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Surface and Ground Water Quality Status in and Around Vedanta Alumina Ltd. Lanjigarh, Odisha, India

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Abstract— Background: *Vedanta's Alumina Refinery at Lanjigarh is having zero discharge system i.e. no water or effluent is discharged to any outside water bodies from the refinery. The effluent is recycled within the plant which helps to reduce external water by more than 60%. There is sustainable in every stage of operation starting from design, technologies, construction, and monitoring and management. The industry meet its water requirements from Tel River at Kesinga, Odisha. However development has both positive and negative aspect; it is unlikely that the plant would be able to consume all the wastewater even if they use it for dust suppression, gardening or some other activities. Therefore, there is a high possibility that some amount of wastewater may find its way into the surface and ground water. There is high risk of groundwater and surface water contamination from the red mud and fly ash disposal site.*

Aim: *to investigate the physicochemical qualities of surface and groundwater from the periphery of VAL at Lanjigarh, Odisha due to flyash and red mud disposal. And to determine its suitability for drinking and domestic use from Water Quality Index.*

Methods: *Water samples is collected during monsoon, pre and post monsoon. Sampling is carried out at different sites of Vedanta Alumina Lanjigarh Plant. Total 5 sites are selected for the study i.e 2 surface water sites and 3 tube well. Sampling bottles were rinsed at least three times before sampling was done. At surface water sites sampling bottles were immersed about 10 cm below the water surface. For ground water; samples were collected from hand pump which are used for domestic and drinking purpose. All the samples are acidified with 10% HNO3, and brought to the laboratory in an closed ice box for analysis of physicochemical characteristics and heavy metal concentrations. The analysis of the sample is carried on the basis of standard methods by the American Public Health Association American Public Health Association (APHA, 2005).*

Conclusion: *In the present study to evaluate the pollution status, the samples were analysed and its results were compared with the standard values of Indian water quality Standards. From the present research study, it was concluded that although the Physico chemical parameters of ground water samples and surface water samples in and around Vedanta Aluminium Company at Lanjigarh, Odisha are within safe limits of Indian standard for drinking water quality (IS: 10500) but the toxic level of harmful materials can mix up with the ground water if no precautionary measures were taken for effective treatment of the industrial effluents.*

Index Terms— Surface and Ground Water Quality

I. INTRODUCTION

Water is the source of countless ecosystem services, and critical to industrial, agricultural, household, and recreational activities.It is the most abundant natural resource on the planet. It is witnessed that the beginning of the twenty-first century has seen rapid changes in the domestic and international energy landscape. Development cannot be stopped but the challenges associated with growing demands of population should be met with sustainability. There has been rigorous usage of water in all sector i.e. agriculture, industry and domestic etc. In order to accommodate current and future challenges in account of water, there should be continuous monitoring, treatment and its management. Wastewater generated from industry is in fact a matter of concern for whole biological and physical environment.

Vedanta's Alumina Refinery at Lanjigarh is having zero discharge system i.e. no water or effluent is discharged to any outside water bodies from the refinery. The effluent is recycled within the plant which helps to reduce external water by more than 60%. There is sustainable in every stage of operation starting from design, technologies, construction, and monitoring and management. The industry meet its water requirements from Tel River at Kesinga, Odisha through a 65 km pipeline. The use of pipe conveyor minimise dust generation, ensures generation of minimum noise and avoids the need for road transportation. In addition measures like the use of dry fog system for dust suppression, zero discharge of water by recycling, regular sprinkling of water on haulage roads and overburden heaps and concurrent plantation have been undertaken to minimise air and water pollution. VAL has facilitated setting up of fly ash brick making units by local communities, which has provided a productive use for waste and has become a source of income for the communities.

However development has both positive and negative aspect; it is unlikely that the plant would be able to consume all the wastewater even if they use it for dust suppression, gardening or some other activities. Therefore, there is a high possibility that some amount of wastewater may find its way into the surface and ground water. There is high risk of groundwater and surface water contamination from the red mud and fly ash disposal site. The fly ash generated during

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power plant operations and ash ponds in the disposal area disturbs water quality by increasing the suspended, dissolved solids, heavy metals, ash, oil & grease, mercury, phosphorus, ammonia, urea and acids etc.

