as CO<sub>2</sub>. This type of situation gave evidence that greenhouse gases CH<sub>4</sub>, CO<sub>2</sub> and N<sub>2</sub>O were generated in environment due to burning of fossil fuels and has potential harmful effect on human health through a variety of pathways such as high frequency and intensity of heat waves, cold related deaths, increased floods and droughts *etc.* Indeed, the quantity of CH<sub>4</sub> from eructation of ruminant was higher than from the methanogenesis process in the feces. So, there has been an urgent need to substitute animal manures by fertilizers and to substitute other animal coproducts, because livestock now practice human-inedible food and fiber processing byproducts. Furthermore, people get a greater excess of energy, but still they suffer from a larger number of deficiencies in essential nutrients leading to greater obesity.

### 5. Biopesticides

Biopesticides are pesticides derived from natural materials such as animals, plants, microorganisms, certain minerals *etc.* and are used to regulate pests in agriculture by virtue of explicit biological effects rather than as extensive chemical pesticides. Biopesticides can be a potential replacement of traditional pesticides as they can curtail total agricultural

pollution as they are easy to handle and normally do not affect favorable invertebrates or vertebrates, and have a less half life. Biopesticides typically affect only the target pest and analogous organisms, whereas, commercial pesticides affect organisms like birds, insects and mammals.

### 6. Invasive species

The invasive species term generally attributes to all kind of living organism-an amphibian, plant, insect, fish, fungus, bacteria, or even an organism's seeds or eggs-which is not indigenous to an ecosystem and have a harmful effect. They are often large and small species which may pose serious risks and have disastrous effects on endemic wildlife, human health and economies. These invasive species have frightening impacts on our natural ecosystems and economy, costing billions of dollars every year. These species have the capacity of growing and reproducing at a higher rate, and spreading excessively, causing harm to environment. *Centaurea solstitialis*, an aggressively invasive weed, was apparently introduced to North America in polluted fodder seed. Agricultural practices like tilling and livestock grazing causes very fast spread of these species. These species decrease biodiversity, degrades natural ecosystems, prevents native plants from growing and creates a hurdle for movement of indigenous animals. The increased proliferation of agriculture has resulted in the unintended transit of pests, weeds, and diseases. For example, the transportation of bumble bees pollinators reared in Europe and shifted to the United States and Canada for commercial application has led to the introduction of an old parasite to the new world. This type of introduction mainly contributes to rapid declination of native bumble bee in North America. Agriculturally introduced species can also blend with native species causing a recession in genetic biodiversity, threatening agricultural production. Habitat disruption correlated with farming practices also promote the formulation of these introduced organisms. Polluted machinery, livestock and fodder, crop or pasture seed also contributes to the spread of weeds. Through biosecurity, prevention of the advancement of invasive species can be



administered at a regulated level. Biosecurity is a legal procedure that puts a restriction on the migration of invasive species from areas of their presence to areas of their absence. The World Trade Organization has laid down international regulations regarding biosecurity of pests and diseases under the agreement on the application of sanitary and phytosanitary measures.

### 7. Genetically modified organisms (GMO)

A GMO (genetically modified organism) or “transgenic” organisms are produced in laboratory, whereby genes from the DNA of one species are extracted and artificially inseminated into the genes of other non-related plant or animal. The foreign genes may migrate from bacteria, viruses, insects, animals or even humans causing an increased weediness of the plant or the total elimination of the native species. Moreover, the transgenic plant later on itself may become a weed again if the proper modification improves its robustness in a given environment. There are some concerns raised regarding poisoning of some non-target organisms, such as pollinators and natural enemies through accidental ingestion of plants. The use of GMO crop plants engineered for herbicide resistance can also indirectly enhance the extent of agricultural pollution. For example, the use of herbicide at a higher rate in herbicide-resistant corn fields in United States is reducing the quantity of milkweeds available for monarch butterfly larvae. Livestock are usually modified for high growth-rate, quality of milk composition and production, disease resistance and their long survival. Genetically modified fish are practiced for scientific research, as pets and as a food source. Genetic engineering has paved the way for controlling mosquitos, a vector for many deadly diseases. Taking into

consideration of relative advantages and disadvantages of the process regulation for the transmission of genetic modified organisms can vary depending upon the nature of organism and the concerned country.

### Conclusion

On the basis of a broad study of the emerging contaminants in agriculture as studied above, it is observed that the contaminants include pesticides, heavy metals, organic contaminants, biopesticides, greenhouse gases and genetically modified organisms. These compounds are generally found at very low concentrations in the wastewater, biosolids, fertilizers and manure used in agricultural systems. Furthermore, these contaminants enter the environment in various ways such as products that go down the drain from our homes, from industrial sources, and in the manure of livestock treated with antibiotics. Although extensive research and increased monitoring over the years has identified the presence of these compounds, very little is known about how these emerging contaminants move through the environment, or what impacts they may have on our environment over time. Although no sufficient data and large-scale evidence has proven causal associations between emerging contaminants and adverse effects on the human body, but it is always advisable not to ignore the harmful effects indicated by animal experiments. Further large-scale studies with improved designs are needed to provide more convincing and clear outcomes for the benefit of the ecosystems and our environment as a whole. Until and unless we come across any definite result of the impacts of these emerging contaminants on our environment, it will be a matter of great relief and an appreciated effort that we make only optimum use of these products.

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## Contribution of Women from North-East India in the Field of Science and Technology

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For decades in India, the field of Science and Technology was primarily in control of males, however, since past few years, several women have contributed significantly in science and have also stimulated others to act in accordance with them. follow. In Indian Agricultural Research Institute (IARI), 50% of the departments-including biochemistry, plant pathology, entomology, nematology, microbiology, agricultural physics, agricultural chemicals and agricultural economics are led by women. As per United Nations particulars, the research & development institutions in India are comprised of only 14% of the total 280,000 scientists, engineers and technologists. Nevertheless, in the research programmes, a third of the PhD awardees is women. Women Scientists are contributing significantly for the rapid progression of the country in all disciplines. For celebrating International Women's Day on March 8, 2020, the Indian government has acknowledged its women scientists to encourage more women participation in the field of science. It's a magnificent course of action to commemorate the great women scientists of India.<sup>1</sup> From cytogenetics to organic chemistry and social sciences, the ministry of women and child development, Govt. of India will establish 11 chairs across various universities in India in the honour of 20<sup>th</sup> century women scientists, including eminent anthropologist Irawati Karve and mathematician Raman Parimala.<sup>1</sup>



Women's Science Congress is a significant step towards nation building and remarkable endeavor to motivate and encourage women to have a powerful existence in the field of science and technology. Women's Science Congress is the most important part as it reflects a range of areas where the intellectual attributes, innovations, ideas and many other things of and for women are given a vibrant platform in promoting science and technology. Let us not forget that behind the simple, docile and humble identity of every woman there is a razor-sharp brain and an uncanny ability to execute and converts thoughts into actions without much effort. If women are given the opportunity and support, they would excel in any field. Through the Women's Science Congress more young female minds can be inspired to be a part of scientific community and to engage themselves in active scientific research. North-east Indian women have significant contributions in the field of science and technology. North-east Indian women are brave, courageous and enterprising and they contribute in maintaining peace and harmony in the region. They take major role in economic activities with local and traditional markets being run by women only. Stating that history has always proven the bravery and courageous nature of North-east Indian women right from the British rule in India. Even in times of turmoil or unrest in the region, the women have always come to the forefront to resolve and bring peace. If such brave women are provided with scientific and technological awareness, then they can contribute immensely in the outstanding development of the nation as a whole. Women's Science Congress is being held to salute the enthusiasm of Indian women and commemorate their contribution in the society. Women empowerment is immensely important for the development of the country. However, in spite of women performing exceedingly well in schools and colleges, very few women make science and technology, very few women make science and technology as their chosen career and due to certain limitations raised by our society, they opt out of their

professional career. The most important step to empower women is remove the gender disparity. Indian women can contribute magnificently both in personal life by nurturing and taking care of their children, sharing experience and knowledge with their children and also in professional life by augmenting scientific skills and temperament and hence developing our society. Now a days, women are getting more conscious of their rights, hence making their best efforts to enhance and upgrade their intellectual capability, positive ethics affirmation to fabricate her own definition resolution of herself and consider herself as a perfect human being without any gender prejudice. Women empowerment through science and technology, has the ability to accredit them to realize comprehend their talents, and power and structure their life in agreement with their innovations and creativity. In this modern era, particularly in the 21<sup>st</sup> century, Scientists, Engineers and Medical professionals play a pivotal role. These professionals in these fields, in turn, will explore ways and means in solving the problems faced by people such as problems in energy, sustainability, the environment, water, food, disease and most importantly in the healthcare sector. Since the percentage of the scientific and technological workforce has been increasing day by day, women at this juncture, need to participate and explore solutions to technical problems as well as for generating employment in Scientific and Entrepreneurship. Women in India face several challenges in moving up the academic and administrative ladder due to systemic barriers and structural factors. Gender equality in scientific laboratories and institutions of higher education is not only about numbers but also about various micro and macro level factors operating at institutional level. There exist various policies and enabling environment in different institutions in India but a common approach or guiding principles to bridge the gender gap is still lacking. In science and technology sector it is difficult to assess and evaluate the merit of existing process/procedures from gender lens. This clearly demonstrates a need for multi stakeholder interventions. While gender equality in science is an important consideration, it is also in the larger interest of scientific progress and society.

Women faced great challenges to get education in science subjects, as there was no college or university in those days to provide science education to female students. They had to request from college to college and university to university to get admission to BSc, MSc, and PhD courses. Table I provides the list of lady crusaders, who could achieve their endeavour despite several hurdles.<sup>2</sup>

**Table-I:** Chronology of Indian Women Achievers in Science and Technology<sup>2</sup>

Sl.No.	Year	Name	Degree/Achievement	Name Institute/Organization
1.	1921	E K Janaki Ammal	BSc (Honours) (Botany)	Presidency College, Madras
2.	1931	E K Janaki Ammal	DSc	University of Michigan, Ann Arbor, USA
3.	1933	Kamala Sohonie	BSc	Bombay University, Bombay
4.	1934	Radha Pant	BSc	University of Delhi, Delhi
5.	1935	E K Janaki Ammal	First Woman Fellow	Indian Academy of Sciences
6	1936	Asima Chatterjee	BSc (Chemistry)	Scottish Church College, Calcutta
7.	1939	Anna Mondiyal	BSc(Honours)	Presidency College, Madras
8.	1939	Kamala Sohonie	PhD	Cambridge University, Cambridge
9.	1944	Asima Chatterjee	DSc	Calcutta University, Calcutta
10.		Radha Pant	First Woman Faculty	Science Department,

	1945		Member	Allahabad University, Allahabad
11.	1947	Urmil Eulie Chowdhury	B Arch	University of Sydney, Australia
12.	1948	Rajeshwari Chatterjee	MS (Electrical Engineering)	University of Michigan, Ann Arbor, USA
13.	1953	-do-	First Woman Faculty Member	Engineering Department, Indian Institute of Science, Bangalore
14.	1953	Shakuntala Bhagat	BTech (Civil)	Veer mata Jeejabai Technical Institute, Bombay
15.	1957	E K Janaki Ammal	First Woman Elected Fellow	Indian National Science Academy (INSA)
16.	1961	Asima Chatterjee	First Woman to get Shanti Swarup Bhatnagar Award (Chemical Sciences)	CSIR, India
17.	1968	Hiriyakkamavar Ilah	PhD	Indian Institute of Technology, Kanpur
18.	1968	Priti Shankar	First Woman Graduate	Indian Institute of Technology, New Delhi
19.	1975	Asima Chatterjee	First Woman General President	Indian Science Congress Association.
20.	1983	Sudipta Sengupta	First Woman Member	The Indian Antarctic Expedition
21.	1984	Sneh Bhargava	First Woman Director	All India Institute of Medical Sciences, New Delhi
22.	1985	Urmil Eulie Chowdhury	First Asian woman to get her name registered to IAWA, USA	Academy to International Archive of Women Architecture (IAWA), Virginia Tech., USA.
23.	1990	Bimla Buti	First Indian Woman Fellow	Third World Academy of Sciences (TWAS), Trieste, Italy
24.	1994	Satyavati, Gawdagere Vedanti	First Woman Director General	Indian Council of Medical Research (ICMR), New Delhi.
25.	2005	Raman Parimala	First woman to be awarded in Mathematics and Physics	Third World Academy of Sciences (TWAS), Trieste, Italy

There has been visible gender discrimination across the globe to accept the active involvement of women in the discipline of science and technology. It took a long time to get admission of women in the scientific community. Initially, women were denied membership and fellowship in the scientific academies. However, the situation improved when women gained admission to higher education. More than 50% of the world's population is constituted of women, yet in most developed countries the achievements of women in science are invisible.

