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Study of Toxicity of Heavy Metals Contamination in Drinking Water and Irrigation Water System on Living Organisms

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ABSTRACT: Heavy metal contamination in drinking water poses a threat to humans and is often the root cause of various severe health issues such as cancer and organ damage. The presence of heavy metals cannot be seen with the naked eye but can be detected with a water test. Heavy metals are a slow poison to your health as they don't have any immediate effects on your body. Contaminated drinking water with heavy metals such as mercury, lead, cadmium, arsenic, nickel, chromium, and zinc are major health concerns for the public and healthcare professionals.

KEYWORDS: heavy, metal, cancer, water, test, health, concerns

I. INTRODUCTION

The human body can't discharge these metals and they continue amassing inside the body. It doesn't have a prompt impact on the body, however, can bring about major long-lasting issues a large portion of them influencing the brain. It can bring about reduced mental and central nervous function. It also causes harm to the lungs, liver, kidneys, and other vital organs. Heavy metals are also known as carcinogens that can cause cancer.

Young kids are more susceptible to the harmful effects of heavy metals because their body is in the developing stage. The continuous accumulation of heavy metals in children's bodies can affect their nervous system which can lead to learning difficulties, and memory impairment, and furthermore result in behavioral issues in the form of aggression and hyperactivity.

Health Effects of these Metals on the Human Body

1. Mercury

Enters through the leaching of soil because of acid rain, coal consumption, and industrial, household, and mining waste. Mercury in drinking water can cause damage to the nervous system and kidneys.

2. Lead

Lead in drinking water usually comes from the corrosion of old pipes. The presence of lead in drinking water can cause damage to the kidney, and nervous system, and learning difficulties.

3. Cadmium (Cd):

Found in lead, zinc, copper ores, coal, etc. the deposits of Cadmium are usually the source for surface and groundwater, mainly when in contact with acidic water and low TDS. As per Water Quality Association, Cadmium can potentially cause damage to kidneys, bone, liver, and blood in case of continuous exposure at levels that are higher than the maximum contaminant level.[1,2,3]

4. Arsenic

Arsenic is the most widely recognized reason for heavy metal poisoning in adults. Arsenic is discharged into nature by the refining procedure of copper, zinc, and lead, and also by the manufacturing of chemicals and glasses. Arsenic contamination in drinking water can cause damage to your skin, liver, and eyes and may also cause cancer.

5. Nickel

Nickel is a hard, silvery-white metal used primarily in alloys. It has good corrosion resistance, high ductility and high thermal and electrical conductivity. Nickel is also used as an alloying agent for stainless steel and other alloys.

Nickel is necessary in many organism's diets but can become carcinogenic and toxic in high doses. Women are more commonly allergic to nickel exposure than men. Exposure to skin can cause dermatitis upon contact.

6. Chromium

Chromium is a trace mineral that is naturally present in many foods. The body needs chromium to make use of sugars and fats and to produce energy. Chromium deficiency can cause insulin resistance, which can lead to diabetes and heart disease.

Trivalent chromium plays a role in regulating sugar and fat metabolism, but it is not clear how it does this. Trivalent chromium deficiency is extremely rare and has only been reported in hospital patients unable to eat and who receive intravenous nutrition over a long period of time.

7. Zinc

Zinc is a trace element essential for the growth and development of all organisms. The human body requires zinc for the production of collagen, insulin and testosterone, as well as for the metabolism of vitamin A, iron and copper. Zinc is also necessary for proper immune function.

Zinc deficiency is rare in healthy individuals because the body will adjust its absorption to maintain normal serum levels. However, zinc deficiency can occur when total dietary intake is inadequate or absorption from the intestine is reduced due to disease (Crohn's disease, celiac disease).

Indiscriminate industrialization and urbanization have negatively impacted our environment. One of the common environmental problems in semi-urban areas in India is the discharge of inefficiently treated municipal, industrial and domestic wastewater into the environment, resulting in the degradation of soil and water qualities. Depleting freshwater resources have led Indian farmers to look for easily available, cheaper, and nutrient-rich sources of irrigation water in the form of wastewater; however, this also led to increased pollutant transfer to the soils. Known as persistent pollutants, heavy metals such as cadmium (Cd), copper (Cu), chromium (Cr), lead (Pb), mercury (Hg), and a few others are potentially hazardous due to their non-biodegradable nature, extended biological half-lives, and biological interactions. These heavy metals can bind to soil surfaces and then be absorbed by plant tissues. Vegetables supply micronutrients, antioxidants, vitamins, and other nutrients essential for human growth. Therefore, the consumption of vegetables/crops grown in wastewater-irrigated land poses a potential threat to humans. [5,7,8] Since wastewater irrigation cannot be eliminated in the Indian (semi-)urban areas because of the ever-increasing demand for irrigation water, it is important to assess the impact of wastewater irrigation.

