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RESEARCH ARTICLE

GEO-HYDRO-CHEMISTRY OF LATOSOL MINERALOGY: SMD AND WESTERN CATCHMENT OF CHILIKA LAGOON, INDIA.

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Abstract

Buchanan's laterite in slab form is ranked in construction materials next to concrete and brick, a major groundwater recharging source which covers 10.6% of the inland surface area in India. The residual rock of sandstone (basalt) is soft when in the mines so that it can be easily cut to slabs for structures which gradually strengthen on air exposure. The vesicular character deteriorates the water quality standards both surface and underground of an area. The Laterization process involves detachment/leaching of silica, alkali and alkaline earth materials from sandstone by wetting and drying process in tropics forming sesqui-oxide (Fe_2O_3+Al_2O_3) as laterite rocks or soil (morrum). Present work envisages characteristic study of geotechnical, geochemical, hydrogeological and structural properties of the laterite rock/ soil of the caped/shaded areas in Bhubaneswar, Jatni, Golabai and Tangi of south Mahanadi delta and western catchment of the lagoon Chilika in Khurdha district, Odisha, India. Omnian software and the Epsilon 3 module based XRF spectrometer was used for chemical analysis of the lateritic soil, surface water, and groundwater and the results were compared with BHVO-2 of USGS. The soil samples exhibit Eu^+ anomaly. The results infer the non-availability of toxic heavy metals in surface and groundwater such as F, As, Cd, Cr, Cu, Ag, and Ni are of major concern but an excess of heavy metals of secondary contaminants found are P, Fe, and Sn. The observed in the availability of the aqua habitats and aqua plants in the lakes created in Laterite mines can be explained by higher values of dissolved oxygen and tin.

Introduction:-

In the epoch Anthropocene, the potable water is obtained either from the surface or from the underground. Since surface water source is liable for contamination (Ramachandra et al., 2013)[1]. Hence the modern water supply sources are preferred from the groundwater table (GWT) or subsurface saturated strata. The Groundwater (GW) is

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generally a solution of (HCO_3^-, Cl^-, F^- and SO_3^{-2} *etc*.) alkaline earth or alkali metals. The chemical characteristics are influenced by the geological formation of the area.

Laterite is a sub-recent formation between the alluvial soil and tertiary stratum covering throughout the world. In India Laterite was first place in literature by Buchanon, 1807[2], as a stone having full of cavities and pores with heavy deposits composed of red and yellow ochers of iron is undergoing continuous chemical and exclusion processes. It is the vesicular ironstone formation. The ores are associated with uplifted peneplains and always formed in the areas of low relief subject to high water tables. It is generally formed in the waterlogged areas associated with acidic and weathered.

The lateritic stone and latosol cover ≈350MHa (10.6%) of India. https://www.pmfias. com/ Indian-soil-types-red-soils-laterite-lateritic-soils-timberland mount, 2016. The loamy red soil occurs in 17states mostly abundant in the state of Tamil Nadu and south deltaic areas of Odisha . Red soils cover a region of 248MHa in India (Raychoudhury S.P. 1980)[3] from the summits of WGB Hills, Rajamahal Hills, (Vindhyas, Satpuras, Kerala, Karnataka, and Malwa Plateau) at 1000 to 1500m above MSL, and EGB Hills, West Bengal, Andhra Pradesh, Odisha, and Jharkhand, south Maharashtra, parts of Assam, Meghalaya and Malwa Plateau (https://en. wikipedia.org/wiki/Laterite) **Fig 1.**

Laterites are the hydrating blend of (Al^{+3}, $Fe^{+2 \text{ or } +3}$ and Ti^{+4}) came about because of the decay of alumino-silicate bauxite rocks and/or sandstones resulting loss of antacids, lime, magnesia, and silica leaving aside iron and aluminum salts Wood et al., (1996)[4]. As indicated by Encyclopedia Britannica, laterites contains the oxides of iron; goethite ($HFeO_2$); lepidocrocite; FeO(OH); hematite, (Fe2O3); titanium oxides (TiO2) and with overabundance of gibbsite, Al_2O_3, $3H_2O$. It contain exceptionally poor amount of lime, magnesia, nitrogen, phosphorus, potassium, and magnesia. Eyles (1952)[5] had revealed that a lateritic test cover SiO_2 (6.9%), A12O3 (39.8%), Fe_2O_3 (26.7%) and TiO_2 (3.6%) whereas Panda et al (2013)[6] got the ingredients from BBSR laterite sample were SiO2 (35.78%), A12O3 (19.48%), Fe2O3 (34.72%) and TiO2 (1.98%).

