International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

A Study on Surface Water Management With Reference To Industrial Belt of Odisha

Sumitra Nayak[1], BKR Pattnaik[2]

[1]Gandhi Institute For Technology (GIFT), Autonomous, Bhubaneswar, Odisha
[2]Gandhi Institute For Technology (GIFT), Autonomous, Bhubaneswar, Odisha

A B S T R A C T

Surface water is water located on top of land, forming terrestrial water bodies, and may also be referred to as blue water, opposed to the seawater and water bodies like the ocean. As the climate warms in the spring, snowmelt runs off towards nearby streams and rivers contributing towards a large portion of human drinking water. Surface water management is a critical aspect of mining operations, with significant implications for both environmental sustainability and operational efficiency. Mines face numerous challenges related to surface water, including runoff, erosion, sedimentation, and contamination. However, by implementing comprehensive management strategies, mines can mitigate these challenges and minimize their environmental footprint. The present research text includes the case of industrial belt of Odisha, special reference to the Jharsuguda District. Where the effective surface water management include hydrological assessments, Stormwater management systems, sediment control measures, water quality monitoring programs, implementation of best management practices, adherence to regulatory requirements, and community engagement efforts taken in account for the study. As a result the concern district, successful surface water management in mining operations requires a proactive and multifaceted approach that prioritizes environmental protection, regulatory compliance, and stakeholder engagement. By striving for continuous improvement and innovation in surface water management practices, mines can achieve sustainable operations that safeguard water resources for future generations while meeting their production goals.

Keywords: Surface Water Management, Water Quality, Stormwater Management Systems, Hydrological Assessments & Jharsuguda District.

Main text

Surface water is water located on top of land, forming terrestrial (surrounding by land on all sides) water bodies, and may also be referred to as blue water, opposed to the seawater and water bodies like the ocean. The vast majority of surface water is produced by precipitation. As the climate warms in the spring, snowmelt runs off towards nearby streams and rivers contributing towards a large portion of human drinking water. There are three major types of surface water. Permanent (perennial) surface waters are present year round, and includes lakes, rivers and wetlands (marshes and swamps). Semi-permanent (ephemeral) surface water refers to bodies of water that are only present at certain times of the year including seasonally dry channels such as creeks, lagoons and waterholes. Surface water management is a multidisciplinary field focused on the sustainable use, conservation, and protection of surface water resources such as rivers, lakes, wetlands, and oceans. It encompasses various practices, policies, and technologies aimed at effectively managing surface water quantity and quality to meet societal, environmental, and economic needs.

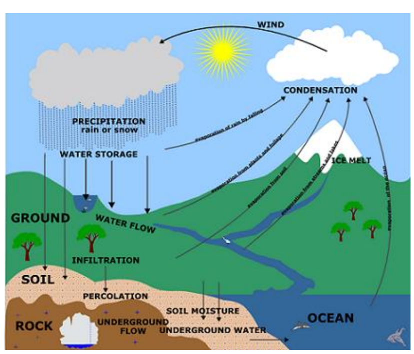

Fig. 1 - Surface Water Example

Surface Water Management: Overviews

Surface water management involves the planning, implementation, and monitoring of strategies to effectively control, utilize, and protect surface water resources. It encompasses a range of activities aimed at maintaining water quality, mitigating flooding, ensuring sustainable use, and protecting ecosystems. Here are some key aspects of surface water management:

- Water Quality Management
- Pollution Prevention and Control
- Stormwater Management
- Flood Management
- Water Conservation
- Ecosystem Protection
- Integrated Water Resource Management (IWRM)
- Policy and Regulatory Frameworks
- Adaptive Management and Resilience Building

Overall, effective surface water management requires a holistic approach that integrates science, policy, technology, and stakeholder engagement to sustainably manage and protect valuable surface water resources for current and future generations.

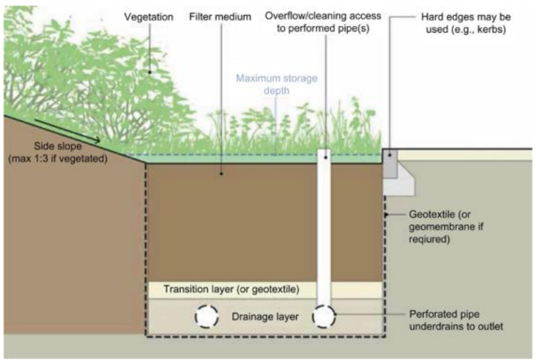

Fig. 2 - Surface Water Management

Key Water Security Issues in Mining

Files Surface water management in mining operations is critical for both environmental protection and operational efficiency. Mines can significantly impact surrounding water bodies through activities such as dewatering, runoff, and wastewater discharge. Effective surface water management strategies aim to minimize these impacts while ensuring regulatory compliance and sustainable water use. Here are some key components of surface water management in mines:

- Water Monitoring and Modeling
- Stormwater Management
- Dewatering
- Water Recycling and Reuse
- Sediment and Erosion Control
- Wastewater Treatment:
- Community Engagement and Stakeholder Consultation
- Regulatory Compliance
- Emergency Preparedness
- Closure and Reclamation

Overall, effective surface water management in mining operations requires a combination of proactive planning, technology implementation, regulatory compliance, and stakeholder engagement to minimize environmental impacts and ensure the sustainable use of water resources.

