DISSERTATION REPORT
ON
"WATERQUALITY ANALYSIS OF PROPOSED ASH POND AT KANHIA BLOCK, ANGUL DISTRICT, ODISHA"

SUBMITTED
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CANDIDATE'S DECLARATION

I, hereby, certify that the report entitled **"WATER QUALITY ANALYSIS OF PROPOSED ASH POND AT KANHIA BLOCK, ANGUL DISTRICT, ODISHA"** has been prepared by the undersigned. This work carried out, during the period of **3rd March 2017** to **3rd May 2017**, is a record of my own work under the supervision of **Dr S.P Rai**, Scientist 'F', Hydrology Investigation Division, National Institute of Hydrology (NIH), Roorkee (Uttarakhand).

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It is certified that the above statement made by the candidate is correct to the best of my knowledge.

2/5/17

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CHAPTER 1 INTRODUCTION

1.1 IMPORTANCE OF WATER QUALITY

Water is a clear liquid that has no colour, taste or smell and have its own chemistry that has fall from cloud as rain and form Rivers, lakes and sea. It is an essential element for the survival of living beings. With two third of earth's surface covered by water and human body consisting of 75% of it, it is evidently clear that water is one of the prime elements responsible for life on earth. Water existing in the soil strata is known as subsurface water and can be separated into soil water and groundwater. The soil water occurs in unsaturated zone, and groundwater occurs in saturated zone. Groundwater is an important source of water supply throughout the world. Groundwater occurs almost everywhere beneath the earth surface not in a single widespread aquifer but in thousands of local aquifer systems and compartments that have similar characters. Water from beneath the ground has been exploited for domestic use, livestock and irrigation since the earliest times. It is however common for the dominant role of groundwater in the freshwater part of hydrological cycle to be overlooked. Groundwater is easily the most important component and constitute about two third of fresh water resources of the world and, if the polar ice caps and glaciers are not considered, Groundwater accounts for nearly 90% all usable freshwater. even if the consideration is further limited to only the most active and accessible groundwater bodies (estimated by Lvov itch 1972 at 4×106 km^3) then they constituent 95% of the total freshwater. Lakes and rivers account for only 1.5 per cent (Freeze and cherry 1979).

Ground water quality is important to humans. Therefore, it is important to ensure its quality is high at all time so that the consumer health is not compromised. Groundwater resources are affected mainly by three major activities: (i) excessive use of fertilizers and pesticides in agricultural areas, (ii) untreated/partially treated wastewater to surface water bodies, and excessive pumping and improper management of groundwater resource. Solid waste disposal in open un-engineered landfill is the one of the factor that causes ground water pollution due to lack of pollution control interventions such as water proof layer, leachate treatment pond, monitoring wells, etc. (Mohamad et al., 2007). Groundwater pollution also occurs due to disposal of toxic wastes, especially from industries, or undetected leakage from pipes, waste storage containers, or underground tanks. According to WHO, about 80% of all the diseases in human beings are caused by water Groundwater once contaminated, its restoration to actual state requires prolonged time and decontamination is not possible by just stopping the ingress of pollutants from the source. Contamination of groundwater by domestic, industrial effluents and agricultural pollutants is a serious problem being faced by developing countries. The industrial waste water, sewage sludge and solid waste materials are currently being discharged directly into the environment indiscriminately. These materials enter subsurface aquifers resulting in the pollution of irrigation and drinking water. High rates of mortality and morbidity due to water borne diseases are well known in India. Therefore, access to safe drinking water supply remains an urgent necessity, as 30% of urban and 90% of rural households still depend completely on untreated surface or ground water (Palanisamy et al., 2007).

1.2 WATER QUALITY ISSUES IN THE STUDY AREA

The quality of water is defined in terms of its physical, chemical and biological parameters. Its development and management plays a vital role in agriculture production, poverty reduction, environmental sustenance and sustainable economic development (Basavaraja, S., et al., 2011). In some areas of the world, people face serious drinking water shortage because of the ground water pollution. Thus, evaluation of groundwater quantity and quality is important for the development of further civilization and to establish database for planning future water resources development and management strategies. The quality of water may depend on geology of particular area and also vary with depth of water table as well as seasonal changes and is governed by the extent and composition of the dissolved salts depending upon the subsurface environment.

The study area around proposed ash pond of TSTPS Kanhia, Angul District Orisha, is surrounded by coal mines, Aluminium smelter and NTPC (National Thermal Power Corporation, Talchir), TSTPS and other industries, and these contaminate continuously form point as well as non-point sources. The mines of MCL, Aluminium smelter and NTPS draw water for their use from the Brahmani and its tributaries and in return they release thousands of gallons of waste water to the river, which contains obnoxious substances like Suspended sediments (SS), TDS, ash, oil and grease, heavy metals, fluorides, phosphorous, ammonia, urea and acids. The fly ash generated during these power plant operations and ash ponds in the coalfield areas also created environmental hazards particularly in water by increasing the suspended, dissolved and heavy metals concentrations. Waste generation due to the operation and expansion of mining, thermal power plants and industrial activity in Angul-Talcher is going to be a serious threat for water resources in nearby area in future. Therefore, the present study is evaluate the current pollution level in the water bodies (Surface and subsurface) of the study area. The objectives of the study area are given below.

1.3 OBJECTIVES

To study the water quality of proposed ash pond area.

- To study the water quality of surface water around ash pond.

- To study the water quality of ground water around ash pond.

CHAPTER-2 STUDY AREA

2.1 GENERAL

2.1.1 Location

Kaniha is located in the centre of state of Odisha and lies between 20° 31 N and 21° 40 N latitude and 84° 15 E and 85° 23 E longitude. The altitude is between 564 and 1187 meters. The district has an area of 6232sq.km. It is bounded by Dhenkanal and Cuttack district in the east, Deogarh, Kendujhar and Sundarhgarh district in north, Sambalpur and Sonepur in west and Boudh and Nayagarh in the south side. The Angul district which has been carved put from earlier Dhenkanal district is one such area in which various industries are located. Angul is recognized as an industrial district in the map of Odisha. Steel Plant, Fertilizer Plant, Cement factory, Ferrovanadium Plant, Machine building factory, Glass and China clay and Spinning mills are some of the major industries of this district. The district is abundant with natural resources. Brahmani, Tikira, Sankh, Koel and IB are the major rivers flowing through this district.

The district is named after the district headquarter town of Angul. Angul district was formed out of the former undivided Dhenkanal district on April 1, 1993. The name Angul is said to be a corruption of Anugola, named after Anu, the last Khond Tribal Chief who was deposed by means of a gol, which literally means battle.

According to the 2011 cencus, Angul district has a population of 1,271,703 roughly equal to the nation of Estonia or the US state of New Hampshire. This gives it a ranking of 380th in India (out of a total of 640).

The district has a population growth rate over the decade 2001-2011 was 11.55%. Angul has a sex ratio of 942 females for every 1000 males and a literacy rate of 78.96%.