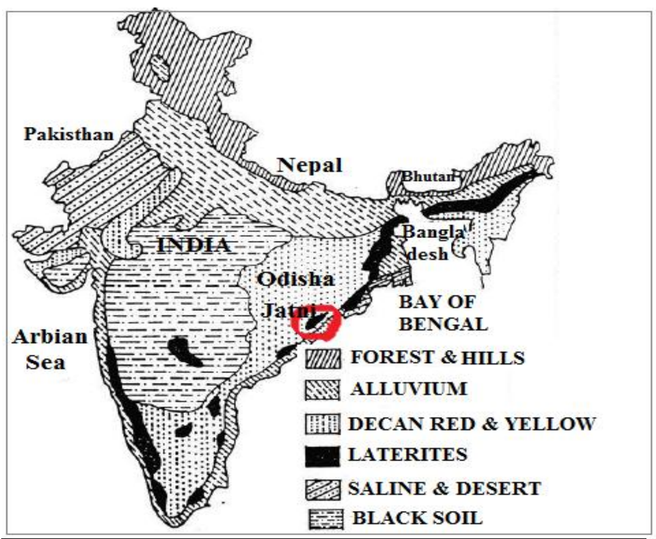

Fig 1:Laterite distribution in India with the study area

The morrum (laterite soil or Latosol) is shaped under high temperature and torrential rainfall with alternate wet and dry periods and weathering. The erratic climate condition initiates soil for leaching, piling the unfertile oxides of iron and aluminum on the surface. The Latosol is Ferruginous soils, Ferralitic soils, Basisols, and Humic latosols, but the underlain crystalline laterite are of five forms in India Table -1.

Table 1:-Different forms of laterites available in India and their physical characteristics

#	Laterite forms	Subdivision if any	Physical Characteristics	Jointing materials
1	Massive	Cellular	Rounded cavities	
		Vesicular	Tubular cavities	
2	Nodular	Cemented nodular	Individual, Rounded or partly concretion	Strongly joined by the iron-stone material.
		Non-cemented nodular	60% concretion by total weight	Concreted by other soil
		Iron concretions	<60% by weight of the total horizon.	concretions separated by soil
3	Re-cemented		fragments of massive laterite	wholly or partlycemented.
4	Ferruginized		Parent rock structure is visible	Mostly isomorphs replacement by iron
5	Soft laterite		Hard mottled iron-rich clay	Formed in contact with air/ Repeated wet& dry.

2.0 Review of literature:-

Alexander and Cady (1862)[7] reported that the Laterite, an exceedingly weathered solid highly containing secondary oxides of ferrous/ferric, aluminum, or both. Raychaudhury et. al., (1942)[8] reported about the special character of laterite in India containing oxides of iron, tourmaline, zircon, chlorite, hornblende, epidote, staurolite, and rutile. Humic latosols at high altitudes of India are the acid soils imperfectly drained and rich in organic matter. Maignien R., (1966)[9] had mentioned that rocks mainly rich either in alumina or combined silica (Kaolin), combined with laterite are known as bauxite and lithomarge respectively in India. Wadia D. N., (1975)[10] have reported that the laterite (caps of depth 15m to 60m) and laterite soils cover 248000 Km^2 in India. Tuncer (1976)(11) have reported that the plasticity and the grain size distribution of lateritic soils are exceptionally varied and erratic. Roychoudhury, (1980)[3] have mentioned that laterites in Odisha are of two types such as lateritic soil (Morrum), laterite rock and even in combination. Wood et al.,(1996)[4] had found methods by constructing laterite made percolating ponds to reduce Cd, Cr and Pb from heavy metal landfill waterlogged areas Hegde et al., (2010)[12], alternative moistening and drying of laterite and lateritic rocks in cycles. The laterite lost its strength with respect to its original strength. Lohani et al. (2011){13] investigated the aquifers of Jatni area and reported that GWT of the area lies in fractures and sedimentary sandstone in succession within laterite and old alluvium of Holocene epoch. Bonsor et al., (2014)[14] reported that the quantity and quality of GW are influenced by permeability properties of Laterites which partition the surface runoff and interflow. Mishra et. al., (2015)[15] reported that at present the GW in Khurdha district and particularly Bhubaneswar area is depleting year after year though not vulnerable to drinking water supply. Mohapatra et al., (2013)[16], had mentioned about a moderate '+ve' Eu anomaly at Udayagiri in EGB hills. The soils are relatively rich in Fe, P, Rb, Sr, Th, Nb, Ta, Y, and REE’s which could be a residual melt product. Wilson, S.A., (1998)[17] had used for the groundwork of BHVO-2, the surface layer of the pahoehoe lava (1995) of the Halemaumau crater and recommended the quantities of elements USGS Basalt, Hawaiian Volcanic Observatory, BHVO-2. Panda et al., (2013)[6] reported that laterite soil shall be nutrient-rich by adding HCl, H_2SO_4 and fly ash. Mishra et al., (2015)[15] reported that laterite soil and rock is a good recharge of groundwater. Mishra et al (2017)[18] reported that in comparison to other watersheds in South Mahanadi Delta, the Daya Bhargovi watershed (Bhubaneswar and Jatni area) are consisting of laterite rock. The soil has high soil loss 14.364 MT/ha/y in comparison to other watersheds. Mishra S. P.(2016)[19] had also reported that the average GWT (2009-2013 data) below surface level in Khurdha district was in Jan to June is 4-10m whereas from Oct to Dec was < 4m.

3.1 Study Area:-

The district Khurdha (Lat. $20^0$18’ Long. $85^0$68’) of the geographical area of about 2887.5 sq. km. and a population of 2.25millions (2011census) generally forms a lateritic upland with inselbergs lies in the south Mahanadi delta (SMD) and western catchment the largest lagoon Chilika in the east coast of India. The district has 10 blocks out of which only two blocks Balianta and Balipatna have no laterite surface as they are covered with alluvium. Rest of the 8 blocks has laterite terrain whereas Tangi possesses abundant terrain with laterite and morrum of area 42258Ha.