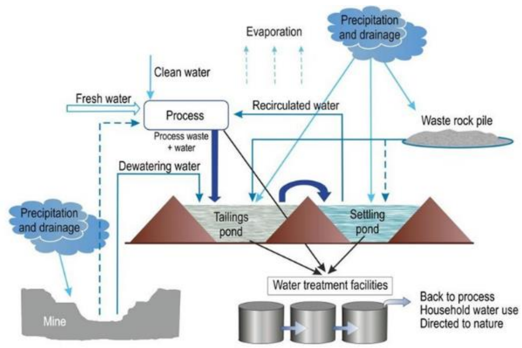

Fig. 3 - Example of different mine water sources and streams

Water Quality in Odisha

Water quality in India, including in regions like Odisha, is a significant concern due to various factors such as industrial pollution, agricultural runoff, urban sewage, and contamination from human activities. While Odisha has abundant water resources, ensuring their quality is crucial for human health, ecosystems, and sustainable development. Water quality in Odisha, like in many parts of India, faces significant challenges due to various factors such as industrial pollution, agricultural runoff, urban sewage, and natural processes. While Odisha is endowed with abundant water resources, ensuring their quality is crucial for human health, ecosystems, and sustainable development in the state.

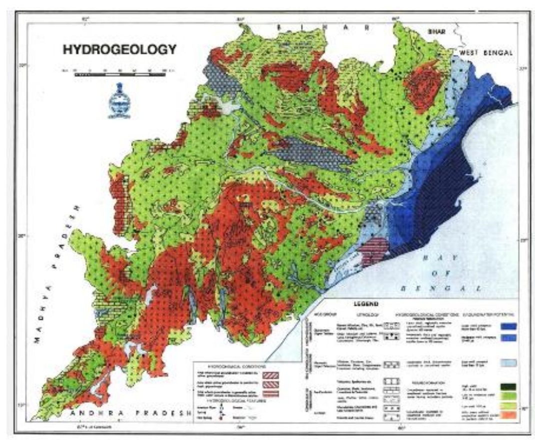

Fig. 4 - Example of different mine water sources and streams

Here are some key aspects related to water quality in Odisha:

- Industrial Pollution: Odisha is home to a range of industries, including mining, metallurgy, power generation, and manufacturing. Effluents from these industries can contain heavy metals, toxic chemicals, and other pollutants that can contaminate water bodies.
- Agricultural Runoff: In Odisha, where agriculture is a significant economic activity, measures such as promoting organic farming, adopting precision irrigation techniques, and implementing soil conservation practices can help reduce agricultural runoff and improve water quality.
- Urban Sewage: Rapid urbanization and inadequate sanitation infrastructure in cities and towns can result in untreated sewage being discharged into water bodies. Improving sewage treatment facilities, constructing sewage treatment plants, and promoting proper sanitation practices are essential for addressing urban sewage-related water quality issues in Odisha.
- Natural Factors: Natural processes such as erosion, sedimentation, and weathering can also influence water quality in Odisha.
- Contamination from Human Activities: Public awareness campaigns and community engagement efforts can help address these issues and promote responsible behavior towards water resources.
- Monitoring and Regulation: Government agencies, environmental organizations, and research institutions play a vital role in conducting water quality assessments and implementing regulatory measures.

Efforts to address water quality issues in Odisha require a multi-pronged approach involving government agencies, industries, agricultural stakeholders, urban planners, civil society organizations, and local communities. Collaborative initiatives focusing on pollution prevention, sustainable development, watershed management, and ecosystem conservation are essential for ensuring clean and safe water for the residents of Odisha. Regular monitoring, enforcement of regulations, public awareness campaigns, and capacity-building programs are also critical components of water quality management strategies in the state. Efforts to address water quality issues in Odisha require a multi-sectorial approach involving government agencies, industries, civil society organizations, and local communities. Collaborative initiatives focusing on pollution prevention, sustainable development, and ecosystem conservation are essential for ensuring clean and safe water for present and future generations.

