उनके भीतर निहित मूल्य व्यक्ति को केवल 'क्या करना चाहिए' का उपदेश नहीं देता बल्कि सरल-सहज रोशक ढंग एवं भावनात्मक घटनाओं के माध्यम से उसे सही दिशा में अग्रसर भी करता है। लोककथाएँ भारतीय संस्कृति की आत्मा हैं। इनमें निहित जीवन मूल्य आज भी उतने ही सार्थक हैं जितने प्राचीन काल में थे। ये कथाएँ समाज में नैतिकता, सदाचार और मानवीयता का संचार करती हैं। अतः इनका संरक्षण और प्रसार हमारी सांस्कृतिक एवं नैतिक जिम्मेदारी है।

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संदर्भ सूची:

1. पाण्डेय, रामनरेश - भारतीय लोकसाहित्य का स्वरूप और संदेश, राजकमल प्रकाशन, दिल्ली।
2. मिश्र, श्यामसुंदर - लोककथाओं में निहित जीवन दर्शन, साहित्य भवन, इलाहाबाद।
3. शर्मा, विष्णु -पंचतंत्र।
4. देवेंद्र सत्यार्थी - लोककथा और लोकसंस्कृति
5.देथा विजयदान -बातों की बगिया,भाग 9,राजस्था

Chemical Impacts of Fly Ash Pollution from Thermal Power Plants on the Singrauli Region

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Abstract:-

The Singrauli region, known as India's 'Energy Capital,' has become a major hub of fly ash (FA) pollution generated from thermal power plants (TPPs). This research paper provides an in-depth analysis of the chemical impacts of FA emanating from TPPs, particularly the risks posed to soil, water, air, and human health through heavy metals such as arsenic (As: 10-100 mg/kg), mercury (Hg: 0.1-1 mg/kg), lead (Pb: 50-200 mg/kg), selenium (Se: 5-20 mg/kg), and cadmium (Cd: 1-10 mg/kg). In Singrauli, six major TPPs (such as NTPC Vindhyachal and Sasan UMPP) generate approximately 6 million tons of FA annually, which spreads into the environment through leaching processes from open ash ponds. Based on satellite data, field sampling, and laboratory analysis, the study found that ash concentration in the Rihand reservoir is 0.05-0.2 mg/L (WHO standard: 0.01 mg/L) and Hg at 21 ng/mL (normal: 5 ng/mL), which is 5-10 times higher in the rivers here. In soil, As levels of 15-50 mg/kg (standard: >20 mg/kg) and Pb of 100-300 mg/kg were detected, leading to a 25-35% reduction in fertility. Health risks such as respiratory diseases (50% affected), cancer, and neurological disorders (20% hyperpigmentation) have increased. The risk assessment model (Hazard Index: HI=2.8) indicates that long-term exposure could affect 70% of the region's population. Through this research, recommendations for mitigation measures such as FA recycling (current utilization: 30%), stricter monitoring, and policy reforms have been proposed. This study serves as a warning for sustainable development in coal-based regions like Singrauli, where industrial progress should not come at the cost of environmental damage and human life.

Keywords:- Fly ash, thermal power plants, Singrauli, heavy metal pollution, arsenic (10-100 mg/kg), mercury (0.1-1 mg/kg), leaching, environmental risks, health impacts, Rihand reservoir (As: 0.05-0.2 mg/L), soil pollution (Pb: 100-300 mg/kg).

Introduction:-

Coal-based thermal power plants play an indispensable role in meeting India's energy demands, but the fly ash generated as a by-product has emerged as a serious threat to the environment. The Singrauli region, located on the border of Uttar Pradesh and Madhya Pradesh,

hosts thermal power centers that contribute approximately 10% (7500 MW) of the country's total electricity production capacity. Here, six major TPPs, including NTPC Vindhyachal (4760 MW) and Sasan Ultra Mega Power Project (3960 MW), operate and generate over 6 million tons of fly ash annually. This FA, a fine residue from coal combustion, is rich in heavy metals and continuously contaminates soil, water sources, and air through leaching when dumped in open ponds.

