

A Shortterm Study- Aquanalco- Assessing Industrial Impact on Aquatic Ecosystem in Damanjodi Area, Korput District, Southern Odisha, India

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Annotation: A three months study was undertaken in the Nalco Damanjodi Area of Koraput district. This fulfils the minor and short term MSc dissertation study on aquatic ecosystems. The landscape is high altitude mountain area with valleys and rifts. Some area have paddy fields which were latter converted to Ash ponds literally the reservoirs of the swage effluents from the Almina Refineries plants at Damanajodi. One another storage pond is Red mud pond which is more toxic, non-living area of the industries, other aquatic waterbodies are Nalco recreation Fish pond, Kolab Dam, Panchupatimali streams. It is seen that the Red Mud pond have Dissolved Oxygen (DO) less than 1mg/L, the PH is 13-14 which is highly alkaline even corrosive to naked hands. and does not sustain no life even bacteria and algae. The Ash pond water has PH is 11- 12 hich is also highly alkaline but not corrosive. The DO is 1-

2mg/L and no titration is obtained. This aquatic waterbody has little life supporting phases, here frogs and aquatic birds can swim and float, they have no aquatic respiration and can just occupy a space to live some spare of time without feeding activity as no other small aquatic fauna has fishes existed. Little aquatic grasses and wild paddy is present in the submerged parts of Ash pond. The Nalco recreational pond in NALCO township has life sustain capability having varied fishes, toads and birds like cormorants, egrets, lesser whistling ducks, frogs, fishes, tree geckos freshwater terrapins, crustacean, prawns, crabs and waterbugs, earthworms, leaches etc. The Pancpatimal hill stream has life supporting properties with High DO 12.39 which is higher values according to the life suitable for hill stream fishes, and other aquatic life forms here as the piped stream after that used for drinking at mining site has DO of 13.41 Mg/ L being the highest in the study. The Kolab water has DO of 12.39 Mg/ L which is suitable for aquatic life in dam after. No such studies were done in the this themes in a restricted area like Nalco mining area which is a high security Zone of the country.

Keywords: Damanjodi, NALCO mining, Dissolved Oxygen, Acidity, alkalinity, drinking water.

1. INTRODUCTION:

Aquatic ecosystems play vital roles in maintaining environmental balance, including: Nutrient Recycling: They facilitate the circulation of essential nutrients, supporting various life forms. An aquatic ecosystem in damanjodi area encompasses communities of organisms interacting with one another and with their environment in water-based habitats. These ecosystems are broadly categorized into two main types: freshwater ecosystems and marine ecosystems.

Freshwater ecosystems are characterized by low salt concentrations and include: Lentic Systems: Standing or still water bodies such as lakes like Kolab, Redmud pond and Fly Ash pond which reserve the toxic water after little treatment at base., ponds, and wetlands. Lotic Systems: Flowing water bodies like rivers and streams. The hill streams like Panchapattimal streams, different streams fall in main river system kolab. Water Purification: Natural filtration processes help in removing pollutants, thereby purifying water. Flood Attenuation: Wetlands and other aquatic systems can absorb excess rainfall, reducing flood impacts. Groundwater Recharge: They contribute to replenishing groundwater supplies through infiltration.. They Serving as homes to a myriad of species, they support biodiversity. Despite their importance, aquatic ecosystems face numerous threats: Koraput district in Odisha is endowed with a diverse array of aquatic ecosystems, including rivers, streams, reservoirs, and waterfalls, which support rich biodiversity and play a crucial role in the livelihoods of local communities

The district is traversed by several significant rivers like 1) Kolab River: A major tributary of the Godavari, the Kolab River flows through the district, providing habitat for various aquatic species. 2) Indravati River: Draining substantial parts of Koraput, this river and its perennial tributaries contribute to the district's aquatic diversity. 3) Sabari River: Flowing along the western border, it supports diverse freshwater species. Reservoirs and Waterfalls: The district features several reservoirs and waterfalls that enhance its aquatic habitats: 1) Kolab Reservoir: Formed by the Kolab Dam, this reservoir is vital for irrigation, hydroelectric power, and fisheries allied livelihood activities. Duduma Waterfall: A prominent waterfall on the Machkund River, contributing to local aquatic biodiversity and helps in income generation to local community through Eco-tourism..

Biodiversity conservation Koraput's water bodies are home to a variety of fish species: A study recorded 26 fish species across eight orders and 13 families, with 24 species being first-time records for the region. In 2023, researchers discovered a new freshwater fish species, *Garra laishrami*, in the Kolab River. o Aquatic Avifauna: The district's wetlands and water bodies attract various 23 aquatic bird species, serving as indicators of environmental health. and ecological richness of the region. Ecological Significance and Conservation: The aquatic ecosystems of Koraput are integral to the district's ecology and the livelihoods of its predominantly tribal population. Rivers like the Kolab and Indravati provide water for agriculture, fishing, and daily needs. However, these ecosystems face challenges such as habitat degradation and pollution. Conservation efforts are essential to preserve the biodiversity and ensure the sustainability of these vital resources. Koraput's aquatic ecosystems are characterized by their diversity and ecological importance, necessitating continued research and conservation initiatives to maintain their health and productivity.

Study area

A one month study was carried out in the Industrial area aquatic ecosystems which includes 5 stations two in Reservoirs and three in rivers streams

Koraput district spans an area of 8,379 square kilometers, making it one of the largest districts in Odisha. Geographically, it is located between 18° and 19° North latitude and 82° and 83° East longitude. The district's topography is characterized by rugged mountains interspersed with intermontane valleys. Elevations in the hilly terrains range from 900 to 1,400 meters above mean sea level, with the highest peak reaching 1,620 meters. The average elevation of Koraput town itself is approximately 856 meters.

Damanjodi, being part of this district, shares similar topographical features, including hilly terrains and lush green landscapes. The region's natural beauty, combined with its industrial significance due to NALCO, makes it a notable area within Odisha.

The study was conducted by sampling at ten locations representing the regions of Koraput. The sampling locations were from –

1. Beheraguda river site
2. Panchpatimali drinking stream water 1
3. Panchpatimali stream water 2
4. Nalco Ash pond
5. Nalco Red mud pond
6. Maa kanta Bausani isolated Temple pond, Damonjodi
7. Forest pond, Jeypore
8. Kolab dam eastern bays, Koraput
9. Stream water under SH bridge, inlet to Kolab dam, Koraput
10. Ghataguda river site

4.1. GEOGRAPHICAL LOCATION:

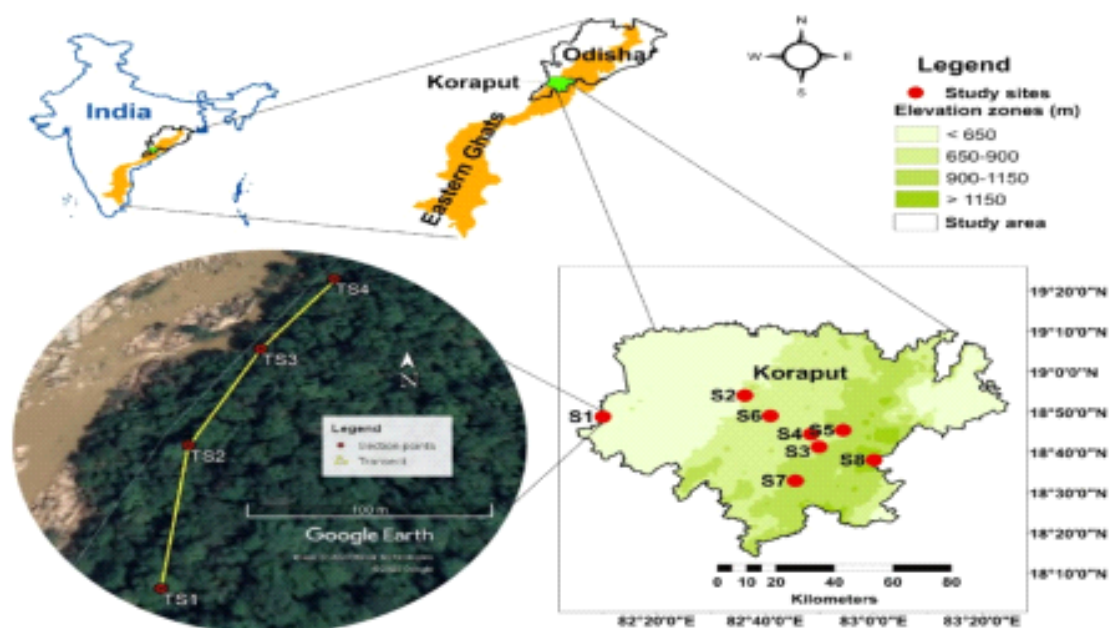


Fig-1 Map of study site in India

Damanjodi is a town situated in the Koraput district of Odisha, India. It lies approximately 20 kilometers southeast of the district headquarters, Koraput. The geographical coordinates for Damanjodi are approximately 18.7743° N latitude and 82.9125° E longitude. The town is renowned for housing the National Aluminium Company Limited (NALCO), which was established to exploit the bauxite-rich deposits of the Panchpatmali Range. Damanjodi is well-connected by road to major cities in Odisha. The nearest railway station is Koraput, and the closest airport is Jeypur and the nearest sea port is Visakhapatnam Airport, approximately 200 km away. The city is aesthetically manourvoured by temples such as the Jagannath Temple, Maa Kantabausini Temple, Shirdi Sai Baba Temple, and Hanuman Temple. Other places of worship include the Union Church and Damanjodi mosque. Recreational facilities in the area encompass stadiums, parks, walking tracks, gardens, and waterfalls, making it an attractive destination for visitors and tourists. Damanjodi offers a picturesque landscape characterized by lush greenery and a serene environment. The town reflects a cosmopolitan culture and acknowledges several religions, featuring

The climate

Elevation Influence: Both Damanjodi and Koraput are located in a **hilly region (850–1, 400 meters)**, which moderates temperature and increases rainfall compared to coastal

Odisha. **Summer** 20°C – 35°C Moderate to warm. Nights remain relatively cool due to elevation. **Monsoon** 18°C – 28°C Cool and humid; cloud cover limits temperature extremes. **Winter** 5°C – 20°C Quite chilly, especially at night; mornings can see mist/fog.