Khurdha district lies at the fag end of EGB hills range and near 85^0 ridges. The district encompasses the largest brackish water Lagoon Chilika in the NE. The lagoon has diversified lithology and limnology. Since the district is thickly populated and also growing at a faster rate, the lithology, surface and groundwater quantity need to be monitored. Major part of the study area lies as lateritic upland with lateritic capping above the clastic stratified sedimentary sandstone and Precambrian rocks. Since laterites are porous more stress is to be given on the quality of the groundwater under the laterite bed which is the main source for water supply [Fig 2 (a, b, & c)]. The red/ yellow laterite soil and slabs are one of the major sources for building construction and WBM road. The maximum thickness of extension of laterite beds is 5m to 20m in the profile. Laterite capping is thin on steep slopes and high gradients of the hillocks. Bushes and small trees are found as vegetation on the top laterite soil. Astonishingly the lakes formed in the mines have no aquatic habitats (fishes or frogs) or phytoplankton.

Laterites on deformation of sandstones near Khandagiri at Bhubaneswar exhibit numbers of voids. The voids developed by leaching of kaolinite are seen as spotted white kernels within vermillion patches. Ferruginous laterites are seen in and around Khurdha. Hard pisolitic duricrust to cavernous patches of laterites is found over the underlain sandstones. The depth GW aquifers in the Khurdha district 20 to 40m lying at a depth of 50 to 80m below ground level (mbgl) having an average yield of 50 to 60 lps with an average drawdown of 6 to 10m as either unconfined or confined aquifers Choudhury et al., (2009)[20] Fig 3.

3.1.1Profiles and infiltrative properties of laterites:-

The profile of laterite in mines is almost alike but individual units may differ. The bottommost parent rock is overlain by a lithomarge zone followed by laterite stone and vermicular laterite rocks covered by morrum or humus soils. The study area receives 1400 to 1500mm of yearly rainfall. The high porosity characteristic of the laterites and the lateritic soil recharge the groundwater at a faster rate in the area. The permeability character of laterites is different in different areas depending upon the textural properties (fragmental or vesicular). The GWT below laterites are always mutable and a huge amount of water is also stored in the pores as a source of groundwater.

The profile in the laterite mines in Khurdha district consists of (a) the parent rock (mostly Feld spathic schistose), (b) the kaolinite clay horizon, (c) Laterite stone of varying depth, (d) the ferruginous surface material (morrum) with soil/sand overburden. The Laterite mines have underlain deposits of rounded pebbles of different sizes of dissimilar rocks in the study area (Fig 2 a). The rounded pebble submits the rock has undergone fluvial transport. In the process of weathering and fluvial transportation the elements like Mg, Ca, Na, K and Si are leached out whereas insoluble elements like Fe, Al, Ti and Mn get retained as oxides and hydroxides along with some clay materials.

Fig 2 (a): Laterite cap over bedrock, Tangi 2(b) Laterite quarry at Jatni 2(c)Laterite Quarry at Golabai

3.1.2 Wet and dry periods in the area:-

Atmosphere, hydrosphere, cryosphere, land surface, and biosphere are responsible for the climate of an area. The study area enjoys tropical monsoon climate having main seasons *i.e.* winter, summer and rainy in a year. The mean daily maximum temp is of 38^0 C from May to June, while the min. average temp was 15 to 16^0 C in the months Dec-Jan. The annual average rainfall is 1436.1mm and the RH varies from 48 to 85 % at Bhubaneswar. The Khurdha district has mean monthly PET values varies from 57mm in Jan to 284mm in May. The district has extreme hot days ($\geq 40^oC$) was lowest (7 days) in 1995 and highest (42 days) in 2014. The number of cold days ($\leq 15^oC$), was highest (43 days) in 1995, while lowest (14 days) in 2009. The district receives in average 1463 mm of rainfall annually in an average 63 rainy days whereas mean SW monsoon rainfall is highest at Bhubaneswar, and Jatni blocks; the major laterite zone Panigrahi et al., (2016)[21].

4. **Methods and methodology:**-

Since Buchannan's naming of laterite (1807), various researchers have worked on the materials as building materials. The research gap lags for the quantity and quality of the groundwater underlain through the porous lateritic ore. The laboratory tests were conducted (a) Finding the physical, chemical, mechanical and engineering properties of the laterite slab and the soil. In physical properties, the specific gravity, the color, texture, and porosity of the slab was found out. The solid stone is crushed in to powder and the major chemical ingredients were found with the help of XRF spectrometer. Cubes of 150mm x 150mm x 150mm from the local laterite stones were cut and their porosity and compressive strength were found by the help of compressive testing machine (CTM) and confirmed by the universal testing machine (UTM) of the CUTM Civil Engineering lab, at Jatni, Khurdha for the mechanical and engineering properties of the sample laterite stones.

X-ray fluorescence (XRF) spectrometers are instruments used as a non-destructive chemical analysis of fluids, minerals, residues, sediments of rivers and rocks in powder form with a minimal preparation Shackley S., (1995)[22]. The X-ray fluorescence study uses sequential wavelength dispersive spectrometers technique is similar to an EPMA (Electron Microscope) but restricted to distinguish elements whose atomic number more than fluorine or $Z > 11$. The XRF is best suited for finding nonmetallic elements Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K and P. The method can quantify elements in trace (> 1ppm) like Ba, Ce, Co, Cr, Cu, Ga, La, Nb, Ni, Rb, Sc, Sr, Rh, U, V, Y, Zr and Zn. The instrument cannot distinguish isotopes or ions of the same element at different valence state (ous/ic state).The powered form of the ore were studied by the XRF spectrometers and results were discussed.