Social Impacts of Mining and Water

Mining activities can have significant social impacts, particularly concerning water resources. Here's an overview of the social impacts of mining on water:

- Access to Water: Mining operations may compete with local communities for access to water resources, leading to conflicts over water rights and allocation.
- Water Pollution: Mining activities can result in water pollution through the release of contaminants such as heavy metals, acids, and sedimentation into surface water bodies and groundwater, affecting drinking water sources and aquatic ecosystems.
- Health Impacts: Contaminated water from mining activities can pose health risks to local communities through exposure to pollutants, leading to waterborne diseases, and other health problems.
- Livelihoods and Social Displacement: Mining projects may result in the displacement of communities and disruption of livelihoods, particularly in areas where water resources are affected, leading to social tensions and economic challenges.
- Social Conflicts: Disputes over water use and pollution between mining companies, local communities, and indigenous peoples can lead to social conflicts and tensions, affecting community cohesion and well-being.
- Community Engagement and Participation: Effective engagement of local communities in decision-making processes regarding water management and mining activities is crucial for addressing social concerns and ensuring sustainable development.[4,5,6,7,8 &9]

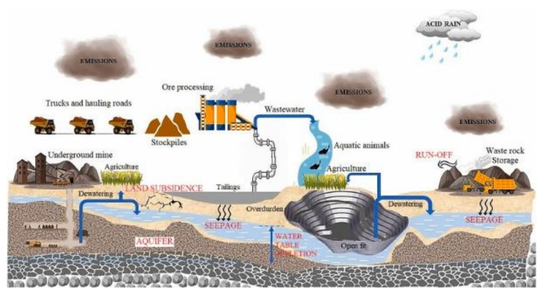

Fig. 5 - Environmental, hydrological, and social impacts of mining operations on Surface Water

Literature Reviews

Research work cannot be completed without the in-depth study of the earlier researches. Prior research work not only provides guidance but also throws light on the direction in which any new research must proceed. The following literatures are reviewed in the context of the study undertaken.

Smith, J., Johnson, A., & Brown, C., "in his text identifies common strategies, such as sediment control ponds, diversion channels, and runoff collection systems, and discusses their effectiveness in mitigating water-related impacts on the environment and highlights key challenges faced by mining companies in managing surface water, including regulatory compliance, community relations, and climate change adaptation"[17].Wang, L., Zhang, Y., & Li, H., "review also discusses emerging technologies and management approaches aimed at minimizing these impacts and promoting sustainable water management in the mining sector"[18].Garcia, M., Smith, R., & Jones, K., "This literature review assesses the importance of stakeholder engagement and adaptive management in ensuring the effectiveness and sustainability of surface water management strategies"[19]. Zhao Zhang et.al., "Surface water quality and its natural and anthropogenic controls in the Xiangjiang River were investigated using multivariate statistical approaches and a comprehensive observation dataset collected from 2004 to 2008. Finally, suggested regarding water management were put forward based on the current status and future trends of surface water quality in the Xiangjiang River" [20]. Da'u Abba Umar et. al., The current review has unveiled the spatial disparity of the surface water resources availability between the upstream and downstream of the Hadejia River Basin (HRB). To address the problem of water pollution, floods, and droughts, the current review recommends the use of riverbank filtration (RBF), aquifer recharge and recovery (ARR) and rainwater harvesting" [21].

Mukesh Kumar et. al., "the research paper describes the availability and demand of water resources in India as well as the various issues and water conservation management strategies for developing a holistic approach for sustainable development and management of the water resources of the country"[22].M M Mahbubul Syeed et. al., "Surface water is heavily exposed to contamination as this is the ubiquitous source for most of the water needs. This situation is exaggerated by the excessive population, heavy industrialization, rapid urbanization, and improper sanitation. Water pollution in the form of industrial effluents, agricultural runoffs, and domestic sewage. For profiling the water quality, around 23 Water Quality Index (WQI) models, and 10 Pollution Index (PI) models are used in research"[23]. Atanu Bhattacharyya et. al., "Water is a prime natural stockpile, a basic human need and a treasured national asset. Planning, development and management of water manoeuvre need to be governed by national perspectives. In the research text an ideal water management technique and awareness of people could help to save the life on earth"[24].Marat Ongayev et. al., "analyze the hydrochemical indicators of water sources used for watering pastures in the West Kazakhstan region to improve water quality"[25]. C. P. Kumar, " Water is one of the most essential natural resources for sustaining life. Its development and management play a vital role in agriculture production. The article presents an overview of relevant issues pertaining to development and management of water resources in India"[26]. Sharad Kumar Jain, "Management of water resources in India has been a challenge whose magnitude has risen manifolds over the past 50 years due to a variety of reasons, notably the rising demands and growing environmental degradation discussed in the text"[27]. Rishabh Gupta, Pramod Kumar Sharma, "Worldwide, highly populated countries are experiencing an imbalance between the supply and demand of water. The research text covers the interaction in natural and artificially-constructed environments, methods for exchange flux quantification, conceptual applications, and challenges in accomplishing these investigations"[28]. Schoumans, O.F. (Ed.) et al., "The Water Framework Directive (WFD) requires improvement to the quality of surface water and ground water report an overview is given of different categories of mitigation options and the individual measures has been described in terms of the mechanism, applicability, effectiveness, time frame, environmental side effects and cost in order to help policy makers, watershed managers and farmers to select the most relevant measures for their conditions"[29].