Hottest Months: April to June **Coldest Months:** December to January

Temperature Peak: Around **May**, occasionally reaching 35°C

Rainfall Patterns

Temperature Low: Often drops to 5°C or lower in hillier areas during December January
Season Rainfall (mm) Description

Southwest Monsoon (Jun–Sept) 1, 000–1, 400 mm Accounts for ~75–80% of annual rainfall.

Post-monsoon (Oct–Nov) 100–200 mm Light to moderate rain; tapering off. **Winter** (Dec–Feb) <50 mm Mostly dry with occasional drizzles. **Summer (Pre-monsoon)** (Mar–May) 50–100 mm

Thunderstorms and convectional showers common. **Annual Rainfall:** ~1, 300 to 1, 600 mm

Rainy Days: ~80–100 days per year

Humidity: High during monsoon (70–90%), lower in winter (40–60%)

The Aquatic ecosystem in around Damanjodi

The Kolab River, originating in the Sinkaran hills of the Eastern Ghats in Koraput district, Odisha, supports a diverse aquatic ecosystem, serving as a major source of water for irrigation, electricity, and drinking water for the region, and also as a habitat for various fish species, including the recently discovered *Garra laishramui*. **Origin and Flow:** The Kolab River, also known as Sabari River, originates in the Sinkaran hills of the Eastern Ghats in Odisha. It flows towards the western slopes of the Eastern Ghats and is a major tributary of the Godavari River. **Catchment Area:** The Kolab river catchment area spans approximately 3566 sq. km, encompassing the region between Tekegurha and north of Gupteshwar cave temple up to Taluru. **Water Resources:** The Kolab reservoir, formed by the Kolab Dam, is a crucial water resource for the Koraput-Jeypore region, serving as a primary source of drinking water and irrigation. **Upper Kolab Hydroelectric Project:** The Upper Kolab Hydroelectric Project, located in Koraput district, utilizes the Kolab River's water potential for electricity generation.

Aquatic Ecosystem: Fish Diversity: The Kolab River supports a rich diversity of fish species, including the newly discovered *Garra laishramui*. These fish are typically found in the torrential streams and rivers, under rocks and among stones and boulders. **Other Aquatic Life:** The river likely supports a variety of other aquatic life, including invertebrates, algae, and other plant life, forming a complex food web. there are so many aquatic birds depending on Kolab Reservoir **Water Quality:** The Kolab River's water quality is important for the health of the aquatic ecosystem and the well-being of the communities that depend on it. Engaging local communities in conservation efforts is essential for long-term success. **Research and Monitoring:** Continued research and monitoring of the river's ecosystem can help inform conservation strategies. The Kolab River's Aquatic Ecosystem: The Kolab River, with its rich biodiversity and ecological significance, faces numerous challenges, including pollution, overfishing, and habitat degradation. Conservation efforts are crucial to ensure the long-term health of this vital ecosystem and the well-being of the communities that depend on it.

14.2. Aquatic ecosystem of Panchpatmali of Koraput district:

The aquatic ecosystem of Panchpatmali, a region within Koraput district in Odisha, is significantly impacted by bauxite mining operations, particularly those of the National Aluminium Company (NALCO), leading to water pollution, habitat degradation, and a decline in biodiversity.

Geographical Context and Bauxite Mining Panchpatmali Hills: The Panchpatmali hills in Koraput district are renowned for their extensive bauxite deposits, making the region a major bauxite mining area in Odisha. **Bauxite Mining Operations:** NALCO, a major player in the

bauxite mining industry, operates in this area, extracting bauxite ore, which is a raw material for aluminum production. **Environmental Impact:** The mining activities, including the extraction, processing, and transportation of bauxite, have led to significant environmental consequences, including water pollution and habitat degradation.

Water Pollution:

Mining Waste: Bauxite mining generates large quantities of waste, including mine tailings, which contain heavy metals and other pollutants. **Runoff:** Rainwater runoff from mining areas carries pollutants into nearby water bodies, leading to water contamination.

Acid Mine Drainage (AMD): The oxidation of sulfide minerals in bauxite ore can result in the formation of acidic drainage, which can severely impact aquatic life. **Sedimentation:** Mining activities can cause increased sedimentation in rivers and streams, which can smother aquatic habitats and reduce water quality.

Chemical Contamination: The use of chemicals during bauxite processing and transportation can lead to chemical contamination of water bodies, posing a threat to aquatic life and human health.

Habitat Degradation:

Land Clearing: Bauxite mining requires large areas of land to be cleared, which can lead to the destruction of natural habitats and the loss of biodiversity.

Water Diversion: Mining operations can involve the diversion of water resources, which can disrupt the natural flow of rivers and streams and impact aquatic ecosystems.

Sedimentation and Turbidity: Increased sediment load in water bodies can reduce light penetration, which can negatively affect aquatic plants and other organisms.

Impact on Biodiversity:

Species Decline: Water pollution and habitat degradation can lead to the decline or extinction of aquatic species, reducing the biodiversity of the region.

Loss of Ecosystem Function: The loss of key species can disrupt the functioning of the aquatic ecosystem, affecting the food web and other ecological processes.

Threat to Fish Populations: The fish populations in the region are particularly vulnerable to the impacts of bauxite mining, as they are directly exposed to pollutants and habitat degradation.

14.3. Aquatic ecosystem of ash pond and Red mud pond NALCO The Red Mud Pond in the NALCO (National Aluminium Company) area is a site associated with the industrial processes of aluminum extraction. The red mud pond refers to a byproduct of the Bayer process used to refine bauxite into alumina. When bauxite is processed, a large amount of red-colored waste is generated, called "red mud." This waste is typically stored in large ponds, which can sometimes have environmental concerns related to their management, as they may contain toxic substances. Proper containment and treatment of these ponds are crucial to prevent contamination of surrounding areas. This affect the aquatic ecosystem and the biodiversity of that particular area.

Ash pond: An **ash pond** is a site used to store the byproducts of burning coal in thermal power plants. byproducts are primarily in the form of fly ash and bottom ash. In the context of the NALCO area or other industrial regions, ash ponds are often used for disposal of ash produced from power generation units, which are a common part of aluminum and other heavy industries.

Water contamination: Ash ponds can sometimes leak, leading to the contamination of nearby groundwater and surface water bodies.

Air pollution: If not properly managed, the ash can be blown into the air, causing air quality issues. **Health hazards:** Some of the chemicals in the ash can be toxic and harmful to both human health and wildlife

C. Soil Erosion and Sedimentation: Large-scale mining and deforestation can cause soil erosion, especially in the hilly and sloped areas around the NALCO facilities. Sedimentation can also clog fish breeding grounds and alter the natural flow of rivers, disrupting ecosystems.

The NALCO ash pond, a man-made impoundment near Koraput, Odisha, poses significant challenges to the local aquatic ecosystem due to the presence of heavy metals and other pollutants in the red mud, which can contaminate water bodies and harm aquatic life. NALCO, a major alumina refinery, uses the pond to store the red mud, a byproduct of the Bayer process used in alumina production. **Red Mud Composition:** Red mud is a complex mixture of materials, including heavy metals like iron, aluminum, and trace amounts of other elements, along with silicates and other compounds. **Environmental Concerns:** The presence of these heavy metals and other pollutants in the red mud raises significant environmental concerns, particularly regarding the potential contamination of nearby water bodies and soil, impacting the aquatic ecosystem and human health.

