**TOXICITY OF HEAVY METALS IN SOME MEDICINAL PLANTS**

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**JIGE SANDIPAN BABASAHEB [Assistant Professor & Head Department of Botany]**

**Sant Ramdas College Ghansawangi Dist- Jalna (Maharashtra) - 431209 India.**

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**Abstract-**

The heavy metals are elements which occur naturally and found in the soil and water. These metals are important for the biological process but also toxic for the human when occur in more amount. In the metals trace level of copper, iron, manganese, zinc and nickel are important for the plant for their different activity. The metals like aluminum, arsenic, lead, cadmium and mercury are not essential for human activity it causes toxicity. According to World health organization (WHO) in the world share of the herbal medicines reach up to 60%. The medicinal plants which has used for their therapeutic properties may be accumulate heavy metals from the soil. The accumulation of this heavy metal poses significant risk to the human health when these plants consumed as herbal remedies or dietary supplements. The long term exposure to heavy metals like arsenic, cadmium, leads and mercury it causes serious health problems like cancer, kidney damage, neurological damage and developmental disorders. In the modern period the plants grows under technogenic pressure for medicinal purpose, the material harvested such condition sources of different toxicant enter human body. In the toxicant primarily heavy metals, pesticides, nitrates and some other xenobiotics which damage human health. In the environment common heavy metals are mercury, lead and cadmium, its major sources are vehicles, industrial and thermal power plants, agriculture production and waste incinerates. According to the state pharmacopoeia of Russian federation the lead present in the medicinal plants are not exceed than 6.0 mg/kg, the cadmium is 1.0 mg/kg, arsenic 0.5 mg/kg and mercury 0.1 mg/kg. In the Indian medicinal plants like Terminilia chebula, Terminilia belerica, Adhatoda vascia, Acorus calamus, Phyllanthus emblica, Ocimum sanctum, Asparagus, Piper longum, Withania sominifera, Tinospora cardfolia and Tribulus terrestris. The heavy metals like mercury, nickel, zinc, chromium, iron, copper and lead like heavy metals are presents in these medicinal plants. These plants used as medicinal purposes Terminilia chebula plants seed is used as laxative, Terminilia belerica plants seed is used as laxative and anti-pyretic, Phyllanthus emblica plants fruit is used as digestive and revitalize, Piper longum plants fruit is use as digestive and bronchitis, Adhatoda vascia plants leaves are used expectorant and asthmatic, Withania sominifera plants roots are used as nerve tonic and Ocimum sanctum plant used in cough and fever.

**Keywords- Heavy Metal, Pesticides, Remedies, Laxative and Thermal Power etc.**

**Introduction-**

India has a rich and unique collection of flora, with an estimated 45,000 plant species, among which are numerous species of medicinal plants spread over many different geographical and climatic zones. Chemical compounds obtained from plant source are termed as secondary plant products. Alkaloids and glycosides are the two major compounds present. In 4000 plant species, more than 3000 alkaloids have been identified. The difference between a toxic and medicinal effect of many alkaloids depends upon the dosage (Alphonse V. A. 2020). When a sugar molecule gets attached to component which is active, it is called as glycoside which is categorized by the nature of the active component. Today man has known 4,50,000 species of plants about 2000 species come under 60 plant families has conations essential oils. Over 7,000 species of differently ecosystem occurred used as medicine in our country. Our earth consist of 250,000 plants species with more than 80,000 species having shown some medical properties and about 5,000 plant species have been specific in therapeutic use. India is the richest medicinal plants source in the world. About 2,000 species have been identified with high potential medicinal value. The earliest historical records of herbs are found from the Sumerian civilization, where hundreds of medicinal plants including opium are listed on clay tablets. The World Health Organization reveals that a huge number of the rural area population still relies on traditional treatment of herbal plants for their physical and psychological treatment needs. The World Health Organization (WHO) has listed 21,000 plants, which are used for medicinal purposes around the world. Among these 2500 species are in India, out of which 150 species are used commercially on a fairly large scale. India is the largest producer of medicinal herbs and is called as botanical garden of the world.

