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THE IMPACT OF COAL FLY ASH OF AMARKANTAK THERMAL POWER STATION ON THE KIDNEY OF SELECTED COMMERCIAL FISH *(CHANNA PUNCTATUS)*

Zoology

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ABSTRACT

The Amarkantak thermal power plant, located at Chachai, is one of the coal-based plants in Madhya Pradesh. This electricity plant utilizes bituminous coal as a fuel, which contains high levels of ash (up to 40%), sulfur (0.2-0.6%), and various heavy metals such as Hg, Mn, Cu, Pb, Ni, Fe, Cr, and Cd. In fly -ash, approximately 50% consists of silica along with oxides of Al, Fe, and Ca making up 95 to 99% of its contents, while Na, Mg, Ti, K, C, and S constitute 0.5 - 3.5%, and the remaining ash comprises trace elements (Davison et al., 1974). The plant disposes of ash combined with warm wastewater into the Sone River, resulting in an adverse impact on the river's water quality. Studies have shown a significant presence of heavy metals such as lead, copper, nickel, and silicon in the disposal water, altering the quality of the water in the ecosystem. The concentration of metals such as Pb, Al, Fe, and Cr in the water was found to exceed the permissible limits prescribed by the WHO and Indian Standards. The accumulation of different metals in various parts of fishes can lead to tissue degeneration in organs like the liver, kidney, gills, skin, and intestine, affecting the ecosystem.

KEYWORDS

Coal Fly-ash, Chemical Composition, Heavy Metals, Snakehead Fish, Amarkantak Thermal Power Plant.

INTRODUCTION

In the twenty-first century, there has been a growing interest in metals as environmental pollutants due to the increased exposure of living organisms to metal contamination resulting from progressive industrialization. Pollution has become a significant cost of advanced technological progress and a consequence of all human activities, often leading to casualties in the name of progress. Today, we are confronted with a dilemma: the need for industrialization to meet our basic needs clashes with the industrial pollution that threatens life itself. Ironically, these developments have led to a surge in the use of natural resources and the generation of large quantities of waste products. India is currently seeking new energy resources to support its rapid development across all sectors (Desai, 2008). As a result, the country relies on coal for 70% of its electricity, which is predominantly used in thermal plants (Kumar, 2003; Mishra, 2004; Saravanan and Sundaramoorthy, 2008).

Fly ash contains hazardous toxic compounds and is a significant contributor to metal pollution according to NRC, 2006 and US EPA in 2007. Many toxic elements and heavy metals like zinc, lead, mercury, chromium, nickel, cadmium, selenium, arsenic, fluoride etc. are highly rich in fly ash produced from thermal power stations. It has appeared as a major environmental concern because of the problems associated with its disposal in water bodies and the property of being deposited as sediment. Thus, when fly ash accumulates in water resources, it can escort to adverse changes in the aquatic ecosystem as well as dangerous effects on aquatic organisms including fish and fish food organisms (Srivastava and Srivastava, 2012, Shyam, 2000, Bhattacharya and Chattopadhyay, 2005; Ratan et al., 2005). Water quality mostly deteriorates due to anthropogenic activities. Power stations are one of the activities that can lead to water pollution as explained by van Vuren in 1999 and Rudra in 1999. One of the most significant environmental problems in the coal-fired industry stems from the production of wastewater from ash ponds, which contain trace elements such as Heavy meals and other chemical substances.

A new report released on "Coal Ash in India - A Compendium of Disasters, Environmental and Health Risks" try to remedy that. It reveals 76 major coal ash pond accidents between 2010 and June 2020 that have caused death and property damage and have resulted in widespread pollution of nearby water sources, soil and air. Fly ash is left after coal is burnt. Coal fired power stations are the major sources of fly ash, which comprise toxic metals such as arsenic, cadmium, barium, lead and nickel, along with others. These may cause cancer, heart and lung diseases, neurological harm, and premature mortality too. A Report published by Healthy Energy Initiative India and Community Environmental Monitoring, Chennai, confirmed that the accidents have complied by the above report is only the tip of the iceberg because many incidents related to fly-ash are unreported, though they are happening regularly. Although, a number of plan and regulatory involvements, coal ash management remains a challenge in India.