4.1 Mechanical properties:-

The laterite ores in mines are softer but on exposure to air harden. So the slabs are cut in situ and allowed to harden on exposure to air and then only displaced from the quarry. The upper strata are harder than the underlain stratum. The darker the laterite is the harder, heavier and more resistant to moisture in the region. The dark variety is preferred for buildings and architectures.The150mmx150mmx150mm laterite cubes were cut by stone cutting machine and checked/ rechecked for its size. Six cubes were dried in an oven at 100^0C. Similar M-20 concrete cubes with 28days curing were prepared and local made fly ash bricks were collected and their compressive strengths were tested in the compressive testing machine (CTM). The behavior of compressive strength of the laterite cubes, concrete cubes and fly ash brick were tested under the universal testing machine (UTM) and the results were given in Table 2

Table 2:-The Porosity and Mechanical Strength Comparison Between Dry, Wet Laterite Cubes, Rcc Cubes, And Standard Bricks

Test conducted	Dry Laterite cube (150 x 150 x 150)mm	Laterite cube from mine (150 x150x150)mm	Cement grouted laterite cubes (150 x 150x150) mm	M-20 Concrete cube (150x 150x150)mm	Std. bricks 210 mm X 100 mm X90mm
Comp. strength (av.)	16.75 KN	11.17 KN	35.17KN	49KN	35KN
Water absorption (av.)	33.74%	32.45%	18.61%	11.97%	15.16%

Laterite rocks are of recent formation from old alluvium with (iron + Aluminum) origin. The rock is in a state continuous process of exclusion of kaolin and alluvial material due to wetting and drying from the cavities to give the rock a vesicular form. The materials elements present in the laterite rock need to be studied for which the XRF spectrometry of the powdered samples was prepared from rocks of Bhubaneswar (where sandstones are predominant), Jatni, Golabai, and Tangi area where plenty of laterites as stone or soil cover (Fig -3).

4.2: Geotechnical Properties:

The geotechnical properties of the lateritic soil of the areas in Khurdha district had been tested and the average value of the specific gravity was found to be 2.65 to 2.70. The particle size distribution of the dry soil had been done and the average effective particle size D_{10} = 0.30mm, $D_{30=}$ 1.18mm, D_{50} =2.5mm and D_{60}= 4.75mm whereas C_u (uniformity coefficient) and Cc (curvature Coefficient) were found to be 15.83 and 0.97 respectively (tending as well-graded soil).

4.3: Geo Chemical Properties:

The chemical analysis of the laterite samples were done with the help of X-Ray spectrometer for the alkali nonmetals, heavy metals and rare earth metals were done Fig 6 (a) and (b). The conjunct of Omnian software and the Epsilon 3 module is used for X-Ray fluorescent analysis to characterize soil and water samples (Fig 6). By using the Adaptive Sample Characterization (ASC), the software can be fine-tuned for increased accuracy. The analysis of the powdered laterite stones crushed to powdered form after collection of pieces of laterite from four places Bhubaneswar (20.29 61° N/ 85.8245° E), Jatni (20.17° N/ 85. 71° E), Golabai (20°1′21″N /85°33′0″E) and Tangi (19.92665N / 85.395546 E) areas where coverage are prominent. The oxides of alkali and alkaline earth metals, metal oxides and oxides of rare earth elements contained in the samples (of the four sites) were compared with geochemical reference standard by Hawaiian Volcanic Observatory, BHVO-2 and exhibited in Table -3

Table 3:-Spectroscopic analysis of the powdered laterite stones in Khurdha district, Odisha, India, April 2018: https://www.ptable.com/ and https://crustal.usgs.gov/geochemical_reference_standards/basaltbhvo1.html