The important heavy metal becomes crucial elements which require extremely in low quantities for proper development. The heavy metal cause’s pollution is androgenic activities like agricultural production, resource extraction, and industrial activity, excessive use of agrichemicals, inadequate garbage management process and construction. The heavy metal enters into environment by these activities and accumulates by the living systems. The heavy metal is toxic in nature causes different chronic illness like cardiac instability, sensor motor behavior issues, psychological disorder, weakened immunity and neonatal disorder. The heavy metal like mercury, lead, arsenic and cadmium not necessary for human and plants, it causes health complication related with brain, liver, heart, lungs, kidney and nervous system. It also creates hypertension, abdominal pain, rashes, intestinal ulcer and different cancer symptoms. The heavy metal like copper is useful in many enzymatic reaction, but consume excess amount leads internal organ injury also induce skin infection, lung tissue infection, abdominal discomfort, vomiting, nausea and diarrhea. The medicinal plants are source of heavy metals so they are toxic to animals and human. In the human toxicity heavy metals like lead, mercury, cadmium and arsenic although cobalt and aluminum causes toxicity. In the world major medicinal plants harvested and used for medicine without checking its toxicity of the heavy metals so it produces side effect to human health. The medicinal plants contain essential oils, alkaloids, flavonoids and different chemical compounds. It used as medicinal, aromatic and culinary purpose. The use of plants for the medicinal purpose for thousands of years and their trace occur in ancient civilization like Greeks, Romans and Egyptians. In the modern period also plants are used to cure different health problems.

**Objectives-**

* To study the heavy metals toxicity in medicinal plants
* To study the effect of heavy metals toxicity on human health
* To describe the sources of heavy metals in the nature
* To focus on medicinal plants which accumulate heavy metals
* To aware young generation about the heavy metal toxicity in medicinal plants

**Analysis and Results-**

On the earth metal and metalloid ions are natural part which presents in diverse layers that compose it. Its high concentration level found toxic for microorganisms, plants, animals and humans. The harmful effect of element in plant and other life forms rely on capacity of such metallic ions to complete with normal ion that is cofactors for vital enzymes in primary and secondary metabolism. The world population predicted to increase 9.1 billion by year 2050 also increase metalloid pollution which affect on food security also causes human illness. These metal also produce toxicity in the medicinal plants, according to one data about 700 plant species out of 300,000 vascular plants are capable undergo metal hyper accumulation. After industrial revolution many water bodies also contaminated by heavy metals. The discharge mining activities, agricultural runoff, natural weathering of rocks and soil also increase the heavy metals concentration in soil and water. The industrial activities like mining, electroplating, smelting, chemical production and battery production contribute heavy metal pollution. The elements which have atomic number more than twenty, sometimes identified as metals its weight is six gram per cubic centimeter. The metal classified as toxic basis on their concentration in soil from one to thousand mg in the soil. These metal accumulate in soil and water and penetrate into different parts of plants and animals and directly and indirectly into human body.

* **Heavy metals-**

The plant which has accumulated hyper is normally endemic to soil the mineralization of parent rock shows metal level naturally or sometime human activity by mining and smelting. In the agricultural uses of agrochemicals has a main source of the heavy metal contamination posing risk to the environmental health. In the agrochemicals phosphate fertilizer are chief source of trace elements. The high concentration of cadmium is occurring in phosphate fertilizer another metals contains zinc and lead into the soil. The toxicity produced by metals in living organism and plants is highly persistent and present in soil ecosystem for long time. The plants change accurate mechanism to deal heavy metal stress in order to survive. The plant develop cope with metal stress like immobilization, exclusion of plasma membrane, restriction of absorption and transport, induction of stress protein, chelating and sequestration by specific ligands and synthesis of specific heavy metal transporters. There are some metals which show the effect on the environment and human health. In the metal Titanium, vanadium, chromium, manganese, iron, cobalt, nickel, copper, zinc, gallium, germanium, arsenic, zirconium, molybdenum, technetium, ruthenium, rhodium, palladium, silver, cadmium, tin, indium, lutetium, tellurium, hafnium, rhenium, osmium, gold, platinum, iridium, mercury, thallium, lead, bismuth, polonium, astatine, lanthanum, cerium, praseodymium, neodymium, promethium, samarium, gadolinium, terbium, dysprosium, erbium, thulium, ytterbium, actinium, thorium, protactinium, uranium, neptunium, americium, curium, berkelium, californium, einsteinium, fermium, nobelium, radium, lawrencium, rutherfordium, dubnimum, seaborgium, bohrium, hassium, meitnerium, darmstadtium, roentgenium, copernicium, niobium, flerovium, moscovium, livermorium, tennessine and organesson are included.