Impacts on the Aquatic Ecosystem: **Water Contamination:** The red mud, if not managed properly, can leach into surrounding water bodies, leading to increased levels of heavy metals and other pollutants. **Altered Water Quality:** The presence of these pollutants can alter the chemical and physical properties of the water, making it unsuitable for aquatic life. **Toxicity to Aquatic Organisms:** Heavy metals and other pollutants can be toxic to aquatic organisms, causing mortality, reduced growth, and developmental problems. **Sedimentation and Turbidity:** The red mud can also lead to increased sedimentation and turbidity in the water, reducing light penetration and affecting photosynthesis in aquatic plants. **Habitat Degradation:** The accumulation of red mud and the resulting changes in water quality can lead to the degradation of aquatic habitats, reducing their ability to support diverse and healthy ecosystems. **Impact on Fish Populations:** Fish populations can be negatively affected by the presence of pollutants in the water, leading to reduced abundance, altered behavior, and even extinction of certain species. **Bioaccumulation:** Heavy metals can bioaccumulate in aquatic organisms, meaning they become concentrated in the tissues of these organisms as they move up the food chain. **Human Health Impacts:** The contamination of water bodies and the accumulation of pollutants in aquatic organisms can pose risks to human health, particularly for communities that rely on these water bodies for drinking water, fishing, and other activities.

Specific Aquatic Organisms Affected: **Algae and Phytoplankton:** These primary producers are sensitive to changes in water quality and can be negatively affected by pollutants, leading to reduced growth and even death. **Zooplankton:** These small animals that feed on algae and phytoplankton can also be negatively affected by pollutants, leading to reduced populations and disruptions in the food web. **Invertebrates:** Many invertebrates, such as insects, crustaceans, and mollusks, are sensitive to pollutants and can be negatively affected by changes in water quality and habitat degradation. **Fish:** Fish are a key indicator of water quality and can be negatively affected by pollutants, leading to reduced populations, altered behavior, and even death. **Other Aquatic Life:** Other aquatic organisms, such as amphibians, reptiles, and mammals, can also be negatively affected by changes in water quality and habitat degradation.

Mitigation and Remediation Efforts: **Improved Ash Pond Management:** Implementing better management practices for the ash pond, such as using liners to prevent leakage, regular monitoring of water quality, and ensuring proper disposal of the red mud, can help to reduce the risk of contamination. **Water Quality Monitoring:** Regular monitoring of water quality in nearby water bodies can help to identify potential problems early on and allow for timely intervention. **Restoration of Degraded Habitats:** Restoring degraded aquatic habitats, such as wetlands and rivers, can help to improve water quality and create more resilient ecosystems.

OBJECTIVE OF THE STUDY

1. To examine the history and development of NALCO's industrial activities and their impact on the surrounding ecosystem.
2. To assess the environmental consequences of NALCO's operations, including air and water pollution, land degradation, and loss of biodiversity.
3. To identify the key stakeholders affected by NALCO's industrial activities, including local communities, wildlife, and the environment.
4. To evaluate the effectiveness of NALCO's environmental management practices and policies.
5. To investigate the water quality and aquatic life in the NALCO industrial area, including rivers, streams, and wetlands.
6. To assess the impact of NALCO's industrial activities on the aquatic ecosystem, including pollution, habitat destruction, and changes to water chemistry.
7. To identify the key aquatic species affected by NALCO's operations and their ecological significance.
8. To evaluate the potential risks and consequences of NALCO's industrial activities on the aquatic ecosystem and human health.



Fig-2 restoration quote at Stone painting at Minig site Panchpatmali, hill



Fig- 3 Refinery site at Damanjodi tonship



Fig- 4 Kolab Dam – the ultimate reservoir of the entire Damanjodi, Sunabeda and Similiguda landscape.

CHAPTER-5

MATERIALS AND METHODOLOGY

5.METHODOLOGY:

5.1. Data Collection Methods in the Context of NALCO:

5.1.1. Field Surveys for Site Analysis:

Field surveys are critical to NALCO's environmental management and project planning processes. Before initiating any mining or industrial activity, NALCO conducts extensive site analysis to understand the geographical, ecological, and socio-economic aspects of the area. These surveys help identify the current land use patterns, topography, soil type, vegetation cover, and human settlements.

For instance, in NALCO's bauxite mining projects in Odisha, field surveys involve the collection of GPS based data, soil testing, and mapping of sensitive zones. This is essential not only for ensuring regulatory compliance with the Ministry of Environment, Forest and Climate Change (MoEFCC) but also for minimizing ecological disruption. These surveys also help in designing effective rehabilitation and reclamation plans for mined-out areas.

Moreover, socio-economic surveys are conducted to assess the potential impact on local communities. Data regarding local livelihoods, access to natural resources, and community health are collected to implement Corporate Social Responsibility (CSR) initiatives and environmental mitigation strategies.

5.1.2. Water Sampling at Multiple Locations and Time Periods:

Water quality monitoring is a cornerstone of NALCO's environmental sustainability strategy. Given the water-intensive nature of alumina refining and smelting processes, NALCO undertakes systematic water sampling at different stages of production and at multiple geographic locations.

Sampling is carried out in surrounding water bodies such as kolab dam water from the bays, Panchpatmali stream water, Panchpatmali stream drinking Water, Red mud pond, Ash pond and mine-pit water reservoirs. These samples are collected between morning 8:15 to 11:04 am and again at evening between 3:39 to 4:08 pm.

The parameters tested include pH, Biochemical Oxygen Demand (BOD), heavy metals (like arsenic, lead, mercury), turbidity. This helps in detecting any contamination arising from mining runoff, leachate from red mud ponds, or discharge from industrial operations.

NALCO's water sampling protocols are aligned with the guidelines of the Central Pollution Control Board (CPCB). Such proactive monitoring ensures the protection of aquatic ecosystems and safe drinking water for local communities.

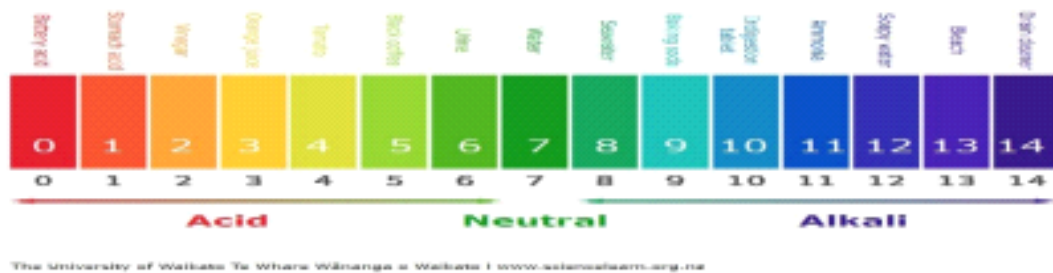
5.2 Water Quality Analysis:

Water Quality Analysis in the Context of NALCO Water quality analysis plays a critical role in environmental monitoring and industrial process control. At National Aluminium Company Limited (NALCO), maintaining water quality is essential not only for regulatory compliance but also to ensure the safe and efficient operation of industrial processes such as smelting, refining, and power generation. Among the **many parameters tested, pH, dissolved oxygen (DO), turbidity, and heavy metals are key indicators of water quality**. Laboratory techniques are used to accurately assess these factors, guiding wastewater treatment and pollution control strategies. ---

5.2.1. pH Measurement:

The pH of water indicates its acidity or alkalinity and is a fundamental parameter in water analysis. At NALCO, pH testing is routinely conducted on intake water, process water, and

effluents to ensure optimal process conditions and compliance with environmental discharge norms. The water is collected from different water bodies in a clean, chemically neutral container (bottle).



Using pH paper or litmus paper

Materials required:

-pH test strips, distilled water, beaker or sample container, gloves

Procedure:

1. collect water in a clean container.
2. Dip the strip into the water for 1-2 seconds.
3. Remove and wait a few seconds for the color to develop
4. Compare the color of the strip to the color chart.
5. Record the pH value.

Acceptable range:

For discharge into natural water bodies, pH is generally maintained between 6.5 and 8.5 as per CPCB (Central Pollution Control Board) norms.

Observation:

The water sample 1 of stream water under the bridge determines pH 5 which turns out to be slightly acidic.

The water sample 2 of kolab dam water from the bays, sample 3 Ghataguda, sample 4 of Bheraguda and sample 5 of panchpatmali stream water determine pH 4 which turn out to be slightly acidic.

The water sample 6 of panchpatmali stream drinking water determine pH 4 which turn out slightly alkaline.

The water sample 7 of Ash pond water determine pH 4 which is slightly acidic.

The water sample 8 of Red mud pond water (drainage pipe) determine pH 14 which turn out to be alkaline. The water sample 9 of Maa kanta bausuni temple determines pH 7 which turn out to be alkaline. The water sample 10 of Forest pond jeypore determines pH 8 which turn out to be alkaline.

Result:

The pH scale is used to measure how acidic or basic a substance is, with a range of 0.14. A pH 7 is neutral and less than 7 is acidic and greater than 7 is acidic

Fig 7 Taking Digital PH scale from Mobile online and Offline screens pH of Red mud pond pH of Kolab dam water from bays.

5.2.2. Dissolved Oxygen (DO):

Dissolved Oxygen is crucial for the survival of aquatic life and serves as a key indicator of the water's ability to support aerobic biological processes. At NALCO, DO levels are monitored in both influent and effluent streams to assess water body health and biological treatment efficacy.

Laboratory Method:

Method: Winkler titration or DO meter (electrochemical probe).