The aim of the present study is to add some new facts about the effects of coal fly ash on selected experimental fish *Channa punctatus*. Fly ash being heavy gets deposited at the bottom of water bodies. *Channa punctatus* is a bottom-dwelling fish that is in direct contact with fly-ash. Apart from these, the reason behind this choice is that these fish are robust in nature and react to minor environmental changes as well.

DESCRIPTION OF THE STUDY SITE

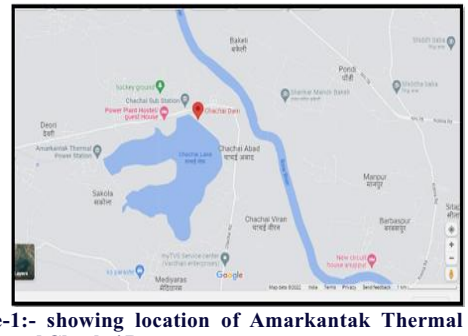


Image-1:- showing location of Amarkantak Thermal power station and Chachai Dam

Amarkantak thermal power plant is located at Chachai this electricity plant is one of the major coal-based plant of Madhya Pradesh. This power plant turned into set up in 1962-1965. Chachai Dam is a multipurpose River Valley project constructed on river Sone located inside the Gangas Basin in Madhya Pradesh, at village Chachai in Anuppur district, At a distance of 172 km. from Katni and 30 km from Shahdol, Its catchment area spans 25 square miles.

This is a fully running thermal electricity plant and the electrical energy from the plant is connected to the regional grid. Here coal is employed because the primary fuel and heating oil is employed because the secondary fuel. The primary source of coal for the plant is from south eastern coal area confined and the primary supply of cooled water is from a dam, that's constructed on Sutna Nala of Sone River, the pond has a general capacity of 700 acre. Mercury control tool not used at the plant. The plant has three units. Two units have an installed capacity of 120 megawatt whereas remaining has the capacity of 210 megawatt. The first unit is started on 23 November 1977 and the second unit is started on sixteen may 1978 while third unit came in existence on 15 June 2008. ACC Vickers and Babcock (AVB) ACC associated cement company, Durgapur is the boiler producer of the plant. The turbine and generator producer of the plant is Bharat Heavy Electricals Limited (BHEL) Bhopal. State government has the ownership of this plant.

Amarkantak Thermal electricity plants utilize bituminous coal as a fuel, which incorporates excessive amount of ash (as much as 40 %), sulphur (0.2- 06%) and heavy metals like mercury, manganese, copper, lead, nickel, iron, chromium & cadmium in varying

proportion. However fly ash generally includes just about 50% silica which together with oxides of Aluminum, iron and , and Calcium increases 95 to 99 % of its contents whereas Na(Sodium), Mg(Magnesium), Ti(titanium), K(Potassium), C(Carbon) & S (Sulfur) make up 0.5 3.5%. The rest of the ash consists of trace elements. (Davison et al., 1974)

Image:-2- Showing Power Plant

Image:-3-Showing side view of Chachai dam

MATERIALS AND METHODS :-

- **Water sampling and Laboratory Testing**
- **Determination of Fly-ash composition**
- **Fish sampling**
- **Calculation of LC -50 for Fly-ash**
- **Histological slide Preparation**
- **Microphotography**

WATER SAMPLING TESTING IN THE LABORATORY

Samples of water were gathered from Chachai -Dam in order to assess the impact of fly- ash on water quality. The gathered samples underwent testing through the use of standard laboratory methods. The testing aimed to determine various physico-chemical parameters including pH, turbidity measurement, total dissolved solids, electrical conductivity, measurement of water temperature and concentration of heavy metals.