#	Oxides of elements	Formulae	BBSR Samp-1 (%)	Jatni Samp-2 (%)	Golabai Samp-3 (%)	Tangi Sam- 4 (%)	BHVO recommendation -2 (USGS)
A	Alkali/Alkaline earth/Non/poor metal Oxides						
1	Aluminum	Al_2O_3	33.183	23.245	25.754	22.196	13.5 ± 0.2
2	Silicon	SiO_2	45.031	35.071	33.704	25.532	49.9 ± 0.6
3	Phosphorous	P_2O_5	0.601	0.549	0.547	0.511	0.27 ± 0.02
4	Sulphite(ppm)	SO_3	147.4	535.5	0.129	785.5	150ppm (IS Std.)
5	Chlorine	Cl	0.285	0.210	0.201	0.160	250ppm (IS Std.)
6	Potassium	K_2O	1.188	1.579	0.976	0.335	0.52 ± 0.01
7	Calcium	CaO	0.681	0.427	0.627	0.415	11.4 ± 0.2
8	Rubdium	Rb_2O	144.1	175.9	140.9	411.4	11.0 ± 2
9	Strontium (ppm)	SrO	73.9	52.7	50.1	58.8	403± 25(ppm)
B	Transition and other metal Oxides (in ppm or mg/l)						
1	Vanadium	V_2O5	611.1	0.101%	0.101%	0.118%	317 ± 11 (ppm)
2	Titanium	TiO_2	1.861%	1.381%	1.294%	1.116%	2.71 ± 0.06
2	Chromium	Cr_2O_3	480.8	819.6	775.4	0.118	280 ± 19 (ppm)
3	Manganese	MnO	65.1	0.101%	353.8	371.3	0.17 ± 0.01
4	Ferric (%)	Fe_2O_3	16.739%	36.85%	36.21%	49.102%	12.3 ± 0.2 (%)
5	Nickel Oxide	NiO	270.3	367.8	280.6	382.5	119 ± 7
6	Cupric Oxide	CuO	159.1	232.303	295.8	328.6	127 ± 7
7	Zinc	ZnO	152.0	178.8	150.6	157.9	103 ± 6
8	Gallium	$Ga_2 O_3$	116.3	99.5	98.6	104.4	21.7 ± 0.9
9	Arsenic	$As_2 O_3$	0.0	0.0	0.0	0.0	Not available
10	Yttrium	Y_2O_3	41.2	38.5	0.0	0.0	26 ± 2
11	Zirconium	Zr_2O3	0.104%	865.9	822.9	587.4	172 ± 11
12	Niobium	Nb_2O5	56.8	44.4	48.1	44.4	18 ± 2
13	Stannic	SnO_2	107.5	0.0	118.5	150.5	190
14	Irridium	IrO_2	4.7	0.0	0.0	0.0	Not available
15	Lead	PbO	156.6	317.6	286.7	461.1	2.1%
16	Osmanium	OsO_4	0.0	30.2	0.0	0.0	Not available
17	Bismuth	Bi_2O_3	0.0	0.0	17.9	120.6	Not available
C	Oxides of REE (ppm)						
1	Europium	Eu_2 O3	549.2	0.126%	994.0	0.0	2.06 ± 0.08%
2	Ytterbium	Yb_2 O3	51.9	129.5	114.3	0.0	26 ± 2
3	Thorium	ThO_2	80.0	0.0	0.0	0.0	1.2 ± 0.3
4	Rhenium	Re	3.4	0.0	0.0	7.0	Not available

The difference between real vs. model mortality levels was found for 6 elements (pH, KCl, Mg, Ca, Sr, Ba, Zn). On limiting the indicators breast cancer mortality has decreased for ≈ 0.79 cases/ 100,000 population Ferusson J. E. (1990)[23]. The soil mass does not contain CO2, Arsenic, Mercury in the test samples. Osmanium is highly toxic but nowadays are used for anticancer drugs. The geo chemical reference standard by Hawaiian volcanic Observatory, BHVO-2 of USGS had been compared. It is observed that the soil sample had excess of the oxides of alkali/alkaline/nonmetals and poor metals were aluminum, and strontium, transition and metal oxides were Vanadium (V), Chromium (Cr), Manganese (Mn), Iron (Fe),

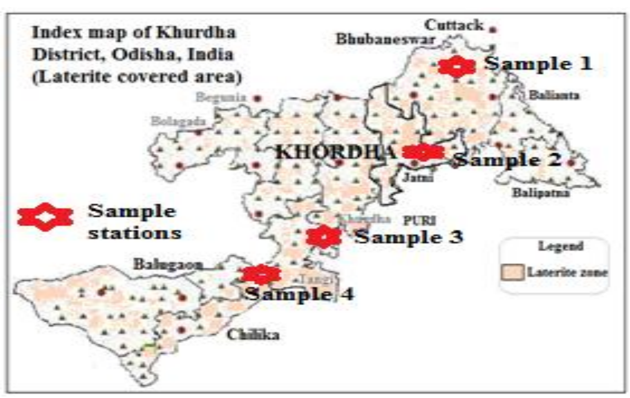

Figure 3: The Study area for laterites, Khurdha

Nickel(Ni), copper (Cu), Zinc(Zn), Gallium(Ga), Yttrium(Y), Zirconium (Zr), and Niobium (Nb). The REE metals which were present in those samples were Europium, and Ytterbium. The soil analysis exhibits a trend of +Eu anomaly in the area which may be due to a mafic source like basalt of the clastic sedimentary rocks.

4.2 Physical properties of drinking water:-

Water quality of one area maintains the health of the inhabitants of the area and also the flora, fauna, aqua fauna and avifauna. So drinking water quality has been standardized by the IS code 10500: 2012 to maintain the water excellence. The parameters such as color, order, pH, turbidity, dissolved oxygen (DO), acidity, alkalinity, chloride ions, hardness, iron content and Biological Oxygen demand (BOD) has been estimated in the lab. Das et al., (2011)[24], reported that Fluoride in high concentration is available in GW of Tarabalu, Singhpur Balasinghi, Singhipur, etc. near the study area having laterites and the concentration was ranging from 1.4 to 13.2mg/L/

The organizations like APHA, WHO, ISI, CPCB, and ICMR have fixed different norms for the permissible limits of drinking water which is adhered by the water supply schemes, health officers, doctors, and researchers. In the present case, the samples of water were collected from ponds/lakes generated in laterite mines, bored deep wells and dug wells. The digital pH meter, turbidity meter, BOD incubators, COD digester and DO meter, TDS meter, Turbidity meter and XRF spectrometers were used to ascertain different parameters in the laboratory. The results were tabulated in Table 2.