Materials Required:

Erlenmeyer, Pipette, Burette, Beaker, Conical flask, Measuring cylinder, Electronic weighing balance. **Chemicals Required:**

Manganese sulphate monohydrate ($\text{MnSO}_4 \cdot \text{H}_2\text{O}$), NaOH , KI Sodium Azide Concentration Sulphate acid ($\text{conc. H}_2\text{SO}_4$) Starch Powder Sodium Thiosulphate

Winkler Method:

Manganese sulfate and alkaline iodide are added to the sample, forming a precipitate. Upon acidification, iodine is released, which is titrated with sodium thiosulfate.

Principle of Winkler's method:

The Winkler method is based on a redox (oxidation-reduction) reaction where dissolved oxygen oxidizes manganese(II) ions under basic conditions, and the amount of oxidizing product is later measured by titration.

1. Manganese (II) sulfate is added to the water sample. 2. An alkaline iodide solution (usually a mixture of potassium iodide and sodium hydroxide or potassium hydroxide) is added. This causes a white precipitate of manganese(II) hydroxide $[\text{Mn}(\text{OH})_2]$ to form. 3. If oxygen is present, it oxidizes $\text{Mn}(\text{OH})_2$ to brown-colored manganese(III/IV) hydroxide. 4. Upon acidification (usually with sulfuric acid), the manganese hydroxide reacts with iodide (I^-) to liberate iodine (I_2) in proportion to the amount of oxygen originally present.

Chemical Reactions:

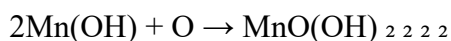
Here are the chemical reactions involved in Winkler's method for determining dissolved oxygen:

Step 1: Formation of Manganese(II) Hydroxide

Manganese sulfate reacts with a strong base (like NaOH or KOH) to form manganese(II) hydroxide: $\text{MnSO}_4 + 2\text{NaOH} \rightarrow \text{Mn}(\text{OH})_2 + \text{Na}_2\text{SO}_4$

Step 2: Oxidation by Dissolved Oxygen

The dissolved oxygen in water oxidizes the white precipitate to a brown precipitate of higher oxidation state manganese hydroxide (like $\text{MnO}(\text{OH})$):



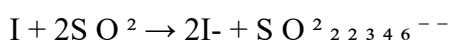
Step 3: Acidification and Iodine Liberation

When the solution is acidified (with sulfuric acid), the oxidized manganese reacts with potassium iodide to release iodine:



Step 4: Titration with Sodium Thiosulfate

The liberated iodine is titrated with sodium thiosulfate solution:



This sequence links the amount of dissolved oxygen directly to the amount of sodium thiosulfate used in the titration.

Preparation of Chemicals Reagents

1. Manganese Sulphate Monohydrate Solutions:

48gm of $MnSO_4 \cdot H_2O$ dissolved in 100ml of distilled water. ^{4 2}

2. Alkaline Iodine Solution:

70gm of KOH and 15gm of KI dissolved in 100ml of dissolved water (distilled water) along with 1gm of NaN (Sodium azide). ³

3. Sodium Thiosulphate Solution:

3.1gm of sodium thiosulphate is taken in Erlenmeyer flask and 250ml of distilled water is added and then add 2-3 sodium palletete.

4. Starch Indicator:

Take 1gm of starch soluble powder, add slowly in 20% NaOH solution 100ml solution and stir it vigorously by swirling method until the starch powder get settled. Then add 2ml of Glacial acetic acid and then add conc. HCL until the solution turn just acidic as rebuild by litmus paper test.

5. 20% NaOH solution:

Add 20gm of NaOH solution and make upto 100ml adding distilled water.

Procedure.

1. Collection of Water Sample- Collect the water sample in a 250mL BOD (Biochemical Oxygen Demand) bottle without any air bubbles. Seal immediately to prevent atmospheric oxygen from entering.
2. Addition of Manganese Sulfate ($MnSO_4$) -Add 2 mL of $MnSO_4$ solution carefully using a pipette. Let the tip of the pipette reach just below the surface of the water to avoid air contamination.
3. Addition of Alkaline Iodide-Azide Solution – Add 2mL of alkaline iodide-azide solution the same way. Stopper the bottle tightly and invert it several times to mix.
4. Formation of Precipitate - A brownish-orange precipitate (manganese hydroxide complex) forms if DO is present. Allow the precipitate to settle.
5. Acidification Add 1 mL of concentrated sulfuric acid (H_2SO_4) carefully down the neck of the bottle. Restopper and invert several times to dissolve the precipitate, forming iodine (I_2) equivalent to the amount of DO.
6. Titration - Take 50 mL of the acidified sample and titrate with 0.025 N sodium thiosulfate ($Na_2S_2O_3$) until the solution turns pale yellow. Add a few drops of starch indicator, turning the solution blue. Continue titrating until the blue color disappears — this is the end point.

A precipitate is formed and settles at the bottom indicating presence of DO.

- a. White ppt -Oxygen content little
- b. little brown ppt – oxygen content low
- c. Reddish brown ppt – oxygen content high

Tabulation:

SAMPLE 1 –ASH POND

No dissolved oxygen in the sample because the initial oxidation step doesn't happen. No iodine is produced, therefore no color appears and starch doesn't form the blue-black complex.

SAMPLE 2 – FOREST POND

| Sl.no | Volumne of water sample taken for Titration | Burette reading IBR | FBR1 | FBR2 | Difference FBR2-IBR | Mean |
|-------|---|---------------------|------|------|---------------------|------|
| 1 | 50ml | 0.3 | 2.6 | 3.8 | 3.5 | 3 |
| 2 | 50ml | 3.8 | 5.9 | 6.3 | 2.5 | |

Calculation

Dissolved oxygen = $v \times N \times E \times 1000$ ₁

$V_4 \times (v - v)$ _{2 3}

V_2

Where, v = volume of titrant consumed = 3 ₁

V = total sample solution = 250ml ₂

V = volume of MnSO₄ + Alkaline iodide solution added (2+2)=4ml ₃

V = volume of analyte = 50ml ₄

E = Equivalent weight of oxygen = 8

N = Normality of hypo solution = $0.025 \times 8 \times 1000 = 12.19 \text{mg/l}$

SAMPLE 3 - RED MUD POND

No dissolved oxygen in the sample because the initial oxidation step doesn't happen. No iodine is produced; therefore no color appears and starch doesn't form the blue -black complex. **Sample 4- Panchpatmali Stream Water**

| Sl.no | volume of water sample taken for titration | IBR | FBR1 | FBR2 | Difference between FBR2- IBR | Mean |
|-------|--|------|------|------|------------------------------|------|
| 1 | 50ml | 11.2 | 12 | 14 | 2.8 | 3.05 |
| 2 | 50ml | 14 | 17 | 17.3 | 3.3 | |

Calculation:

$3.05 \times 0.025 \times 8 \times 1000 = 12.39 \text{mg/l}$

SAMPLE 5 KOLAB DAM (BATHING GHAT)

| Sl.no | Volume of water sample taken for titration | IBR | FBR1 | FBR2 | Difference between FBR2- IBR | Mean |
|-------|--|------|------|------|------------------------------|------|
| 1 | 50ml | 17.3 | 19.3 | 20.2 | 2.9 | 3.05 |
| 2 | 50ml | 20.2 | 21.9 | 23.4 | 3.2 | |

Calculation:

$3.05 \times 0.025 \times 8 \times 1000 = 12.39 \text{mg/l}$

SAMPLE 6 PANCHPATMALI DRINKING WATER

| Sl.no | Volume of water sample taken for titration | IBR | FBR1 | FBR2 | Difference between FBR2-IBR | Mean |
|-------|--|------|------|------|-----------------------------|------|
| 1 | 50ml | 23.4 | 25.5 | 26.5 | 3.1 | 3.3 |
| 2 | 50ml | 26.5 | 29.1 | 30 | 3.5 | |

Calculation:

$$3.3 \times 0.025 \times 8 \times 1000 = 13.41 \text{ mg/l}$$

5.2.3. Turbidity:

Turbidity measures the cloudiness or haziness of water caused by suspended solids, microorganisms, and other particulate matter. NALCO assesses turbidity in raw water sources and treated effluent to ensure physical cleanliness and process compatibility.

Laboratory Method: Instrument: Nephelometric Turbidity Unit (NTU) meter.

Procedure: The instrument measures light scattered by particles in the sample. The result is given in NTU.

Standards: For drinking water, turbidity is typically maintained below 1 NTU, while industrial standards vary based on application. High turbidity can interfere with disinfection, increase chemical treatment costs, and indicate poor

sedimentation or filtration. At NALCO, optimizing turbidity control enhances both water reuse potential and environmental compliance.

5.2.4. Heavy Metal Analysis:

Heavy metals such as lead (Pb), cadmium (Cd), mercury (Hg), chromium (Cr), and arsenic (As) are toxic even at trace levels. Industrial processes at NALCO may introduce these metals into water streams, making their detection and control a priority.

Laboratory Methods: Atomic Absorption Spectroscopy (AAS) or Inductively Coupled Plasma Mass Spectrometry (ICP-MS).

Procedure: Samples are digested using acids (like HNO and HCl), filtered, and analyzed for metal concentration.