Some of the significant contributions made by women of North-East India in the field of science and technology are briefly highlighted in this paper.

**1. Joyanti Chutia:**



This Indian physicist did her specialization in the field of solid-state physics and plasma physics. Among all Indian women, she was the first women to lead scientific institutions in India. In 2005, she became the Director of the Institute of Advanced Study in Science and Technology (IASST) in Guwahati, Assam, which is the first premier research institution established in North East India. She is an Emeritus Scientist at the Department of Science & Technology in the Government of India as well as the fellow of National Academy of Sciences. She was born in 1948 at Sivasagar, Assam, India.

Dr. Chutia was one of the first girls in her school to opt for mathematics as a main subject. Later on, she completed her B.Sc in physics from Cotton University, Assam in 1967 and completed her MSc in 1969 and Ph.D on a fellowship in 1981 from Dibrugarh University, Dibrugarh. Dr. Chutia taught for some time as a lecturer at Cotton College, eventually deciding to continue with research. Her research focused on the conduction mechanism of thin polymer films After the completion of her Ph.D, Chutia continued her research at Dibrugarh University for another year as a CSIR-postdoctoral fellow. She plunged into the area of plasma physics at the Physical Research Laboratory in Ahmedabad and thereafter connected with the Institute for Plasma Research in Gandhinagar. After few years, she returned back to the Institute of Advanced Study in Science and Technology as a faculty member and established the Plasma Physics Laboratory. She was awarded the Japanese government fellowship in 1988 to work at the Plasma Laboratory of the Institute of Space and Astronautical Science, Tokyo. Chutia's research interests mainly includes biomedicine, material science and biotechnology. Her research has lead the way for the growth and evolution of a long-lasting and compostable cut stitching material from Muga Silk. She is a recipient of various awards such as Durlav Deka Memorial Award, Basanti Bordoloi Award, Sadhani Saurya Award, Ghanashyam Goswami Award, and K K Barua National Award.

**2. Priyanka Das Rajkakati:**



Priyanka Das from Assam has been appointed as the ambassador of “For Girls and Science”, an initiative launched in 2014 that will now see her encouraging girls to take up scientific careers and pursue it to higher education levels. Priyanka Das is breaking the conventional thinking of the society that science is always been dominated by males and science and women are often considered as an unfamiliar coalescence. From all over

the world, 75 high-quality women are selected for the prestigious Homeward Bound Antarctica Mission's fifth edition and Ms. Das has also been chosen along with them. The aim of the mission is to provide support to women from STEMM (science, technology, engineering, mathematics and medicine) background for enhancing their skill in policy-making capacity and leadership ability. Das was brought up in New Delhi and currently settled in France. She is the daughter of Manoj Kumar Das and Dr Ajanta Baruah Das, who hails from Assam. Her both parents have a science background, and due to their efforts, she got exposure into the field at an early age. Das was having interest in various co-curricular activities like dancing, playing violin, sports etc. She also received the best all-rounder award just prior to leaving school. Das remains to be an all-rounder till date and the labels which describe her are, "Aerospace engineer, data scientist, artist, language enthusiast and ambassador for the L'Oréal-UNESCO girls in Science Initiative." Currently, Das is pursuing her Ph.D studies in satellite navigation, in an aerospace company called Safran in France. The topic for her Ph.D is "how to make positioning by GNSS (an example that we all know of is GPS) more precise, in the order of a few centimetre (it is in reality a few metre)". This technology can be highly useful from security point of view level in autonomous cars which are present at one meter distance from each other. Meanwhile, she is also continuing her studies on the feasibility of using Earth-based satellite systems for navigating on the Moon. Apart from this, her role as the ambassador for L'Oréal-UNESCO for Girls in Science Initiative in France is breaking all stereotypical rigid thinking about women working in scientific fields. For example, she said, "I do not spend entire time in a laboratory with a lab-coat-I actually get to be an artist on the side and travel to my heart's content." The scientist is very dynamic and energetic even in her late 20s and is certainly setting an example, for all the girls who are reluctant of selecting the stream, she said, "If you are curious about life, science should naturally come to you." She was also promoted by Gorgeous You India campaign, which kicked off under the initiative of the Shirin Latif, to reach out and to public light the stories of 100 successful Indian women, who could serve as role model for the young generation. Das completed her graduation in physics from St Stephen's College, New Delhi, where she ascertained that her aerospace dream could literally become a reality. After then, she completed her postgraduation from École Polytechnique in Paris and obtained a double diploma exchange from ISAE- Supaéro. With the advancement of her career in the field of science, Das did not surrender her affection for art. She said she always desired to become a professional artist, but due to confusion at the early stage of her career, she couldn't make a balance between both the fields. Another significant milestone in her life was the Caltech Space Challenge 2015, which was a five-day long international student space mission design competition bringing 32 talented and highly-motivated students to the Caltech campus, Pasadena, USA, to take part in a week-long space mission design competition. The participants worked very hard under the guidance of experts from the industry, NASA and academia to design their mission concept from scratch to final proposal. Furthermore, Das also got the opportunity to visit the NASA Jet Propulsion Laboratory (JPL).

### **3. Rural Women From Assam Prepare Products Like Hand Sanitizer, Homemade Mask To Combat covid-19:**

Rural women of Jorhat, Assam have played a significant part in the preparation of various products such as hand sanitizer, homemade mask, and liquid disinfectant with the help of Rural Women Technology Park (RWTP) under CSIR-North East Institute of Science and Technology, Jorhat, supported by SEED Division, Department of Science and Technology (DST), the products distributed freely among family members and poor people in the neighbouring villages to help combat COVID-19 in the area. Professor Ashutosh Sharma, Secretary, DST said, "Meeting a challenge such as COVID-19 needs strong community participation and support. Self-help groups and dedicated NGOs are perfect vehicles in the current scenario for awareness creation, introducing relevant solutions, making and distributing the low-tech items such as masks and disinfectants". Rural women from the region were imparted training in the production of homemade mask from traditional 'Gamocha' (a traditional Assamese cotton towel) by RWTP, Jorhat. For this purpose, around 150 Gamochas were procured and two sewing machines were organized (6 homemade masks can be prepared from one Gamocha). It has been put forwarded that the homemade mask should be distributed to at the rate of Rs.15/- per mask. Beside this, 200 liters of liquid disinfectant (prepared from the raw materials like dettol, ethanol, glycerine, essential oil) is also being produced. The disinfectant will also be distributed freely among the family members and poor people in the nearby village. The women of RWTP were fully trained and later on they prepared about 50 litres of hand sanitizer, 160 litres of liquid disinfectant, which have been distributed among the 60 women participants and their family members. The RWTP also prepared posters and leaflets on 'COVID-19: Do's and Don'ts' in Assamese language for making people conscious about the Corona Virus and precautionary measures to be taken during the pandemic situation.





Liquid Disinfectant



Hand Sanitizer



Homemade Mask from Gamocha

#### 4. Jubilee Purakayastha:



When the Defence Research and Development Organization (DRDO) evolved the anti-COVID drug, there was extra reason for Assam residents to feel joyous and cheerful. A scientist from the Karimganj District of Assam, Jubilee Purakayastha, was among the scientists who pioneered the anti-COVID drug in the DRDO lab. The breakthrough research of the Institute of Nuclear Medicine and Allied Sciences (INMAS)- a lab of Defence Research and Development Organization (DRDO)- in collaboration with Dr Reddy's Laboratories (DRL), Hyderabad has led to the discovery of an oral drug 2-deoxy-D-glucose (2-DG) for the treatment of moderate to severe coronavirus patients. Clinical trials have proved that this molecule assists in the faster recovery of hospitalized patients and reduces supplemental oxygen dependence.

Jubilee did her schooling at Mahisasan School, followed by Karimganj College. She did her PhD from the North East Institute of Science and Technology (NEIST) in Jorhat, Assam and joined the Defense Research Laboratory of DRDO in Tezpur as a scientist in 2008. The daughter of Lt Sudarshan Purakayastha and Mrs Binoy Kumari Purakayastha, Jubilee said she was inspired by her mother's smile and she would continue to serve the nation. Pursuing the Prime Minister's address to the nation for the discovery of drug made in India,

which can fight against the pandemic, DRDO started the great initiative of evolving of an anti-COVID drug and later on they could successfully implement the therapeutic application of 2-DG drug. In April 2020, during the first wave of the pandemic, INMAS-DRDO scientists conducted laboratory experiments and observed that 2-DG drug performs at high rate against the SARS-CoV-2 virus and inhibits viral growth of disease. Based on these results, the Drugs Controller General of India's (DCGI) Central Drugs Standard Control Organization (CDSCO) permitted a Phase-II clinical trial of 2-DG in COVID-19 patients in May 2020. As per the efficacy trends, the patients treated with 2-DG showed faster symptomatic cure and recovery than Standard of Care (SoC) on various endpoints. Compared to SoC, a remarkably commending drift (2.5 days difference) was observed with reference to the median time for attaining regulating of specific particular necessary symptoms parameters.

## 5. Amiya Rajbongshi:



On International Day of Women and Girls in Science, Dr Deepa Agashe, Assistant Professor, National Centre for Biological Sciences, Tata Institute of Fundamental Research, Bengaluru, tweeted a touching message, saying, "Science is for everyone and needs everyone. I love being a scientist and waking up every day with the opportunity to ask questions to understand the world. Join us in appreciating, inspiring and supporting female scientists." In her small speech, Agashe, summarised her pride, passion and also subtly hinted at how our world needs science, and science needs women and girls. The pride and passion pointed out by Agashe is the connecting bridge among all the other nine acclaimed women performers in the field of science and technology whose achievements were acknowledged and were felicitated by the President last year. The awardees included Dr Amiya Rajbongshi, retired vice-principal, North Lakhimpur College, Lakhimpur, Assam, who won the National Award for magnificent efforts in Science and Technology Communication through print media in 2020, and Dr Uma Kumar, Professor and Head, Department of Rheumatology, AIIMS, New Delhi, who was honoured with the National Award for Outstanding Efforts in Science and Technology Communication in the electronic media. Apart from Agashe, Dr Niti Kumar, Scientist, Central Drug Research Institute, Lucknow, and Dr K Geetharani, Assistant Professor, Department of Inorganic and Physical Chemistry, Indian Institute of Science, Bengaluru, were honoured with the SERB Women Excellence Award last year. Dr Shalini Gupta, Associate Professor, Department of Chemical Engineering, IIT, Delhi, and Dr Shweta Rawat, Scientist, Defence Institute of Physiology and Allied Sciences, DRDO, Delhi, were conferred the national award for young woman showing excellence through application of technology for societal benefits. The three women researchers who were honoured with the Augmenting Writing Skills for Articulating Research (AWSAR) Award included Dr Joyita Sarkar (in the Post Doctoral category), S. Chris Felshia and ML Bhavya (both in the Ph.D Scholar category). Many other women from all over India were AWSAR awardees in the PDF category.

Rajbongshi owes it all to her parents - father Biren Phukan and mother Lakhima Phukan. After matriculation, she joined cotton college in guwahati, graduated in 1968 and obtained first class and also secured first position in Assam. She did her master's degree from Gauhati University in 1970 in first class, again obtaining the first position in the state and Ph.D from Osmania University, hyderabad." She was inclined towards teaching and so joined the North Lakhimpur college as a teacher. She enjoyed teaching profession by visiting different villages and bringing science to the common people by being associated with science societies. She was trying to inculcate scientific temperament in young minds of students. Rajbongshi mentions her husband, Dr. Mukunda Rajbongshi, as her main support system. "His active involvement in the pursuit of knowledge and his

commitment towards serving the society has always been an inspiration for me," she says, beaming with pride. Rajbongshi has a vital point to add to the role that women have played in science. "From Marie Curie, Rosalind Franklin to Kalpana Chawla, history speaks of the success stories and the unfailing attitude of women and their commitment towards science. If observed at the grassroots level, women's role in science has challenged society's narrow shackles. Women uphold the responsibility of moulding the family, the society and then the nation at large. Therefore, we must try and imbibe a scientific temper in them early on so that they can mould the younger ones. Women can also use science to challenge superstitious and help make the society move forward. "Further, when women are actively involved in scientific endeavours, they act both as pioneers and role models for thousands of other women," says Rajbongshi. accordingly." Humbled at receiving the national award, Rajbongshi says, "It is indeed a great honour for me. It recognises my consistent efforts in building a scientific temper among the masses. This recognition is also an inspiration that instils the courage to commit to the goal." The pandemic was a challenging one, both mentally and physically, for all of us. But Rajbongshi got ample time to complete the remaining part of the translation of "Origin of Species" by Charles Darwin and is currently working on the publication process. She plans to work more on spreading scientific awareness among the masses and reaching out to more people through her efforts.