Fly ash is a waste material generates on the combustion of coal in power station. Fly ash contains major elements like Silica, Aluminum and Iron with significant amount of Calcium, Magnesium, Potassium, Phosphorous and Sulphur (Ivanova *et al*., 2011; Aswar, 2001). It also contain trace amount of some heavy metals like Molybdenum, Mercury, Selenium and Cadmium etc. (Adriano *et al*., 1980). Fly ash in itself is a waste product and contains a huge problem for disposal.

Fly ash is disposed off in ash pond by collecting it in the form of wet slurry (Singh *et al*., 2010). Disposal of fly ash in surface water bodies can damage the aquatic life. Mosquitoes and bacteria may grow in large number in slurry disposal lagoons/settling tank (Nawaz, 2013). The soil and water contamination from ash ponds has been a major subject of research all over the world (Theis*et al*., 1978; Theis and Richter, 1979; Theis and Gardner, 1990; Carlson and Adriano, 1993; Deshmukh *et al*., 1994; Deshmukh *et al*., 1995; Gulec*et al*., 2001; Praharaj*et al*., 2002; Singh *et al*., 2010; Ramya*et al*., 2013; Nawaz, 2013).

Red Mud is a mixture of non- alumina compounds originally present in the parent mineral, bauxite, and the slurry insoluble waste produced during the Bayer process. It is disposed as a slurry having a solid concentration in the range of 25- 55 % (high caustic containing water content), pH in the range of 13 and high ionic strength. Red Mud also contains insoluble chemicals like silica, alumina, iron, calcium, titanium oxides, as well as many other minor and rare earth compounds.

According to WHO organization, about 80% of all the diseases in human beings are caused by water (Kavita and Elangova,2010). In present decades, there has been a tremendous increase in the demand for fresh water due to rapid growth of population and industrialization. Water quality standards are needed to be determined whether surface and ground water of a certain quality is suitable for intended use.

II. AIMS AND OBJECTIVES

The present study aims to investigate the physicochemical qualities of surface and groundwater from the periphery of VAL at Lanjigarh, Odisha due to flyash and red mud disposal. And to determine its suitability for drinking and domestic use from Water Quality Index.

Collection and analysis of water samples is done in pre and post monsoon periods.

III. METHODOLOGY

The study area VAL Lanjigarh, Odisha is situated at latitude 19˚42’43.63”’N and longitude of 83˚23'56.34” E.Water quality index is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy makers. The water is collected from the ground water and surface water at various distances taking the ash and red mud pond as the centre point.

IV. STUDY SITES

S1, S2 Surface Water Samples from the Vedanta Plant inside and outside.

S3, S4, S5 Ground Water /Tube well water samples from tube well inside Vedanta Plant and campus.

The physico-chemical parameters to be studied are as follows:

Physical parameters: Temperature, Turbidity.

Chemical parameters: pH, Electrical Conductivity (E.C), Total Solids (TS), Total Dissolved Solids (TDS), Total Suspended Water samples is collected during monsoon, pre and post monsoon.

Sampling is carried out at different sites of Vedanta Alumina Lanjigarh Plant. Total 5 sites are selected for the study i.e 2 surface water sites and 3 tube well. Sampling bottles were rinsed at least three times before sampling was done. At surface water sites sampling bottles were immersed about 10 cm below the water surface. For ground water; samples were collected from hand pump which are used for domestic and drinking purpose. All the samples are acidified with 10% HNO3, and brought to the laboratory in an closed ice box for analysis of physicochemical characteristics and heavy metal concentrations. The analysis of the sample is carried on the basis of standard methods by the American Public Health Association American Public Health Association (APHA, 2005). Temperature is determined on site by Thermometer. Nephelometric method is used for the measurement of turbidity of water. pH of the samples was noted using meter by electrometric (Systronic Electronic pH meter). EC was determined by conductivity meter. Potassium and Sodium is estimated by systronic flame photometer. Winkler iodometric method is used for the determination of dissolved oxygen in water samples. Dissolved oxygen (DO) levels in natural and waste water depend on the physical, chemical and biochemical activities in the water body. The analysis for DO is a key test in water pollution and waste treatment process control. Total Solid content is determined by Gravimetric method. Total alkalinity and alkalinity due to carbonates, bicarbonates is estimated by titrating the sample with diluted H_2SO_4 using phenolphthalein as an indicator to pH 8.3 and methyl orange as an indicator to pH 4.2 and 5.4. The titrate value gives phenolphthalein alkalinity (PA) and the second one gives total alkalinity (TA).