II. DISCUSSION

Both natural and anthropogenic sources contribute to heavy metals in wastewater and irrigated soils. Natural sources are soil erosion, volcanic eruptions, urban runoffs, and aerosol deposition, while anthropogenic sources are identified as effluents from industrial and household activities.

The growth in population and its allied human activities have led to an increase in the concentration of heavy metals in wastewater. Hence, urbanized areas play an important role in the availability of metals in the sewage and soil (Buzier et al. 2011). The wastewater generated from households is a major component of urban wastewater. Such sources are food, detergents, cosmetics, sanitary fittings, kitchen wastewater, laundry, bath, and water closets (Moriyama et al. 1989). The possible sources of various heavy metals in domestic wastewater are listed in Table 1.



Table 1

Sources of heavy metals in domestic wastewater

Metal	Sources
Pb	Sewer hookups and pipelines, wastewater from laundry
Cr	Cleaning of metal cookware
Ni	Stainless steel materials, cleaning of cookware, feces,
Zn	Food, plumbing materials, detergents, toothpaste, shampoo, and deodorants
Fe	Food coloring, diet supplements, steel and iron products, water supply pipes, paints, and cosmetics
As	Medicines, washing products, glass, wood preservatives, garden products
Mn	Pesticides, food products like grains, nuts, tea leaves
Cu	Copper piping corrosion
Cd	Washing powder, dish wash detergents

Industrialization has also resulted in heavy metal contamination in the soil. Toxic compounds accumulate in the soil due to rapid industrialization and disorderly urbanization, as well as long-term usage of enormous amounts of fertilizers and pesticides (Kishan et al. 2014; Kumar et al. 2015; Rodrigues et al. 2017). The main sources of emissions induced by human activities are liner source (from vehicle transportation), surface source (household emission), and point source (fuel combustion, industrial exhaust through stack). Various heavy metals are generated from different industrial sources, such as chrome from the paint and metallurgical industry, nickel from steel, and cadmium from smelters. Road traffic also leads to the generation of certain heavy metals like lead. Tetraethyl lead was added to gasoline for many years, and its combustion generates Pb in the natural environment (Niec et al. 2013; Zhou et al. 2016), but this source is declining with time. Several investigations reported a significant amount of street dust in pollutants of urban soils along traffic routes (Zereini et al. 2007; Wiseman et al. 2015). Roads with heavy traffic could also be a source of pollution due to the generation of metal-enriched vehicular exhaust (Sternbeck et al. 2002; Wiseman et al. 2015).

Heavy metal contamination is a concern in soils near industrial districts (Murray et al. 2011; Sun & Chen 2018; Sung & Park 2018), adversely affecting nature. Mahmood & Malik (2014) reported that wastewater irrigation affects soil's physicochemical properties. According to various Indian studies, when wastewater is used to irrigate crops, the quantity of heavy metals increases in the soil as well as in agricultural cultivated products (Rattan et al. 2005; Sharma et al. 2006; Singh & Kumar 2006; Singh & Agrawal 2007; Arora et al. 2008; Gupta et al. 2008a, 2008b; Tiwari et al. 2011).[9,10,11]

The concentration of elements in the soil regulates the trace metal content of vegetables. Bedrock is a natural source of these metals in the soil. Metals are also introduced to agricultural soils in combination with organic and mineral fertilizers (mainly calcium and phosphates) (Antisari et al. 2015; Ye et al. 2015). Herbicides and fungicides are also sources of metals in the soils (Kabata-Pendias & Pendias 1999; Antisari et al. 2015; Ye et al. 2015).