DIVISIONS:

Angul district is divided into 4 subdivisions, 8 blocks, 8 Tehsils, and. They are as follow:

Subdivisions	Tehsil	Blocks
Angul	Angul	Angul Sadar
Athamalic	Athamalik	Athamalik Sadar
Talchir	Talchir	Chendipada
Pallahada	Pallahada	Talchir Sadar
	Chendipada	Pallahada Sadar
	Banarpal	Banarpal
	Kishornagar	Kishornagar
	Kanhia	Kanhia

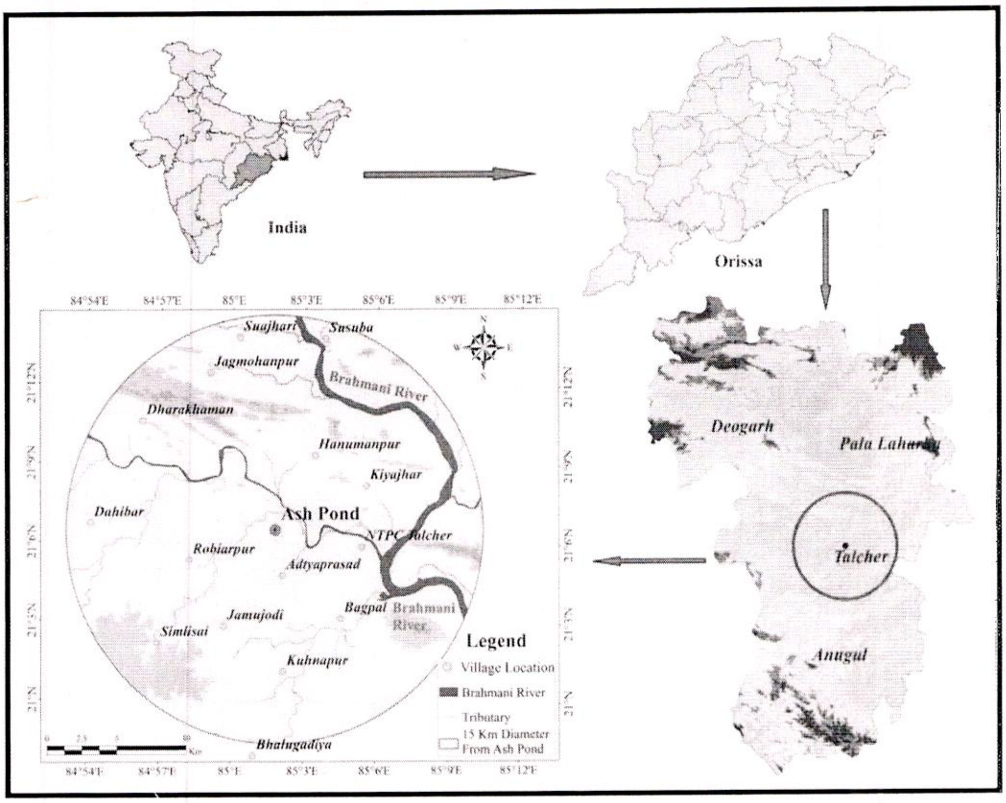


Figure 1: Location Map of the study area Kaniha, Angul District

2.1.2 Geomorphological set up

a) Physiography and Drainage

The Angul district is represented by hills and tables land, the entire district of Angul can be divided into three distinct physiographic regions namely Northern Mountainous Region, Southern and South Western Mountainous Region and Central undulating plain. The northern part of the district is characterized by dense forest of Pallahara subdivision and WNW-ESE trending hills immediately north of the Talchir coal, the area is drained by river Brahmani and Mahanadi River. The valley portion exposes granites and its variants with hillocks of khondalites; the remaining including the study area is characterized by flat country. The South and Western part comprises ranges of the Eastern Ghat Super Group and the Older Metamorphic Group. The Central portion is represented by sediments deposited in the Satpura-Mahanadi graven defined by pronounced NW-SE trending lineaments on a Precambrian platform, almost separating the Eastern Ghat Mobile Belt and Orissa Carton. The northern boundaries of Talcher basin are faulted. Situated at the heart of Orissa, the district of Angul is an integral part of the State contributing towards its rich culture, tradition and socio-economic development. Most of the forests of the district are deciduous in nature. The Angul Forest Division covers forest areas of Angul and Talcher civil sub-division of Angul district. Established in 1885, the Angul Forest Division is the oldest Forest Division in the State. The major part of the Angul district lies between two major river systems of Orisha State i.e. River Brahmani flows in the north east and river Mahanadi which forms the south-south western boundary of the district. The altitude and physiographic set of the area divides the entire district into two distinct catchments, the streams joining the river Mahanadi flows in south-west direction whereas the streams joining the river Brahmani from the central plains flows in north-east direction.

The study area (Proposed Ash Pond) forms a part of Tikira Nadi which is a major tributary of Brahmani river basin. Tikira river and Olhani rivers forms the small watershed in the west (upstream side) while at downstream side Tikira river meets with Brahmani river near Godhsheela. The Tikira River flows in south western corner of proposed ash pond area having NW-SE trend. In general, the major streams show approximately right angle pattern while joining with the river Brahmani, the meanders indicating differential weathering phenomena. The drainage pattern is mostly dendritic and occasionally parallel in hills.