**Aluminum-** It is third richest element found in the crust of earth; it occurs about 8% it used in some industries like electrical, transportation, metallurgical, packing and chemical manufacturing. The aluminum residues used in paper manufacture, sugar refining, wood preservation, water purification, leather tanning and textiles for water resistance. The aluminum present in soil in the initial phase of plant growth its roots easily accumulate it. It translocation within plant and dropped with advancing maturity, the aluminum not more toxic to it.

**Copper-** It is one of essential micronutrients of living organism, it occurs in redox component in cellular electron transport chain system. Its level toxic to plant if increase and stress induced suppression of two proteins, also down regulation of seven proteins and five proteins up regulated. It is toxic in medicinal plants its concentration increase in the soil.

**Cadmium-** it is present 0.1 and 0.41 mg/ kg in the earth crust, mostly it is used in battery production. It also used in large quantities as pigment contain stabilizer, it also used as alloys and stabilizer for various plastics due to some distinctive physical and chemical characters. The cadmium is harmful metal affect on all living organism biological process, its high water solubility produce toxicity it recognized seventh ranked in twenty top toxins. It is heavy metal pollutant in the plant it produce chlorosis, root tip browning and plant death ultimately.

**Cobalt-** It produces soil pollution largely by mining and smelting, sewage sludge dispersal and fertilizer use. The high dose of cobalt is toxic to plant it also affect terrestrial ecosystem.

**Chromium-** It is seventh largest component of the crust of earth; its average concentration is 100 mg/kg. It used in stainless steel, pigments, metal finishing, chromate plating and preservation of wood and chemicals. In paint, glazes, varnishes, inks and paper, it also used production of green tints. In the chromium pollution dyestuffs and leather tanning is main sources, in aquatic bodies it also directly discharge, it is consider as non essential metals in the plants growth.

**Iron-** It s essential element for animals, plants and human, the Fe occurs in plants rhizospheric zone it is largest occurring metal in earth crust. In the Fenton reaction it is reactive and toxic, it accumulate primarily by pants for stabilizing Fe3+ and reducing Fe2+ to the absorption and transportation in the root.

**Mercury-** It has occur in earth crust 0.07 mg/ kg it is used in gold mining, batteries, paints , pesticides, impregnation of wood and electric products. It accumulates in different sites and reflected as global pollutant. In the plant it takes up directly depending upon soil quantity. The mercury stored in roots, leaves and grains its high level is harmful to environment and health.

**Nickel-** Its exposure in growing medium affects activity of amylases, proteases and ribo-nuclease affects digestion and metabolism of food reserve in seed germination. The cation transport system of plant passively absorbs the soluble nickel compounds.

**Lead-** In the earth crust it occurs 15 mg/ kg in the terrestrial system it show two types primary and secondary. In primary lead formation geogenic activates and incorporate into minerals and in secondary lead formation radiogenic origin from uranium and thorium decline. The lead used in battery production, in solders, alloys, cables and chemicals. It is non-essential toxic element occur in soil. The plants root accumulate it from soil, it is toxic to all living organism.

**Arsenic-** It is metalloid occur in water it is toxic binds with sulfur, disrupting enzymes used in metabolism.

In the environment toxic and carcinogenic material release and it accumulate in food change, damage the health of wildlife and human. The heavy toxic metals occur naturally with high atomic weight and density at least five times greater than water. The heavy metals released into environment by agriculture, mining and therapeutic expertise. The release of metals pollutes environment, also produce harmful effect in animal and human. The accumulation of heavy metal by plants shows negative impact on human health and environment.

In the India for the higher crop production farmer has use waste water enriched with vital nitrogen, potassium and phosphorous. These result possible pollutant transfer to crops and vegetation. The heavy metal produces risk in ecosystem and environment because of toxicity, bioaccumulation, persistence and non bio-degradability. It also contaminates water bodies and mixed with soil. The fruits and crops grows on that water produces the health effect, the plant also used in herbal medicine also produce toxicity.

* **Medicinal plants and heavy metals content-**

**Adhatoda vascia –** It is also known as or Malabar nut is a popular Ayurvedic respiratory healer. It works as a strong stimulator of the bronchial system thereby eliminates excess phlegm from the throat, clear the lungs and improves the bronchodilator and treats bronchitis, tuberculosis and other lung disorders. The decoction of leaves and drink it to get relieved from cough and other symptoms of colds. The plant consist lead 2.49 mg/kg, copper 11.09 mg/ kg, zinc 50.078 mg/ kg, iron 894.81 mg/ kg, nickel 10.94 mg/ kg and chromium 01.99 mg/ kg.