#### 6. Nidhi Sharma:



Nidhi Sharma, a woman scientist from Assam has brought laurels to the state as she is associated with India's ambitious lunar mission **Chandrayaan-2**. The young scientist hails from Tinsukia's Na-Pukhuri area in Assam. She is a space scientist in the Indian Space Research Organization (ISRO) and she played a pivotal role in the successful launch of **Chandrayaan-2**. She is holding a very important position in ISRO. Nidhi married Dipakar Deb who is an engineer by profession in the month of January 2019 and since then they have been staying in Bengaluru. It may be mentioned, ISRO's lunar mission started on July 22<sup>nd</sup>, 2019 and as per schedule, the Vikram lander was about to soft-land in the southern part of moon's surface on September 7<sup>th</sup>, 2019 at around 1:30 to 2:30 am. On September 8<sup>th</sup>, 2019 the orbiter of Chandrayaan-2 located the lander on the moon's surface. After Chandrayaan-1, Indian Space Research Organisation (ISRO) developed the second lunar exploration mission, Chandrayaan-2. All three components of Chandrayaan-2 consisting of a lunar orbiter, the Vikram lander, and the Pragyan lunar rover, were developed in India. The primary scientific purpose is to survey the location and abundance of lunar water via Pragyan, and ongoing analysis from the orbiter circling at a lunar polar orbit of 100×100 km. The mission was launched to the Moon from the second launch pad at Satish Dhawan Space Centre on 22 July 2019 at 2.43 PM IST (09:13 UTC) by a Geosynchronous Satellite Launch

Vehicle Mark III (GSLV Mk III). The craft reached the Moon's orbit on 20 August 2019 and began orbital positioning manoeuvres for the landing of the Vikram lander. Vikram and the rover were scheduled to land on the near side of the Moon, in the south polar region at a latitude of about 70° south at approximately 1:50 am on 7 September 2019 and conduct scientific experiments for one lunar day, lasting two Earth weeks. However, at about 1:52 am IST, the lander deviated from its intended trajectory at around 2.1 kilometres (1.3 mi) from landing, and lost communication.

#### 7. Sudeshna Boro Saikia:



For as long as civilisation has existed, human beings have looked upon the cosmos with wonderment. Over time, our questions about the cosmos have evolved to consider our little place in the universe. Truly, why is Earth special? It is the only planet we know that harbours life. Scientists are trying to figure out properties that make Earth habitable. One such astrophysicist, Dr Sudeshna Boro Saikia, is studying the atmospheric conditions for habitability. Currently, at the Institute for Astrophysics (IAU) in Vienna, she studies space weather to uncover clues to this question. The exploration started with her PhD research. Sudeshna described her work on 'stellar magnetic cycles' at the Georg August University of Göttingen. What is a stellar magnetic cycle? Stars are largely made of gas and plasma that constantly move to create a magnetic field. The magnetic field of a star often changes polarity in cycles! These polarity changes are accompanied by violent storms and volatile activity in the stars. This is true for our Sun too! Every 11 years or so, the magnetic field turns over after 11 years or so and the North and South poles of the Sun shift. These changes on the Sun's surface affect the Earth too. Volatile activity on the Sun's surface may cause disruptions to electrical grids and radio on Earth and damage satellites, limiting their lifetime. They can also mean exposure to harmful radiation for the astronauts in space. By studying the solar cycles, we can forecast disruptions in time and safeguard satellites and astronauts in space. Sudeshna worked on detecting the magnetic cycle of stars similar to our Sun, with a focus on the effect of the rotation of a star. Using complex techniques in astrophysics, Sudeshna and her team were the first to detect a sun-like magnetic cycle in 61 CygA, a dimmer and smaller Sun-like star, with a cycle that lasts 7 years. When Sudeshna was around seven, a local boy from her town went to Trinity College, University of Cambridge, to study mathematics. When he returned with the distinction of Wrangler (the highest honour for undergraduates with a Mathematics degree from Cambridge), he drew a large crowd at the local auditorium for his talk. Sudeshna was in the audience that day. Today, Dr Anupam Saikia is a Professor of Mathematics at IIT Guwahati. Sudeshna recalls that it was a rather inspirational moment for her. Someone from her town achieving the highest honours from Cambridge helped her believe that she could follow the same path too. The adulation and praises from the crowd also helped!

Fortunately for her, Sudeshna was always surrounded by science and STEM. Since both of her parents were academics, she was surrounded by books on science right from childhood. She remembers reading about the Special Theory of Relativity and time travel in an Assamese book for the first time. Prof. J. Narliker's books further caught her eye. Sudeshna recalls an annual mobile book fair where they could find all kinds of books. She could get her hands on international publications, publications from the Soviet Union and Assamese science magazines, to feed her curiosity. A turning point for her was obtaining access to Google in its infancy, in the late 90s and early 2000s. A new world of knowledge had opened up for her! Although the local language magazines evoked curiosity, they would leave unanswered questions. She remembers calling up the publisher to find out more about the European Space Agency and was directed towards Google. Soon after, she would frequent cyber cafes and look for answers to her queries. Sudeshna mentions, "When I found that I could find information about anything, I was overjoyed!"

Sudeshna acknowledges that she is uncommonly privileged. "I have been particularly lucky to find amazing and helpful mentors, right from my early days". She recalls one of the largest influences in her was a professor at Glasgow who helped her apply for PhD positions during her master's. With time, her interests grew and she moved from studying stellar magnetic cycles to searching for clues on what makes a planet habitable. Her focus shifted to stellar winds and space weather. Stellar winds are a high-speed flow of material ejected from the stars. Consisting of a wide variety of materials, these winds are complex phenomena and not yet understood. Stellar winds are often studied using advanced computational techniques and sophisticated telescopes. Sudeshna also studies UV radiation; a heavy contributor to atmospheric loss. In the upper planetary atmosphere, high energy UV photons help atmospheric molecules escape more easily. Her experience in multi-wavelength physics as well as the skills she picked up during her PhD serve her well in her quest for her answers today. Sudeshna is a part of multiple working groups for young researchers at IAU. One of these is building a platform for young researchers to unite. Reading stories about Marie Curie revealed sociological impacts of gender identity to Sudeshna. Her identity as a woman researcher remains important to her. She advises young women researchers to overcome inhibitions towards networking. She says, "there are a lot of good people and opportunities out there and we need to be proactive in finding them." Sudeshna is hopeful for the future of Indian Science, especially for students coming from the NE. She feels that while there are still gaps in the systems (better curricula and teaching methodologies are needed), she can see some progress being made. She feels the system needs to work on its flexibility to adapt to new things. "We need to stop being stuck in the past and limit students to textbooks written decades ago." She also believes there is a need to move beyond marks and scores as judgement criteria. She says, "These changes will take time, but as long as we are on the path ahead, the future of Indian science is in good hands!"

#### 8. Anwasha Borthakur:



The young scientist hails from Tinsukia's Gellapukhuri area in Assam. Anwasha Borthakur is a Marie Skłodowska-Curie Postdoctoral Fellow at KU Leuven, Belgium from January 2019. Her research focuses on electronic waste policies in India, South Africa and the EU. Prior to joining KU Leuven, she completed her PhD at Jawaharlal Nehru University (JNU), New Delhi in 2017. Anwasha has been working on electronic waste in the global South for the past ten years. She co-teaches the course on Global Environmental Politics with Prof. Katja Biedenkopf. She has published 67 Research papers in various National and International Journals of repute. She has authored various books on Environment related issues. She has excellent skills and expertise on Environment, Sustainability, Environmental Management, Sustainable Development, Environmental Pollution, Environmental Studies, Environmental Impact Assessment, Environmental Analysis, Environment Protection. Her father, Dr. Achyut Borthakur retired as Head, Department of History, Tinsukia College and her mother Ms. Anjana Goswami retired as Vice-Principal of Tinsukia College. Her husband Dr. Pardeep Singh is Assistant Professor at University of Delhi. Dr. Borthakur has contributed immensely in the awareness and management of Electronic waste (E-waste) and bioremediation of Petrochemical wastes.

#### 9. Mausumi Goswami:



A young scientist from the Karimganj District of Assam, she did her schooling from Girl's Higher Secondary School, Karimganj. Then after doing her graduation from Karimganj College, she joined IIT Guwahati for M.Sc. She completed her PhD from Indian Institute of Science (IISc) Bangalore. She did her Post-doctoral studies from Canada. She has been trained in techniques of Physical Chemistry including instrumentation and microwave spectroscopy with research interest which spans from the discipline of atmospheric chemistry, helium nanodroplets to interstellar chemistry. Currently she has been working as Assistant Professor at VIT, Vellore, Tamil Nadu. Her husband Dr. Banikanta Sarma, is Assistant Professor in the discipline of Chemistry at Jawaharlal Centre for Advanced Scientific Research (JNCASR), Bangalore.

**10. Sarungbam Bimola Kumari Devi:**



Bimola Kumari (left) receiving Padma Shri Award from President Pranab Mukherjee

Sarungbam Bimola Kumari Devi was born in Manipur, India. She is a doctor and the Chief Medical Officer of Imphal west region, Manipur. Since 1979, she has been serving in the Manipur state medical service, substantially functioning in the rural areas and has led the food safety office when Narendra Modi, the Prime Minister of India, visited the state. Kumari was honoured by Dr. B. R. Ambedkar International Award in 2014 and with the Padma Shri, the fourth highest Indian civilian award by the Government of India in 2015.

**11. Jenita Mary Nongkynrih:**



In 2011, ISRO had awarded the prestigious Young Scientist Merit Award to Jenita Mary Nongkynrih, a space scientist at the North Eastern Space Application Centre (NESAC), Umiam (Barapani), for her urban information system project in the North East. The award carries a citation and cash of Rs 50,000. Jenita is a resident of Mawlai Mawroh locality of Shillong city. She did her primary schooling at St. John Bosco Girl's High School, Cherrapunjee and continued her study at St. Mary's High School and College. She completed her Master from North Eastern Hill University. She has specialized in Urban studies, Disaster Management and Natural resources management. She has contributed to the project on National Urban Information System-10K for the North Eastern region. Her technical contributions in urban planning for towns in Meghalaya are worth to mention. She is also involved in national projects for natural resources management in Meghalaya. Her major accomplishments in disaster management are the vulnerability and risk analysis for different hazards in three different urban areas and one district of Assam. She has also chipped in for the project on National Urban Information System-10K for the Northeast as the principal investigator. Nongkynrih's other contributions are in urban planning and national projects for natural resources management in Meghalaya. She has inspired young people to build their career in space-based applications.

**12. Sangeena Salam:**



She completed her Master's degree from University of Mysore, India and PhD from McMaster University, Canada. She has PhD research experience in development of drug screening platform for the neurodegenerative Parkinson's disease model. Currently she is Postdoctoral Associate from Rutgers University, USA and she has Postdoctoral Associate research experience in aging. She is a dynamic and versatile scientist, contributed in a successful collaborative multidisciplinary project - performed drug assays, molecular experiments and fabrication of prototype chip devices. Excellent understanding of molecular biology, drug metabolism, physiology and pharmacokinetics. Her research interests include understanding molecular mechanism of aging, molecular biology experiments, molecular cloning, imaging, microscopy, PCR, sequence analysis, CRISPR technologies, microscopy looking at the neuronal cells, characterizing aging morphology of the neurons.