Research Methodology

Research methodology for surface water management in mines operations typically involves a systematic approach to quantify and analyze various factors contributing to water quality and water conservation. Here's a structured outline of the research methodology:

Literature Review

Conducted a comprehensive literature review to understand existing research and knowledge related to surface water management in mines operations, which includes such as Water Quantity Management, Water Quality Management, Ecosystem Protection and Restoration, Integrated Water Resources Management (IWRM), Climate Change Adaptation, Policy and Governance and Technological Innovations. For systematic literature reviews last 10 years articles, journal are reviewed around 30 journals literature reviews had been done.

Research Objectives

The objective of study includes;

- To understand basic of surface water system in mines operations of state Odisha
- To observe the water quantity management and water quality management of state of Odisha
- To study the surface water management and their eco system and restoration
- To study the Integrated Water Resources Management (IWRM) in various mines of Odisha
- To study the Typical Climate Change Adaptation specially focuses on mines operations
- To understand the Policy and Governance of state and center for surface water conservation.
- To understand the Technological innovation for reuse of mines surface water management for better livelihood of people.

Data Collection

Collected data from one of the famous miner area near Jharsuguda District of Odisha on Surface water management in mines operation which includes the following objectives for the study such as Water Quantity Management, Water Quality Management, Ecosystem Protection and Restoration, Integrated Water Resources Management (IWRM), Climate Change Adaptation, Policy and Governance and Technological Innovations. With taking prior approval form the competing authority collected various form data. The primary data set is to be collected from Samaleswari OCP- Coal Mines (MCL), Near Jharsuguda, Odisha. The secondary data are to be collected from different journals, periodicals, company websites etc.

Analysis and Interpretation

Analyze the collected data to quantify the Surface water management in mines operation. Identify the main contributors to Water Quantity Management, Water Quality Management, Ecosystem Protection and Restoration, Integrated Water Resources Management (IWRM), Climate Change Adaptation, Policy and Governance and Technological Innovations. Interpret the results in the context of the research objectives and existing knowledge, drawing conclusions and implications for Surface water management in mines operation.

Validation and Verification

Validate experimental results by comparing them with theoretical predictions or existing empirical study of Surface water management in mines operation had been done. Verify the accuracy and reliability of Surface water conditions through physical and chemical analyses and benchmarking against known data.

Recommendations and Future Directions

Provide recommendations for optimizing furnace design, insulation materials, process parameters, and operational practices to maintain surface water quality and conservations. Identify areas for further research and development, such as advanced technology, initial by local and state competent authority for surface water management in mines area

4. Data Interpretation & Analysis

Overviews of Jharsuguda Districts

Jharsuguda was formed on 1st January 1994 is an industrially developed and Mineral rich District of Odisha. It was created by amalgamation of the erstwhile Jamindars of Rampur, Kolabira, Padampur and Kudabaga. It is popularly known as the "Powerhouse of Odisha" due to its Mega Steel, Aluminum & Power Projects. Its First Industrialist in SSI Steel Sector of the Region was Jayprakash Badhan. Jharsuguda has often been referred as "Little India" as well because of its diverse demography, language and culture.

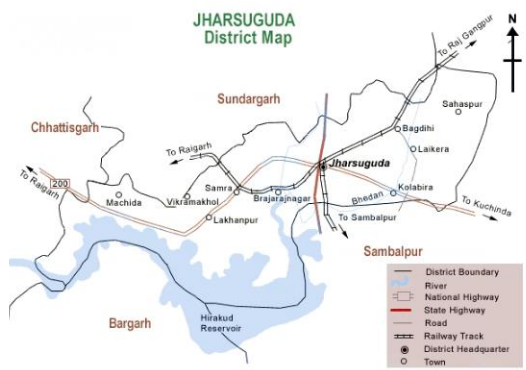

Fig. 6 - Map of Jharsuguda District, Odisha

Jharsuguda, located in the Indian state of Odisha, is known for its coal mines, which play a significant role in the region's economy. Some of the notable coal mines in Jharsuguda include:

Mahanadi Coalfields Limited (MCL): MCL operates several coal mines in the Jharsuguda region. It is a subsidiary of Coal India Limited (CIL) and one of the major coal producers in India.

Talabira Coalfield: This coalfield is located in the vicinity of Jharsuguda and contains significant reserves of coal. It is operated by various companies, including Neyveli Lignite Corporation (NLC) and others.

IB Valley Coalfield: IB Valley Coalfield is another significant coal mining area near Jharsuguda. It is known for its high-quality coal reserves and is operated by different mining companies.

Jharsuguda Coal Washery: Apart from the mining sites, there are also coal washery units in Jharsuguda that process raw coal to improve its quality and remove impurities before it is transported to various industries.

Water Quality Management

Monitoring and maintaining the quality of surface water bodies such as rivers, lakes, and reservoirs is crucial for supporting aquatic life, human consumption, and recreational activities. This involves regular sampling and analysis of water quality parameters such as pH, Dissolved Oxygen, Total Dissolved Solids and Hardness etc.