Permissible Limits (CPCB Guidelines): Lead: <0.1 mg/L Chromium (Hexavalent): <0.1 mg/L Cadmium: <0.01 mg/L Arsenic: <0.05 mg/L At NALCO, periodic heavy metal testing is performed to ensure that wastewater discharges do not exceed permissible levels. Effluent treatment plants (ETPs) are equipped with specific units such as precipitation tanks and ion exchange columns to remove these contaminants.



Fig :- Water sample of Ash pond showing cloudy formation

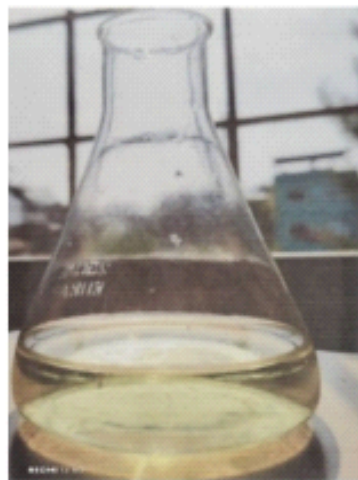


Fig:- After titration turn yellow.

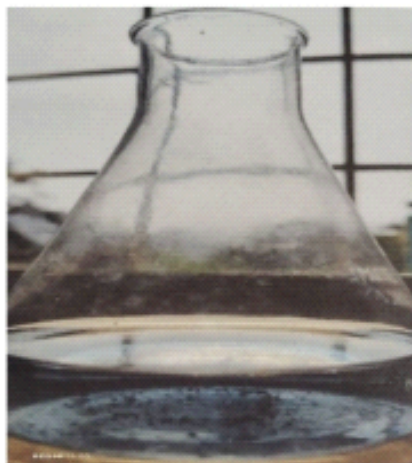


Fig:-After adding Starch indicator.

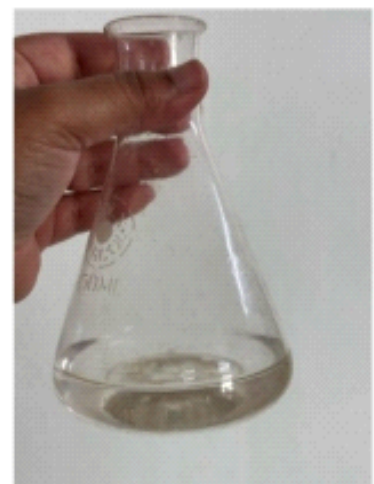


Fig:- Become colorless

ge4 a

Fig-8 All above lab photos during analysis

5.3. DATA ANALYSIS:

Statistical Methods and Software Used for Analyzing Trends in Water Quality and

"Biodiversity" in the context of NALCO (National Aluminium Company Limited): -

Environmental sustainability is at the core of operations for NALCO (National Aluminium Company Limited), a major player in the aluminium industry in India. Given the ecological sensitivity of the areas in which NALCO operates, particularly near water bodies, data-driven environmental monitoring becomes crucial. By using statistical methods and advanced software tools, NALCO can efficiently analyze trends in water quality and aquatic biodiversity, enabling better decision-making and compliance with environmental standards.

Water Quality Monitoring and Analysis NALCO conducts regular sampling and monitoring of surface and groundwater sources near its operational sites (e.g., **Angul and Damanjodi**). These water samples are tested for various parameters such as: **Physical: Temperature, turbidity, color**
Chemical: pH, dissolved

oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), heavy metals (like aluminium, lead) Biological: Coliform count, plankton density

1. **Statistical Methods Used** 1. **Descriptive Statistics** Mean, median, standard deviation, and variance are used to summarize water quality data. Helps understand normal ranges and identify outliers.
2. **ANOVA (Analysis of Variance)**-Used to compare means between multiple sampling locations or times.Helps determine whether changes in biodiversity or water quality are statistically significant.
3. **Correlation and Regression Analysis**-Determines relationships between variables (e.g., how BOD correlates with fish population density).Regression models help in predicting future scenarios.

NALCO's Practical Implementation and Impact

NALCO integrates these statistical tools and software in its Environmental Monitoring Programs (EMPs).

For instance: At the Damanjodi unit, regular water samples from nearby streams and ponds are analyzed, and biodiversity indices are computed.

Statistical reports are submitted to regulatory authorities like CPCB and MoEF&CC.

The trends help NALCO assess the effectiveness of pollution control measures, such as effluent treatment plants and sedimentation tanks.

Data-driven insights support CSR initiatives like pond rejuvenation and community water health awareness.

5.4. LIMITATIONS OF METHODOLOGY:

These arise primarily from sample collection restrictions, seasonal variations, and laboratory constraints. Each of these challenges can significantly influence the reliability, validity, and scope of the findings.

5.4.1. Sample Collection Restrictions One of the primary methodological limitations in the NALCO project pertains to restrictions during the sample collection phase. These restrictions may be physical, regulatory, or logistical in nature.

Restricted Access Areas: Certain parts of the plant premises, mining sites, or effluent discharge zones might be inaccessible due to safety regulations or operational protocols. This limits the ability to gather comprehensive samples across all impacted zones.

Red mud Pond is highly alkaline byprod process used in aluminium production.it may cause skin burns and respiratory issues. **NALCO mining site** are highly risk zone due to heavy machinery such as dumpers, drilling equipment.Blasting operation are conducted to break hard rock which

creates vibration and noise.

Sampling Time Constraints: Industrial operations often follow tight schedules. Gaining access for sample collection may require prior approvals and coordination with plant managers, which can lead to delays or limited sampling opportunities.

Representative Sampling: In complex industrial ecosystems, variability across different sites is high. Collecting representative samples from all relevant zones within a limited timeframe may not always be possible, affecting the accuracy of generalized conclusions. These restrictions can cause bias in the collected data or lead to under-representation of certain critical locations, ultimately impacting the overall quality of the environmental impact assessment or performance monitoring.

2. Seasonal Variations Seasonal changes significantly affect environmental parameters, which must be accounted for in any long-term monitoring or impact assessment study, including NALCO projects. **Air and Water Quality Fluctuations:** Seasonal rainfall, temperature, and wind patterns affect the dispersion of pollutants, groundwater recharge, and surface runoff. For instance, monsoon seasons may dilute waterborne pollutants or increase leachate movement from mining areas.

Biological and Chemical Activity: Microbial activity in soil and water, crucial for understanding effluent degradation, varies with temperature and humidity, potentially skewing data if sampling is done in only one season.

Temporal Comparisons: Comparing data across seasons requires multiple sampling cycles, which may not always be feasible due to budgetary or time constraints. One-time sampling, often used due to such limitations, provides only a snapshot that may not represent annual conditions. In NALCO's case, where both mining operations and aluminium production are affected by seasonal supply chains and resource availability, these variations introduce significant complexity in drawing consistent inferences. 3.

RESULT AND CONCLUSION

The study was conducted by sampling at ten locations representing the regions of Koraput. The sampling locations were from –

1. Beheraguda river site
2. Panchpatimali drinking stream waterv 1
3. Panchpatimali stream water 2
4. Nalco Ash pond
5. Nalco Red mud pond
6. Maa kanta Bausani isolated Temple pond, Damonjodi
7. Forest pond, Jeypore
8. Kolab dam eastern bays, Koraput
9. Stream water under SH bridge, inlet to Kolab dam, Koraput
10. Ghataguda river site

7.1. Result of pH:

The pH levels of five different water samples collected from various locations were measured using a calibrated digital pH meter. The results are summarized in Table 6.1.

| S.No. | Sample | Date and time of collecting samples | pH | Colour | Inference |
|-------|--------------------------------|-------------------------------------|----|----------------|-------------------|
| 1. | Beheraguda river | 07/ 04/2025 10:23 A.M | 4 | Beige | Slightly acidic |
| 2. | Panchpatimali stream water | 07/04/2025 11:02 A.M | 4 | Beige | Slightly acidic |
| 3. | Panchpatimali drinking water | P7/04/2025 | 6 | Lime green | Slightly acidic |
| 4. | Ash pond | 07/04/2025 03: 39 P.M | 4 | Beige | Slightly acidic |
| 5. | Red mud pond | 07/04/2025 04:08 P.M | 14 | Purplish black | Very alkaline |
| 6. | Maa kanta Bausani Temple water | 07/04/2025 05:16 P.M | 7 | Green | Neutral |
| 7. | Forest pond | 08/04/2025 11:01 A.M | 8 | Dark green | Slightly alkaline |
| 8. | Kolab dam water | 07/04/2025 08:16 A.M | 4 | Beige | Slightly acidic |
| 9. | Stream water under bridge | 07/04/2025 08: 15 A.M | 5 | Yellow | Slightly acidic |
| 10. | Ghataguda river water | 07/04/2025 09:01 A.M | 4 | Beige | Slightly acidic |

The pH levels of ten water samples were analyzed, and the values ranged from 4.0 to 14.0. The data set showed a majority of the samples having a pH below 7, indicating acidity in most cases. Table 1 presents the individual pH readings for each sample. The mean pH value of the samples was 6.0, indicating an overall slightly acidic trend. However, one sample had a highly alkaline pH of 14.0, which significantly deviates from the rest of the data and may be considered an outlier.