**13. Role of Tripura Women in Agroforestry**

Agroforestry was recognised as a marked area in agricultural science due to the profits acquired from sustainable combinations of woody perennials and annual crops amalgamated with animal husbandry.<sup>4</sup> It is the most self-contained and sound system as it involves the growing of crops either together or in rotation maintaining the ground cover permanently. Involvement of women is essential to agricultural production and is responsible for preserving the small stock husbandry. Women are also the prime users of various forest products from fuel wood collection to the knowledge about the medicinal value. Women group are considered to be crucial in the agroforestry system. Women are playing noteworthy activities in managing the family needs by participating in various agroforestry practices. The involvement of women in conservation management shall bring profit for overall conservation of forest resources. The components which provide higher benefits must be introduced and practiced in a sustainable way. The problems and recommendations are heard and put into action for better development and to ensure better health and harmony. The versalities and compatibility of agroforestry practices has provided better welfare of the society for overall community development. Women's involvement is also fundamental for maintaining the agricultural production and other management activities. Thus, women are seen to take part in vital activities in fulfilling the family needs by engaging in various works. For women empowerment in the state, their significant contribution in agroforestry should be stimulated and motivated. The investigation of role of women in the traditional agroforestry system has become very popular as the dissimilarities are observed in the deflection of labor and management and receiving various types of products. Many had conducted a successful uncovering on the contribution of women in the success of any system from planting to final destination for self-applu or for sale.

**14. Sapam Ranjita Chanu:**



She has completed her PhD from Indian Institute of Science (IISc) Bangalore in 2013. She was Post-Doctoral Research Fellow Ulsan National Institute of Science and Technology, South Korea. She was also Post-Doctoral Research Associate at University of Strathclyde, Glasgow, United Kingdom. Her research work is based on designing of vacuum chambers for miniaturized cold atom experiments, characterisation of instruments, building different class of lasers, optics and magnetic, electro-optics etc. A young Manipuri woman physicist, Dr Sapam Ranjita Chanu, who is currently a postdoctoral fellow at the Atomic and Optics Lab, UNIST, Korea, has been awarded the prestigious Marie Curie Postdoctoral Fellowship working on precision inertial measurement with cold atom group at Paris, France instituted by the European Commission. Dr Ranjita is the daughter of Sapam Babu of Khongman Okram Chuthek, Imphal East, and the wife of Dr Tomba of Yumnam Huidrom, who is also a scientist working in South Korea. The Marie Curie Fellowship will grant her an opportunity to work in a leading laboratory in Paris for a monthly remuneration of 4500 Euros along with allowance of 600 Euros (approximately 3.62 lakh INR in total). She has worked mainly on the development of optical resonators and realisation of frequency control system of high stability. I enjoy testing and designing as well as characterisation instruments including optical, electronics etc. Image analysis from cavity and optical interferometers, laser spectroscopy. Currently she is working at Centre for Quantum Technologies, Singapore on Barium ion precision measurement and developments of the Lu ion atomic clock. Surface ion trap in Cryogenic environment for Quantum Computation.

**15. Mingkee Achom:**



She completed her B.Sc from Assam agricultural University, Jorhat, Assam. She did her M.Sc from University of Agricultural Sciences, Bangalore in Plant Biotechnology and Plant Molecular Biology. She completed her PhD in Molecular Plant Genes from University of Warwick, United Kingdom. She did one project on analysis of 3D confocal images of plant roots using Morphographx to investigate cellular patterning and generated cellular level atlases of developing roots with network analysis using Cytoscape and graph theory at University of Birmingham, United Kingdom. Currently, she is pursuing her Postdoctoral Research at Cornell University Ithaca, New York, United States.

**16. Bijyalaxmi Athokpam:**



She completed her PhD in Theoretical Chemistry from Indian Institute of Science (IISc) Bangalore. Currently she is doing her Post-doctoral research at Ecole Normale Supérieure de Paris, France.



**17. Grace Lhaineikim Chongloi:**



She did her M.Sc from Delhi University and PhD from Indian Institute of Science (IISc) Bangalore. Currently she is pursuing her Post-doctoral studies from Weizmann Institute of Science, Weizmann, Israel.

**CONCLUSION**

It is a painful commentary on traditional prejudice against women, where their identity and rights have been marginalized in every country and at every level of society. It is a story of changing status of women in the modern world. The paper is a fascinating blend of history, biography, science and gender studies. It will serve as a platform to showcase the glory of Women Scientists in North-East India. It will serve as a source of inspiration to younger generation to be more creative and innovative. Author sincerely hopes that the document will be able to initiate passion and spark for future budding scientists to transform their dreams in to reality.

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## Synthesis and Characterization of three new Schiff-base ligands

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### Abstract

Three new Schiff-base ligands (**L**<sub>1</sub>, **L**<sub>2</sub> & **L**<sub>3</sub>) were synthesized by refluxing aromatic aldehydes with aromatic primary amines in 1:1 (for **L**<sub>1</sub>), 2:1 (for **L**<sub>2</sub>) and 2:1 (for **L**<sub>3</sub>) molar ratio in ethanol solution. The synthesized ligands were characterized by FT-IR, ESI-MS, <sup>1</sup>H and <sup>13</sup>C NMR spectroscopy.

**Keywords:** Schiff-base, NMR, FT-IR, Characterization

### 1. Introduction

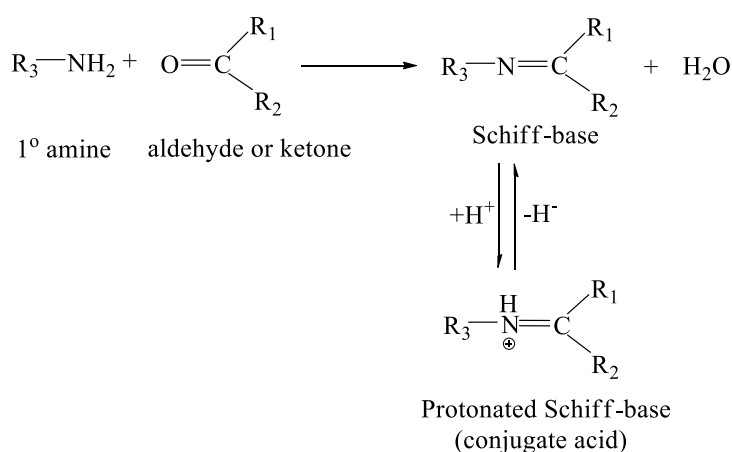
Transition metal catalysts are greatly employed in the organic synthesis and the fine chemical industry. There are numerous processes in chemical industry (with more being developed every year) that utilises organo-transition metal catalysts. Since last few decades, transition metal based homogeneous catalysis has been playing a prominent role in pharmaceutical industry.<sup>[1]</sup> These catalysts also captured an important part in the field of applied chemistry like dye synthesis, polymers etc.<sup>[2-5]</sup> Intense development of this field is due to several evident advantages of these catalysts. They are characterized by high catalytic activity, capability of reacting with only specific substrates (specificity) and in a specific position (selectivity). Application of transition metal based catalysts in industrial processes has increased significantly over the years. These include classical processes such as polymerization on the Ziegler catalysts, olefin oxidation by molecular oxygen to aldehydes, hydroformylation of saturated compounds, preparation of acetic acid from methanol and carbon monoxide by Monsanto's process, synthesis of adiponitrile from butadiene and others. Transition metal based complexes catalyses several reactions, which were previously unknown in chemistry, viz., reduction of molecular nitrogen to hydrazine and ammonia, alkane oxidation and activation, water photodecomposition, etc.

Among various elements, first row transition metals find extensive applications in many organic reactions. For instance, manganese organometallic complexes are able to catalyze a broad diversity of organic transformations leading to the selective formation of one or several carbon-carbon and/or carbon-heteroatom bonds. To date, it appears that only two reactions, namely the hetero-coupling of Grignard reagents and the [2+2+2] cycloaddition of esters with terminal alkynes, are strictly specific to manganese. Mn-catalyzed reactions, namely cross-coupling processes involving Grignard reagents, direct C-H bond activation, alkene epoxidation, hydrosilylation of ketones and electrochemical CO<sub>2</sub> reduction provide a synthetic access to highly valuable organic products.<sup>[6]</sup> Similarly, significant progress has been made in Ni-catalyzed cross coupling of non-activated alkyl halides.<sup>[7]</sup> An efficient catalytic method employing macrocyclic Ni(II) compounds has been developed for the reduction of pralidoxime to its amine derivative.<sup>[8]</sup> Furthermore, iron,<sup>[9]</sup> copper,<sup>[10]</sup> vanadium<sup>[11]</sup> based catalysts are used in organic synthesis for oxidation of alcohols to the corresponding carbonyl compounds. Copper is also a very cost-effective metal for catalyzing cross coupling reaction between alkyl or aryl halides and aryl boronic acids<sup>[12]</sup> and also for partial oxidation of alkanes.<sup>[13]</sup> A dinuclear Fe(II) complex bearing multidentate pyridinyl ligand has been used for hydroxylation of aromatic compounds.<sup>[14]</sup> In a notable advance, PNP-ligated Fe(II) hydride complexes were found to catalyze dehydrogenation and hydrogenation, respectively, of isoquinoline-, indole-, and pyridine-based substrates.<sup>[15]</sup>

Ligand effects are extremely important in homogeneous transition-metal based catalysts. By changing the ligand around metal, one metal can show variety of applications for different catalytic reactions. In ligand accelerated catalysis, the addition of a ligand increases the reaction rate of the chemical transformation. It is known that in transition metal based homogeneous catalysis, the characteristics of the ligand attached to the metal mainly influences the activity of a catalytic system, and so an appropriate ligand selection is crucial for the overall performance of a catalyst. Indeed, there are many processes that do not work at all unless the correct

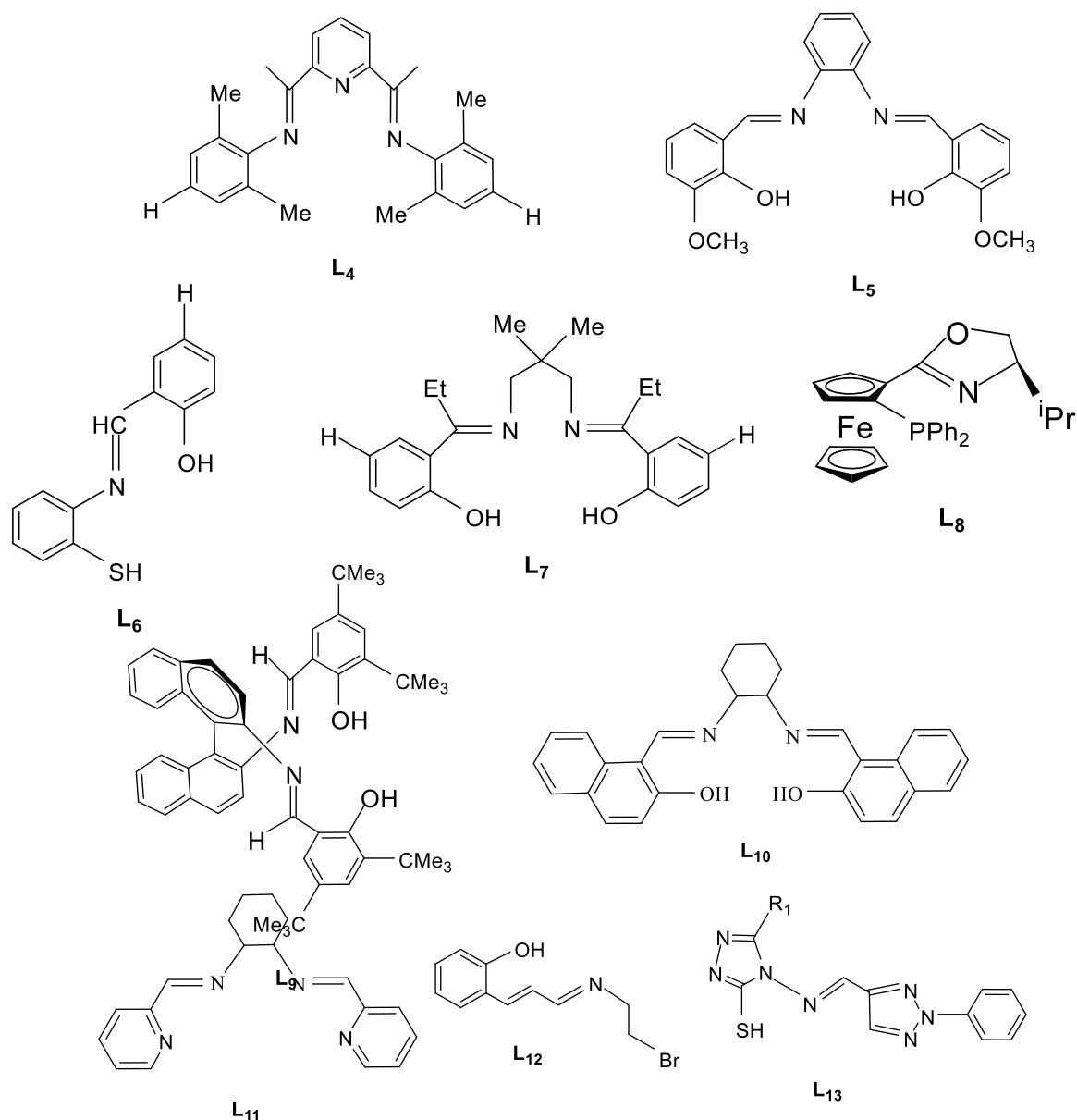
choice of ligand is made. Theoretical studies suggest that the steric and electronic characteristics of ligands are both important for catalysis. The development of selective chemical processes generally requires modifying ligands on the transition metal centre. Although P, N, O, S, Se, C and Te ligands are all known, by far the most important class in catalysis are phosphorus based ligands. For many years, phosphine-based ligands were the preferred class of ligands for various catalytic reactions. The main advantage of using phosphines as ligands is that their steric and electronic properties can be tuned easily by manipulating the functional groups attached to the phosphorus atom. These ligands have a unique ability to stabilise metals in several oxidation states and geometries and, more importantly, they can be tuned to radically change the reactivity of a catalyst. Simple changes to the structure of a phosphorus ligand can completely alter the product distribution, activity, regiochemistry or enantioselectivity of a transition metal catalysed reaction. Among various ligands, the most preferred classes of ligands are the phosphine based ligands, as their properties can be easily tuned by simply changing the functional group attached to the phosphorus atom. Despite considerable success, the major drawbacks associated with phosphine based ligands are their handling problems, synthetic difficulties, high costs, inherent toxicity, air and moisture sensitivity, etc. In this respect, nitrogen-based ligands are generally advantageous as they are easy-to-handle, less expensive than their phosphine counterparts, usually stable to air/moisture, etc. As a result, a plethora of nitrogen-based ligands such as amines,<sup>[16]</sup> N-heterocyclic carbenes (NHC),<sup>[17-18]</sup> oximes<sup>[19]</sup> and others<sup>[20-21]</sup> have been tested as a possible alternative to phosphines in various catalytic reactions. Among the phosphine-free ligands, Schiff-base ligands have received particular attention, mainly because of their simple synthesis, higher stability, air and moisture insensible property. Hence, these ligands are synthesized and characterized.