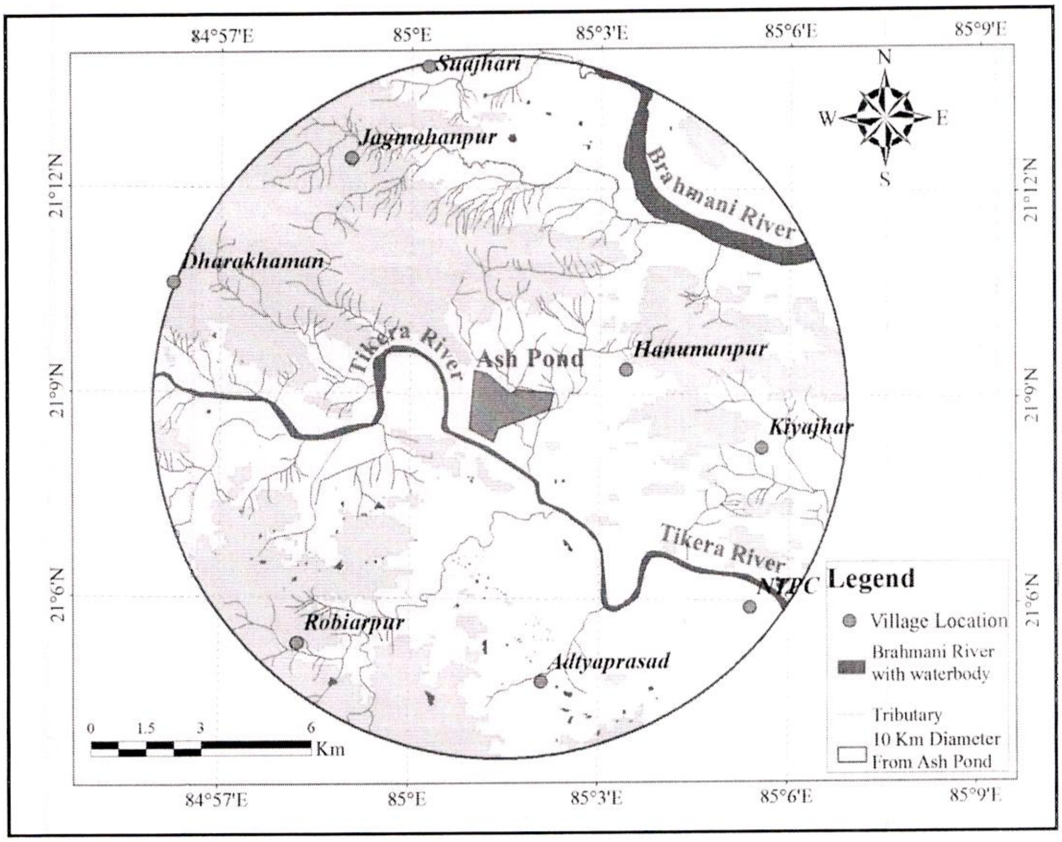


Figure 2: Vicinity Map of Ash pond area, circle covers the radius of 10 km. from the centre of the proposed ash pond of TSTPS, Kaniha.

2.1.3 Soil and land use

The district is dominated by tropical wet and dry climate and locally it has been put under Arid Central Table Land. The district is consisted of mainly three type of soil, namelyAlfisols, Ultisols and Vertisols. Alfisols comprises of red sandy soils, red loamy soils and mixed red and black soils. The red loamy and red sandy soils cover major parts of the district. The red soils are suitable for cultivation of paddy and other crops. Soil plays an important role in over all the availability of surface water as well as recharge to ground water. The red soil are light textured, usually made of lime Kankar and free of carbonates. Sandy clay is common and these soils are suitable for cultivation of paddy and other crops. Ultisols are also found in the western extremity of the study area which consist of red and yellow soils and are rich in clay content. Nearly 45% of the district area is occupied by reserve forest. Paddy is major crop of Kharif season, during Rubi season mainly vegetable and oil seeds are grown.

2.1.4 Climate and rainfall

The study area experiences tropical monsoon climate with mild winter and hot summer. There are three distinct season, good rainfall has been observed in the area through south-west monsoon between May to September every year. The Climatological data including the monthly temperature, humidity and rainfall for the period of last eight years from Angul I.M.D station has been analysed to arrive at the annual normal rainfall of the area and is presented in Table 1. The average annual rainfall of the Angul area has been observed as 1266.7 mm, of which major amount are received during the four months extending from June to September.

Table 1 Climatological Data of IMD Station Angul

Month	**Mean Temperature (°C)**		**Relative Humidity (%)**		**Rainfall (mm)**
	Max	Min	Morning	Evening	
January	28.85	15.61	80	58	17.0
February	32.41	18.19	75	49	16.8
March	37.34	18.63	67	40	21.3
April	39.31	20.00	67	44	40.4
May	40.21	21.46	67	48	93.6
June	35.18	21.23	75	67	212.1
July	31.78	20.57	81	77	258.2
August	31.86	20.81	83	81	317.3
September	32.99	20.47	81	77	165.7
October	32.64	18.21	82	73	93.7
November	31.17	14.59	77	64	23.3
December	28.63	12.69	79	59	7.3
Average	33.53	18.54	76	61	1266.7

2.1.5 Geology of the study area

The district of Angul represents diverse geological sequence, from rocks of Eastern Ghats of Pre-Cambrian age, Iron-ore super group, Gondwana Super group, Laterites to alluvial deposits of Quaternary age (Table 2). The Gondwana rocks are exposed in the central part of the district covering parts of Talchir, Kaniha, Chendipada and Kishorenagar blocks. The plant area occupies the southern portion of Talchir coalfield and is located north-west of Angul town. Major portion of study area is occupied by Precambrian basement rocks except in extreme north eastern corner where Talchir are present (Figure 3).

Table 2 Stratigraphy Units / Sequence of Study Area, Orisha

Age	Formation	Thickness (m)	Lithology
Quaternary	Recent	Around 3-15	Alluvial fills, sand, silt deposits, older and younger flood plain deposits, channel fills etc.
Cenozoic	Laterite	Around 3-5	Laterites, laterised detrital pebble bed
Upper Permian to Triassic	Undifferentiated Kamthi Formation	Up to 250	Fine to medium grained light grey to reddish sandstone and shale at the base and pale greenish sand stones with rare shale and pink clay bands, ferruginous coarse grained to pebbly sandstone at top

Age	Formation	Thickness (m)	Lithology
Upper Permian	Barren Measures Formation		Greenish grey to buff colored pebbly, coarse sandstone with variable proportions of fresh K-feldspar
Lower Permian	Barakar Formation	Up to 500	Medium to coarse grained feldspathic sandstone, grey to dark grey shale and coal seams
Lower Permian	Karharbari Formation	Up to 300	Pale brownish colored massive medium to coarse grained sandstone containing clasts of Talchir shale and coal seams
Upper carboniferous to Lower Permian	Talchir Formation	Up to 325	Diamictite, sandstone, needle shale, turbidite,rhythmite and varves
Unconformity			
Precambrian		-	Granites, gneisses and associated supra-crustal