DETERMINATION OF FLY ASH COMPOSITION

We got the composition of coal-ash detected from the pollution control board of Jabalpur (M.P).

FISH SAMPLING

There are many commercially important fishes are available in Chachai Dam *as Catla catla, Labeo rohita, Labeo bata, Cirrhinus mrigala, Cyprinus carpio, Ctenopharyngodon idella, Tilapia mossambica, Mystus seenghala, Mystus aor, Mystus cavasius, Wallago attu, Heteropneustes fossilis, Clarias batrachus, Channa punctatus, Channa marulius, Zebra danio and Mastacembelus armatus.*

I selected *Channa punctatus* for the experiment because

- **It is a bottom dwelling fish living direct contact with the fly-ash.**
- **It is an air- breathing fish.**
- **It has a short body length .**
- **Its acclimatization was easy.**
- **It required low maintenance.**
- **It was easily available.**

Fish *Channa punctatus* collected from local fish market during every season of the year and acclimatized in the laboratory aquarium with proper aeration and sun light and fed them fish food. The length and weight of the experimental fish ranged from 14.5 to 20.5 cm and 40 g to 60 g, respectively.

CALCULATION OF LC 50 FOR FLYASH OR ACUTE TOXICITY TEST

To estimate the 96 -hour median lethal concentration for acute toxicity, an experiment was conducted.. The average lethal concentration is the concentration of test chemicals representing the pollutant that killed 50% of the test animals in stock during a test time. Fresh water teleost fish *Channa punctatus* taken for the experiment were 14.5 to 20.5cm in length and 40gram to 60gram in weight.

Prior to the experiment, fishes were brought from the local market. Fishes have been acclimatized in laboratory conditions. Tap water was used for the experiment in the aquarium. Some Water Parameters Maintained like temperature from 26^{0}C to 30^{0}C, DO from 6.5 to 7.0 mg/L, pH from 7.0 to 7.5, TA from 175 to 180 mg/L, TH from 100 to 120 mg/L, Free Carbon dioxide from 2.0 to 2.5 mg/L.

Throughout acclimatization, fishes were fed frequently. 24 hours before the experiment feeding was stopped to avoids the interference of excretory materials on the composition of the test solution as Verma and Kasherwani described in their literature of 1980 and 2009 respectively. 20-liter glass tanks were used for the experiment. In each tank, 10 experimental fish were placed in fifteen (15) ltr of water. For each fly-ash concentration separate aquarium was exposed.

Simultaneously, a nontreated (not exposed to the toxicants) aquarium with10experimental fish was also maintained. As et of 4 glass tanks were used for one concentration of fly-ash. Means for the test of one concentration of fly-ash four replicates were used. Diverse concentrations of fly-ash were prepared for the test which was dissolved in water and then added to the test medium.

First, a rough range determining test was performed to determine the dosage range of fish at which mortality takes place. Every 24- hours, the mortality rate of the test fishes was recorded and all dead fishes were counted. Dead fish were immediately removed from the experimental aquarium to avoid any pathogenic contamination in the aquarium. Water was changed after 24 h in all test aquariums. As explained by the previous researchers like Al-Attar in 2005 and Dhara and others in 2013 in their literature. After 96 hours, the mortality rate of the experimental fishes were used to determine the LC 50 value using USEPA-1999 computer software.

At the end of 96 h, the fishes that had survived were anesthetized with clove oil at 100 mg/L, and processed for histopathological analysis.

STATISTICALANALYSIS

The mortality of experimental fish *Channa punctatus* at different concentrations of toxicant (fly- ash) and different times of unveiling (24 hours, 48 hours, 72 hours and 96hours) were evaluated by means of computer software USEPA-1999 and Probit analysis- 1971. This software's (USEPA-1999 and Probit analysis-1971) were also used to calculate LC 50 with Fly- Ash's 95% confidence limit.