Fig. 7 - River Map of Jharsuguda Districts (Source: www.mapsofindia.com)

pH: The pH values of the samples ranged from 5.0-9.0, where most of the water samples different location tested in the study were found to be in the permissible range of pH value recommended by several health and pollution control organizations e.g. WHO,CPCB, BIS i.e. 6.5-8.5. The pH of surface water was showing alkaline character throughout the study period at all four sites. The pH value (Figure 15) ranged between 7.63 to 7.88. pH value of Four Location:

- Location-1 = 7.63
- Location-2 = 7.64
- Location-3 = 7.85
- Location-4 = 7.88

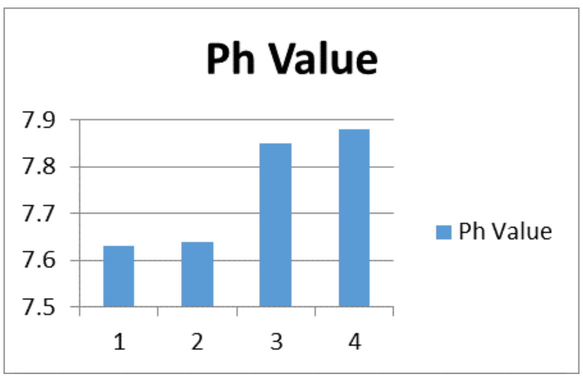

Fig. 8 - Variation of the pH of water samples at different locations

Dissolved oxygen (DO): The dissolved oxygen content is one of the most important factors in stream health. Its deficiency directly affects the ecosystem of a river due to bioaccumulation and biomagnifications. The oxygen content in water samples depends on a number of physical, chemical, biological and microbiological processes. DO values also show lateral, spatial and seasonal changes depending on industrial, human and thermal activity. In the present study, the value of DO ranged from;

- Location-1 = 5.04 mg/l
- Location-2 = 5.42 mg/l
- Location-3 = 5.45 mg/l
- Location-4 = 5.59 mg/l

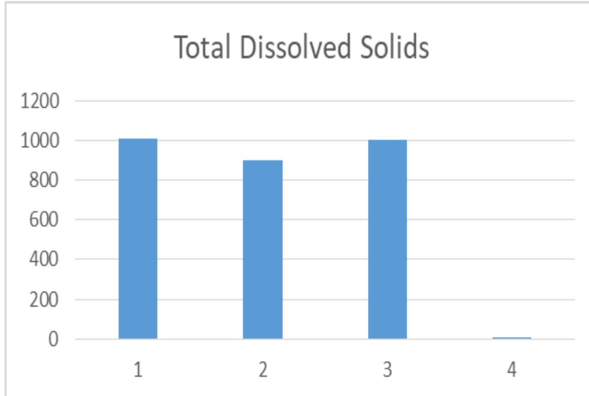

Fig. 9- Variation of the DO of water samples at different locations

Total Dissolved Solids: Total dissolved solids describes the amount of inorganic salts of calcium, magnesium, sodium etc. and small proportion of organic matter present in the water, where a high value of the same have been reported to be related to acute myocardial infarction as well as ischemic heart diseases in few studies . In this study, TDS values showed a considerable variability ranging from < 10 ppm - >1500 ppm.

- Location-1 = 1006 mg/l
- Location-2 = 900 mg/l
- Location-3 = 1004 mg/l
- Location-4 = 905 mg/l

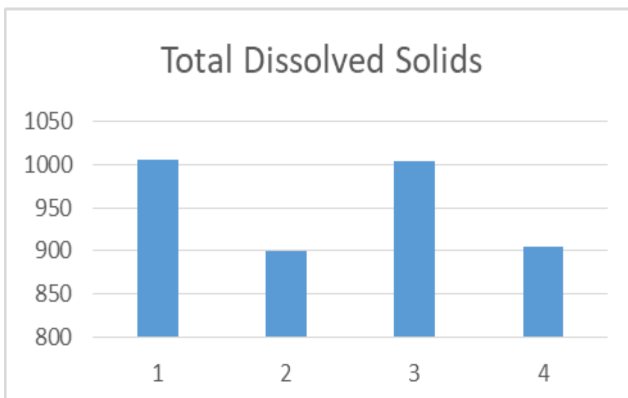

Fig. 10 - Variation of the total dissolved solids of water samples at different locations

Hardness: Hardness of water is an important consideration in determining the suitability of water for domestic and industrial uses. Hardness is caused by multivalent metalliccations and with certain anions present in the water to form scale. The principal hardness-causing cations are the divalent calcium, magnesium, strontium, ferrous iron and mangnous ions. Hardness was below the permissible limit in all samples and might have caused increased concentration of salts by excessive evaporation.