The physicochemical parameters of the UG water and surface water in the ponds in laterite stratum, samples from leachates in a landfill in laterite areas, open wells, and deep bore wells were collected and tested for Physical properties (pH, turbidity, Dissolved Oxygen, acidity, Alkalinity, chloride ion, hardness and iron content and Biological Oxygen Demand in environmental lab of CUTM Civil engineering Dept., Jatni, Khurdha in the period Feb 2018. The results of chemical parameters of the samples were taken from ponds, tube wells and dug wells are given in Table 4.

Table 4:-Table showing physic-chemical parameters of drinking water collected from ponds, bore well and dug well in the study area (IS 10500/2012, WHO, ICMR, and CPCB.

#	Physical	Unit	Instrument used	Std. IS 10500/12	Pond	Tubewell	Dug well
1	Colour	Hazen	Eye estimation	5-15	Clear	faint yellow	clear
2	Odor	No unit	By smell	agreeable	agreeable	agreeable	agreeable
3	Taste	No unit	tasting	agreeable	agreeable	agreeable	agreeable
3	pH	No unit	pH-meter (digital)	6.5-8.5	6.7	6.27	5.7
4	Turbidity	NTU	Turbidity meter digital	1-5	0	7-11	0
5	DO	mg/lit	Titration method	0-18mg/l	16.67	16.67	14
6	Acidity	mg/l	Titration method		10	16	22
7	Alkalinity	mg/l	Titration method	600 (CPCB)	48.8	36.6	36.6
8	Chlorides	mg/l	Titration method	250	11.83	16.56	23.6
9	Hardness	mg/l	Titration method	200-600	1300	1000	1274.5
10	BOD	Mg/l	Titration method	minimum	0.67	3.34	7.33

Notes: (i) **The color** of the water is due to organic content in it. Tea has a color of ≈ 2500 Hazen units (HU). 15 HU can be noticed in a glass of water but 5 HU can be seen in a water body only (Australian Drinking Water Guidelines Version 2.0 Updated December 2013 548) **(ii) Hardness considered by WHO**: Soft; 60–120 mg/l, moderately hard; 120–180 mg/l, >180 mg/l, very hard.

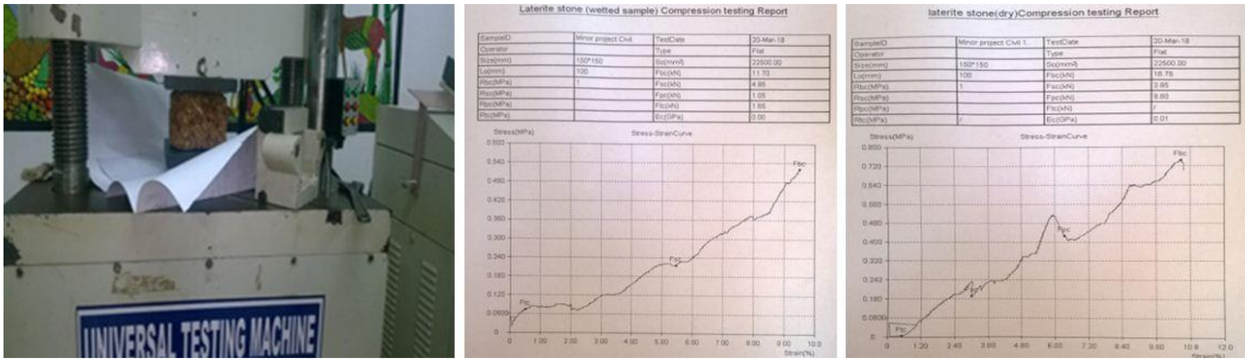

Fig 4: The 150mmx150mmx150mm laterite cubes when tested under UTM m/c for compressive strength (a) while testing (b) when wet (c) when dry

4.2.1 Water quality in the Study area:-

The chemical ingredients of GW in an area depend upon the type, depth and underlain geological formations. It is also influenced by surface water bodies, climatic condition of the area and anthropogenic interventions and exploitations of the area Raychoudhury et al., (2014)[25]. The study made by Central Ground Water Board, Government of India (CGWB, GOI) in 2011 reported that presence of chemical elements exceeding the approved limit in the water is Electrical Conductivity, Fluorine, Arsenic, and Iron. The geohydrology studies by CGWB 2011 had shown pre and post-monsoon max depths of GWT were 13.30m and 7.70 mbgl in different places of the Khurdha district. The GW contained 1mg/l to 4.6mg/l in Bhubaneswar. Groundwater quality was studied by Mishra et al., (2015)[15] (Fig 5)

Table 5:-The quantity of Alkali/Alkaline earth/Non/poor metal Oxides present in water sample.

Place of observation	Compound	Si	P	S	Cl	K	Ca	H2O
	Unit	ppm	ppm	ppm	ppm	ppm	ppm	%
Bhubaneswar	bore well	0	490	0	557.4	0	171.8	99.864
Jatni	bore well	759.5	538.9	0	556.8	0	188.6	99.777
Jatni	lake water	0	550.6	83.1	546.2	0	65.5	99.846
Golabai	bore well	762.1	547.4	90.3	591	0	221.4	99.764
Golabai	lake water	0	559.1	109.1	527.2	62.3	214.4	99.844
Tangi	bore well	769.5	527.3	0	558.6	0	177.8	99.783
Bhubaneswar	bore well	0	490.9	0	557.4	0	171.8	99.864

Excess of potassium, chlorine, and calcium in water is essential for all living beings and needed for agriculture. IS 10500: 2012 prescribes the limits potassium (4700mg/day), calcium (75mg/l to 200mg/l) and chlorine (250mg/l to 1000 mg/l) has less impact on portability of water. The alkali/alkaline earth elements Na, K, Mg and Ca do not chemically react with other elements and soluble in water. They are uninvolved and flows away with infiltrating water Fig 6, **Table 5.**

Silicon: is a dietary necessity for humans, animals even for plants. Daily ingestion for an adult may vary between 20 to 1200 mg taken by food and water. The sample observed has Si within limits. The silicic acid in drinking water is safe. But $SiCl_4$ is toxic and / skin irritant, cause breathingproblemshttps://www.lenntechcom/ periodic / water/silicon/silicon-and-water.htm#.