The soil conditions play a very important role in the bioavailability of heavy metals and their uptake by plants. These conditions include soil pH, soil type, (soil) humidity, and the initial concentration of metal found in the soil (Kabata-Pendias & Pendias 1999; Jarup 2003; Leitzmann 2003). For example, granulometric soil tended to accumulate more cadmium in the soil (Wlasniewski & Hajduk 2012). They also reported that the cadmium content of the crops studied (wheat) was linked, to a small extent, to the features of the top layer of soil, including total and soluble cadmium levels in the soil. According to Kabata-Pendias & Pendias (1999), when the soil pH is acidic, it generally enhances crops' heavy metal absorption. Bielecka et al. (2009) reported that the pH of the soil is in the range of 7.1–8.1, and the presence of a higher concentration of organic matter (OM) lowers the bioavailability of metals like Cd in the soil. Hence, there is a decrease in the uptake of metal by plants.[12,13,15]

Table 2

Concentration of heavy metals in the edible portion of leafy vegetables

Study area	Heavy metals	Sources of heavy metals
Outskirts of Bombay city	Pb, Cd, Cu, and Zn	Atmospheric deposition
Kanpur	Fe, Cr, Zn, Mn and Cu	Treated tannery wastewater is a source of pollution
Amritsar, Punjab	Cd, Cu, Fe, Pb, and Co	Effluents from industrial units
Rewa, Madhya Pradesh	Fe, Zn, Cu, Pb, Cd, Mn, and Cr	Effluents from a cement factory
Sri Ganganagar district, Rajasthan	Fe, Mn, Cu, and Zn	Continuous and long-term irrigation with wastewater



Study area	Heavy metals	Sources of heavy metals
Hyderabad	Zn, Cr, Cu, Ni, Co, and Pb	Sewage disposal to the river and use of river water as a source of
Delhi	P, K, S, Zn, Cu, Fe, Mn and Ni	Sewage effluents are the primary source of pollution
Suburban of Varanasi	Cu, Zn, Cd, Pb, Ni, and Cr	Industrial effluents
Lucknow	Cr, Ni, Zn, Cu, and Cd	Effluent from an electroplating industry
Bangalore	Fe, Zn, Cu, Ni, Cr, Pb, and Cd	Sewage is the main source of pollution
Varanasi	Cd, Ni, Cu, Cr, Pb, and Zn	Sewage sludge
Northern India	Cd, Cr, Ni, and Pb	Treated sewage
Titagarh, West Bengal	Pb, Zn, Cd, Cr, Cu, and Ni	Municipal wastewater irrigation
Korba, Chhattisgarh	Fe, As, Cr, Mn, Cu, Zn, Pb, Cd, and Hg	Industrial deposition
Vadodara, Gujarat	As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn	Use of industrial effluent for irrigation

Table 3

Concentration of heavy metals in the edible portion of nonleafy vegetables

Study area	Heavy metals	Sources of heavy metals
Visakhapatnam, Andhra Pradesh	Pb, Zn, Ni, and Cu	Deposition of metals due to emissions from industrial and transport sectors
Amba Nalla in Amravati City, Maharashtra	Pb and Cd	Wastewater from domestic sources
Vadodara, Gujarat	As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn	Use of industrial effluent for irrigation
Amritsar, Punjab	Fe, Co, Cu, Cd, and Pb	Wastewater drain
Delhi	P, K, S, Zn, Cu, Fe, Mn, and Ni	Sewage effluents are the primary source of pollution
Kanpur	Fe, Cr, Zn, Mn, and Cu	Treated tannery wastewater is a source of pollution

DISCUSSION

Metal toxicity or metal poisoning is the toxic effect of certain metals in certain forms and doses on life. Some metals are toxic when they form poisonous soluble compounds. Certain metals have no biological role, i.e. are not essential minerals, or are toxic when in a certain form.^[1] In the case of lead, any measurable amount may have negative health effects.^[2] It is often thought that only heavy metals can be toxic, but lighter metals such as beryllium and lithium may also be in certain circumstances. Not all heavy metals are particularly toxic, and some are essential, such as iron. The definition may also include trace elements when abnormally high doses may be toxic. An option for treatment of metal poisoning may be chelation therapy, a technique involving the administration of chelation agents to remove metals from the body.[17,18,19]

Toxic metals sometimes imitate the action of an essential element in the body, interfering with the metabolic process resulting in illness. Many metals, particularly heavy metals are toxic, but some heavy metals are essential, and some, such as bismuth, have a low toxicity. Most often the definition of toxic metals includes at least thallium, cadmium, manganese, lead, mercury and the radioactive metals.^[3] Metalloids (arsenic, polonium) may be included in the definition. Radioactive metals have both radiological toxicity and chemical toxicity. Metals in an oxidation state abnormal to the body may also become toxic: chromium(III) is an essential trace element, but chromium(VI) is a carcinogen.