Hardness of water is not a specific constituent but is a variable and complex mixture of cations and anions. It is caused by dissolved polyvalent metallic ions. Total hardness of the samples is analysed by titration with EDTA using Erichome black-T as an indicator. The determination of chloride is easily made by $AgNO_3$ titration (Mohr’s titration) method in which silver reacts with chloride forming while

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Volume 12 Issue 12 December 2025

AgCl precipitate in the presence of sulphuric acid. When all the chlorides are precipitated, potassium chromate (the indicator used) shows the brick red colour at the end point due to the formation of silver chromate. The traces of sulphate occur universally in all types of waters. Sulphate can be determined turbidimetrically. The sulphate content is determined by the extent of turbidity created by precipitated barium Sulphate suspension. Barium chloride is added to ensure fine and stable suspension of $BaSO_4$ at a pH of about 4.8. It also eliminates the interface of phosphate and silicate. Fine suspension of $BaSO_4$ is stabilized by Gum Acacia and the degree of turbidity measured by Turbidimeter or Spectrophotometer.Calcium and calcium hardness by EDTA Titrimetric. Magnesium and magnesium hardness is estimated by EDTA Titrimetric. Determination of nitrate is based on the reduction of nitrate to nitrite in the presence of Zn/NaC. UV-Visible spectrophotometer is used to determine nitrate. Phosphate by stannous chloride method. Flouride by Ion-Selective Electrode Method. The fluoride electrode is an ion-selective sensor. The key element in the fluoride electrode is the laser-type doped lanthanum fluoride crystal across which a potential is established by fluoride solutions of different concentrations. The crystal contacts the sample solution at one face and an internal reference solution at the other. The fluoride electrode measures the ion activity of fluoride in solution rather than concentration. Fluoride ion activity depends on the solution total ionic strength and pH, and on the solution total ionic strength and pH, and on fluoride complexing species. Adding an appropriate buffer provides a nearly uniform ionic strength background, adjust pH, and breaks up complexes so that, in effect, the electrode measures concentration. The open reflux method will be used to determine COD. The organic matter gets oxidised completely by potassium dichromate ($K_2Cr_2O_7$) with silver sulphate as catalyst in the presence of concentrated H_2SO_4 to produce CO_2 and H_2O. The excess $K_2Cr_2O_7$ remaining after the reaction is titrated with ferrous ammonium sulphate [Fe $(NH_4)_2(SO_4)_2$].

V. RESULT AND DISCUSSIONS

Table 1: Ground water and surface water Physico chemical Test In summer

Sample	Temperature (°C)	PH	Turbity (FTU)	Electrical Conductivity	DO (mg/l)	TDS (mg/l)	Total Alkalinity (mg/l)	Total Hardness (mg/l)	Cl- (mg/l)	SO42- (mg/l)	Ca (mg/l)	Mg (mg/l)	NO3- (mg/l)	PO4- (mg/l)	F (mg/l)	COD (mg/l)
S1	25.3	8.6	18	756.7	6.7	1143.3	223	570	144.1	116	49.1	29.1	35.9	1.80	2.27	39.6
S2	24.2	7.8	14.2	688.5	6.4	1195	204	484.7	169.9	111.7	45.2	35.1	26	3.30	2.4	44.9
S3	**20.8**	**6.9**	**2.9**	**355.3**	**4.2**	**258**	**167.3**	**462**	**24.9**	**27.5**	**41.5**	**25.6**	**18.8**	**2.1**	**0.7**	**15.6**
S4	21.1	7.9	6.8	426.0	2.06	120.7	114	514.7	74.8	22.1	38	19.6	13.7	1.1	0.71	15.6
S5	**19.47**	**7.1**	**5.1**	**552.6**	**3.6**	**116**	**206.7**	**317.7**	**51.5**	**86.2**	**43.3**	**21.7**	**19.8**	**0.5**	**0.8**	**20.7**