Phosphorous: Phosphorous is essential for growth of animals and plants. Safe limiting Conc. of phosphorus should not exceed 100µg/liter and considered a threat to water bodies. In all the phosphorous content was 490 to 559 mg/l which creates favorable condition for eutrophication, an environmental drawback. .

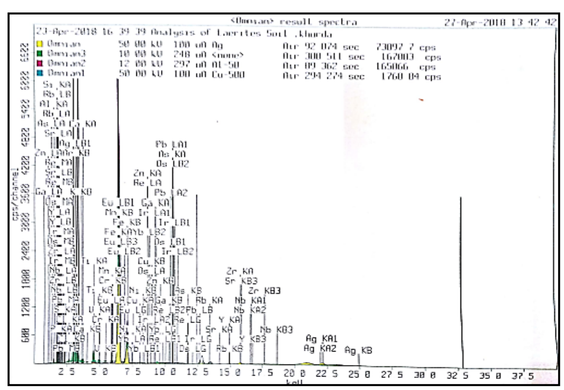

Fig 5: The Omaniyan spectrum of elements of XRF

Sulphur: Living being needs sulfur in average 900mg/day The amino acid methionine formation of human contains and supplemented by food and water intake. Imbalanced intake sulphur can have neurological disorder, blood circulation, suffocation, damage to the heart, eye, immune system, liver, kidney and immune system of Homo sapiens and animals https://www. Lenntechcom /periodic/elements/s.htm#i

4.3 Transition and other metal oxides:-

It is known that presence of As, Pb, Cd, Cr, Cu, Hg, Ni, and Zn (Fergusson 1990).On testing the transition and other metal oxides in the groundwater and lake water of Khurdha district it was found the iron and strontium content was high ranging 13.8% to 44.5% and 42.2 to 52.2 mg/l. The iron content is too high which make the water unfit for flora and fauna and for the human **Table 6.**

Table 6:-The quantity of Transition and other metal oxides present in a water sample in Khurdha

Place of Obsns.	Compound	Mn	Fe	Co	Te	Sn	H2O
	Unit	ppm	ppm	ppm	ppm	ppm	%
Bhubaneswar	bore well	0	16.1	0	0	52.2	99.864
Jatni	bore well	0	21.9	0	0	42.6	99.777
Jatni	lake water	0	44.5	0	0	48.8	99.846
Golabai	bore well	0	24	0	0	50.9	99.764
Golabai	lake water	0	41.8	0	0	47.2	99.844
Tangi	bore well	0	13.8	0	48.3	44.4	99.783

Iron:-

The iron in the adult human is about 4 g, of which 70% is present in the red blood. Deficiency of Iron causes anemia, headache. Excess iron in potable water is a secondary contaminant of water as per the EPA. Iron is supplemented through diet @ of 7mg/day. The limiting healthy level of iron is 0.3 mg/L (EPA norms). Excess of it cause hemochromatosis which further leads to liver, heart and pancreatic damage, finally leading to diabetes, wrinkling of the skin. Excess intake of iron in food/water instantly lead to stomach problems, nausea, vomiting, https://www.lenntech.com /periodic/ water/iron/iron-and-water.htm #ixzz5E2fsiMP4

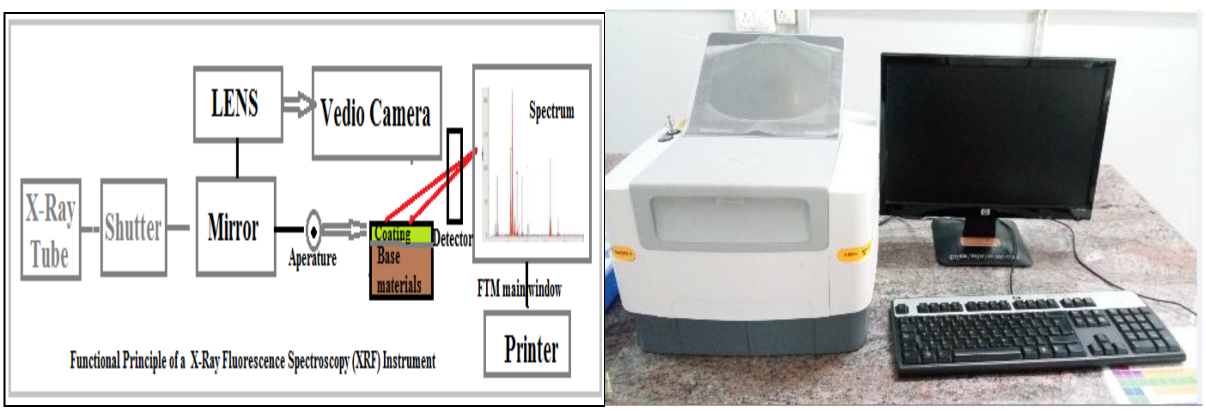

Fig 6: The block diagram and the photograph of the X-Ray Fluorescent spectrometer