7.1.1. DISCUSSION:

The majority of the water samples (60%) exhibited a pH of 4.0, which is strongly acidic and falls well below the WHO recommended range for drinking water (6.5–8.5). This level of acidity could be harmful for human consumption and might indicate contamination from acid rain, industrial discharge, or decaying organic matter.

Sample 5, with a pH of 14.0, is an extreme outlier. This value is highly basic, suggesting either a measurement error or severe contamination — possibly from a strong base like sodium hydroxide or industrial alkaline waste.

Samples 6, 7, and 9 had pH levels of 7.0, 8.0, and 5.0, respectively. The first two are within the acceptable range and are likely safe for drinking. However, the pH 5.0 sample is mildly acidic and might indicate the early stages of contamination.

The safe pH range for drinking water, according to the World Health Organization, is 6.5 to 8.5. Only three samples (pH 6, 7, and 8) fall near or within this range. The rest, particularly the repeated pH of 4, are unsafe for consumption and could be corrosive to plumbing and harmful to health if ingested over time.

In summary:

6 samples (pH 4.0): strongly acidic — likely unsafe.

1 sample (pH 14.0): highly basic — very likely contaminated.

2 samples (pH 7.0 & 8.0): within safe range.

1 sample (pH 5.0): mildly acidic — borderline unsafe.

These findings suggest that most of the sampled water sources are not suitable for consumption without treatment. The data also raises concern about possible industrial or chemical pollution in the sampling area. Further chemical analysis and repeated sampling are recommended for confirmation.

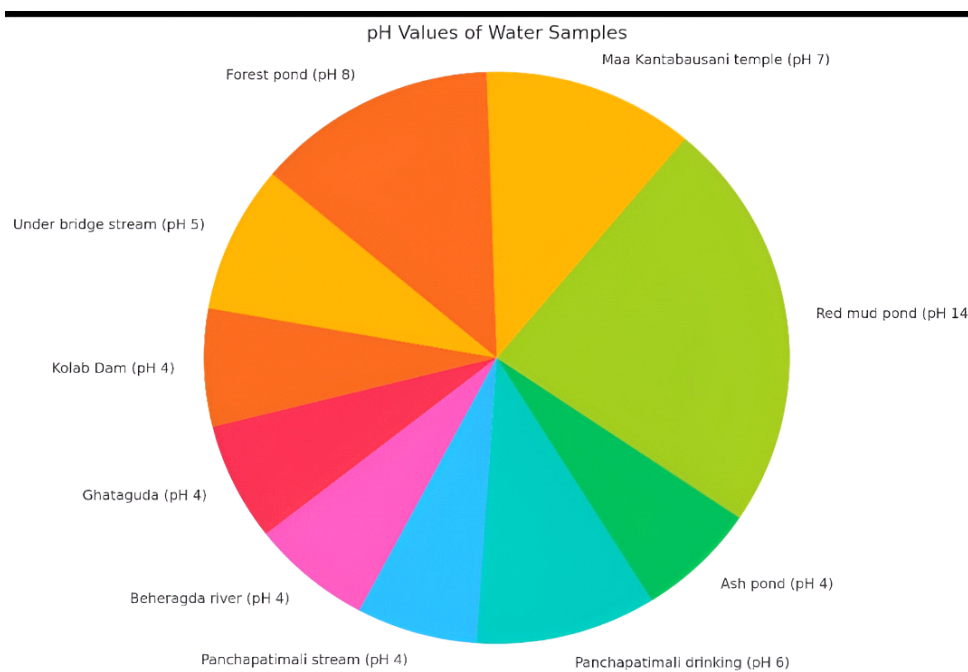
Possible sources for the acidic samples could include nearby industrial activities, agricultural runoff, or improper waste management. Further chemical testing (e.g., for heavy metals, nitrates, or organic pollutants) is recommended to identify specific causes of pH imbalance.

7.2. RESULT OF D.O. TEST:

The Dissolved Oxygen (D. O.) values of various water samples collected from different sources were determined and are presented below. D.O. is a critical parameter that indicates the amount of dissolved oxygen required by aerobic biological organisms to break down organic material in water. It serves as a key indicator of water quality, particularly in relation to organic pollution levels.

| Sample No | Sample name | D.O (mg/L) | Remarks |
|-----------|-------------------------------|-----------------------|---|
| 1 | Ash pond water | No titration occurred | Not suitable for life |
| 2 | Forest pond | 12.19mg/l | Very good for aqua life |
| 3 | Red mud pond | No tiration occurred | Not suitable for life, no bacteria, alge, no weeds |
| 4 | Panchpatimali stream water | 12.39mg/l | Goot for stram fishes and other aquatic life, irrigation |
| 5 | Kolab dam water from the bays | 12.39mg/l | Good for aquatic arthropods and amphibians, fishes, wetland birds |
| 6 | Panchpatimali drinking water | 13.41mg/l | No Bacteria, suitable for drinking, cooking, cattle feeding |

Table 6.1- pH of different water samples collected



1. Sample 1: Ash Pond Water

No titration result was obtained for this sample, possibly due to the absence of significant biological activity or the presence of substances that interfered with the DO. testing process. Ash pond water often contains high concentrations of inorganic materials and heavy metals that can suppress microbial activity, making D.O. determination challenging.

| S.No | Sample | D.O. calculated (mg/L) |
|------|-------------------------------|------------------------|
| 1. | Ash pond water | No titration occurred |
| 2. | Forest pond water | 12.19 mg/L |
| 3. | Red mud pond water | No titration occurred |
| 4. | Panchapatimali stream water | 12.39 mg/L |
| 5. | Kolab dam water from the bays | 12.39 mg/L |
| 6. | Panchapatimali drinking water | 13.41 mg/L |

2. Sample 2: Forest Pond Water The D.O. of the forest pond water sample was found to be 12.19 mg/L, suggesting a relatively low level of biodegradable organic matter. This indicates little significant organic pollution, likely due to natural organic debris such as leaves, soil runoff, or possibly human and animal activity around the pond.

3. Sample 3: Red Mud Pond Water

Similar to the ash pond, no titration result was recorded for this sample. Red mud is a by-product of alumina production and contains caustic and toxic compounds. These conditions are generally hostile to microbial life, resulting in negligible or non-measurable D.O. levels.

4. Sample 4: Panchapatimali Stream Water

The DO. of this sample was measured at 12.39 mg/L, which also signifies a high level of organic contamination. This value is slightly higher than that of the forest pond and could be attributed to

inflow from nearby settlements, agricultural runoff, or industries.

Sample 5: Kolab Dam Water

The D O. value of the Kolab dam water was **12.39 mg/L**, matching the level observed in the Panchapatimali stream. This again reflects a high organic load, possibly from upstream sources or catchment area activities like agriculture and domestic waste disposal.

Sample 6: Panchapatimali Drinking Water

Surprisingly, the DO. of the drinking water source in Panchapatimali was **13.41 mg/L**, the highest among the tested samples. This is a cause for concern as such a high DO. is not suitable for drinking purposes. It may indicate contamination due to inadequate treatment, poor sanitation infrastructure, or infiltration of wastewater.

Overall Analysis:

The DO. values from Samples 1 to 4 indicate a concerning level of organic pollution across natural and drinking water sources in the studied region. Particularly, the high DO. in the drinking water sample calls for immediate attention and intervention. Samples 5 and 6 showed no measurable DO., likely due to the chemical nature of the ponds, which inhibit biological degradation processes.



Photo of the landmark at hill top entrances to Minig restricted area at Panchpatimal hill

7.2.1. Discussion:

High DO values indicate a high level of Oxygen saturation and low DO which may be affected due to result from domestic sewage, industrial effluents, or decaying natural matter. The BOD is a critical parameter used to evaluate the organic pollution load in water bodies. It reflects the amount of dissolved oxygen required by aerobic microorganisms to decompose organic matter in a water sample over a specified period, typically five days at 20°C. But this parameter could not be done as no sophisticated instruments available in the dept.

In the present study, DO values were measured for six different water sources around the Panchapatmali region, including a forest pond, stream, drinking water supply, a dam, an ash pond, and a red mud pond.

Samples 1 and Sample 3, from the ash pond and red mud pond respectively, showed no titration results. This could be due to extremely low or high contamination that made the standard DO test ineffective, or possibly due to experimental or sampling errors. Ash ponds and red mud ponds are typically associated with industrial waste, especially from thermal power plants and aluminum refineries. These environments often contain toxic substances or extreme pH levels that inhibit microbial activity, which may explain the inability to obtain measurable BOD results. Sample 6 taken from a drinking water source in Panchapatmali, showed a DO of 13.41 mg/L, the highest among the tested samples. This is a matter of concern, as drinking water sources should ideally have very HIGH DO values, generally to be considered safe and free from organic contamination. The elevated DO value here suggests NO CONTAMINATION of the drinking water with organic pollutants, which may pose health risks and highlight the need for immediate intervention, such as improved filtration or source protection. This indicates organic pollution, likely from anthropogenic activities or natural decomposition processes. The unusually high DO of the drinking water source particularly demands immediate remedial action and further investigation into its contamination sources. The lack of data for the industrial ponds also suggests the need for alternative testing methods that account for extreme chemical conditions.