HISTOLOGICAL STUDY

The kidney were removed from the fish body, both from treated and nontreated fish simultaneously. They were thoroughly wiped using blotting paper to remove blood and other body fluids before being cut into small pieces. Following this, the tissues were immediately fixed in a fixative for a period of 24 hrs.

Steps in volved in histological procedures
Following are the important steps for histopathological study-

Tissue Procurement Fixation Dehydration Clearing Infiltration Embedding Sectioning Staining Mounting

MICROPHOTOGRAPHY

After clearing the slides with xylene twice, they were mounted in DPX medium. The slides were then examined under a microscope, specifically the LEICA PM-5000, with a camera attachment for photographing at both high and low power resolutions. During examination, the nuclei appeared blue, while the cytoplasm displayed various shades of pink.

OBSERVATIONS

Observations were made in the following heads:-

- Results of water testing in the laboratory
- Details of Fly-ash composition
- Value of LC-50 for Fly-ash
- Histopathological observations of target organ (Kidney)

Results of water testing in the laboratory

Table:-1 Showing physico-chemical data of the water of Chachai Dam

S.N	Parameters	Unit	BIS-10500/WHO	Site-1	Site-2
	Physical Parameters				
1	pH	-	6.5-8.5	7.1	6.2
2	Temp	-	-	24.5	24.0
3	Turbidity	NTU	5	67	22
4	*TDS*	Mg/l	500	218	156
	Chemical Parameters				
5	DO	Mg/l	-	8.1	9.2
6	Total Hardness	Mg/l	300	178	110
7	Ca Hardness	Mg/l	-	110	68
8	Mg Hardness	Mg/l	-	48	38
9	Alkalinity	Mg/l	200	126	120
10	Chloride	Mg/l	250	56	18
11	Pb	Mg/l	0.05	18.2	14.6
12	Al	Mg/l	0.2	18.34	16.78
13	Fe	Mg/l	0.3	14.68	10.32
14	Cr	Mg/l	0.03	1.6	2.2

The turbidity of the water was significantly higher than the permissible limits, according to the table. Contamination levels of four metals: Lead (Pb), Aluminum (Al), Iron (Fe), and Chromium (Cr) were also high, exceeding the World Health Organization (WHO) target values.

FLY ASH COMPOSITION

Table-2:- Showing results of chemical parameters of fly-ash collected from the surrounding of Chachai Dam

S.N	TEST PARAMETERS	UNIT	RESULT
1	Magnesium oxide(MgO)	%	3.02
2	Aluminum oxide(Al_2O_3)	%	18.34
3	Phosphorus (P_2O_5)	%	0.74
4	Sulphate(SO_3)	%	2.46
5	Potassium (K_20)	%	2.92
6	Calcium(CaO)	%	2.29
7	Titanium(TiO_2)	%	<0.01
8	Manganese (MNO)	%	0.92
9	Iron (Fe_2O_3)	%	14.68
10	Sodium oxide(NaO)	%	0.89
11	Silicon dioxide(SiO)	%	47.32
12	Lead (Pb)	Ppm	18.2
13	Chromium (Cr)	Ppm	1.6
14	Loss of Ignition	%	3.09

During observations on fly-ash composition collected from the Chachai Dam, it was found significant amounts of Manganese (MNO), Potassium (K20), Chromium (Cr), Magnesium oxide (MgO), Sulphate (SO3), Iron (Fe2O3), Sodium oxide (NaO), Aluminum oxide (Al2O3) and Lead (Pb) in both studied ash (fly-ash and pond ash) as shown below.

Flyash – Manganese (0.92) <Chromium (1.6) <Sulphate (2.46) <Potassium (2.92) <Magnesium oxide (3.02) <Iron (14.68) <Lead (18.2) <Aluminum oxide (18.34) <Silicon dioxide (47.32) .