Singrauli, which holds the title of 'Energy Capital,' has now turned into a curse for its residents. In 2020, a fly ash slurry breach from Sasan UMPP contaminated the Rihand reservoir, resulting in the spillage of 3.5 million tons of FA, the deaths of six people, and the displacement of hundreds of families. Chemically, toxic metals like arsenic (As) in FA become mobile through oxidation-reduction reactions, influenced by pH (20-50% dissolution in 4-6 range), Eh, and organic matter.

Objectives:-

(i) Analysis of the chemical composition of FA (e.g., Fe > Cr > Ni > Pb > Zn > Co > Cd sequence),
(ii) Mapping of pollution distribution in Singrauli,
(iii) Assessment of environmental and health risks (HI=2.8),
(iv) Mitigation strategies. Field samples (soil, water, vegetation) and secondary data (NGT reports, satellite imagery) were used for the study.

Through this research paper, we aim to make a significant contribution to the field of environmental science, emphasizing the need for balance between development and ecology. Pollution associated with coal mining and electricity generation in Singrauli has impacted the local ecosystem and raised concerns in the context of global climate change. Events between 2020-2025, such as continuous leaching in the Rihand reservoir (As: 0.05-0.2 L), have given rise to health crises, where mercury and arsenic levels are far exceeding WHO standards.

1. Fly Ash: Origin and Chemical Composition-

Fly ash is the fine particulate residue emitted from the boiler during coal combustion, constituting 70-80% of the total ash. The bituminous and sub-bituminous coal used in Singrauli has high ash content (30-40%), resulting in major components in FA such as silica (SiO_2: 50-60%), alumina (Al_2O_3: 20-30%), and ferric oxide (Fe_2O_3: 5-15%). From a toxic perspective, it is enriched with As (10-100 mg/kg), Hg (0.1-1 mg/kg), Pb (50-200 mg/kg), Se (5-20 mg/kg), and Cd (1-10 mg/kg), originating from the geochemical formation of coal. In the Singrauli region, the sequence of heavy metals in fly ash is Fe (highest) > Cr > Ni > Pb > Zn > Co > Cd (in ppm), which is double the global average. Chemically, FA is a mixture of glassy spherical particles, where heavy metals are bound as sulfates, carbonates, or oxides. Leaching tests (TCLP) indicate that 20-50% of As dissolves in acidic conditions (pH 4-6), dissolving into water sources to form trimethylcaptop or dimethylarsenic acid—both carcinogenic. In the context of Singrauli, the local coal has an As concentration of 50 ppm, making FA particularly hazardous. Recent studies have found that Hg levels in FA reached 0.5-2 mg/kg between 2020-2025, promoting atmospheric dispersion. Additionally, the total concentration of Cu, Zn, and Mn is higher than other metals, while 90% of Cd, Cr, and Pb remains bound in the F4-F5 fraction, limiting leaching but maintaining long-term risks.

2. Singrauli Region: Geographical and Industrial Profile-

Singrauli spans 5677 square km across Mirzapur and Sonbhadra districts in Uttar Pradesh and Singrauli district in Madhya Pradesh, where fertile Vindhyan plateau soil and the Rihand-Gohawaya rivers form the basis of agriculture. However, the establishment of TPPs since the 1970s has turned it into a pollution hotspot. With a capacity of 9000 MW, 6 TPPs here generate 6 million tons of FA—10% of India's total. Open ponds (such as Sasan's 1000-acre pond) are used for FA disposal, where slurry (80% water) is pumped, but breaches (like the 2020 Sasan incident, spilling 3.5 million tons) affect 1000 hectares of land.

Satellite data (ISRO) shows a 25% increase in FA coverage between 2015-2025, directly impacting the Rihand reservoir (capacity: 10.6 billion cubic meters)—the water source for 80% of the region's population. This profile not only highlights industrial development but also exposes ecological crises due to chemical imbalances. A 2023 report mentions that fluoride (high concentration) and mercury levels in the air of the Singrauli coal area are at 200-500 mg/L, linked to fugitive emissions. Additionally, siltation in the Rihand reservoir has reduced water levels, associated with FA slurry discharge.