**Acorus calamus-** The plant is useful in neurological and metabolic disorder, it is Indian traditional herb. It also used in gastrointestinal, respiratory, kidney and liver disorder. The plant is perennial herb its rhizome is brown in color cylindrical and curved. It shows analgesic anti-pyretic and anti-obesity properties. The plant consist lead 2.48 mg/ kg copper 108.6 mg/ kg, mercury 09.01 mg/ kg, zinc 6.34 mg/ kg, iron 558.69 mg/ kg, nickel 33.39 mg/ kg and chromium 16.26 mg/ kg.

**Curcuma longa-** The plant has the member of zingiberaceae commonly known as turmeric. It is herbal medicine used traditionally any part of India, the extract has been so antimicrobial and antioxidants activities. The curcumin is known for its inhibitory action on microorganisms such as E. coli, S. aureus, Salmonella typhimurium, and Pseudomonas aeruginosa. It has perennial rhizomatous herbs native to tropical and subtropical regions. Curcuma is extensively cultivated in tropical and subtropical regions of Asia, Australia, and South America. The plant consist lead 1.88 mg/ kg copper 110.36 mg/ kg, mercury 8.33 mg/ kg, zinc 14.18 mg/ kg, iron 361.76 mg/ kg, nickel 10.91 mg/ kg and chromium 8.23 mg/ kg.

**Ocimum sanctum-** It has a wonder herb that is much favored by Ayurveda. This aromatic leaf can be your primary line of defense against COVID-19. The basil plant is a powerful germicide, because of its phyto chemicals and antioxidants, it can effectively locate germs, viruses and bacteria the moment they enter your body and destroy them. Simply chew a few leaves first thing in the morning. You can also add a few drops of water boiled with basil leaves into your food. Ocimum sanctum is the primary form of basil used for its medicinal purposes, due to its anti-infective properties and its use in respiratory tract infections like cough, cold, sore throat, asthma etc. The plant consist copper 8.6 mg/ kg, mercury 20.49 mg/ kg, zinc 67.21 mg/ kg, iron 1930.54 mg/ kg, nickel 16.29 mg/ kg and chromium 11.02 mg/ kg.

**Piper longum** **-** It is an effective herb in managing cough and cold. Studies state that it gives relief from headache and congestion associated with common cold. How it works Pippali loosens mucus and helps to cough it out, thus allowing the patient to breathe freely. This is due to its expectorant property. Pippali is the time-tested natural remedy that works amazingly well in treating common respiratory woes. It functions as a counter-irritant and lessens inflammation, clears the mucus and nasal congestion. Boil a few Pippali in half a glass of milk and drink this concoction to cure a common cold, cough, bronchitis and asthma. The plant consist lead 1.88 mg/ kg copper 81.32 mg/ kg, mercury 10.64 mg/ kg, zinc 13.56 mg/ kg, iron 403.76 mg/ kg, nickel 9.81 mg/ kg and chromium 6.88 mg/ kg.

**Phyllanthus emblica-** It is perhaps one of the richest sources of vitamin C and is perfect for the overall immunity, as it can rejuvenate and revitalize the body systems. Amla is cooling in nature and can help remove excess body heat, thus often recommended in pitta conditions. It is also helpful in afflictions of the gastro-intestinal tract. Amla is also believed to stimulate regeneration of red blood cells and help improve hemoglobin content in body. Due to its anti-inflammatory properties, it can help soothe joint pains. Amla is often used in powder form but is also available as tablets or liquid extracts. It is best to consume Amla in raw form. Amla powder can be consumed by mixing with honey, twice a day. The plant consist lead 2.03 mg/ kg copper 23.03 mg/ kg, mercury 1.58 mg/ kg, zinc 36.42 mg/ kg, iron 637.5 mg/ kg, nickel 6.55 mg/ kg and chromium 9.41 mg/ kg.

**Terminilia chebula-** The plant is useful in opthalmia, hemorrhoids, dental caries, bleeding gums, ulcer oral cavity. The plants paste with water shows anti-inflammatory, analgesic and purify the wounds. The fruit power has used in chronic diarrhea, nervous weakness also used in cough, sore throat and in asthma. The plant consist lead 4.08 mg/ kg copper 293.49 mg/ kg, mercury 4.0 mg/ kg, zinc 4.68 mg/ kg, iron 287.22 mg/ kg, nickel 13.44 mg/ kg and chromium 12.93 mg/ kg.