Table 4: BIS/CPCB /EPA Water Quality Criteria

Serial No.	Characteristic	Requirement Acceptable limit	Permissible Limit in absence of alternate source	BIS
1.	Temperature	NA	NA	
2.	Turbidity NTU	01	05	As per BIS IS 10500: 2012
3.	pH	6.5-8.5	No relaxation	As per BIS IS 10500: 2012
4.	Electrical Conductivity	NA	NA	
5.	Dissolved Oxygen mg/l	6 or more		As per CPCB
6.	Total dissolved Solids mg/l	500	2000	As per BIS IS 10500: 2012
7.	Total Alkalinity mg/l	200	600	As per BIS IS 10500: 2012
8.	Total Hardness mg/l	200	600	As per BIS IS 10500: 2012
9.	Chloride mg/l	250	1000	As per BIS IS 10500: 2012
10.	Sulphate mg/l	200	400	As per BIS IS 10500: 2012
11.	Calcium mg/l	75	200	As per BIS IS 10500: 2012
12.	Magnesium	30	100	As per BIS IS 10500: 2012
13.	Nitrate mg/l	45	No relaxation	As per BIS IS 10500: 2012
14.	Phosphate	NA	NA	Public water systems (PWSs) commonly add phosphates to drinking water to prevent the release of metals in drinking water
15.	Flouride	1.0 mg/l	1.5	As per BIS IS 10500 : 2012
16.	Chemical Oxygen Demand	10 mg/l		As per EPA

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Volume 12 Issue 12 December 2025

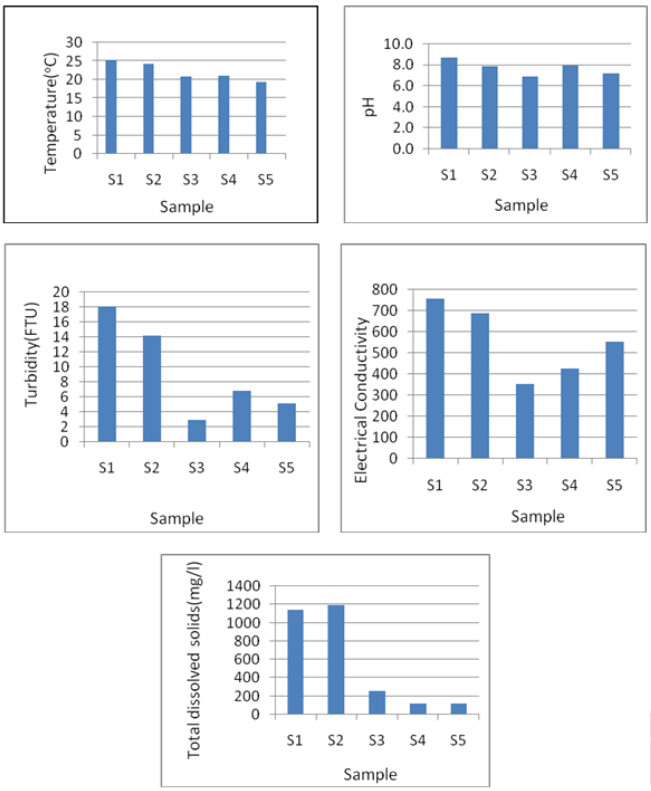


Figure 2: Graph showing Ground water and surface water Physical parameter in summer

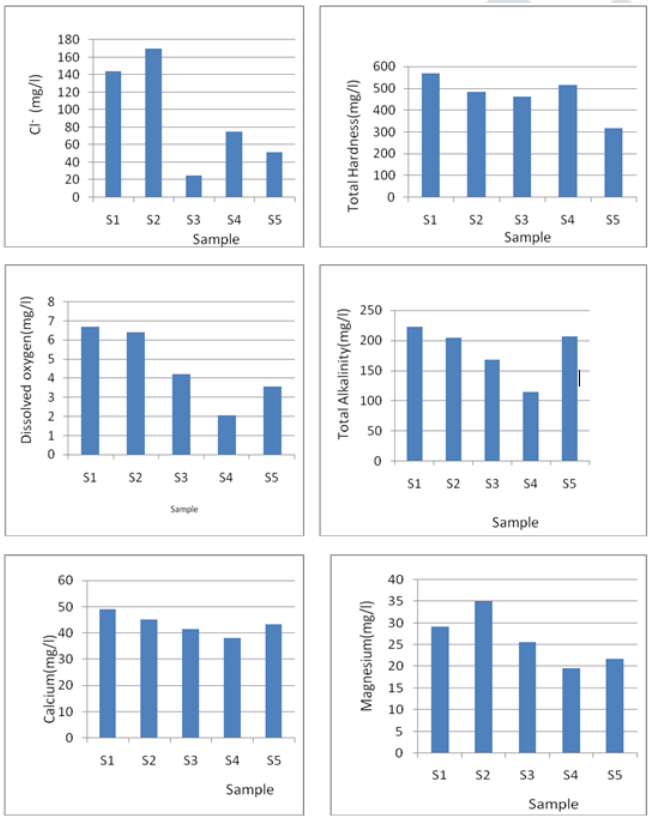


Figure 3: Graph showing Ground water and surface water chemical parameter in summer