TABLE-3:- VALUE OF LC 50 FOR FLYASH

	24 hours	48 hours	72 hours	96 hours
Con. Of flyash (g/L)	Mortality percentage	Mortality percentage	Mortality percentage	Mortality percentage
1.0	10	10	10	10
3.25	10	10	20	20
3.50	10	10	20	30
4.50	10	20	30	40
5.25	20	20	40	40
6.25	20	20	40	50
6.50	30	30	50	60
7.50	40	30	50	70
8.25	40	50	60	70
9.50	50	60	70	80
10.0	60	70	90	90

S.N.	Duration	LC 50 values
1	24 hour's	15.98
2	48 hour's	11.02
3	72 hour's	08.33
4	96 hour's	06.02

VALUE OF LC- 50 FOR FLY-ASH

The observation aimed to collect data on the range of fly-ash concentrations that cause adverse effects in experimental fish within a specified exposure time, in order to determine the toxicity of fly ash based on a dose-response relationship. Various doses of fly-ash were administered to the test fishes during the experiment. Throughout the experiment, an increase in fish mortality was observed due to a corresponding rise in the concentration of coal ash. The experiment recorded the mortality rates of the test fishes and determined the Sub Lethal concentration (LC-50) of fly-ash at different time periods, using the Finney Probit Analysis Method of 1971. The LC-50 values for fly ash in the current experiment at standard time periods (24 h, 48 h, 72 h, and 96 h) are provided in Table-03.

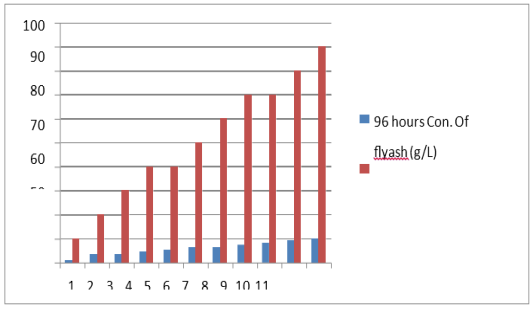


Figure-1:-Histogram showing relation between concentration of fly-ash and mortality in fish (Channa punctatus)

HISTOPATHOLOGICAL OBSERVATIONS OF TARGET ORGAN (KIDNEY)

Histopathological alterations are frequently utilized as a biomonitoring tool to assess the health status of fish that have been exposed to environmental pollutants. Fish are often employed in histological studies to understand the structural changes that take place in their organs as a result of pollutant effects. The nature of pollutants, body parts, duration of exposure, and quality of the medium can all lead to varying structural changes in fish organs.

The kidney is a crucial organ in the body, responsible for maintaining homeostasis. Its functions include the removal of waste from the blood and selective reabsorption, which helps regulate the volume and pH of blood and body fluids as well as erythropoiesis (Iqbal F, 2004). Due to the high volume of blood flowing through the kidney, it is an ideal organ for histological examination to identify potential environmental contamination based on any lesions found (Kadry SM, 2003). In environmental studies, fish muscles are commonly analyzed to assess the bioaccumulation of toxic metals and the resulting pathological changes (Soegianto Hamami A, 2007; Andreji J, 2006). These studies serve various purposes, many of which are linked to concerns about food security and public health (Ashoka, 2011).

In the current experiment, researchers studied the response of Channa punctatus fish kidneys to sublethal concentrations of fly ash (6.02g/L). During the observation, the fish treated with fly ash exhibited signs of illness, including skin rashes and erythematic (skin redness) condition, in comparison to the control group. Additionally, there was a noticeable change in the color of the fish's skin following the fly ash treatment.