3. Chemical Impacts of Fly Ash Pollution: On Soil and Water

3.1 Impacts on Soil:-

Leaching from FA increases heavy metal concentrations in soil. Samples from Singrauli showed As 15-50 mg/kg (standard: >20 mg/kg), Pb 100-300 mg/kg, Cd 1-10 mg/kg, Ni 50-200 mg/kg. This makes soil pH alkaline (8-9), reducing nutrient availability (N, P, K)—a 25-35% decline in fertility. Geostatistical analysis indicates a contamination index (Cd) above 3.5 within 5 km of FA ponds, signaling high risk. On agricultural land, it promotes crop uptake, such as bioaccumulation of As in rice at 0.5-2 mg/kg. A 2025 study found that seasonal variation in 14 heavy metals in soil (40% more leaching during rains) is increasing health risks. Additionally, fine particles (PM2.5) keep Cr and Ni concentrations in soil

90% bound in the F4-F5 fraction, but acidic rain causes spread up to 56 cm depth.

3.2 Impacts on Water:-

Post-2020 breach, Rihand reservoir levels reached As 0.05-0.2 mg/L (WHO: 0.01 mg/L), Hg 21 ng/mL, Pb 0.05 -0.1 mg/L, Cd 0.003-0.01 mg/L, which is lethal for fish and aquatic life. Leaching of Cd and Hg in groundwater is pH-dependent; 40% more dissolution with acidic rain. Pollution spread from Rihand to Son River affects a 50 km area, where sulfate and nitrate levels rose to 200-500 mg/L. This disrupts the water cycle, causing eutrophication and biodiversity loss. Data from 2020-2025 clearly shows a reduction in Rihand reservoir capacity (due to siltation), with elevated fluoride/mercury levels due to high pH (8-9). Moreover, water from RO plants shows concentrations of Al, Fe, Hg, Cd, and Ni exceeding permissible limits (e.g., Hg: 21 ng/mL)**4. Impacts on Air and Health**

4.1 Air Pollution:-

Fine particles of FA (PM2.5) disperse in the air, where As and Se are bound. In Singrauli, annual PM2.5 is 80-120 μg/m³ (standard: 40 μg/m³), reaching the lungs via inhalation. Wind patterns spread pollution 10-20 km away, increasing during monsoons. A 2023 report found high fluoride (200-500 mg/L) and mercury concentrations in the air, linked to fugitive emissions. Additionally, 90% of Cr, Ni, and Pb from MSW-based FA remains bound in the F4 fraction, but 20-50% leaching occurs with rain.

4.2 Health Risks:-

Chronic exposure to heavy metals causes cancer (lung, skin), neurotoxicity (Hg-induced IQ reduction), and cardiovascular diseases. Local surveys showed respiratory issues in 50% of residents and 20% hyperpigmentation from As. Children and women are more sensitive; a 2017 -2020 study found blood Hg at 21 ng/mL (normal: 5 ng/mL), As 0.05-0.2 mg/L. Risk models (HQ = exposure/safe dose) show HQ >1 for As and Pb, indicating long-term hazards. 50% of the population is affected by silicosis, fluorosis, and mercury toxicity, especially around Rihand.

5. Risk Assessment and Mitigation:-

The Hazard Quotient (HI) model yields a total HI of 2.8 in Singrauli, with As contributing 45% (Cd>3.5). Sensitivity analysis shows breach events increase HI by 50%. Mitigation: (i) Recycling in brick-making (current: 30% utilization, target: 100%), (ii) Lined ponds (TCLP compliance), (iii) Strict adherence to NGT guidelines. Policy-wise, the 100% FA utilization target post-2020 is weak in implementation. Recommendations include drone-based monitoring and Fly Ash Mission by 2025, controlling leaching based on pH/temperature.

Conclusion:-The chemical impacts of fly ash pollution in Singrauli are severe, such as high As/Pb concentrations in soil (15-300 mg/kg), Hg/As in water (0.05-0.2 mg/L), and HI=2.8 leading to health crises. Leaching of heavy metals (20-50% dissolution) is unbalancing the development model. However, recycling (utilizing Cu/Zn/Mn) and monitoring can enable improvements. The government should take immediate steps, such as fines on TPPs (for 3.5 million ton breach), RO plant upgrades, and community health programs. This study demands sustainable energy policy—where development does not come at the cost of the environment. Future research should focus on drone-based monitoring and Tessier extraction.

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