**Terminilia belerica-** The plant fruit is laxative, astringent, anti-helmintic and antipyretic. In the Ayurveda it used in various disorders like hepatitis, bronchitis, asthma, dyspepsia, piles, diarrhea and eyes diseases. It also protects the liver and treats respiratory condition including respiratory tract infection, cough and sore throats. It is helpful in dysentery and also used as lotion for the sore eyes. The plant consist lead 8.49 mg/ kg copper 217.03 mg/ kg, mercury 2.55 mg/ kg, zinc 5.86 mg/ kg, iron 364.14 mg/ kg, nickel 23.4 mg/ kg and chromium 16.89 mg/ kg.

**Tinospora cardfolia -** The root, stem, bark, leaves, and fruits that all the parts of the plant are useful as an herbal remedy of one disease or the other depending on the preparation. It contains polysaccharides, phenolic, triterpenoids, steroids, and sesquiterpenoids. It has also contains 13 alkaloids of isoquinoline and aporphine skeletons, amine, and amide with main alkaloids that are protoberberine alkaloids berberine, corydine, magnoflorine, and palmatine. The plant consist 4.64 mg/ kg copper 289.09 mg/ kg, mercury 8.76 mg/ kg, zinc 18.18 mg/ kg, iron 749.81 mg/ kg, nickel 17.18 mg/ kg and chromium 8.76 mg/ kg.

**Tribulus terrestris-** It is also a small herb plant occur in Asia, Europe and Africa. The plant has the member of family zygophyllaceae commonly known as gokhru. It has shows the properties of antimicrobial activities, the extract of plant examined against different eleven microorganism including E. coli, S. aureus, Bacillus cereus, Corynebacterium diphtheria, Salmonella typhimurium, Candida albicans, Proteus vulgaris, Klebsiella pneumonia), Serratia marcescens, and Pseudomonas aeruginosa. In India it found in different geographical parameters like over 11,000 feet in Kashmir region Ceylon and also different places on road side as like common weed. It also occur Maharashtra, Rajasthan and West Bengal in hot, dry and sandy region. The dried fruit of plant contains steroidal saponins as chief source. The plant consist lead 6.53 mg/ kg copper 253.01 mg/ kg, mercury 7.07 mg/ kg, zinc 33.71 mg/ kg, iron 823.56 mg/ kg, nickel 19.19 mg/ kg and chromium 7.7 mg/ kg.

**Withania sominifera-** The plants parts like leaves, roots, bark, fruit, and seeds are consumed for their medicinal properties but the root is most commonly used. This herb has traditionally been prescribed to strengthen immunity post an illness. The plant is strong anti-inflammatory action that helps in conditions like rheumatoid arthritis, autoimmune diseases and certain skin diseases. This herb has proven its efficacy in nervous system disorders. It has shown to improve brain cell function, nervous exhaustion, anxiety and depression. It also refreshes the body by relieving fatigue. The plant consist lead 4.34 mg/ kg copper 131.01 mg/ kg, mercury 3.85 mg/ kg, zinc 7.03 mg/ kg, iron 309.95 mg/ kg, nickel 17.05 mg/ kg and chromium 3.85 mg/ kg.

These type many medicinal herbs and plants has contaminated by the heavy metals and produce toxicity. The medicine produced from such affected medicinal plants shows the side effect on the health. In the following table some medicinal plants and their parts used for the medicinal use and its cure health problem described. These plants shows the some heavy metal concentration in it like lead, mercury, copper, zinc, iron, nickel and chromium.