Tin (Sn):-

Tin inorganic bonds is poisonous to humans particularly triethyltin. The uptake of tin causes eye and skin irritations, headaches, stomachaches, sickness and dizziness, severe sweating, breathlessness, urination problems. Long-term exposure can cause depressions, damage to liver and brain. Organic tins can percolate from sludge and join surface and GW and are harmful to aquatic fauna. They are very toxic to fungi, algae, and phytoplankton and disrupt the aquatic food chain https://www.lenntech.com/periodic/elements/sn.htm#ixzz5E4ccS6gf

4.4 Rare earth elements:-

Table 7:- The number of rare earth elements present in water samples in surface and GW in Khurdha

Place of Obsns.	Compound	Er	Dy	Eu	H2O
	Unit	ppm	0	PPM	%
Bhubaneswar	bore well	72.2	0	0	99.864
Jatni	bore well	69.1	0	0	99.777
Jatni	lake water	0	0	1.9	99.846
Golabai	bore well	69.2	0	0	99.764
Golabai	lake water	0	0	0	99.844
Tangi	bore well	0	28	0	99.783

On study, no other REE's are found in water (surface and GW) in Khurdha district except Erbium **Table 7.**

Erbium:-
The lanthanide has a little biological role. The erbium is present in the bones, but kidneys and liver of human being. The Erbium is somewhat toxic if drank.

5.0 The cause of loss of aqua fauna in laterite water body:-
DO analysis estimate the quantity of O_2 (gaseous state) dissolved in water. Oxygen enters the water by the process of diffusion from the air or by aeration or by excess in the photosynthesis process. DO content in water have a severe environmental impact when its value exceeds 110% (above 13-14 mg/l). Concentration above this level can be harmful to aquatic life. Fish and aquafauna suffer from gas bubble disease when DO value is high. There is a chance of occurrence of external bubbles emphysema. Adequate dissolved oxygen is necessary for good water quality but excess DO may lose total aqua habitats. Since in the present study the DO values are found to be >13mg/l there is no living fauna in the water bodies in laterite mines in and around Bhubaneswar, Jatni and Khurdha areas. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3482709/

The leachates generated from a university of 10000 population has been considered. The liquid of the drain leading to the quarry has been collected and studied by the XRF spectrometer and the chemicals observed are in **Table -8**

Table 8:-The chemicals observed on XRF spectroscopy from the leachate draining to the lake in the mine.

#	Al_2O_3	SiO_2	SO_3	Cl	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_2O_3	NiO	ZnO	Rb_2O
	%	%	%	%	%	%	%	ppm	ppm	%	%	ppm	ppm	ppm
	11.01	21.36	3.06	0.19	ppm	59.41	0.91	117	22	0.48	2.26	22.5	34.6	43.2
#	SrO	Y_2O_3	ZrO_2	SnO_2	BaO	Nd_2O_3	Eu_2O_3	Yb_2O_3	ThO_2	CO_2	Re			
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm			
	722.7	121	652	101	467	2.9	0.0	20.7	32.6	0.0	10.1			

On the study of the chemistry of leachate, it is recruited that the leachate contains high % of calcium oxide and silicon dioxide. CaO is obtained from egg shells and foodstuffs received from the CUTM campus whereas geochemical analysis exhibit the quantity of CaO is less. The leachate does not include the health deteriorating elements like F, As, Cd, Cr, Cu, Ag, and Ni in high percentage.

Conclusion:-

On Geo-hydro-chemical analysis of soil and water above/ below the surface of latosol, the groundwater and the water bodies in laterite mines, which cover a major portion of Khurdha district, the results were:

1. **Geotechnical properties:**- The specific gravity ranges between 2.65 to 2.70 whereas Cu (uniformity coefficient) and Cc (curvature Coefficient) were found to be 15.83 and 0.97 respectively (tending well-graded soil).
2. **Geo Chemical analysis:-** Omnian software and the Epsilon 3 module based XRF spectrometer was used for chemical analysis of the lateritic soil and compared with BHVO-2 of USGS, the oxides of alkali/alkaline/nonmetals and poor metals found were aluminum, and strontium, transition and metal oxides were Vanadium (V), Chromium (Cr), Manganese (Mn), Iron (Fe), Nickel(Ni), copper (Cu), Zinc(Zn), Gallium(Ga), Yttrium(Y), Zirconium (Zr), and Niobium (Nb). The REE's in the soil is Europium and Ytterbium. The presence of Eu shows Eu^+ anomaly.
3. **Physicochemical parameters:-** The pH values of dug wells show acidic character. The DO values are on higher side. The water is hard water and the BOD is high.

4. **Presence of oxides of Alkali/Alkaline earth/ metals and REE's:-** Other than Si and P Fe, Sn, all other metals are harmless as their concentration was less. But an excess of Fe, tin causes health hazard like diabetes, aged and urinary tract problems.
5. **Lack of flora and fauna in water bodies:-** Excess of DO and tin metal have resulted in defaunation of aquatic flora and fauna in the water bodies in the laterite mines in Khurdha district.

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