Hugo Schiff reported the condensation between an aldehyde and an amine leading to a Schiff-base in 1864.<sup>[22]</sup> Schiff-bases are synthesised when any primary amine reacts with an aldehyde or a ketone under specific conditions (**Scheme 1**). Structurally, a Schiff-base is a nitrogen analogue of an aldehyde or ketone in which the carbonyl group (CO) has been replaced by an imine or azomethine group. The resultant imines ( $R_1HC=N-R_2$ ) participate in binding with metal centres via nitrogen lone pair electrons. Like aldehydes, the ketones are also able to form Schiff-base ligands ( $R_1R_2C=N-R_3$ ), although Schiff-bases with ketones are formed less readily than with aldehydes. The mono-, di-, tri- and multi-dentate chelating Schiff-base ligands are designed according to the binding environments of metal atoms. Schiff-bases display a borderline character between hard and soft Lewis bases, and also exhibit stability under various diverse conditions.<sup>[23]</sup> In coordination chemistry, the role of Schiff-bases as ligands is highly remarkable and widespread.<sup>[24]</sup> The metal complexes with Schiff-bases as ligands have been playing an important part in the development of coordination chemistry due to their preparative accessibility, structural diversity and variability. Schiff-bases containing polyfunctional groups have not only produced stable metal complexes of transition, non-transition, inner-transition and actinide metals, but these ligands and their metal complexes have also played a significant role in the domains of model systems of biochemical interest, analytical chemistry, catalysis, polymers.<sup>[25]</sup> Over the past few years, there have been many reports on their applications in biology including anti-bacterial,<sup>[26]</sup> anti-fungal,<sup>[27]</sup> anti-cancer,<sup>[28]</sup> anti-oxidant,<sup>[29]</sup> anti-inflammatory,<sup>[30]</sup> anti-malarial<sup>[31]</sup> and anti-viral activity.<sup>[32]</sup> The development in the field of bio-inorganic chemistry has increased the interest in schiff-base complexes, since it has been recognized that many of these complexes may serve as models for biologically important species. Schiff-base ligands are able to coordinate metals through imine nitrogen and are able to stabilize many different metals in various oxidation states, controlling the performance of metals in a large variety of useful catalytic transformations. Many Schiff-base complexes of metal ions show high catalytic activity and played a significant role in various organic reactions to enhance their yield and product selectivity. The convenient route of synthesis and thermal stability of Schiff-base ligands have contributed significantly for their possible applications in catalysis.<sup>[33]</sup> Schiff-base complexes of transition metal ions are efficient catalysts both in homogeneous and heterogeneous reactions at high temperature ( $>100^\circ\text{C}$ ) and in the presence of moisture.<sup>[33]</sup>



**Scheme 1:** General scheme for formation of Schiff-bases

Souane *et al.*<sup>[34]</sup> reported iron(III) and cobalt(II) complexes with pyridine bis(imine) ligand **L**<sub>4</sub> showed significant activity in the polymerization of ethylene. These complexes were also used successfully for copolymerization of ethylene with 1-hexene. The iron(III) Schiff-base complex showed higher yield and activity than the cobalt(II) complex. Lin Che *et al.*<sup>[35]</sup> synthesized and structurally characterized a series of Mn(III) and Co(II) complexes with symmetric tetradentate Schiff-base ligand bis(3-methoxysalicylidene)-*o*-phenylenediamine (**L**<sub>5</sub>). The result showed that complexes have a good catalytic activity for the reduction of thionyl chloride, which improves the cell voltage, the rate of discharge, and the lifetime of Li/SOCl<sub>2</sub> batteries. Tamizh *et al.*<sup>[36]</sup> very recently synthesized new ruthenium(II) complexes of composition [RuL<sub>6</sub>(CO)(PPh<sub>3</sub>)<sub>2</sub>] with dianionic ONS donor Schiff-base ligand (**L**<sub>6</sub>). This complex was found to be effective catalyst for the oxidation of alcohol at room temperature using N-Methylmorpholine-N-Oxide (NMO) as oxidant. Maurya *et al.*<sup>[37]</sup> reported a copper (II) Schiff-base complex encapsulated in zeolite-Y as an active catalyst for the oxidation of phenol, styrene and methyl phenyl sulfide using H<sub>2</sub>O<sub>2</sub> as oxidant. Heshmatpour *et al.*<sup>[38]</sup> reported two mononuclear copper (II) complexes by the reaction of two ONNO type Schiff-base ligand, [bis(2-hydroxypropionophenone)2,2'-dimethylpropanediamine] (**L**<sub>7</sub>) with Cu(OAc)<sub>2</sub>·H<sub>2</sub>O in 1:1 M ratios. The selective oxidation of styrene to benzaldehyde was carried out with Cu(II) Schiff-base (**L**<sub>7</sub>) complex as catalyst using *tert*-butylhydroperoxide with 100% conversion. Nishibayashi *et al.*<sup>[39]</sup> reported Schiff-base (**L**<sub>8</sub>) complex of Ru metal as efficient catalyst in carrying out asymmetric reduction of dialkyl ketones to alcohols. Evans *et al.*<sup>[40]</sup> reported Al(III) complex with diaminobinaphthyl derived Schiff-base ligand (**L**<sub>9</sub>) and screened as catalyst for reaction between 5-methoxyoxazoles and benzaldehydes to produce optically active *cis*-oxazoline adducts. Lu *et al.*<sup>[41]</sup> synthesized a Schiff-base complex by the condensation of 1,2-diaminocyclohexane with N,N'-bis(2-hydroxy-1-naphthalidene) cyclohexanediamine (**L**<sub>10</sub>) and pyridinecarboxaldehyde (**L**<sub>11</sub>), and, followed by the metallation with manganese, cobalt, copper and iron salts. Mn complex resulting from **L**<sub>10</sub> ligand was considerably active for the catalytic epoxidation of styrene under mild conditions, in which the highest yield of styrene oxide reached 91.2 mol%. Grivani *et al.*<sup>[42]</sup> recently synthesized a Schiff-base ligand N-salicylidin-2-bromoethylimine (**L**<sub>12</sub>) derived Vanadium(IV) complex, which was tested as catalyst for epoxidation of alkenes. Various alkenes can be converted efficiently and selectively to their corresponding epoxides in the presence of catalytic amount of vanadyl Schiff-base complex. Yang *et al.*<sup>[43]</sup> reported Schiff-base (**L**<sub>13</sub>) derived Cu(II) complex to be an effective catalyst for the condensation reaction of indole with aldehydes using ethanol as the solvent. The products were obtained in high yields (up to 98%).



**Fig. 1:** Structures of some Schiff-base ligands

## 2. Experimental

### 2.1. Materials and methods

Benzaldehyde, Salicylaldehyde, 4-Hydroxybenzaldehyde, 4-Chloro-*o*-phenylenediamine, 3-Nitroaniline and 3,4-Diaminoacetophenone were procured from Sigma-Aldrich and Merck. The solvents of analytical grade were procured from Spectrochem and distilled previous to use. The Elemental (CHN) analyses were carried out using Perkin Elmer 2400 series II analyser. The IR spectra (4000-400 cm<sup>-1</sup>) were recorded in KBr pellet by using Shimadzu (Prestige-21) spectrophotometer. The <sup>1</sup>H and <sup>13</sup>C NMR spectra were recorded on a Bruker Avance II 400 MHz spectrometer.

### 2.2. Synthesis of Ligand L<sub>1</sub>

A solution of the benzaldehyde (0.15 g, 1.41 mmol) in 20 mL ethanol was added drop wise to a solution of 3-nitroaniline (0.19 g, 1.41 mmol) in 20 mL ethanol. The reaction mixture was heated at 70°C for 13 h. The solvent

was then evaporated under reduced pressure to get a solid mass which was then washed with hexane. Finally, the ligand was obtained as brown solid which was recrystallized from dichloromethane. Yield: 88%; Anal. Calcd. For  $C_{13}H_{10}N_2O_2$ : C: 69.01; H: 4.45; N: 12.38 %. Found: C, 68.8; H, 4.41; N, 12.32 %. MS-ESI (MeOH):  $m/z$ : 227  $[M+H]^+$ ; 152  $[M-Ph+2H]^+$  FT-IR ( $cm^{-1}$ , KBr): 1609 ( $\nu_{C=N}$ : imine);  $^1H$  NMR (400 MHz,  $CDCl_3$ )  $\delta/ppm$ : 8.76 (s, 1H, CH=N), 8.01 (d,  $J = 6.8$  Hz, 2H, Ph), 8.13 (d,  $J = 6.8$  Hz, 2H, Ph), 7.74 (d,  $J = 7.2$  Hz, 1H, Ph), 6.97 (d,  $J = 7.6$  Hz, 1H, Ph), 7.60 (dd,  $J = 7.6$  Hz, 1H, Ph);  $^{13}C$  NMR (100.62 MHz,  $CDCl_3$ )  $\delta/ppm$ : 163.56 (CH=N), 119.06-132.05 (Ph).