The findings highlight the necessity for consistent water quality monitoring and implementation of conservation measures to protect aquatic ecosystems and public health in the Panchapatmali region.

7.3. Results and Discussion: Turbidity:

The turbidity of the water sample was measured using a Nephelometric Turbidity Unit (NTU) meter, which quantifies the intensity of light scattered by suspended particles in the water. For drinking water, the standard turbidity level is typically maintained below 1 NTU.

Elevated turbidity levels can interfere with disinfection processes by shielding microorganisms from chemical disinfectants and increasing the demand for treatment chemicals. Moreover, high turbidity may indicate the presence of microbial contamination or other pollutants. Therefore, maintaining turbidity within acceptable limits is essential for ensuring water safety and treatment efficiency.

At NALCO, monitoring and optimizing turbidity not only ensures compliance with water reuse and environmental standards but also enhances operational efficiency.

7.4. Results and Discussion: Heavy Metal Analysis:

The concentration of heavy metals, including lead (Pb), cadmium (Cd), mercury (Hg), chromium (Cr), and arsenic (As), was analyzed using Atomic Absorption Spectroscopy (AAS) or Inductively Coupled Plasma Mass Spectrometry (ICP-MS). The samples were digested with acids such as HNO₃ and HCl, filtered, and assessed for individual metal concentrations.

Any exceedance would pose significant health and environmental risks, as these metals are toxic even at trace levels. Industrial activities at NALCO have the potential to introduce such metals into water bodies, thus making their routine monitoring critical.

Effluent treatment plants (ETPs) at NALCO are equipped with targeted treatment units such as precipitation tanks and ion exchange columns to minimize heavy metal discharge. Regular testing ensures environmental compliance and helps protect aquatic ecosystems and public health.

These results emphasize the importance of stringent monitoring and process optimization to maintain discharges within regulatory limits.

7.5. Results and Discussion: Biodiversity Assessment:

The biodiversity assessment focused on evaluating the presence and diversity of aquatic organisms in water bodies potentially affected by industrial activities at NALCO. Parameters such as species richness, abundance, and the presence of indicator species were considered to determine the ecological health of the aquatic environment. High levels of turbidity and elevated concentrations of heavy metals, as identified in previous analyses, can adversely affect aquatic biodiversity. Suspended solids can reduce light penetration, affecting photosynthetic organisms, while toxic metals can bioaccumulate and impact sensitive aquatic species.

The results highlight the importance of maintaining water quality not only for compliance but also for the sustainability of local ecosystems. Regular monitoring of both physicochemical parameters and biological indicators ensures early detection of ecological imbalance and supports targeted environmental management strategies at NALCO.

9. IMPACT ON AESTHETIC, RECREATIONAL, AND CULTURAL ENVIRONMENT:

- a. Degradation of Landscape Beauty: - Massive pits, conveyor belts, red mud ponds ruin natural scenic vistas of the Eastern Ghats. Dust clouds often obscure sunrise/sunset views.
- b. Impact on Tourism and Nature Trails: -Nearby destinations like Deomali hill, Duduma waterfalls lose attractiveness due to industrial encroachment.
- c. Cultural Alienation: -Traditional tribal art, festivals, and dress patterns decline as youth assimilate into migrant industrial culture.

Fig 13 Silver oak plantation after mining site Northern sector



Fig: - 14 the dusts and SPM are little absorbed by Natural vegetations in the non mining area.

8.3. Mitigation Measures:

a. Land Environment: Topsoil Management: Carefully removed, stored, and reused for land reclamation and plantation.

Overburden Dump Stabilization: Use of terracing, vegetation, and retaining walls.

Reclamation: Progressive backfilling and eco-restoration of mined-out areas to reduce long-term impact. **b. Air Quality:** Dust Control: Water sprinklers on roads, fog cannons at material handling points. Emission Control: ESPs and bag filters at emission sources; fluoride scrubbers in the calcination unit.

Green Belt: Thick vegetation barrier around the plant and red mud ponds to trap dust and improve

air quality.

c. Water Resources: Effluent Treatment: Advanced treatment units to ensure Zero Liquid Discharge (ZLD).

Red Mud Pond Safety: Lined with HDPE sheets to prevent leachate; monitored regularly. Rainwater Harvesting: Rooftop and surface water harvesting systems installed.

d. Biodiversity: Afforestation: Planting of native species as compensatory afforestation. Wildlife Protection: Maintaining corridors for elephant movement and enrichment of forest habitat. Flora and Fauna Monitoring: Regular biodiversity surveys and protection of rare species. **e. Noise Control:** Engineering Measures: Acoustic covers, silencers, and controlled blasting. Green Barriers: Vegetative walls around high-noise areas.

Worker Protection: Earplugs and earmuffs provided to workers.

f. Waste Management: Red Mud: Dry stacking method; exploring reuse in cement and construction. Solid Waste: Segregation and composting of biodegradable waste.

Hazardous Waste: Safe disposal as per CPCB guidelines.

8.4. Environmental Management Plan (EMP):

Monitoring Programme: Air, water, noise, and soil quality monitored monthly/quarterly. Dedicated Environment Cell: Technical staff to oversee compliance and monitoring.

Training and Capacity Building: Regular awareness and skill development for workers. Budget Allocation: Specific funds for pollution control, afforestation, CSR, and emergencies. Disaster Response Plan: Detailed on-site emergency plan for chemical spills, fire, or red mud breaches.



Fig- 15 and 16 Ex-Situ conservation at Mining Nursery, Kitchen farm and Poly house.

9.3. CONSERVATION OF THE AQUATIC ECOSYSTEM IN THE NALCO AREA:

NALCO (National Aluminium Company Limited) operates in the region of Damanjodi and Koraput in Odisha, which are surrounded by several rivers and streams. The Kolab Reservoir is one of the significant water bodies in this region, and several smaller streams also feed into it. However, industrial activities like mining and alumina refining can have negative effects on water quality and aquatic life.

9.3.1. Negative Impacts on Biodiversity:

a. Habitat Destruction and Fragmentation:

Mining Activities: Bauxite mining, particularly the open-pit mining method used by NALCO, involves the removal of large areas of forest and natural habitats, leading to deforestation and habitat fragmentation. This loss of habitat negatively impacts many species of flora and fauna that depend on these ecosystems for survival.

Forest Loss: The NALCO mining operations in Koraput and Damanjodi are located near forests that are home to a rich diversity of plant and animal species. Deforestation can result in the loss of critical habitats for many species, such as the bear, jackel, wild boar. Birds like asian koel, spotted dove, asian green bee eater, common myna, rock pigeon, little swift etc and other birds and

reptiles.

Disruption of Ecosystem Services: Deforestation and habitat destruction affect ecosystem services, including soil fertility, water retention, and climate regulation, which in turn impacts local communities and wildlife.

b. Pollution:

Water Pollution: The effluent discharge from alumina refining operations can pollute nearby rivers, streams, and the Kolab Reservoir. Industrial effluents, if not adequately treated, can introduce heavy metals, acids, and other harmful chemicals into the water, adversely affecting aquatic life. This can lead to eutrophication, reducing oxygen levels and harming fish and other aquatic organisms.



Photo- The team at Mining site at hill top - Panchpattimal hill Nalco site

9.3.2. Positive Impacts of NALCO on Biodiversity Conservation:

a. Environmental Management Initiatives:

Afforestation and Reforestation: NALCO has implemented afforestation programs around its mining areas to help mitigate the impacts of deforestation. These programs involve planting trees to restore lost vegetation cover and help in soil stabilization. In some cases, native plant species are being used to help restore the natural ecosystem balance.

Biodiversity Monitoring: NALCO has undertaken environmental monitoring programs to track the impact of its operations on local wildlife and ecosystems. This data helps in adjusting management practices to minimize ecological damage and improve the sustainability of operations.

Waste Management: NALCO has invested in technologies to reduce the environmental impact of its waste. For example, efforts have been made to manage red mud (a by-product of alumina refining), which can have significant environmental consequences if not managed properly.

Renewable Energy: NALCO has moved towards using renewable energy sources like hydropower for its operations, reducing the carbon footprint and mitigating the impact on the climate. This contributes to biodiversity conservation indirectly by helping address climate change.

b. Restoration of Degraded Lands:

Post-Mining Rehabilitation: NALCO has undertaken land reclamation and rehabilitation activities in mining areas to restore ecosystems. These efforts focus on restoring soil quality and introducing vegetation to help bring back biodiversity to disturbed lands.

Fig 17

The Author and the guide at Fishermen community interaction and understanding sound aquatic bio-diversity at Kolab Dam

Climate Change Adaptation: Develop a strategy to adapt to **climate change** impacts, particularly for water availability and ecosystem stability. This could include water conservation initiatives, drought-resistant crops, and preparing for extreme weather events.

Review of past literatures

The comprehensive assessment conducted through the AQUANALCO study underscores the pressing environmental concerns arising from industrial activities in Damanjodi, Koraput. Home to significant industrial establishments, especially those engaged in mining and aluminum processing, this region has witnessed a gradual but consistent deterioration of its aquatic ecosystems. Our study has revealed alarming alterations in key water quality parameters such as pH, dissolved oxygen, turbidity, and heavy metal concentration, all of which directly influence the health of aquatic flora and fauna. These changes indicate not only the physical and chemical degradation of water bodies but also the loss of ecological balance within aquatic habitats.