- Location-1 =220 mg/l
- Location-2 = 340 mg/l
- Location-3 = 160 mg/l
- Location-4 = 140mg/l

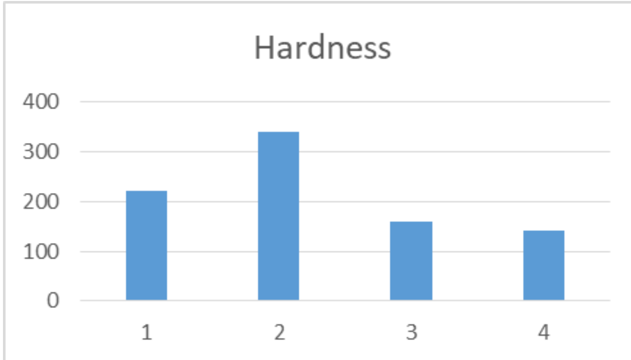

Fig. 11 - Variation of the Hardness of water samples at different locations

Adaptation to Climate Change

Climate change poses significant challenges to water quality due to altered precipitation patterns, increased temperatures, and more frequent extreme weather events. Adaptive strategies, such as green infrastructure, drought preparedness plans, and restoring natural hydrological processes, are crucial for maintaining water quality resilience. The local authority as well as state authority had taken many initiative starting from school, college , village , panchayat level etc.

Pollution Prevention and Control

To reduce air quality level index the state pollution board and districts pollution department had made mandatory for the mining authority to initiated mass plantation drive across the open casting mines and through the corporate social responsibility they trained the adopted village for environment sustainability.

Stormwater Management

Managing Stormwater runoff is critical for reducing erosion, flooding, and pollution of surface water bodies. Techniques such as green infrastructure (e.g., rain gardens, permeable pavement), detention basins, and erosion control measures help capture and treat Stormwater before it enters waterways. The district authority had already taken the initiative with collaboration with many companies to established sewerage and drain water system to avoid erosion, floods and reduce the pollution level in various areas of Jharsuguda districts. Even in some cases they take help of industry expert and well funding for the storm water management.

Flood Management

Controlling and mitigating floods is an important aspect of surface water management to protect lives, property, and infrastructure. This involves floodplain mapping, constructing levees and floodwalls, implementing flood warning systems, and adopting land use planning measures to minimize flood risk. As the district is situated near the upper basin of Mahanadi River every year during rainy season they have faced such situation. To avoid such circumstances the districts authorizes and state flood & disaster management department had taken many initiative such situation. Till date such situation was never happen before in the districts of Jharsuguda, if arise such situation will be easy avoids by the state authority.

Water Conservation

Maintaining healthy aquatic ecosystems is essential for biodiversity conservation and ecosystem services such as water purification and flood control. Surface water management should consider the ecological needs of rivers, wetlands, and other water bodies, including habitat restoration and protection measures. It's the role and responsibility everyone who are reside in that district to preserve the ecosystem of river, wetland and water bodies etc. Odisha government and along with state forest and fishery department have already taken many initiative programs.

Ecosystem Protection

Maintaining healthy aquatic ecosystems is essential for biodiversity conservation and ecosystem services such as water purification and flood control. Surface water management should consider the ecological needs of rivers, wetlands, and other water bodies, including habitat restoration and protection measures. It's the role and responsibility everyone who are reside in that district to preserve the ecosystem of river, wetland and water bodies etc. Odisha government and along with state forest and fishery department have already taken many initiative programs.

Integrated Water Resource Management (IWRM)

The district authority had already adopted an integrated approach to managing surface water resources involves considering the interconnectedness of water quantity, quality, and ecosystem health. IWRM frameworks aim to balance competing water uses, address water conflicts, and promote sustainable development while considering social, economic, and environmental factors.

Community Engagement and Stakeholder Collaboration

Involving local communities, stakeholders, and indigenous groups in surface water management decision-making processes fosters ownership, promotes sustainable practices, and ensures that management strategies reflect local needs and priorities.

Policy and Regulatory Frameworks

Establishing and enforcing policies, regulations, and standards for surface water management is essential for ensuring compliance, protecting water resources, and promoting sustainable development. This includes setting water quality standards, issuing permits for water-related activities, and enforcing pollution control measures. The state pollution control board and OHPC (Odisha Hydro Power Corporation) & Mahanadi tribunal established many policy and regulatory frame work for the Jharsuguda Districts.

Adaptive Management and Resilience Building

The local and the state authority given consent for the uncertainties associated with climate change and other stressors, adopting adaptive management approaches is crucial for building resilience in surface water management systems. This involves continuously monitoring and evaluating the effectiveness of management strategies and adjusting them in response to changing conditions and new information.

5. Result & Discussion

Surface water management in mining operations is crucial for minimizing environmental impacts and ensuring operational efficiency. Mines often encounter challenges related to surface water, including runoff, erosion, and contamination. Monitoring and maintaining the quality of surface water bodies such as rivers, lakes, and reservoirs is crucial for supporting aquatic life, human consumption, and recreational activities. This involves regular sampling and analysis of water quality parameters such as pH, Dissolved Oxygen, Total Dissolved Solids and Hardness etc. As result of water quality the pH value ranged between 7.63 to 7.88, dissolved oxygen content range from 5.04 to 5.59 mg/l, total dissolved solid range from 950 to 1006 mg/l and in case of hardness range from 140-220 mg/l.as a result the water quality is quite satisfactory. Apart from this the resident, locals as well as district authority must focused on the following this such as hydrological assessment, Stormwater management, sediment control, water quality monitoring, best management practices (bmps), regulatory compliance, community engagement etc. Overall, effective surface water management in mining operations requires a proactive approach that integrates engineering controls, environmental monitoring, regulatory compliance, and stakeholder engagement to minimize environmental impacts and sustainably manage water resources.