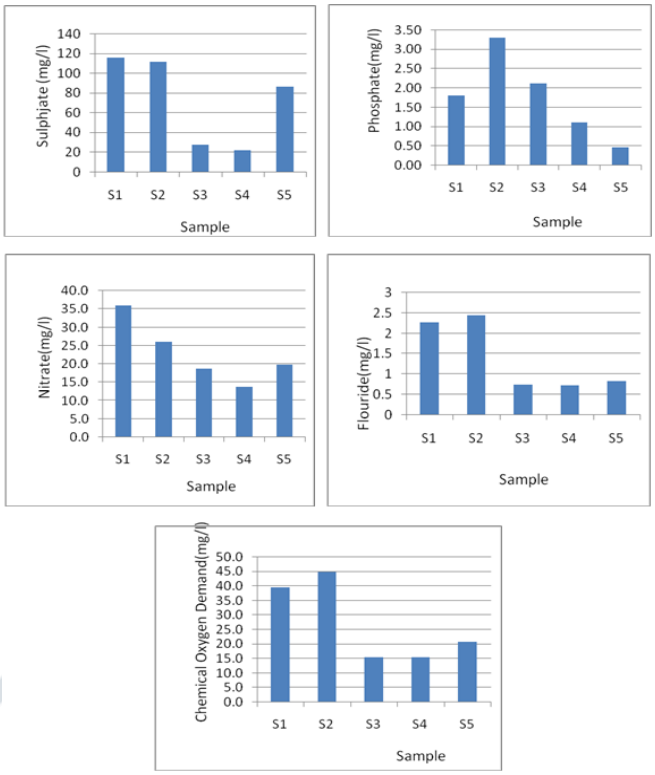


Figure 4: Graph showing Ground water and surface water chemical parameter in summer

Water temperature varied in surface water as (25.3°c to 24.2°c), (23.1°c to 19.83°c), (17.93°c to19.16 °c) in ground or tube well water (20.8°c to 19.47°c), (16.5.3°c to 16.88°c) and (2°c to 1°c) respectively in summer, monsoon and winter. This show there was little impact of human activities on water.

pH is important as most of the chemical reactions in aquatic environment are controlled by any change in its value. Highly acidic or alkaline would kill marine life. Aquatic organisms are sensitive to pH changes and any changes need biological treatment or monitoring. The toxicity of heavy metals also gets enhanced at particular pH. In present work the pH of the water samples observed surface water as (8.6 to 7.8), (9.23 to 9.06), (8.13 to 8.66) and in ground or tube well water (6.9 to 7.1), (8.6 to 7.1) and (7.51°c to 7.44) respectively in summer, monsoon and winter which indicates that the pH value ranges somewhat in between the permissible limit.

Water turbidity in surface water (18FTU to 14.2 FTU), (46.73FTU to 39.23 FTU) and (12.9FTU to 11.8FTU) which are not in permissible limits and tube well or ground water ranges from (2.9FTU to 5.1 FTU), (3.06FTU to 7.23FTU) and (1.93FTU to 3.3FTU) which are in permissible limits respectively in summer, monsoon and winter.

The Electrical conductivity values for surface water varied from (756.7 to 688.5) µs/cm; (971.2 to 888.96) µs/cm; (595.33 to 510.667) µs/cm whereas EC in ground water samples varied from (355.3 to 552.6) µs/cm and (440.4 to 478.23) µs/cm and (406.33 to 348.33) respectively for summer, monsoon and winter.

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International Journal of Science, Engineering and Management (IJSEM)
Volume 12 Issue 12 December 2025

Dissolved Oxygen

Dissolved Oxygen (DO) is found to be (6.7 to 6.4), (7.23 to 7.66) and (7.03 to 6.33) in surface water and tubewell or ground water ranges from (4.2 to 3.6), (4.09 to 4.03) and (3.83 to 2.93) respectively in summer, monsoon and winter are well within permissible limits.

Total Dissolved Solids

The total dissolved solids in observed surface water varied from (1143.3 to 1195), (1370.33 to 1402), (1109 to 1253) and in ground or tube well water (258. To 116), (368 to 290) and (351.66 to 148.66) respectively in summer, monsoon. All are within permissible limits.