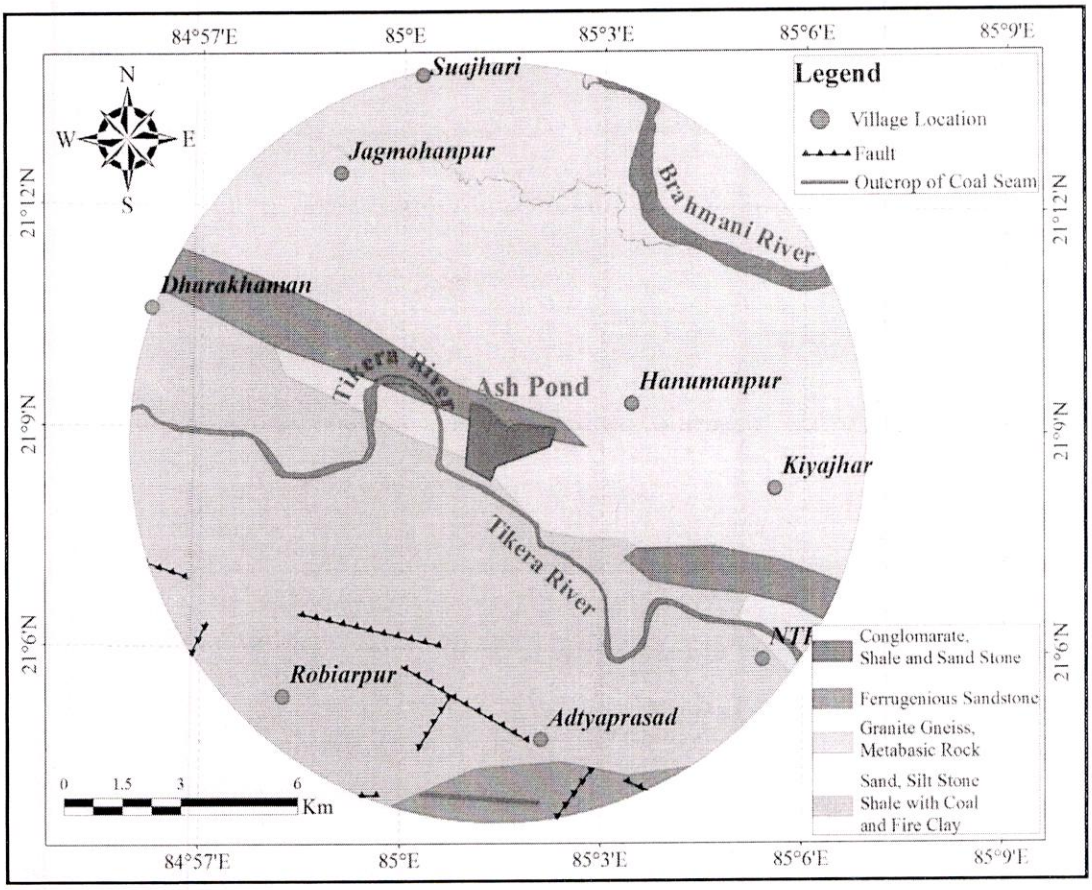


Figure 3: Geological map the proposed Ash pond area.

2.1.6 Hydrology

The major part of the total water requirement for domestic, irrigation and industries of the district as well as the study area are met from surface water sources. The district is also dotted with numerous small water bodies which cater to the domestic water needs. The river Mahanadi marks the southern boundary of this district River Brahmani enters the district through Rengali reservoir and passes through Talcher sub-division. Both these great rivers have innumerable tributaries large and small. Pallahara and Talcher sub-division and major portion of Angul sub-division form a part of the Brahmani basin. The Mahanadi basin is spread over Athamallik and part of Angul sub-divisions. Other rivers of Angul are mountain streams which are torrents in the rains and in summer contain little or no water. Their banks in most part are high, their beds rocky and they are not used for navigational purposes Brahmani basin is the largest basin of the district with 68.02% of the total geographical area and the Baitarani basin is the smallest covering only about0.36% of the total geographical area of Rayaga district. The Mahanadi basin with about 32% area of the district is another prominent basin here.

2.1.7 Water Sampling Locations

Groundwater conditions of the study area were studied by carrying out water sampling. Water samples were collected from different sources of the study area such as river, ponds, ash pond and hand pump. Table 3 and figure 4 includes the details of the sampling location of the collected samples from the study area.

Table 3 Sampling locations of water samples around ash pond

S. No.	Sample code/ ID	Date of collection	Source	Location	Long.	Lat.
1	SWTL-1	16/1/2017	RIVER	BRAHMANI	85.1625	21.0965
2	SWTL-2	16/1/2017	RIVER	TIKIRA (UPS)	84.9597	21.1489
3	SWTL-3	16/1/2017	RIVER	TIKIRA (DNS)	85.0409	21.1209
4	AWTL-4	16/1/2017	A. P. W. STG I	NTPC KANIHA	85.0412	21.1002
5	AWTL -5	16/1/2017	A. P. SEEP. STG I	NTPC KANIHA	85.0289	21.1054
6	AWTL -6	16/1/2017	A. P. SEEP W. STAGE II	NTPC KANIHA	85.0142	21.1184
7	AWTL -7	16/1/2017	RAW (MAKE UP) WATER	NTPC KANIHA	85.0761	21.0879
8	GWTL-8	17/1/2017	HAND PUMP	BALRAMPUR	84.9730	21.2157
9	GWTL-9	17/1/2017	HAND PUMP	SAGADIPAL	85.1212	21.0997
10	GWTL-10	17/1/2017	HAND PUMP	KULABIR	85.0784	21.1959
11	GWTL-11	17/1/2017	HAND PUMP	KANHIA	85.0426	21.0979
12	GWTL-12	17/1/2017	HAND PUMP	HANUMANPUR	85.0597	21.1453
13	GWTL-13	17/1/2017	HAND PUMP	KHAJURIA	85.0276	21.1372
14	GWTL-14	17/1/2017	HAND PUMP	MANDUA	84.9847	21.1563
15	GWTL-15	17/1/2017	HAND PUMP	BADAGUNDARI	85.0022	21.0755

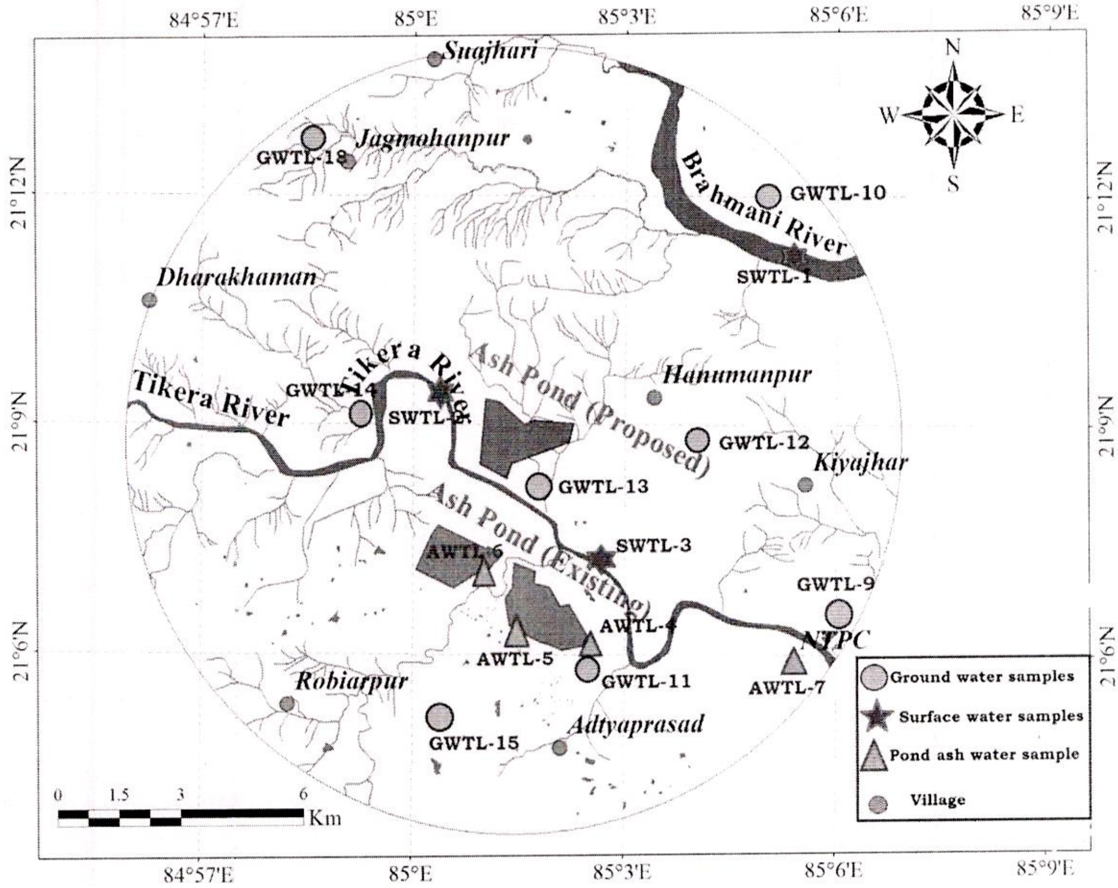


Figure 4: Sample Location Map for Water Quality Parameters around ash pond within 10 km