A notable decline in aquatic biodiversity, including sensitive species of fish, macroinvertebrates, and plankton, reflects the toxic stress exerted by industrial effluents and runoff. Furthermore, sediment analysis and bioindicator studies suggest bioaccumulation of harmful substances, posing threats not only to aquatic organisms but also to human populations reliant on these water bodies for sustenance and livelihood.

The findings call for immediate intervention through stringent regulation of industrial waste discharge, adoption of environmentally sustainable technologies, and regular environmental monitoring. Restoration initiatives such as riparian zone replantation, construction of effluent treatment systems, and community based water management can play a critical role in reversing the damage.

In conclusion, the AQUANALCO study highlights the interconnectedness between industrial development and ecological sustainability. It serves as a wake-up call for policymakers, industries, and the public to acknowledge and address the environmental costs of unchecked industrialization. Protecting the aquatic ecosystems of Damanjodi is not only an ecological imperative but also essential for the long-term health, economy, and resilience of the region. Sustainable development, driven by science and community engagement, remains the pathway forward.

The environmental implications of red mud disposal in eastern India, specifically focused on NALCO's red mud pond in Damanjodi. They pointed out that the red mud generated here contains high concentrations of sodium hydroxide, iron oxide, and titanium, making it hazardous if leaked. Their research emphasized the need for integrated waste utilization strategies, such as using red mud in cement and brick manufacturing, which NALCO had piloted on a limited scale (S. K. Mishra and P. K. Rath, 2010),)

While industrial growth brought by NALCO has undeniably contributed to regional infrastructure, employment, and economic stimulation, it has also imposed considerable ecological and social

costs, especially on the aquatic systems and communities dependent on them.

Red mud, a byproduct of the Bayer process used in alumina refining, is generated in massive quantities and stored in engineered ponds. Similarly, ash ponds, which contain fly ash produced from the captive power plants, are prone to leakage and leaching mishra and Ratha 2010

NALCO bring infrastructure and employment, they also generate massive quantities of toxic waste such as red mud, a highly alkaline byproduct of bauxite refining. Improper management of these ponds can lead to groundwater contamination, soil degradation, and long-term ecological damage. They found that while NALCO complied with the Central Pollution Control Board's basic standards, seepage from the ash pond was a potential risk to nearby agricultural lands. They advocated for technological interventions like pond lining and dry ash handling systems to reduce environmental risk. Kuntala Lahiri-Dutt (2007)

Women bore the brunt of displacement impacts. In displaced communities near NALCO's project areas, women lost access to forest resources and natural water sources, which had been integral to their daily lives and food security. Tripathy also observed that while some displaced youth accessed education and jobs offered by NALCO, the majority struggled to adapt due to language barriers and cultural dislocation. Manoranjan Tripathy (2010)

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Photo Gallery -1 Fig- 5 All of the Sampling at Kolab dam site near Bridge close to CUO campus

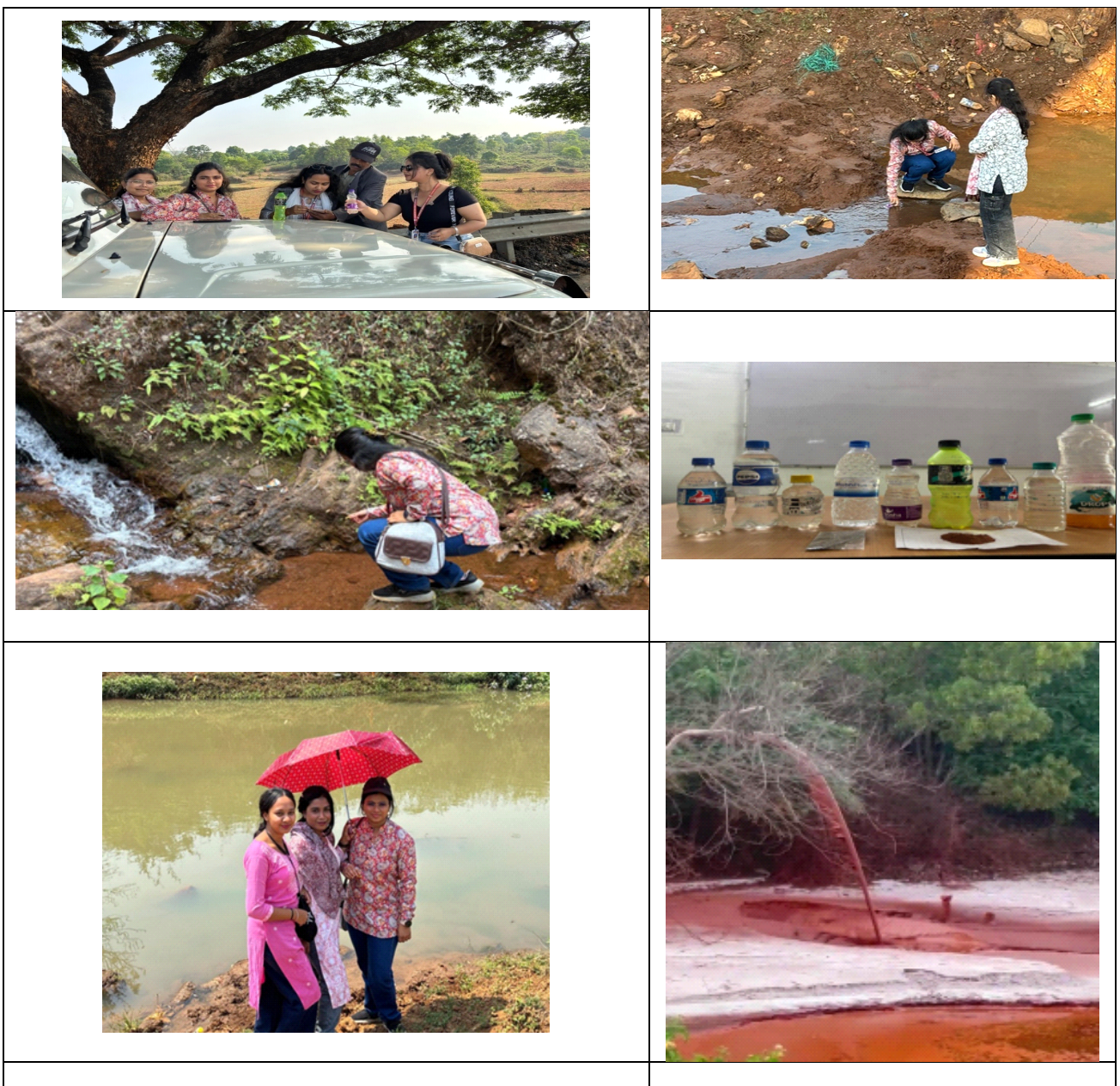


Photo Gallery -II Fig-

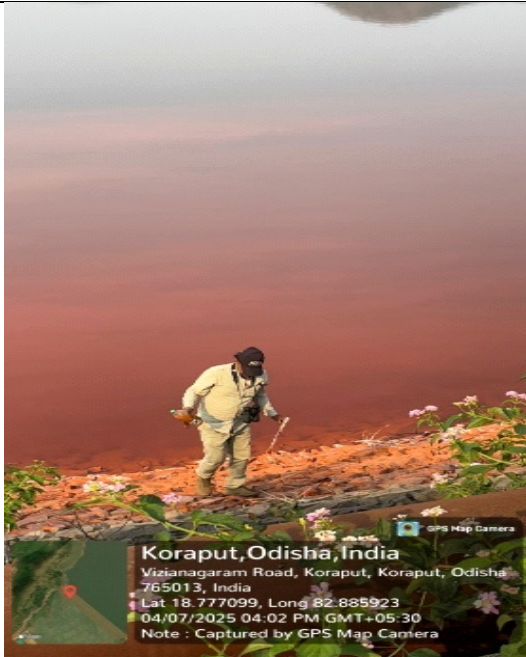
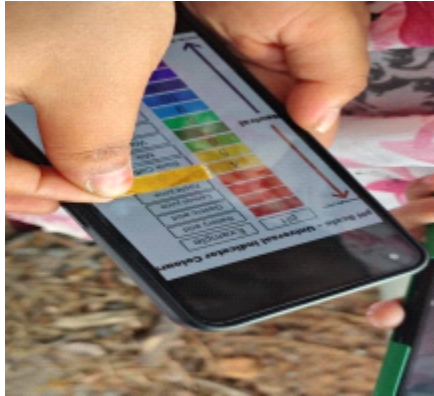


Fig-6 Myself sampling of Redmud pond highly alkanine water.



Fig:- 9 and 10 NALCO WASTAGE (Ash Pond)



Reclamatioan at post mining sites in the Eastern Panchpattimal mines



Watersampling and aquatic fauna survey in kolab dam - Fig Fali fish- *Notopterus notopterus*



Fig:- 11 and 12 NALCO Solid WASTAGE (Red mud Pond water after dried to hard red soil.)