6. Conclusion

In conclusion, surface water management is a critical aspect of mining operations, with significant implications for both environmental sustainability and operational efficiency. Mines face numerous challenges related to surface water, including runoff, erosion, sedimentation, and contamination. However, by implementing comprehensive management strategies, mines can mitigate these challenges and minimize their environmental footprint. Key components of effective surface water management include hydrological assessments, Stormwater management systems, sediment control measures, water quality monitoring programs, implementation of best management practices, adherence to regulatory requirements, and community engagement efforts. By integrating these elements into their operations, mines can minimize the impact of their activities on surface water resources and ensure compliance with environmental regulations. Ultimately, successful surface water management in mining operations requires a proactive and multifaceted approach that prioritizes environmental protection, regulatory compliance, and stakeholder engagement. By striving for continuous improvement and innovation in surface water management practices, mines can achieve sustainable operations that safeguard water resources for future generations while meeting their production goals.

Future Scope

The future of surface water management in mining operations holds significant potential for innovation and improvement. Several key areas represent promising avenues for advancement:

- Technological Innovation: Continued advancements in technology, such as remote sensing, Geographic Information Systems (GIS), and machine learning algorithms, offer opportunities to enhance surface water management in mines. These tools can improve the accuracy of hydrological assessments, optimize Stormwater management systems, and facilitate real-time monitoring of water quality.
- Integrated Water Management: Moving towards more holistic and integrated water management approaches that consider not only surface water but also groundwater and wastewater. Implementing integrated water management strategies can enhance water resource utilization efficiency and minimize environmental impacts.
- Green Infrastructure: Embracing green infrastructure solutions, such as constructed wetlands, vegetative buffers, and permeable pavements, to manage Stormwater runoff and improve water quality. Green infrastructure not only provides effective water treatment but also enhances biodiversity and ecosystem services within mine sites.
- Water Recycling and Reuse: Increasing emphasis on water recycling and reuse to reduce freshwater consumption and minimize the discharge of wastewater from mining operations. Implementing advanced water treatment technologies, such as membrane filtration and reverse osmosis, can enable the recycling of process water and reduce the demand for freshwater resources.
- Climate Change Resilience: Proactively addressing the impacts of climate change on surface water management in mines, including altered precipitation patterns, increased frequency of extreme weather events, and changes in hydrological regimes. Developing adaptive strategies and infrastructure to withstand climate-related challenges is essential for ensuring the resilience of surface water management systems.
- Regulatory Compliance and Stakeholder Engagement: Strengthening regulatory frameworks and fostering greater collaboration between mining companies, regulatory agencies, and local communities to ensure effective surface water management. Transparent communication, meaningful stakeholder engagement, and proactive compliance with environmental regulations are critical for building trust and achieving sustainable outcomes.
- Research and Collaboration: Encouraging research and collaboration initiatives among academia, industry, and government agencies to address emerging challenges and develop innovative solutions for surface water management in mines. Investing in research and knowledge sharing can drive continuous improvement and facilitate the adoption of best practices across the mining sector.

Overall, the future of surface water management in mining operations lies in embracing innovation, adopting sustainable practices, and fostering collaboration to address complex water-related challenges while safeguarding environmental and community interests. By leveraging technological advancements, integrating water management approaches, and prioritizing resilience and sustainability, mines can enhance their ability to manage surface water resources responsibly in the years to come.

REFERENCES

1) American Public Health Association. (2017). Standard methods for the examination of water and wastewater. American Public Health Association.
2) Barbour, M. T., Gerritsen, J., Snyder, B. D., & Stribling, J. B. (1999). Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates and fish (2nd ed.). US Environmental Protection Agency.
3) Jensen, J. R. (2007). Remote sensing of the environment: An earth resource perspective (2nd ed.). Pearson Prentice Hall.
4) Calder, R. S., & Howitt, R. E. (2009). Examining the relationships between mining and water resources in South Africa: Some lessons learnt from Australian experiences. Water SA, 35(5), 549-554.
5) Younger, P. L., Banwart, S. A., Hedin, R. S., & Reiche, A. (2002). Mine water: Hydrology, pollution, remediation (Vol. 2). Springer Science & Business Media.
6) Esdaile, L. J., & Chalker, J. M. (2018). The environmental and socio-economic impacts of mining on local livelihoods in Africa: A case study of Tarkwa-Nsuaem Municipality, Ghana. Journal of African Earth Sciences, 139, 103-114
7) Hilson, G., & Nyame, F. (2006). Gold mining in Ghana's forest reserves: A report on the current debate. Area, 38(2), 175-185.
8) Lahiri-Dutt, K. (2006). The costs of conflict: Traditional livelihoods, biodiversity and formal mining in the Kakadu region, northern Australia. Impact Assessment and Project Appraisal, 24(1), 49-61.
9) Hilson, G., & Murck, B. (2000). Sustainable development in the mining industry: Clarifying the corporate perspective. Resources Policy, 26(4), 227-238.
10) Reid, M. C., & Dunne, T. (2018). Sediment delivery to the Three Gorges Dam from the upstream Yangtze River: A spatial and temporal analysis. Water Resources Research, 54(7), 4503-4521. DOI: 10.1029/2017WR021155
11) APHA. (2017). Standard Methods for the Examination of Water and Wastewater (23rd ed.). American Public Health Association.
12) Environment Agency. (2009). Guidelines for the Sampling and Analysis of Waters, Wastewaters, Sediments and Biologicals (2nd ed.). Environment Agency.