Toxicity is a function of solubility. Insoluble compounds as well as the metallic forms often exhibit negligible toxicity. The toxicity of any metal depends on its ligands. In some cases, organometallic forms, such as methylmercury and tetraethyl lead, can be extremely toxic. In other cases, organometallic derivatives are less toxic such as the cobaltocenium cation.

Decontamination for toxic metals is different from organic toxins: because toxic metals are elements, they cannot be destroyed. Toxic metals may be made insoluble or collected, possibly by the aid of chelating agents, or

through bioremediation. Alternatively, they can be diluted into a sufficiently large reservoir, such as the sea, because immediate toxicity is a function of concentration rather than amount. Another method of decontamination of heavy metals in the soil is using a method called phytoremediation.^[4] This method uses plants to extract and lower the concentration of toxic heavy metals in the soil.^[4]

Toxic metals can bioaccumulate in the body and in the food chain.^[5] Therefore, a common characteristic of toxic metals is the chronic nature of their toxicity. This is particularly notable with radioactive heavy metals such as radium, which imitates calcium to the point of being incorporated into human bone, although similar health implications are found in lead or mercury poisoning.^[20,21,22]

Testing for poisoning

People are continually exposed to metals in the environment.^[6] Medical tests can detect metals often, but this is to be expected and alone is not evidence that a person is poisoned.^[6] Metal screening tests should not be used unless there is reason to believe that a person has had excessive exposure to metals.^[6] People should seek medical testing for poisoning only if they are concerned for a particular reason, and physicians should consider a patient's history and physical examination before conducting tests to detect metals.^[7]

Treatment for poisoning

Chelation therapy is a medical procedure that involves the administration of chelating agents to remove heavy metals from the body. Chelating agents are molecules that have multiple electron-donating groups, which can form stable coordination complexes with metal ions. Complexation prevents the metal ions from reacting with molecules in the body, and enable them to be dissolved in blood and eliminated in urine. It should only be used in people who have a diagnosis of metal intoxication.^[8] That diagnosis should be validated with tests done in appropriate biological samples.^[9]

Chelation therapy is administered under very careful medical supervision due to various inherent risks.^[10] Even when the therapy is administered properly, the chelation drugs can have significant side effects.^[9] Chelation administered inappropriately can cause neurodevelopmental toxicity, increase risk of developing cancer, and cause death;^[9] chelation also removes essential metal elements and requires measures to prevent their loss.

Specific types of poisoning

Aluminium phosphide poisoning

Aluminium has no known biological role and its classification into toxic metals is controversial.

Acute aluminium phosphide poisoning (AALPP) is a large, though under-reported, problem in the Indian subcontinent. Aluminium phosphide (ALP), which is readily available as a fumigant for stored cereal grains, sold under various brand names such as QuickPhos and Celphos, is highly toxic, especially when consumed from a freshly opened container.^{[11][12]} Death results from profound shock, myocarditis and multi-organ failure.^[13] Aluminium phosphide has a fatal dose of between 0.15 and 0.5 grams (0.0053 and 0.0176 oz).^[14] It has been reported to be the most common cause of suicidal death in North India.^[15] The very high toxicity of aluminium phosphide is attributed to the phosphine content and is not related to aluminium. Calcium phosphide and zinc phosphide are similar poisons.

Arsenic poisoning

Arsenic poisoning is a medical condition caused by elevated levels of arsenic in the body. The dominant basis of arsenic poisoning is from ground water that naturally contains high concentrations of arsenic. A 2007 study found that over 137 million people in more than 70 countries are probably affected by arsenic poisoning from drinking water.^[16]

Beryllium poisoning

Beryllium poisoning is illness resulting from the toxic effect of beryllium in its elemental form or in various chemical compounds.^[23,25,27] The toxicity of beryllium depends upon the duration, intensity and frequency of exposure (features of dose), as well as the form of beryllium and the route of exposure (i.e. inhalation, dermal, ingestion). According to the International Agency for Research on Cancer (IARC), beryllium and beryllium compounds are Category 1 carcinogens; they are carcinogenic to both animals and humans.^[17]