CHAPTER-3 METHODOLOGY

3.1 GENERAL

The Physico-chemical analysis is performed as per the standard methods (APHA, 1992). To check the results of laboratory analysis, ionic balance has also been done. A total number of eleven water quality parameters were selected. The details of various water quality parameters, analytical methods and equipment's are given in Table 4.

Table 4 Details of Analytical Methods and Equipments

S. No.	Parameter	Method	Equipment
1	pH	Electrometric	pH Meter
2	Conductivity	Electrometric	Conductivity Meter
3	TDS		Conductivity/TDS Meter
4	Bicarbonate	Titration by H_2SO_4	Titration
5	Sulphate	Conductivity Method	Ion Chromatography
6	Chloride		
8	Calcium		
9	Magnesium		
10	Sodium		
11	Nitrate		
12	Hardness	Titration by EDTA	Titration

3.2 METHODOLOGY FOR WATER QUALITY PARAMETERS

In the present study, various water quality parameters as given in Table 4are described in detail as follows:

3.2.1 pH

pH value is a measure of hydrogen ion concentration and is the negative exponent of the logarithm of the hydrogen ion concentration. A low pH solution has a high hydrogen ion concentration and is therefore, acidic while high pH solution is low in hydrogen ion concentration and is alkaline (pH 7 being neutral).

The pH value of natural water is an important index of acidity or alkalinity and is the resulting value of the acidic/basic interaction of a number of its mineral and organic components. In pure or slightly polluted water, the value of pH is determined mainly by the correlation between the concentrations of free carbon dioxide, bicarbonate and carbonate ions. This correlation, in turn depends substantially on the intensity of the process of photosynthesis and the biochemical oxidation of organic substances as well as on chemical conversions of some mineral substances. pH of most natural waters range from 4 to 9 and are often slightly basic due to the presence of carbonates and bicarbonates.

A major deviation from the normal pH for given water indicates the industrial wastes. Practically every phase of water supply and wastewater treatment, e.g., acid- base neutralization, water softening, precipitation, coagulation, disinfection and corrosion control, is pH dependent.

PROCEDURE: -

i) For detailed instructions, follow manufacturer's manual, Standardize the pH meter by immersing the electrode in buffer solution of known pH. Read the pH and correctly, adjust with the control until the meter indicates the correct value for pH of buffer solution.

ii) Remove electrodes from first buffer, rinse thoroughly with distilled water, blot dry with a soft tissue, and immerse in second buffer, the reading should be within 0.1 unit for the pH of the buffer. If the response shows a difference greater than 0.1 pH unit from expected value, look for trouble with the electrode or pH meter.

iii) Rinse the electrodes in distilled water and immerse them in the sample. Let the reading stabilize. Read the pH value.

3.2.2 Electrical Conductivity (EC)

Conductivity is a measurement of water's capacity for conveying electrical current and is directly related to the concentrations of ionized substance in the water. Solutions of most inorganic acids, bases and salts are relatively good conductors. Conductivity measurements are commonly used to determine the purity of demineralized water and total dissolved solids in boiler and cooling tower water. Electrical conductivity is generally measured in terms of µS/cm.

REAGENTS: -

i) **Conductivity water:** Pass distilled water through a mixed bed deionizer and discard first litre. Conductivity should be less than 1µmho/cm.

ii) **Standard potassium chloride solution, 0.01 N:** Dissolve 745.6 mg anhydrous KC1 in conductivity water and dilute to 1000 ml at 25°C. This is the standard reference solution, which at 25°C has a conductivity of 1413 µmho/cm. It is satisfactory for most samples when the cell has a constant between 1 and 2.

PROCEDURE: -

i) For detailed instructions, follow manufacturer's manual, Standardize the EC meter by immersing the electrode in distilled water of known EC. Read the EC is 0, Remove electrodes from distilled water and immerse in KCL EC meter read 1413 μmho/cm.

ii) Remove electrodes from KCL, rinse thoroughly with distilled water, and blot dry with a soft tissue. Immerse them in the sample. Let the reading stabilize. Read the EC value.

3.2.3 Total Dissolved Solids (TDS)

Solids refer to matter suspended or dissolved in water or waste water. Solids may affect water or effluent quality adversely in a number of ways. Waters with high dissolved solids generally are of inferior palatability and indices an unfavourable physiological reaction in the transient consumer. For these reasons, a limit of 500 mg/l is desirable for drinking water. A well-mixed sample is filtered through a standard glass fiber filter, and the filtrate is evaporated to dryness in a weighed dish and dried to constant weight at 180°C. The increase in dish weight represents the total dissolved solids (TDS). Total dissolved solids are determined using the equation given below and are expressed in terms of mg/l.

3.2.4 Bicarbonate

Bicarbonate is a major element in our body. Bicarbonates are naturally produced by the gastric membrane in the stomach. This production will be low in alkaline conditions and will rise in response to acidity. In healthy individuals this adaptive mechanism will control the pH perfectly. Bicarbonate is measured in terms of mg/L.:

REAGENTS: -

1-Sulphuric Acid 0.02N:

Dilute 0.72 ml of concentrated sulphuric acid to 1000ml with distilled water and standardize against standard sodium carbonate.

2-Sodium carbonate solution (0.02N): *Dissolve 0.27gm sodium carbonate in distilled water and make up to 250ml.*

3-Phenolphthalein indicator: *Dissolve 5gm of the indicator in 500ml of ethanol and dilute to 1000ml with distilled water.*

4-Methyl orange indicator: *Dissolve 0.5gm of the indicator (acid free type, in 1000ml distilled water.*

PROCEDURE: -

1-Pipette 20ml of the water sample into a 250 ml clean conical flask.

2-Add two drops of phenolphthalein indicator. If a pink colordevelops, carbonate is present.

3- Titrate this against 0.02N sulphuric acid till the pink color disappears.

4-To the sample in the conical flask, add 1 or 2 drops of methyl orange indicator.

5- Continue the titration till the straw yellow color changes to pinkish red.

Calculations:

Volume of water sample taken= 20ml.