Total Alkalinity

Total alkalinity in surface water ranges from (223 to 204); (562.33 to 674.66); (332.33 to 412.33) whereas in ground water samples varied from (167.3 to 206.7) and (297.33 to 283) and (303 to 143.33) respectively for summer, monsoon and winter are not within permissible limits.

Total Hardness

Total hardness attributes to presence of bi-carbonate, sulphate, chlorides and nitrates of calcium and magnesium. For surface water total hardness in this study is found to be in the range of (570 to 484.7) mg/l, (805.6 to 646) mg/l, (793 to 531.667) mg/l and (462 to 317.7) mg/l, (244.3 to 374.33), (332.66 to 229) mg/l respectively for summer, monsoon and winter.

The range of calcium are (49.1 to 45.2) mg/l,(101.73 to 63.7)mg/l,(82.66 to 49)mg/l in surface water sample and(41.5 to 43.3)mg/l,(54.6 to 54)mg/l and (51.93 to 40.33)mg/l in ground water where as magnesium content ranges from (29.1 to 35.1) mg/l,(44.75 to 51.33)mg/l,(36.46 to42.66)mg/l in surface water sample and(25.6 to21.7)mg/l,(31 to 32.6)mg/l and (21.66 to 19.56)mg/l in ground water respectively for summer, monsoon and winter which are within permissible limits.

The chloride content ranges from (144.1 to 169.9) mg/l, (293.66 to 313.8) mg/l, (826.7 to 249.33) mg/l in surface water sample and (24.9 to 51.5) mg/l, (77.6 to 57.43) mg/l and (51.1 to 49) mg/l in ground water respectively for summer, monsoon and winter which are in permissible limits.

Sulphate Ion

The sulphate SO_4^{2-}concentration varied from (116 to 11.7) mg/l, (165 to 181.66) mg/l, (139 to 127.33) mg/l in surface water sample and (27.5 to 86.2) mg/l, (43.7.6 to 5.63) mg/l and (37.26 to 35) mg/l in ground water respectively for summer, monsoon and winter.

Nitrate

The nitrate (NO^{3-}) concentration in surface water sample from two sites respectively for summer, monsoon and winter varied from (35.9 to 26) mg/l, (50.63 to 47.33) mg/l, (48.83 to 30) mg/l and (18.8 to 19.8) mg/l, (18.83 to 34.56) mg/l and (15 to 27.56) mg/l in ground water respectively for summer, monsoon and winter. The surface water samples nitrite content ere not found to be within permissible limit in monsoon which could be due to rain and debris mixing rom surrounding.

Phosphate in drinking water shows the degree of pollution of water system. The phosphate concentration in water samples varied from (1.8 to 3.30) mg/l, (1.11 to 3.18) mg/l, (1.11 to 3.18) mg/l and (2.1 to 0.5) mg/l, (2.59 to 0.78) mg/l and (2.5 to0.78) mg/l in ground water respectively for summer, monsoon and winter within the prescribed norm.

Flouride

In case of Flouride ion, surface water samples contain in the range of (2.27 to 2.4) mg/l,(3.23 to 3.53)mg/l,(1.96 to 2.6)mg/l respectively for summer, monsoon and winter and in ground water the fluoride content varied from (0.7 to 0.8)mg/l,(1.44 to 1.88)mg/l and (1.44 to 1.88)mg/l for summer, monsoon and winter which are well within permissible limits.

Chemical Oxygen Demand (COD)

COD varied from (39.6 to 44.9) mg/l, (41.33 to 51.8) mg/l, (39 to 52.33) mg/l in surface water sample and (15.6 to 20.7) mg/l, (16.8 to 19.8) mg/l and (14.93 to 20.73) mg/l in ground water respectively for summer, monsoon and winter which are within permissible limits.

VI. CONCLUSIONS

In the present study to evaluate the pollution status, the samples were analysed and its results were compared with the standard values of Indian water quality Standards.

The above results are showing that the ground water and surface water quality in and around Vedanta Aluminium Limited are not that polluted**.**From the present research study, it was concluded that although the Physico chemical parameters of ground water samples and surface water samples in and around Vedanta Aluminium Company at Lanjigarh, Odisha are within safe limits of Indian standard for drinking water quality (IS: 10500) but the toxic level of harmful materials can mix up with the ground water if no precautionary measures were taken for effective treatment of the industrial effluents.

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