Image-4: - Showing Erythematic and Rashes on the Skin of Experimental Fish(*Channa punctatus)*

As per Ogawa's classification of teleostian kidneys in 1961, *Channa punctatus* is categorized as having type II kidneys. The teleostian

kidney is comprised of a head kidney, which contains hematopoietic, lymphoid, and endocrine tissue, and a body kidney, which consists of multiple nephrons surrounded by interstitial lymphoid tissue. The head kidney, located at the front of the kidney, contains lymphoid tissue, while the body kidney is composed of numerous nephrons and intestinal lymphoid tissue. The interstitial tissue serves as the primary hematopoietic tissue in the body, and each nephron is made up of a glomerulus and a urinary canal. Bowman's capsule, which surrounds the glomerulus, is comprised of inner and outer layers of single flattened epithelium, and the renal tubules consist of a single layer of epithelial cells. The kidney plays a crucial role in maintaining the body's homeostasis in terms of water and salts.

In the current study, experimental *Channa punctatus* displayed an unhealthy kidney with histomorphological changes compared to the control fish, including degenerating epithelial cells of the uriniferous tubule, disintegration of epithelium, vacuolated epithelial cells of the uriniferous tubule, and the presence of hemorrhagic tissues (Image-07, 08).

Image-05: - Showing Position of the Kidney in Dissected Fish

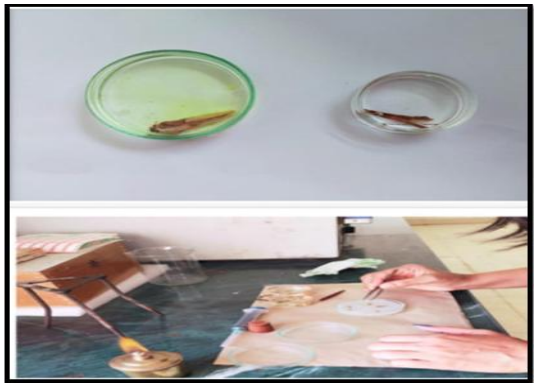


Image-06: -Showing, kidney after fixation in Petridish

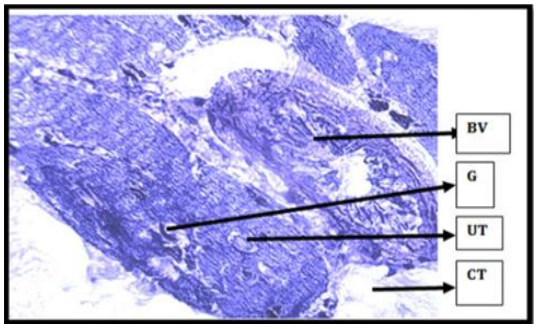
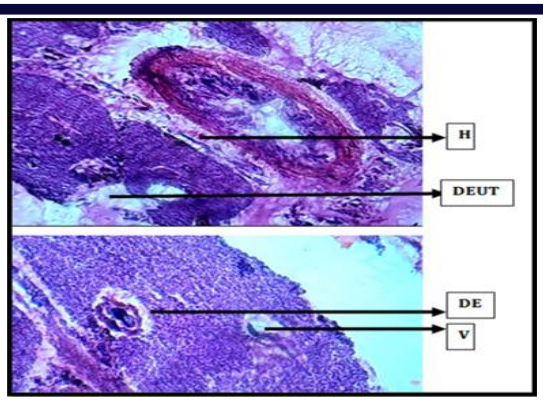


Image-07:-T.S. of Kidney of *Channa punctatus*, illustrating normal structure shows sections of uriniferous tubules (UT), (G) Glomerulus, blood vessels (BV) and connective tissues (CT) (X100-5µ).

Image-08:-T.S. of Kidney of *Channa punctatus*, illustrating the histomorphological Changes as evidenced by- Degenerating Uriniferous Tubule (DEUT), Disintegration of Epithelium (DE), Vacuolated Epithelium Cells of Uriniferous Tubule (V) and Haemorrhage (H) (X100-5µ).