Volume of 0.02N H_2SO_4 used for phenolphthalein end point = Xml

Volume of 0.02N H_2SO_4 used for methyl orange indicator.

$$HCO_3^- \text{ (mg/l)} = (Y-2X) * 0.02 * 61/20 * 100.$$

3.2.5 Ion Chromatography

Ion chromatography is used for water analysis. The measurement of concentration of major anions such as fluoride, chloride, nitrate, nitrite and sulphate as well as major cations such as lithium, sodium, ammonium, potassium, calcium and magnesium in the parts-per-million.

The analyser, suppressor, column, detector is the component of ion chromatography. In ion chromatography, as an ion extraction liquid runs through the column, the absorbed ions begin separating from the column. The retention time of different species determines the ionic concentration in the sample.

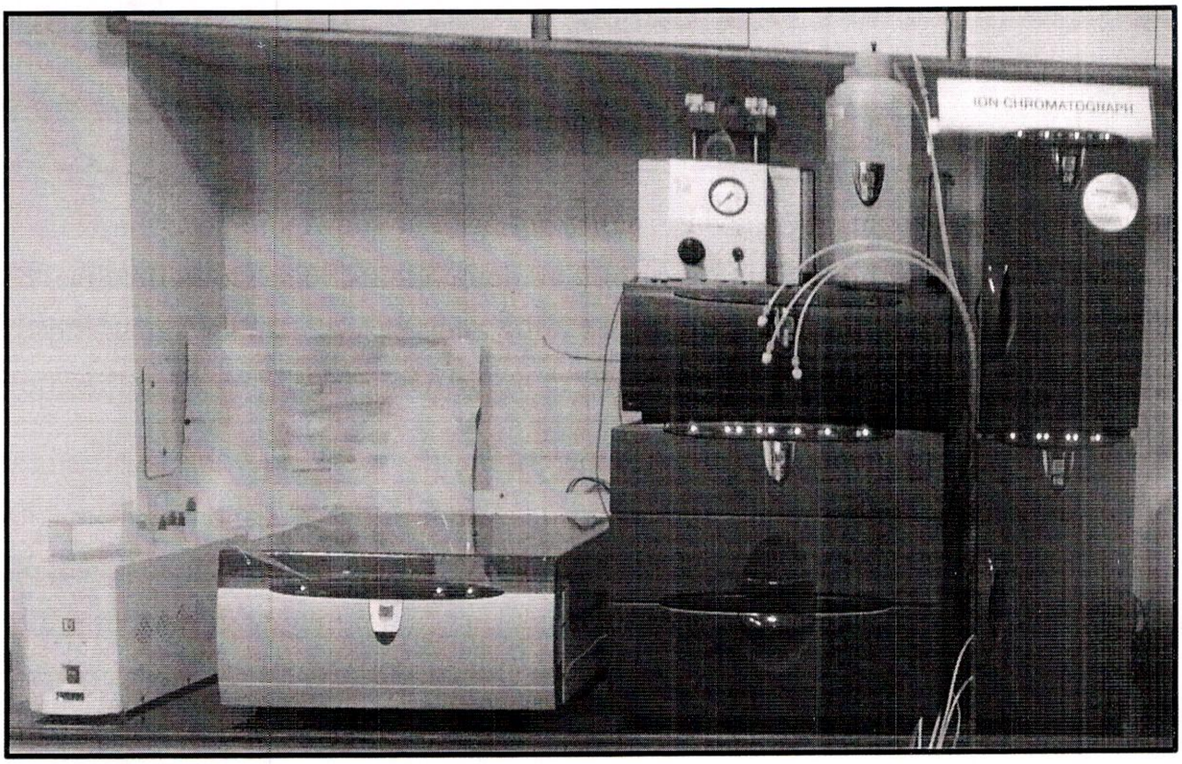


Figure 5: Ion Chromatograph

Working

In ion chromatography, the samples are passed through analyzer where the mixtures of sample are injected into a carrier fluid (eluent). Then the solutions are passed to suppressor where the conductance of eluent is reduced and at the same time it enhances the conductance of the sample. Then the sample solutions passed through a pressurized chromatographic column where ions are absorbed by column constitutes i.e. adsorbent. Different materials are adhering to adsorbent with different forces. As the eluent are flows through column the components of analytic are moved down the column at different speed and therefore they separate from one another. As the analyte are emerge from the column, the detector gives the output at the end of column.

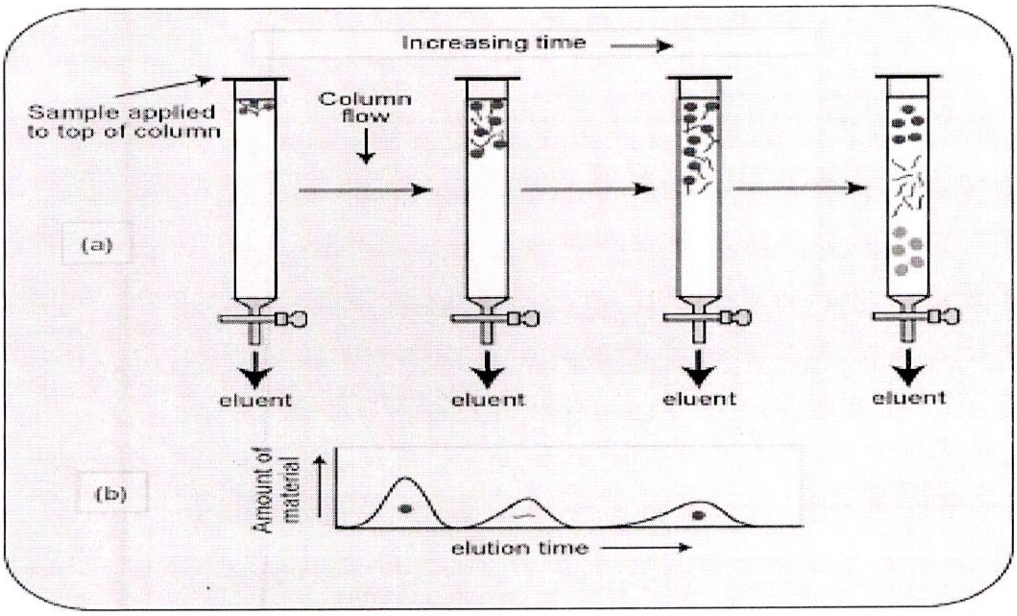


Figure 6: working of component of ion chromatograph

Outcome of ion chromatography

The outcome of ion chromatography is given by detector. Detector generates a measurable signal when the analyte are emerges from the column. These signals are represented as the peaks on the chromatogram.