### 2.3. Synthesis of Ligand $L_2$

A solution of the 4-hydroxybenzaldehyde (0.256 g, 2.10 mmol) in 20 mL ethanol was added drop wise to a solution of 4-Chloro-*o*-phenylenediamine (0.15 g, 1.05 mmol) in 20 mL ethanol. The reaction mixture was heated at 70°C for 16 h. The solvent was then evaporated under reduced pressure to get a solid mass which was then washed with hexane. Finally, the ligand was obtained as brown solid which was recrystallized from dichloromethane. Yield: 83%; Anal. Calcd. For  $C_{20}H_{16}N_2O_2Cl$ : C: 64.92; H: 5.69; N: 20.64 %. Found: C, 64.90; H, 5.65; N, 20.61 %. MS-ESI (MeOH):  $m/z$ : 351  $[M-H]^+$ ; 389  $[M-2H+K]^+$ ; 317  $[M-Cl+H]^+$ . FT-IR ( $cm^{-1}$ , KBr): 1614 ( $\nu_{C=N}$ : imine);  $^1H$  NMR (400 MHz,  $CDCl_3$ )  $\delta/ppm$ : 12.75 (s, 2H, OH), 9.41 (s, 2H, CH=N), 8.02 (d,  $J = 8.4$  Hz, 4H, Ph), 7.78 (d,  $J = 8.4$  Hz, 4H, Ph), 6.95 (d,  $J = 8.4$  Hz, 1H, Ph), 6.84 (d,  $J = 8.4$  Hz, 1H, Ph).  $^{13}C$  NMR (100.62 MHz,  $CDCl_3$ )  $\delta/ppm$ : 163.28 (CH=N), 120.57-159.42 (Ph).

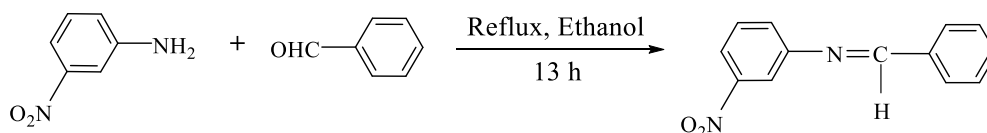
### 2.4. Synthesis of Ligand $L_3$

A solution of the 4-Chloro-*o*-phenylenediamine (0.15 g, 1.05 mmol) in 20 mL ethanol was added drop wise to a solution of 3,4-diamino acetophenone (0.315 g, 2.10 mmol) in 20 mL ethanol. The reaction mixture was heated at 70°C for 17 h. The solvent was then evaporated under reduced pressure to get a solid mass which was then washed with hexane. Finally, the ligand was obtained as brown solid which was recrystallized from dichloromethane. Yield: 81%; Anal. Calcd. For  $C_{22}H_{23}N_6Cl$ : C: 64.92; H: 5.69; N: 20.64 %. Found: C, 64.88; H, 5.66; N, 20.61 %. MS-ESI (MeOH):  $m/z$ : 407  $[M]^+$ ; 431  $[M+H+Na]^+$ . FT-IR ( $cm^{-1}$ , KBr): 1614 ( $\nu_{C=N}$ : imine);  $^1H$  NMR (400 MHz,  $CDCl_3$ )  $\delta/ppm$ : 8.5 (s, 2H, CH=N), 5.49 (s, 8H,  $NH_2$ ), 7.84 (d,  $J = 8.8$  Hz, 2H, Ph), 6.94 (d,  $J = 8$  Hz, 2H, Ph), 6.42 (d,  $J = 4$  Hz, 1H, Ph), 6.58 (dd,  $J = 8.4$  Hz, 1H, Ph), 7.52 (t, 7.2 Hz, 1H, Ph), 7.609 (t, 7.2 Hz, 1H, Ph), ( $^{13}C$  NMR (100.62 MHz,  $CDCl_3$ )  $\delta/ppm$ : 121.25-141.39 (Ph), 193.97 (CH=N).

## 3. Results and discussion

### 3.1. Characterization of ligand $L_1$

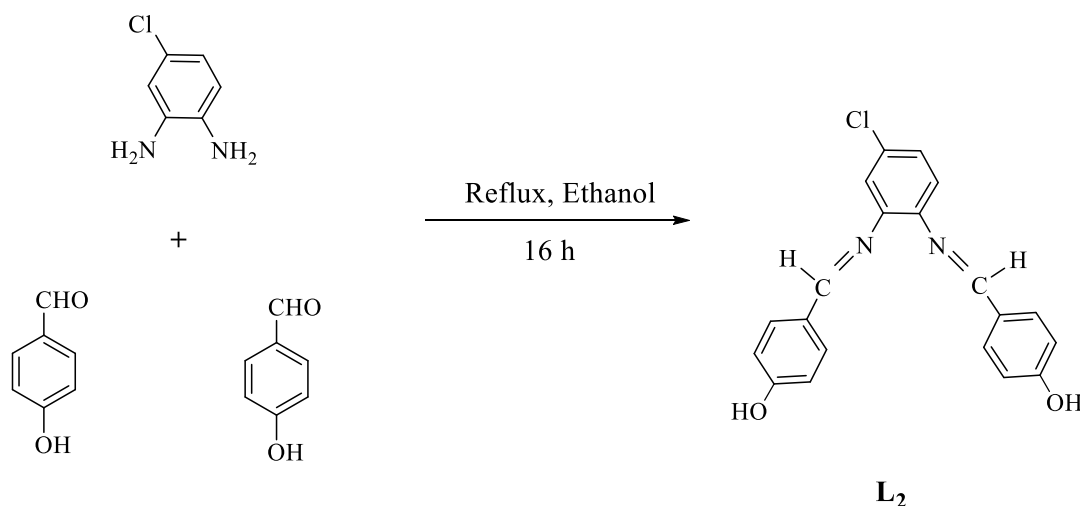
The ligand  $L_1$  was prepared by treating benzaldehyde with 3-nitroaniline in 1:1 molar ratio (**Scheme 1**). The compound was isolated as brown solid which is stable to air both in solid state and in solution. The identity of the compounds was fully established by elemental analyses, ESI-mass, FT-IR,  $^1H$  and  $^{13}C$  NMR spectroscopy. The elemental analyses values and the appearance of molecular ion peak in the ESI-mass spectra (**Fig. 2**) of ligand supports its proposed composition. In the FT-IR spectra, the  $\nu_{C=N}$  stretching band appeared at 1609  $cm^{-1}$  respectively indicating the formation of CH=N bond. In the  $^1H$  NMR spectrum (**Fig. 3**), signal due to imine proton appeared as singlet at  $\delta$  8.76 ppm, indicating the presence of imine bond. In the  $^{13}C$ -NMR spectra (**Fig. 4**), a sharp peak at 163.56 ppm was observed, which corroborates the presence of imine bond.



**Scheme 1.** Synthesis of Schiff-base ligand  $L_1$ .

### 3.2. Characterization of ligand $L_2$

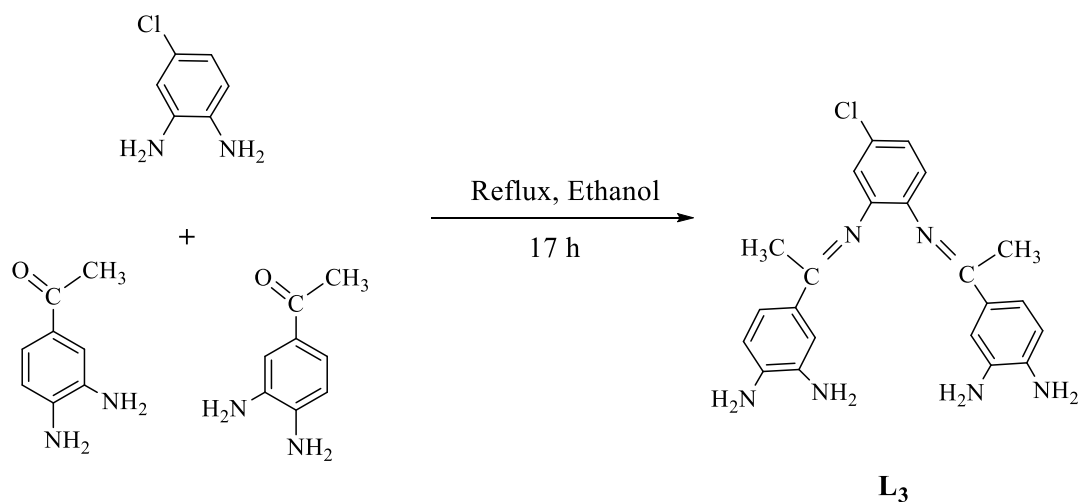
The ligand  $L_2$  was prepared by treating 4-hydroxybenzaldehyde with 4-Chloro-*o*-phenylenediamine in 2:1 molar ratio (**Scheme 2**). The compound was isolated as brown solid which is stable to air both in solid state and in solution. The identity of the compounds was fully established by elemental analyses, ESI-mass, FT-IR,  $^1\text{H}$  and  $^{13}\text{C}$  NMR spectroscopy. The elemental analyses values and the appearance of molecular ion peak in the ESI-mass spectra of ligand supports its proposed composition. In the FT-IR spectra, the  $\nu_{\text{C=N}}$  stretching band appeared at  $1614\text{ cm}^{-1}$  respectively indicating the formation of  $\text{CH=N}$  bond. In the  $^1\text{H}$  NMR spectrum (**Fig. 5**), signal due to imine proton appeared as singlet at  $\delta$  9.41 ppm, indicating the presence of imine bond. Furthermore, a peak at 12.75 ppm confirms the presence of OH groups in the compound. In the  $^{13}\text{C}$ -NMR spectra (**Fig. 6**), a sharp peak at 163.28 ppm was observed, which corroborates the presence of imine bond. The appearance of molecular ion peak in the ESI-mass spectra (**Fig. 7**) of ligand supports its proposed composition.



**Scheme 2.** Synthesis of Schiff-base ligand  $L_2$ .

### 3.3. Characterization of ligand $L_3$

The ligand  $L_3$  was prepared by treating 3,4-diamino acetophenone with 4-Chloro-*o*-phenylenediamine in 2:1 molar ratio (**Scheme 3**). The compound was isolated as brown solid which is stable to air both in solid state and in solution. The identity of the compounds was fully established by elemental analyses, ESI-mass, FT-IR,  $^1\text{H}$  and  $^{13}\text{C}$  NMR spectroscopy. The elemental analyses values and the appearance of molecular ion peak in the ESI-mass spectra of ligand supports its proposed composition. In the FT-IR spectra, the  $\nu_{\text{C=N}}$  stretching band appeared at  $1614\text{ cm}^{-1}$  respectively indicating the formation of  $\text{CH=N}$  bond. In the  $^1\text{H}$  NMR spectrum (**Fig. 8**), signal due to imine proton appeared as singlet at  $\delta$  8.5 ppm, indicating the presence of imine bond. In the  $^{13}\text{C}$ -NMR spectra (**Fig. 9**), a sharp peak at 193.97 ppm was observed, which corroborates the presence of imine bond. The appearance of molecular ion peak in the ESI-mass spectra (**Fig. 10**) of ligand supports its proposed composition



Scheme 3. Synthesis of Schiff-base ligand  $L_3$ .

WATERS, Q-TOF MICROMASS (ESI-MS)

BIPLAB LIG-01 16 (0.297) Cm (14:20)