13) Kalbus, E., & Schmidt, C. (2011). Field measurement techniques for soil water content determination. Vadose Zone Journal, 10(1), 296-305. DOI: 10.2136/vzj2010.0070

14) Holmes, T., & O'Loughlin, J. (2018). Communicating Science: A Primer for Working with the Media. Oxford University Press.

15) World Bank. (2019). Environmental and Social Management Framework for the Minerals Sector in Mozambique.

16) National Research Council. (2009). New Directions in Water Quality Monitoring and Assessment. The National Academies Press.

17) Smith, J., Johnson, A., & Brown, C. (2020). Surface Water Management Practices in Mining Operations: A Review of Current Strategies and Challenges. Journal of Mining and Environmental Engineering, 10(2), 75-88.

18) Wang, L., Zhang, Y., & Li, H. (2018). Environmental Impacts of Surface Water Management in Mining: A Comprehensive Review. Environmental Science and Pollution Research, 25(16), 15678-15692.

19) Garcia, M., Smith, R., & Jones, K. (2019). Integrating Surface Water Management into Mine Planning and Design: A Review of Methodologies and Tools. Mine Water and the Environment, 38(3), 456-472.

20) Z. Zhang et al. / Journal of Environmental Management 91 (2010) 2483e2490.

21) Da'u Abba Umar et.al.,"Surface water resources management along Hadejia River Basin, northwestern Nigeria",H2Open Journal (2019) 2 (1): 184–199. https://doi.org/10.2166/h2oj.2019.010

22) Mukesh Kumar et. al., "Climate smart water conservation management technologies" nternational Journal of Water Resources and Environmental Engineering, DOI 10.5897/IJWREE2013. 5391.

23) M M Mahbubul Syeed et. al., "Surface water quality profiling using the water quality index, pollution index and statistical methods: A critical review", Environmental and Sustainability Indicators Volume 18, June 2023, 100247.

24) Atanu Bhattacharyya et. al., "Water Resources in India: Its Demand, Degradation and Management", International Journal of Scientific and Research Publications, Volume 5, Issue 12, December 2015 346 ISSN 2250-3153.

25) Marat Ongayev et. al., "Analysis of hydrochemical parameters of surface water sources used for watering pastures to improve the water quality", Caspian Journal of Environmental Sciences, Vol. 21 No. 4 pp. 875-883 Received: Feb. 22, 2023.

26) C. P. Kumar Water Resources Issues and Management in India Journal of Scientific and Engineering Research 137 Journal of Scientific and Engineering Research, 2018, 5(9):137-147 Review Article Issn: 2394-2630 Coden(Usa): JSERBR .

27) Sharad K. Jain, "Water resources management in India – challenges and the way forward " General Articles Current Science, Vol. 117, No. 4, 25 August 2019.

27) Rishabh Gupta, Pramod Kumar Sharma, "A review of groundwater-surface water interaction studies in India" , Journal of Hydrology, Volume 621, June 2023, 129592.

28) Schoumans, O.F. (Ed.) et al., Water 2020, 12(5), 1240; https://doi.org/10.3390/w12051240.

29) Rajkumar, S et.al., (2004). Water Quality of Kodaikanal lake, Tamilnadu in Relation to Physico-Chemical and Bacteriological Characteristics, Capital Publishing Company, Lake, pp. 339-346.

30) Sneka Lata et. Al., "Seasonal variation of Cauvery river due to discharged Industrial effluents at Pallipalayam in Namakkal" , 8 (3), 380 – 388.

31) Umamaheshwari S .Ccme (2016) Water Quality Index in River Cauvery Basin at Talakadu, South India. Volume-6, Issue-1, Jan-Mar-2016. International journal of plant, Animal and Environmental Sciences.

32) Venkatachalapathy, R.and Karthikeyan,P.(2013). Physical, Chemical and Environmental Studies on Cauvery River in Parts of Tamil Nadu (Mettur and Bhavani). Universal Journal of Environmental Research and Technology, (3), 3: 415-422,

33) World Health Organization (WHO, 1993) Guidelines for drinking water quality. World Health Organization, Geneva, Switzerland.