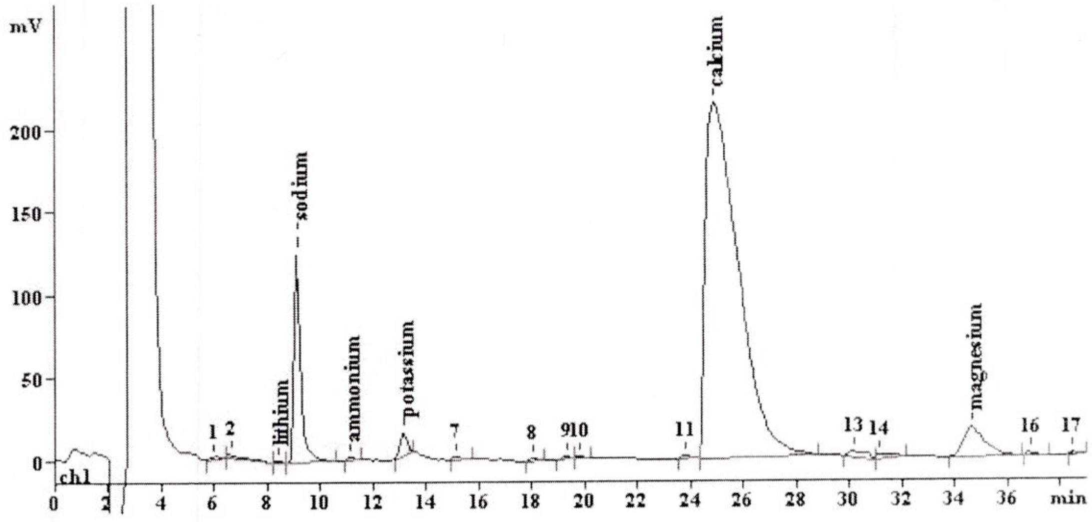


Figure 7: Representation of peaks in chromatogram

Chromatogram is the record of the outcome of detector as in the form of electrical conductivity versus time of the analyte passes through the chromatographic system.

3.2.6 Total Hardness

The Hardness of water was originally defined in terms of its ability to precipitate soap. Calcium and magnesium ions are the principle causes although iron, aluminium, manganese, strontium, zinc and hydrogen ions are capable of producing the same effect. High concentrations of the latter ions are not commonly found in natural waters. In conformity with current practice, total hardness is defined as characteristic of water which represents the total concentration of calcium and magnesium expressed as their calcium carbonate equivalent. Hardness is measured in terms of mg/l. Temporary hardness is caused by the presence of bicarbonates of calcium and magnesium. Permanent hardness is mostly due to Sulphate. When the total hardness has a value greater than total alkalinity, the amount of hardness equivalent to the alkalinity is called carbonate hardness and the excess amount is non-carbonate hardness. When total hardness is equal or less than the total alkalinity

REAGENT: -

1. Inhibitor: Dissolve 4.5 g hydroxyl amine hydrochloride in 100 ml 95% ethyl alcohol. Eriochrome block T indicator: Mix 0.5 g dye with 100 g NaCl to prepare dry powder or dissolve 0.19 of Eriochrome black T in 20 ml of ethyl alcohol.

2. Sodium hydroxide 2N: Dissolve 80 g NaOH and dilute to 1 L.

3. Standard EDTA solution, 0.01 M: Dissolve 3.723g EDTA sodium salt and dilute to 1000 ml. Standardize against standard calcium solution, 1 ml=1mg $CaCO_3$.

PROCEDURE: -

1. Take 100 ml water sample in a conical flask and add to it 1-2 mL buffer solution followed by 1 mL inhibitor.

2. Add 2 drops Eriochrome black T indicator and titrate with standard EDTA solution, 0.01 M, till wine red colour changes to blue. Note the volume of EDTA used.

3. In another flask take 100 mL sample ad add 1 ml sodium hydroxide solution to raise the pH to 12.0 and a pinch of murex indicator.

4. Titrate with standard EDTA solution, 0.01M, till pink colour changes to purple. Note the volume of EDTA used.

$$\text{Total Hardness, mg/l} = \frac{A \times C}{\text{Volume of sample, ml}}$$

$$\text{Calcium Hardness, mg/l} = \frac{B \times C}{\text{Volume of sample, ml}}$$

A = Volume of EDTA solution used with Eriochrome black T indicator.
B = Volume of EDTA solution used with murex indicator, ml, and,
C = mg $CaCO_3$ equivalent to 1.0 ml EDTA titrate.

Magnesium Hardness, mg/l = [Total Hardness – Calcium Hardness] × 0.243

3.2.7 Oil and grease

The concentration of dispersed oil and grease (OG) is an important parameter for water quality and safety. OG in water can cause surface films and shoreline deposits leading to environmental degradation, and can include human health risks when discharged in surface or ground waters. Additionally, OG may interfere with aerobic and anaerobic biological processes and lead to decreased wastewater treatment efficiency. Regulatory bodies worldwide set limits in order to control the amount of OG entering natural bodies of water or reservoirs through industrial discharges, and also to limit the amount present in drinking water.

Oil and Grease Measurement procedure

Oil and Grease include any material collected as a substance that is soluble in the n-hexane extractant. These include substances such as relatively non-volatile hydrocarbons, vegetable oils, animal fats, waxes, soaps, greases and related materials. Initially all the samples were acidified by HCl (pH=2), samples were sequentially extracted three times using hexane, shaken vigorously for ten minutes per extraction. The ratio of solvent to sample should be no less than 1:20. The solvent extracts are drop wisely passed through a drying funnel. Distillation was done to acquire hydrocarbon residue. It was put into oven and set temperature as 70°C then put into desiccators for cooling. Determination of the residue was done by analytical electronic balance. When measuring oil and grease (HEM: n-Hexane Extractable Materials) gravimetrically, the substances are removed from the sample with n-hexane, then the n-hexane is dried. The residue left is weighed to determine the concentration of oil and grease materials in mg/l. The method is based on prior Environmental Protection Agency (EPA) methods for determination of "oil and grease" and "total petroleum hydrocarbons". This method is not applicable to measurement of materials that volatilize at temperatures below approximately 85°C. In this method detection limit (MDL) is 1.5 mg/l.

A 1/l sample is poured into the separator funnel and the sample acidified by adding 5ml HCL (1:1) to lower pH <2. Add 30 ml of n-hexane to the sample bottle and seal the bottle with the original bottle cap. Shake the bottle to rinse all interior surfaces of the bottle, including the lid of the bottle cap (**Figure 8**). Allow the organic phase to separate from the aqueous phase for a minimum of 10 minutes. Drain the aqueous layer (lower layer) into the original sample container. Drain the n-hexane layer (upper layer-froths) from the separatory funnel into the pre-weighed boiling flask containing the boiling chips. Repeat the extraction twice more with fresh 30mL portions of n-hexane, combining the extracts in the boiling-distillation flask. Rinse the tip of the separatory funnel, the filter paper, and the funnel with 2–3 small (3–5 ml) portions of n-hexane. Collect the rinsing in the flask. Put the boiling- distillation flasks in a water bath or a steam bath to distil off the n-hexane. Distillation is complete when there are no boiling bubbles or the distillation flask is dry. The residue left is weighed to determine the concentration of oil and grease.