SAIF/CIL,PANJAB UNIVERSITY,CHANDIGARH

TOF MS ES+  
1.29e4

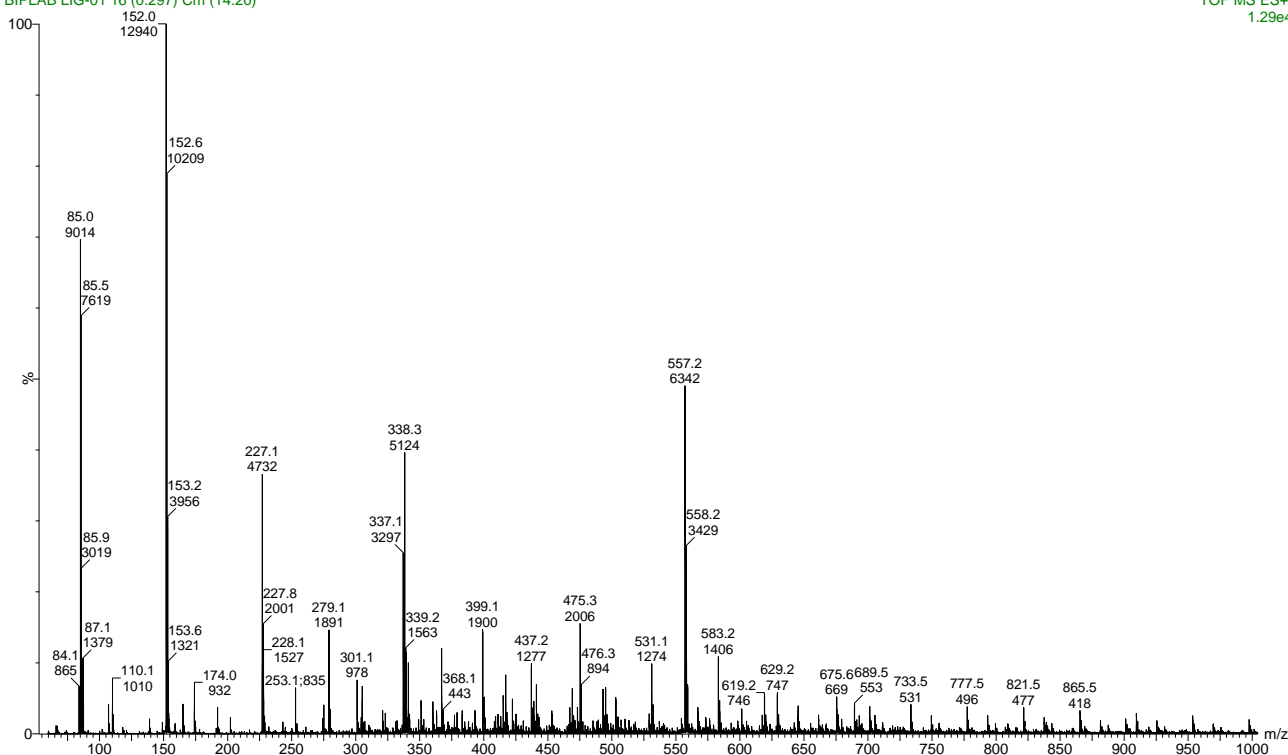
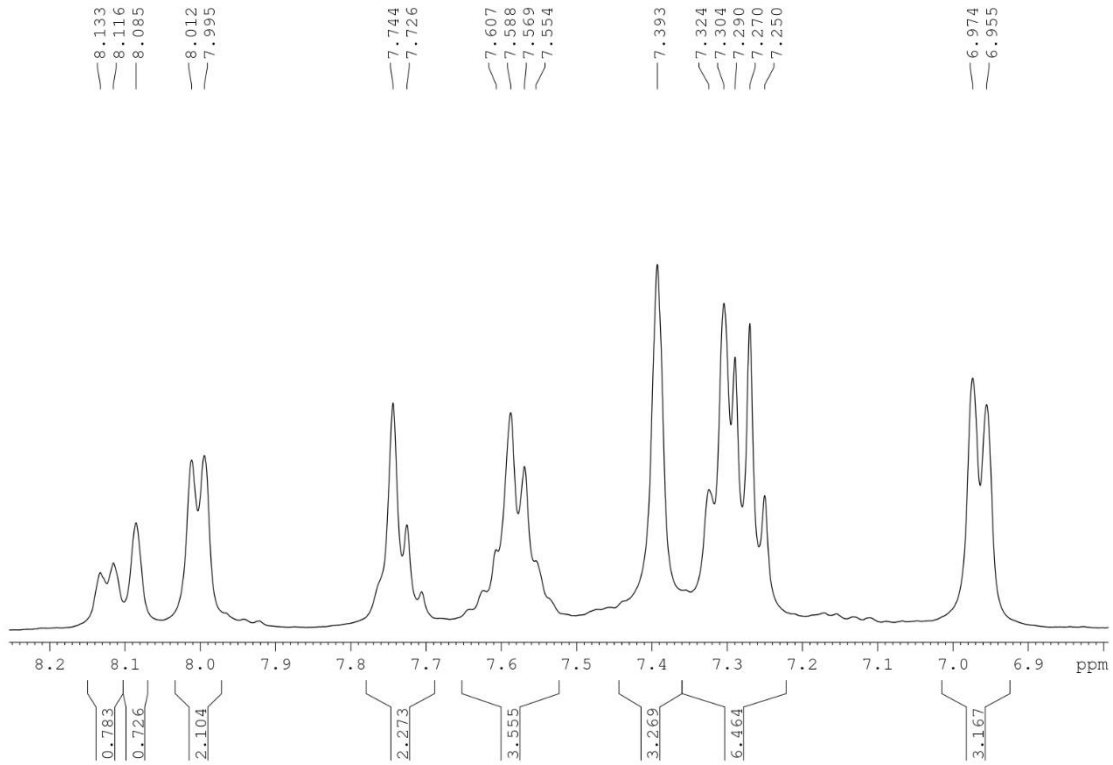


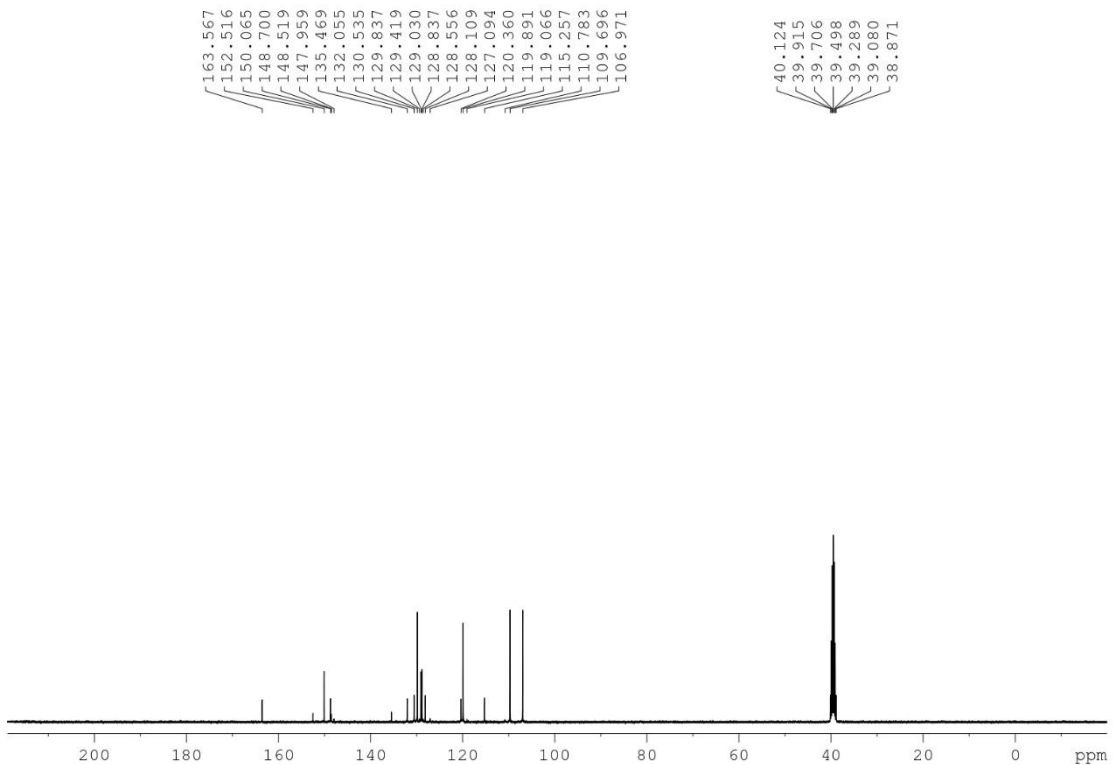
Fig.2 : ESI-MS spectrum of  $L_1$



LIG-01



LIG-01



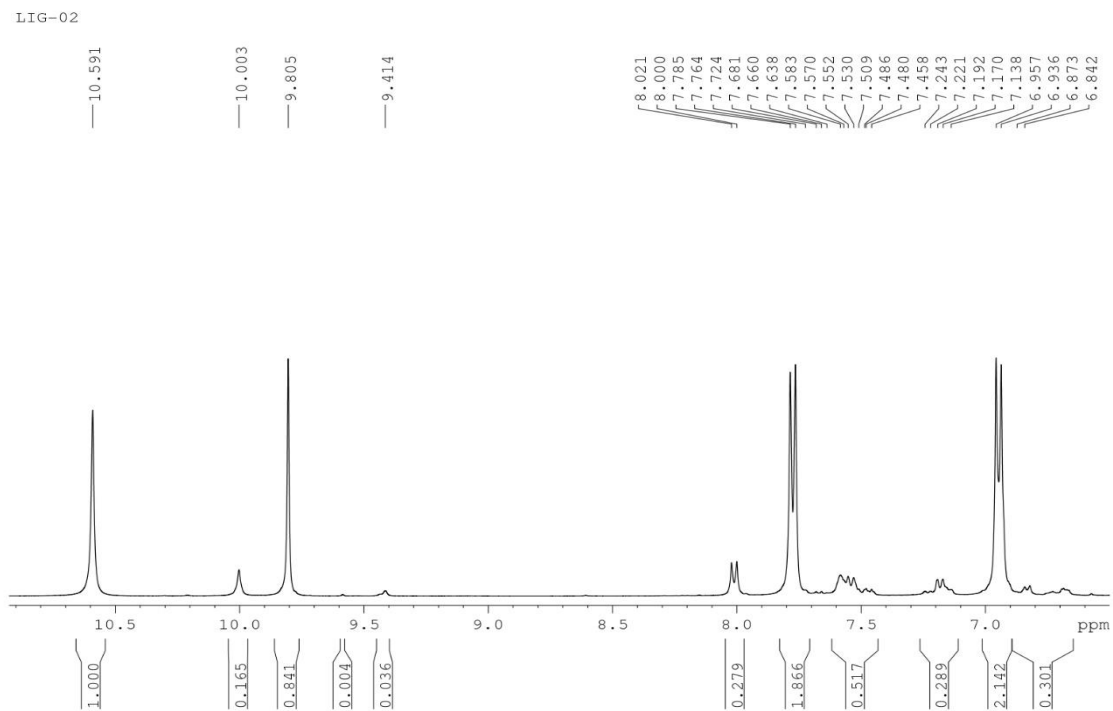


Fig.5 :  $^1\text{H}$  NMR spectrum of  $\text{L}_2$

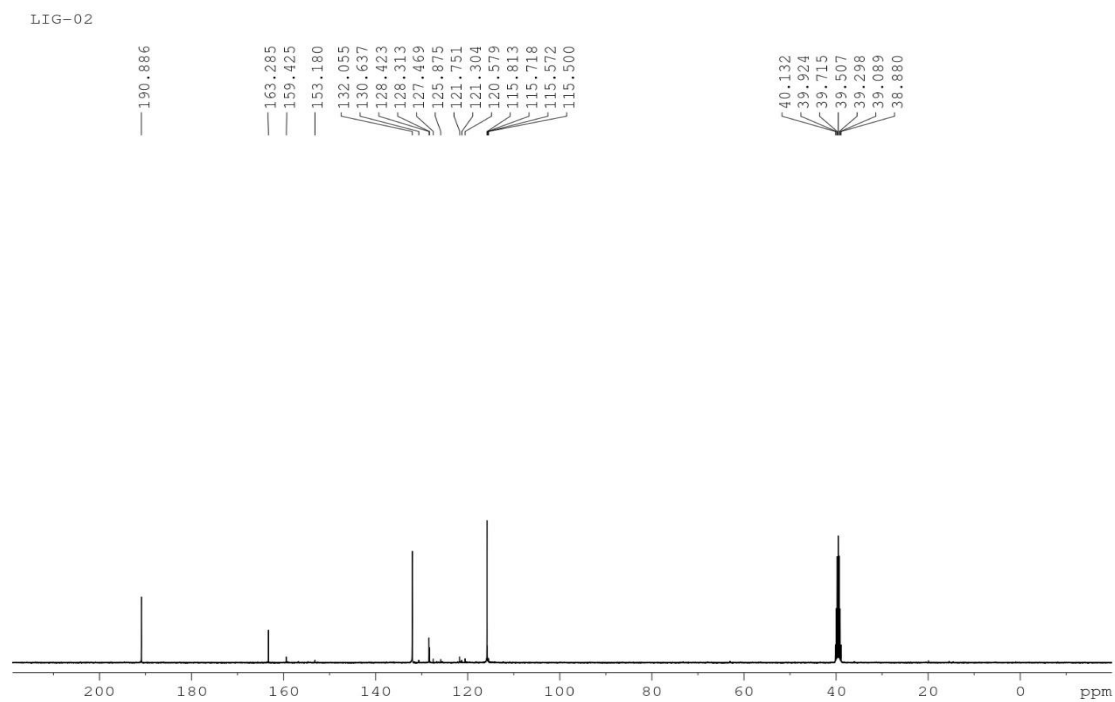


Fig.6 :  $^{13}\text{C}$  NMR spectrum of  $\text{L}_2$

WATERS, Q-TOF MICROMASS (ESI-MS)  
 BIPLAB LIG-02 16 (0.297) Cm (11:27-39:55)