DISCUSSION

In present observation it was found many alterations in the liver and kidney tissues of experimental fish *Channa punctatus*. These alterations might have due to accumulation of heavy metals found in fly-ash beyond the permissible limits of WHO as Mn (0.92), Cr (1.6), Sulphate (2.46), K (2.92), Magnesium oxide (3.02), Fe (14.68), Pb (18.2), Aluminum oxide (18.34), Silicon dioxide (47.32). The results of the present study are about similar as the above researchers (Abd El-Rahman AA, 2017), who noted hepatic and renal alterations in teleost fishes. In present study it was also observed that the occurrence of necrosis is one of the most visible damage in tissues affected by pollutants.

Water quality in any ecosystem provides crucial information about the available resources to support life within that ecosystem. A variety of physical, chemical, and biological parameters of water can indicate the quality of water bodies, which can fluctuate under the toxic effects of pollutants. In the current observation, the concentration of metals such as Pb, Al, Fe, and Cr was found to be significantly higher than the permissible limits set by the WHO and Indian Standards. Pollution has become a widespread issue, and each country bears responsibility due to anthropogenic activities, sewage and industrial waste disposal, mining, and leaching. Human activities are directly or indirectly polluting the environment for their own interests, particularly leading to the pollution of aquatic bodies as a result of increasing industrialization and urbanization. Various types of pollutants contaminate our water bodies, with a major concern focused on heavy metals. It is well-known that the presence of metals in the form of pollutants poses a significant danger, even in small amounts over a prolonged period, and has proven to have harmful effects on aquatic organisms.

CONCLUSION & SUGGESTIONS

- Recent research has confirmed that Coal Fly-ash is a significant contributor to aquatic pollution
- The contamination of the Sone River is attributed to the disposal of ash mixed hot waste water from a power plant, resulting in adverse effects on the river's physical and chemical parameters.
- The present study has identified various metals in fly-ash, with the following concentrations: Manganese (0.92), Chromium (1.6), Sulphate (2.46), Potassium (2.92), Magnesium oxide (3.02), Iron (14.68), Lead (18.2), Aluminum oxide (18.34), and Silicon dioxide (47.32). Excessive levels of metals such as Pb, Al, Fe, and Cr were found in water samples, surpassing the permissible limits set by the WHO and Indian Standards.
- In an experiment involving *Channa punctatus* fish exposed to coal fly -ash, the toxic levels were quantified in terms of LC-50 value.
- The sub-lethal (LC50) values for Channa punctatus were determined to be 15.98, 11.02, 08.33, and 06.02 g/l for exposure durations of 24h, 48h, 72h, and 96hrs.
- The survival rate of the fish decreased as the concentration and duration of exposure to fly ash increased.
- This study establishes a correlation between the duration of exposure and the concentration of fly ash, highlighting the lack of comprehensive data on the toxic levels of coal fly ash for fish.
- Notably, changes in the liver and kidney tissue of the experimental fish indicate the toxic effects of flyash on both fish and other aquatic flora and fauna.
- The implications of coal fly ash on human health, aquatic life, and the environment are of grave concern. India urgently needs to regulate the disposal of toxic fly ash from coal-fired power plants to mitigate the environmental and health risks faced by local communities.

- Attention must be directed towards addressing the significant carbon emissions resulting from mining and coal burning. Despite the evident risks posed by coal fly ash to both human health and the environment, it has received insufficient public attention, considering it is the residual product of coal combustion in thermal power plants.
- According to reports, states such as Madhya Pradesh (M.P), Odisha, Jharkhand, West Bengal, Tamil Nadu, Chhattisgarh, and Maharashtra have the highest concentration of coal-fired thermal power plants, leading to a high incidence of coal fly ash-related incidents.

SUGGESTIONS

- After coal combustion, it is essential to ensure proper treatment of fly -ash to minimize environmental impact.
- Ongoing monitoring of metals and other pollutants in water bodies is crucial to assess and address potential environmental hazards.
- The establishment and implementation of national environmental quality standards for water, as well as regulations for toxic metal content in fish, are necessary to safeguard public health and the environment.
- Government authorities, including pollution control boards, public health and engineering departments, and irrigation departments, play a vital role in understanding and effectively implementing their responsibilities for environmental protection.

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