Cadmium poisoning

Cadmium is an extremely toxic metal commonly found in industrial workplaces. Due to its low permissible exposure limit, overexposures may occur even in situations where trace quantities of cadmium are found. Cadmium is used extensively in electroplating, although the nature of the operation does not generally lead to overexposures. Cadmium is also found in some industrial paints and may represent a hazard when sprayed. Operations involving removal of cadmium paints by scraping or blasting may pose a significant hazard. Cadmium is also present in the manufacturing of some types of batteries. Exposures to cadmium are addressed in specific standards for the general industry, shipyard employment, construction industry, and the agricultural industry.^[18]

Copper toxicity

Copper toxicity, also called copperiedus, refers to the consequences of an excess of copper in the body. Copperiedus can occur from eating acidic foods cooked in uncoated copper cookware, or from exposure to excess copper in drinking water, as a side-effect of estrogen birth control pills, or other environmental sources. It can also result from the genetic condition Wilson's disease.

Iron poisoning

Iron poisoning is an iron overload caused by a large excess of iron intake and usually refers to an acute overload rather than a gradual one. The term has been primarily associated with young children who consumed large quantities of iron supplement pills, which resemble sweets and are widely used, including by pregnant women—see overnutrition (approximately 3 grams is lethal for a 2 year old).^[19] Targeted packaging restrictions in the US for supplement containers with over 250 mg elemental iron have existed since 1978, and recommendations for unit packaging have reduced the several iron poisoning fatalities per year to almost nil since 1998.^{[20][21]} No known cases of iron poisoning have been identified that are associated with iron mining.

Lead poisoning

Lead poisoning, also called Plumbism is a medical condition in humans and other vertebrates caused by increased levels of the heavy metal lead in the body. Lead interferes with a variety of body processes and is toxic to many organs and tissues including the heart, bones, intestines, kidneys, [28,29,30]and reproductive and nervous systems. It interferes with the development of the nervous system and is therefore particularly toxic to children, causing potentially permanent learning and behavior disorders. Symptoms include abdominal cramping, constipation, tremors, mood changes, infertility, anemia, and toxic psychosis.^[22]

Lithium poisoning

Lithium is used in some medications, specifically to treat bipolar disorder. The level of "sufficient" medication is thought by many physicians to be close to toxic tolerance for kidney function. Therefore, the patient is often monitored for this purpose.^{[23][24]}

Manganese poisoning, or manganism

Manganism or manganese poisoning is a toxic condition resulting from chronic exposure to manganese and first identified in 1837 by James Couper.^[25]

Mercury poisoning

Mercury poisoning is a disease caused by exposure to mercury or its compounds. Mercury (chemical symbol Hg) is a heavy metal occurring in several forms, all of which can produce toxic effects in high enough doses. Its zero oxidation state Hg^0 exists as vapor or as liquid metal, its mercurous state Hg_2^{2+} exists as inorganic salts, and its mercuric state Hg^{2+} may form either inorganic salts or organomercury compounds; the three groups vary in effects. Toxic effects include damage to the brain, kidney, and lungs. Mercury poisoning can result in several diseases, including acrodynia (pink disease), Hunter-Russell syndrome, and Minamata disease.

Symptoms typically include sensory impairment (vision, hearing, speech), disturbed sensation and a lack of coordination. The type and degree of symptoms exhibited depend upon the individual toxin, the dose, and the method and duration of exposure.

Silver poisoning (Argyria)



A 92-year-old Caucasian man (right) with pigmentary changes had used nose drops containing silver for many years. His skin biopsy showed silver deposits in the dermis, confirming the diagnosis of generalized argyria.^[26]

Argyria or argyrosis is a condition caused by inappropriate exposure to chemical compounds of the element silver, or to silver dust.^[27] The most dramatic symptom of argyria is that the skin turns blue or bluish-grey. It may take the form of generalized argyria or local argyria. Generalized argyria affects large areas over much of the visible surface of the body. Local argyria shows in limited regions of the body, such as patches of skin, parts of the mucous membrane or the conjunctiva.^[28]

Thallium poisoning

Thallium and its compounds are often highly toxic.^[29] Contact with skin is dangerous, and adequate ventilation should be provided when melting this metal.^[30] Many thallium(I) compounds are highly soluble in water and are readily absorbed through the skin. Exposure to them should not exceed 0.1 mg per m² of skin in an 8-hour time-weighted average (40-hour work week). Thallium is a suspected human carcinogen.^[30]