SAIF/CIL,PANJAB UNIVERSITY,CHANDIGARH  
 TOF MS ES+  
 3.13e4

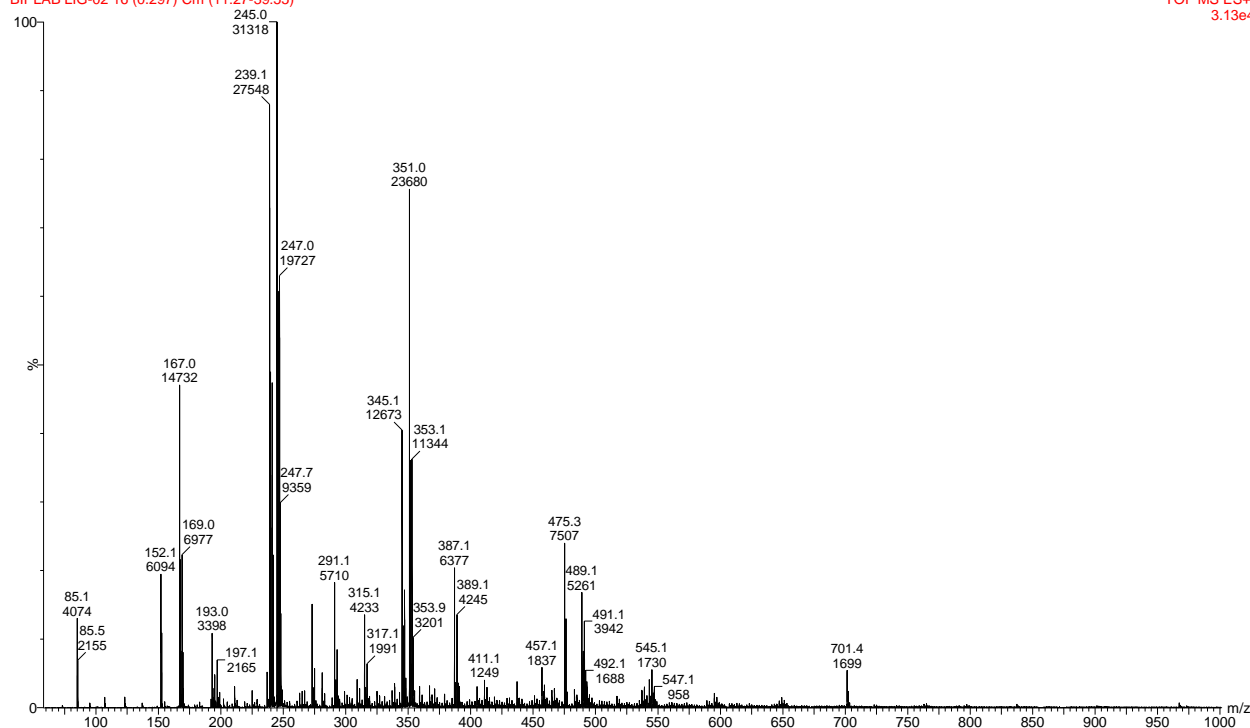


Fig.7 : ESI-MS spectrum of L<sub>2</sub>

LIG-04

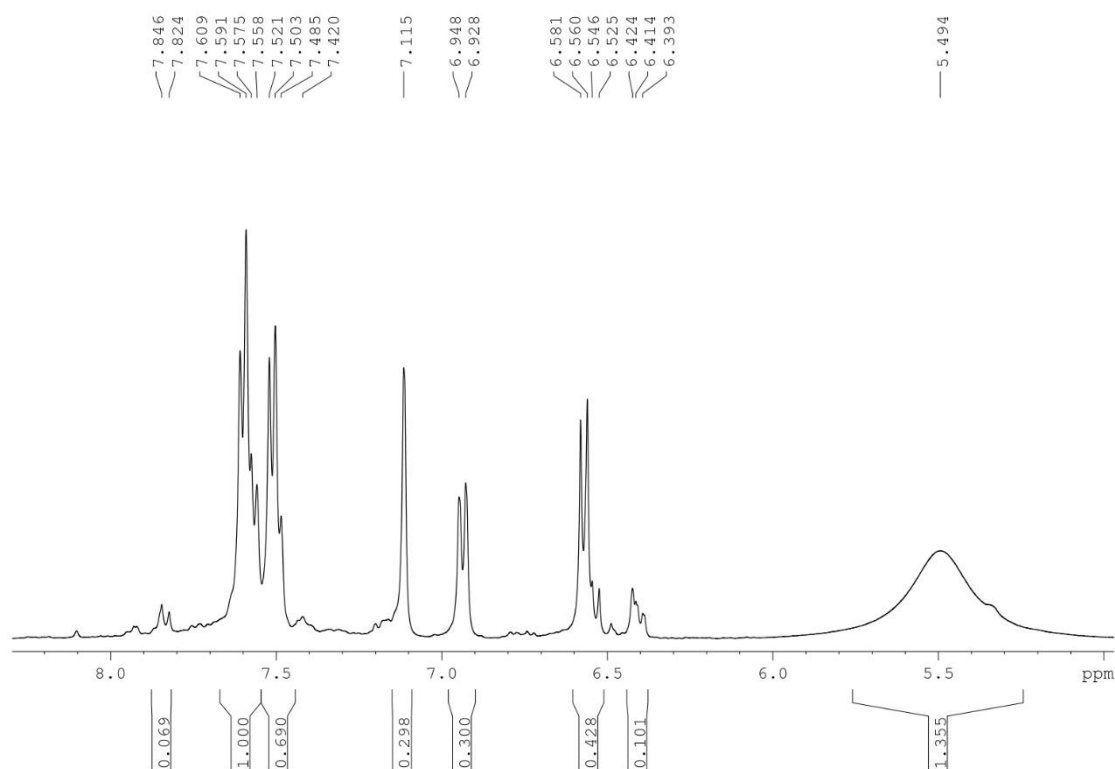
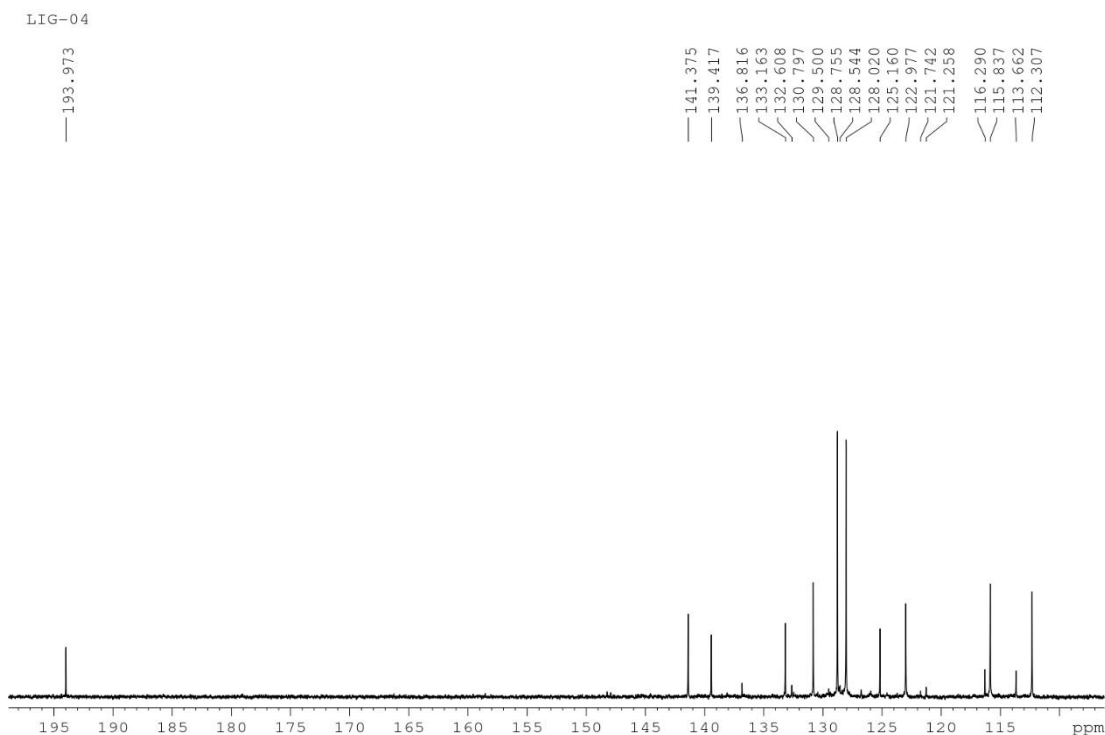


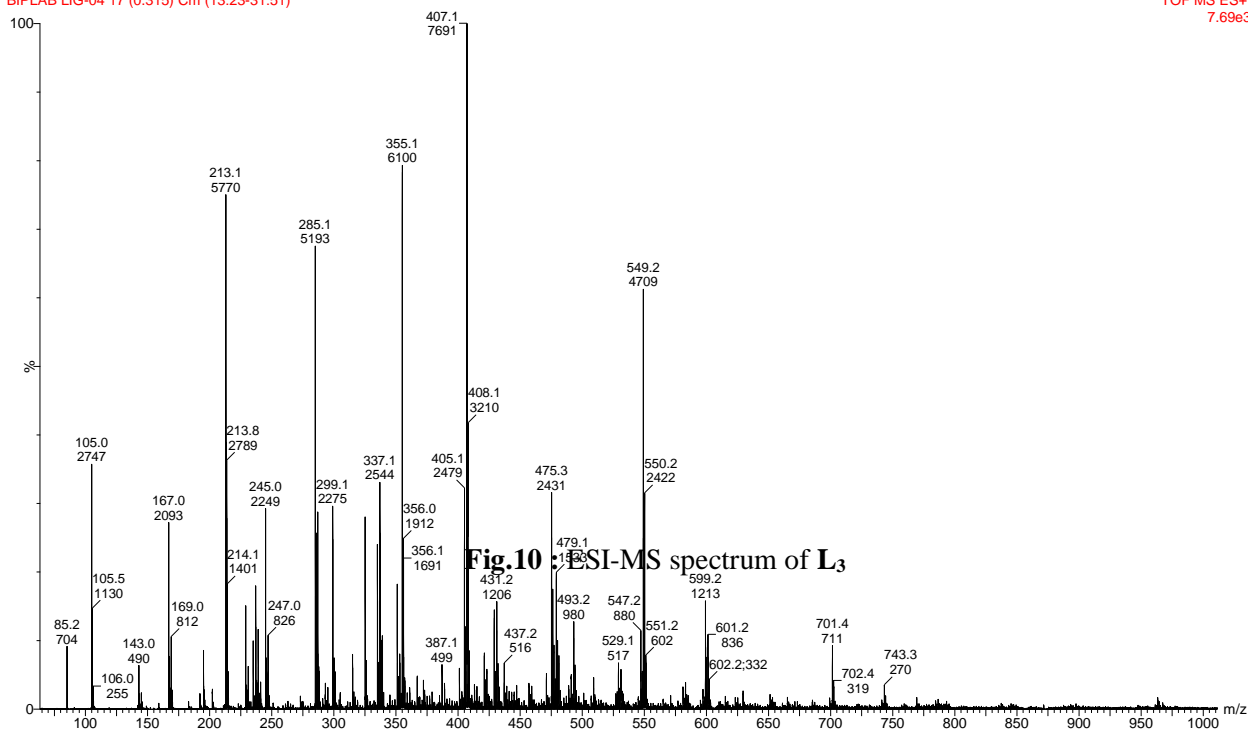
Fig.8 : <sup>1</sup>H NMR spectrum of L<sub>3</sub>



**Fig.9 :**  $^{13}\text{C}$  NMR spectrum of  $\text{L}_3$

WATERS, Q-TOF MICROMASS (ESI-MS)  
 BIPLAB LIG-04 17 (0.315) Cm (13:23-31:51)

SAIF/CIL, PANJAB UNIVERSITY, CHANDIGARH  
 TOF MS ES+  
 7.69e3



**Fig.10 :** ESI-MS spectrum of  $\text{L}_3$

**Conclusion:**

Three new Schiff-base ligands were synthesized by refluxing variety of aromatic aldehydes with aromatic primary amines. The synthesized ligands were characterized by FT-IR, ESI-MS, <sup>1</sup>H and <sup>13</sup>C NMR spectroscopy.

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