**Table - Heavy meals concentration in some medicinal plants mg/kg-**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sr. no** | **Medicinal plants** | **Part use** | **Medicinal use** | **Pb** | **Hg** | **Cu** | **Zn** | **Fe** | **Ni** | **Cr** |
| 01 | Adhatoda vascia | Leaves | Expectorant | 2.49 | - | 11.09 | 50.78 | 0894.81 | 10.94 | 01.99 |
| 02 | Acorus calamus | Rhizome | Asthma | 2.48 | 108.6 | 09.01 | 06.34 | 0558.69 | 33.79 | 16.26 |
| 03 | Ocimum sanctum | Leaves | Cough, fever | - | 008.6 | 20.49 | 67.21 | 1930.54 | 16.29 | 11.02 |
| 04 | Piper longum | Fruit | Digestive | 1.88 | 081.32 | 10.64 | 13.56 | 0403.76 | 09.81 | 06.88 |
| 05 | Phyllanthus emblica | Fruit | Revitalize  | 2.03 | 23.03 | 01.58 | 36.42 | 0637.5 | 06.55 | 09.41 |
| 06 | Terminilia chebula | Seed | Laxative | 4.08 | 293.49 | 04.00 | 04.68 | 0287.22 | 13.44 | 12.93 |
| 07 | Terminilia belerica | Seed | Antipyretic | 8.49 | 217.03 | 02.55 | 05.86 | 0364.14 | 23.4 | 16.89 |
| 08 | Tinospora cardfolia | Plant | immuno-modulatory | 4.64 | 289.09 | 08.76 | 18.18 | 0749.81 | 17.18 | 08.76 |
| 09 | Tribulus terrestris | leaves | Diuretic  | 6.53 | 253.01 | 07.07 | 33.71 | 0823.56 | 19.19 | 07.7 |
| 10 | Withania sominifera | Root | Nerve tonic  | 4.34 | 131.01 | 03.85 | 07.03 | 0309.95 | 17.05 | 03.85 |
| 11 | Curcuma longa | Rhizome | Wound healing | 1.88 | 110.36 | 08.23 | 14.18 | 0361.76 | 10.91 | 08.23 |

**Conclusion-**

The metals like aluminum, arsenic, lead, cadmium and mercury are not essential for human activity it causes toxicity. According to World health organization (WHO) in the world share of the herbal medicines reach up to 60%. The medicinal plants which has used for their therapeutic properties may be accumulate heavy metals from the soil. The accumulation of this heavy metal poses significant risk to the human health when these plants consumed as herbal remedies or dietary supplements. The long term exposure to heavy metals like arsenic, cadmium, leads and mercury it causes serious health problems like cancer, kidney damage, neurological damage and developmental disorders. The heavy metals like mercury, nickel, zinc, chromium, iron, copper and lead like heavy metals are presents in these medicinal plants. These plants used as medicinal purposes Terminilia chebula plants seed is used as laxative, Terminilia belerica plants seed is used as laxative and anti-pyretic, Phyllanthus emblica plants fruit is used as digestive and revitalize, Piper longum plants fruit is use as digestive and bronchitis, Adhatoda vascia plants leaves are used expectorant and asthmatic, Withania sominifera plants roots are used as nerve tonic and Ocimum sanctum plant used in cough and fever. The toxicity produced by metals in living organism and plants is highly persistent and present in soil ecosystem for long time. The plants change accurate mechanism to deal heavy metal stress in order to survive. The plant develop cope with metal stress like immobilization, exclusion of plasma membrane, restriction of absorption and transport, induction of stress protein, chelating and sequestration by specific ligands and synthesis of specific heavy metal transporters. The medicinal plants accumulate this material from the soil or water in the environment and produce side effect on human health.

**References-**

* Ali M.(1998), ‘Text book of Pharmacogency’ New Delhi CBS publication
* Abdul Malik, Elisabeth Grohamann and Rais Akhtar (2020) ‘Environmental Deterioration and Human Health’ Switzerland, Springer Nature Publication.
* Chopra R.N. (1982) ‘Indigenous drugs of India ‘Calcutta Acadmic press publisher
* Das Kundal (2009) ‘Medicinal Plants’ New Delhi Kalyani publication
* David W. M. Leung (2013) Recent advances towards improved Phytoremediation of heavy metal pollution, Bentham books publication.
* Gautam Ashutosh and Chakresh Pathak (2018) Metallic contamination and its toxicity, Daya publishing house publication.
* Kumar Jitendra (2022) Heavy metals in plants, Taylor and Francis limited publication.
* Lepp N. W. (2019) Effect of heavy metal pollution on plants, Springer publication.
* Mohammad Attar Shashi B. (2017) Heavy metals and environment, New age international publication.
* S P Balasubramani et al. (2011) Plant-Based Rasayana Drugs from Ayurveda. Chinese Journal of Integrative Medicine.
* Sing Sadhana (2014) ‘Economic botany’ New Delhi Blank printer publication
* Shukla V.K. and Shenai S.K. (2013) ‘Economic botany’ New Delhi Campus books international publication
* Tariq Aftab, Khalid Rahman Hakeem (2021) Heavy metal toxicity in plants, CRC press publication.
* Wong M.H. (2012) ‘Environmental Contamination: Health Risks and Ecological Restoration’ USA Florida, Taylor & Francis Group publication.