Tin poisoning

Tin poisoning refers to the toxic effects of tin and its compounds. Cases of poisoning from tin metal, its oxides, and its salts are "almost unknown"; on the other hand certain organotin compounds are almost as toxic as cyanide.^[31]

Zinc toxicity

Even though zinc is an essential requirement for a healthy body, excess zinc can be harmful, and cause zinc toxicity. Such toxicity levels have been seen to occur at ingestion of greater than 225 mg of zinc.^[32] Excessive absorption of zinc can suppress copper and iron absorption. The free zinc ion in solution is highly toxic to bacteria, plants, invertebrates, and even vertebrate fish.^{[33][34][35]}

Society and culture

It is difficult to differentiate the effects of low level metal poisoning from the environment with other kinds of environmental harms, including nonmetal pollution.^[36] Generally, increased exposure to heavy metals in the environment increases risk of developing cancer.^[37]

Without a diagnosis of metal toxicity and outside of evidence-based medicine, but perhaps because of worry about metal toxicity, some people seek chelation therapy to treat autism, cardiovascular disease, Alzheimer's disease, or any sort of neurodegeneration.^[9] Chelation therapy does not improve outcomes for those diseases.^[9]

III. RESULTS

There are 764 river quality monitoring stations in India, spread over 28 states.

Out of the 33 monitoring stations in Ganga, 10 had high levels of heavy metals contaminants.

The Central Water Commission examined water samples from 688 sites for heavy metals between August 2018 and December 2020.^[31,32,33]

Total coliform and biochemical oxygen demand were high in 239 and 88 of the 588 water quality stations examined for pollution throughout 21 states.

It indicates that wastewater treatment from industry, agricultural, and domestic households is inadequate.

According to the Center for Science and Environment's State of the Environment Report 2022, the river, which is the focus of the Namami Gange mission, contains high levels of lead, iron, nickel, cadmium, and arsenic (CSE).

The report is a yearly compilation of data on environmental development obtained from public sources.

According to the Central Pollution Control Board, ten states do not treat their sewage at all.

In India, 72% of sewage waste is dumped untreated.

What are the Consequences of the Heavy Metal Pollution?

These toxic heavy metals entering the environment may lead to bioaccumulation and biomagnifications.

Bioaccumulation:

The net accumulation of a pollutant in an organism from all sources, including water, air, and food, is known as bioaccumulation.'

Biomagnifications:

Biomagnification is the accumulation of a chemical by an organism as a result of water and food exposure, resulting in an increase in concentration that is higher than would have been expected from equilibrium.

Some heavy metals have an effect on biological activities and growth, while others accumulate in one or more organs, resulting in a variety of severe diseases such as cancers, skin diseases, nervous system disorders etc.[35,37]

Metal toxicity results in the production of free radicals, which damages DNA.

These heavy metals are not readily degradable in nature and accumulate in the animal as well as human bodies to a very high toxic amount.

Heavy metal intake has been related to developmental retardation, renal damage, a variety of cancers, and even death in extreme cases.

Namami Gange mission is an Integrated Conservation Mission, approved as a 'Flagship Programme' by the Union Government in June 2014 to accomplish the twin objectives of effective abatement of pollution and conservation and rejuvenation of National River Ganga.

It is being operated under the Department of Water Resources, River Development and Ganga Rejuvenation, Ministry of Jal Shakti.

The program is being implemented by the National Mission for Clean Ganga (NMCG), and its state counterpart organizations i.e State Program Management Groups (SPMGs).

NMCG is the implementation wing of National Ganga Council (set in 2016; which replaced the National Ganga River Basin Authority - NGRBA).

The main pillars of the programme are:

Sewage Treatment Infrastructure

River-Front Development

River-Surface Cleaning

Biodiversity

Afforestation

Public Awareness

Industrial Effluent Monitoring

Ganga Gram

IV. CONCLUSIONS

The Central Water Commission is the apex technical organization in the country for development of water resources and is an attached organization of the Ministry of Jal Shakti.

The Commission is responsible for initiating, coordinating and furthering, in consultation with the State Governments, the schemes for control, conservation, development and utilization of water resources throughout the country for the purpose of irrigation, flood management, power generation, navigation etc.[37]

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