Figure 8: Measurement of Oil and Grease in water sample using Hexane Extractable Gravimetric Method

To calculate the test results following equation can be used:

$$\boxed{[(A - B) \div \text{Sample volume}] \times 1000 = \text{mg/L Oil \& Grease}}$$

Where: A = Weight (mg) of residue

B = Weight (mg) of the empty flask with boiling chips

(USEPA: Standard Methods for the Examination of Water and Wastewater, Section 5520B)

CHAPTER 4 RESULT AND DISCUSSION

4.1 WATER ANALYSIS

Water samples were collected for analysing the different parameters at the nuclear laboratory in NIH, Roorkee. The result of water quality parameters are described below. -

4.1.1 pH

The results of the analysis of samples are tabulated in table5. The overall pH varied from 7.0-7.92 in the study area. Among all the samples of water of different sources, river water pH ranged from 7.2 to 7.9 and ground water samples pH varied from 6.1 to 7.8, and ash pond water pH varied from 7.4 to 7.8 with an average value of 7.6 surface water, 7.6 ash water and 7.3 ground water respectively. According to BIS (IS: 10500-1991) the pH value within the 6.5 to 8.5 is suitable for drinking water. The pH of the samples of all type of water is within the BIS prescribed limit;therefore it appears that the water is suitable for drinking purpose.

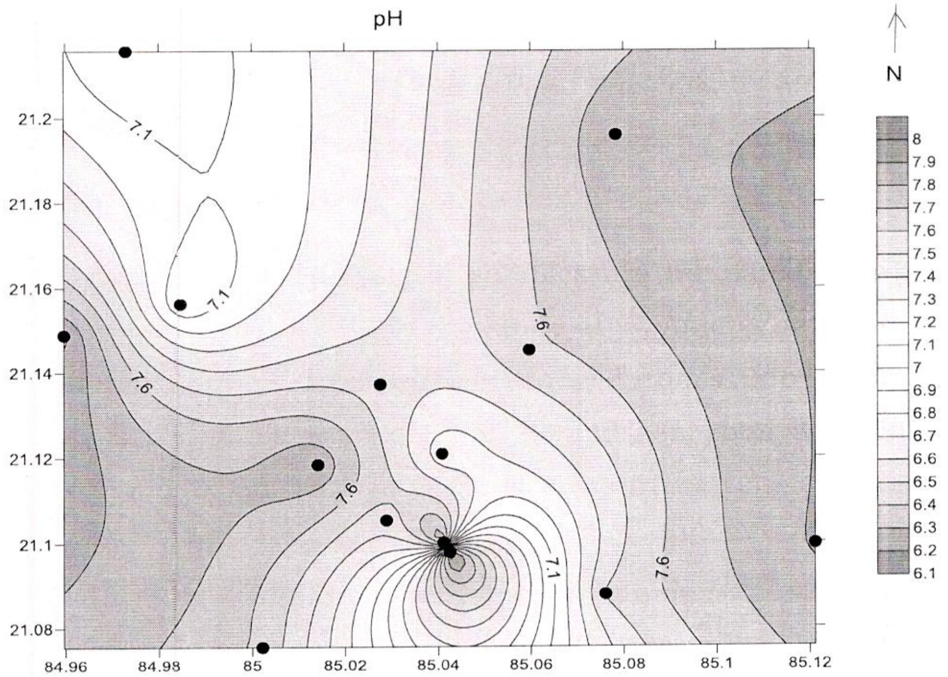


Figure 9: showing pH value of all water samples

Table 5 Physico-chemical characteristics of water samples and nearby area within 10 km. radius of proposed Ash pond

S. No.	Sample ID	Source	PH	EC	TDS	Alk-alnity	TH	F-	Cl-	SO_4^{2-}	NO3-	Ca2+	Mg2+	Na+	K+	SiO_2	Oil & Grease
Surface Water Samples (All concentration in mg/l except pH, EC)																	
1	SWTL-1	River	7.67	138	97	59	44.9	0.37	5.56	6.2	3.3	11.7	3.8	6.1	2.2	1.54	1.50
2	SWTL-2	Pond	7.92	209	148	103	81.2	0.21	20.1	6.8	3.5	25.3	4.4	15.1	2.8	1.81	2.23
3	SWTL-3	River	7.23	344	221	100	129.8	2.1	14.8	40.1	4.1	42.2	7.9	13.9	4.7	1.57	8.44
Ash pond Water Effluent Samples																	
4	AWTL4	L-1, ST- 1	7.80	276	186	145	121.7	1.58	8.1	20.18	0.31	33.1	9.5	9.1	4.2	1.32	6.54
5	AWTL-5	SEP. ST-1	7.43	715	436	303	418.1	2.76	29.1	104.66	17.1	144.3	14.0	22.7	13.3	1.21	6.04
6	AWTL6	SEP. ST-2	7.78	539	348	171	220.0	3.57	22.6	92.85	7.48	57.4	18.7	18.3	5.1	2.20	2.90
7	AWTL-7	RAW (M-U)	7.52	142	98	65.1	41.5	0.39	4.07	6.37	3.34	13.5	4.9	6.5	1.56	2.56	NA
Ground Water Samples																	
8	GWTL-8	H.P.	7.58	621	406	253	255.7	1.09	45.9	11.1	0.74	55.12	30.4	11.6	2.89	2.25	NA
9	GWTL-9	H.P.	7.46	1234	811	375	462.0	1.42	128	65.1	45.01	135.1	30.0	94.1	3.19	2.01	NA
10	GWTL-10	H.P.	7.01	1148	739	361	555.5	2.06	141	58.44	52.08	145.9	47.3	40.0	4.22	1.23	NA
11	GWTL-11	H.P.	7.00	387	290	236	108.9	0.31	8.78	12.19	0.21	67.19	10.9	6.9	4.42	2.91	NA
12	GWTL-12	H.P.	7.58	840	576	371	373.1	1.66	40.9	2.10	1.32	70.10	44.2	21.8	4.12	2.66	NA
13	GWTL-13	H.P.	7.81	645	436	325	247.0	0.81	6.01	17.66	1.28	61.21	20.9	22.7	4.56	1.78	1.84
14	GWTL-14	H.P.	7.77	702	481	346	273.1	0.97	20.9	13.45	3.87	68.23	22.5	42.8	2.34	3.43	3.16
15	GWTL-15	H.P.	6.21	334	211	164	110	0.6	5.3	5.2	4.0	45.3	3.7	5.9	5.0	3.8	2.42

4.1.2 Electrical Conductivity (EC)

The overall range of the electrical conductivity varied between 138μmho/cm and 1053μmho/cm in all the collected samples of water Fig.6 which includes the sources such as river, ash pond and groundwater. EC ranged from 138μmho/cm to 344μmho/cm in the river water. In ash pond water EC ranged from 142μmho/cm to 715μmho/cm and 344μmho/cm to 1234μmho/cm in groundwater. The average value of EC of surface water, ash pond water and ground water is230, 418 and 739 respectively. The EC values are found higher in the groundwater than that of other sources.

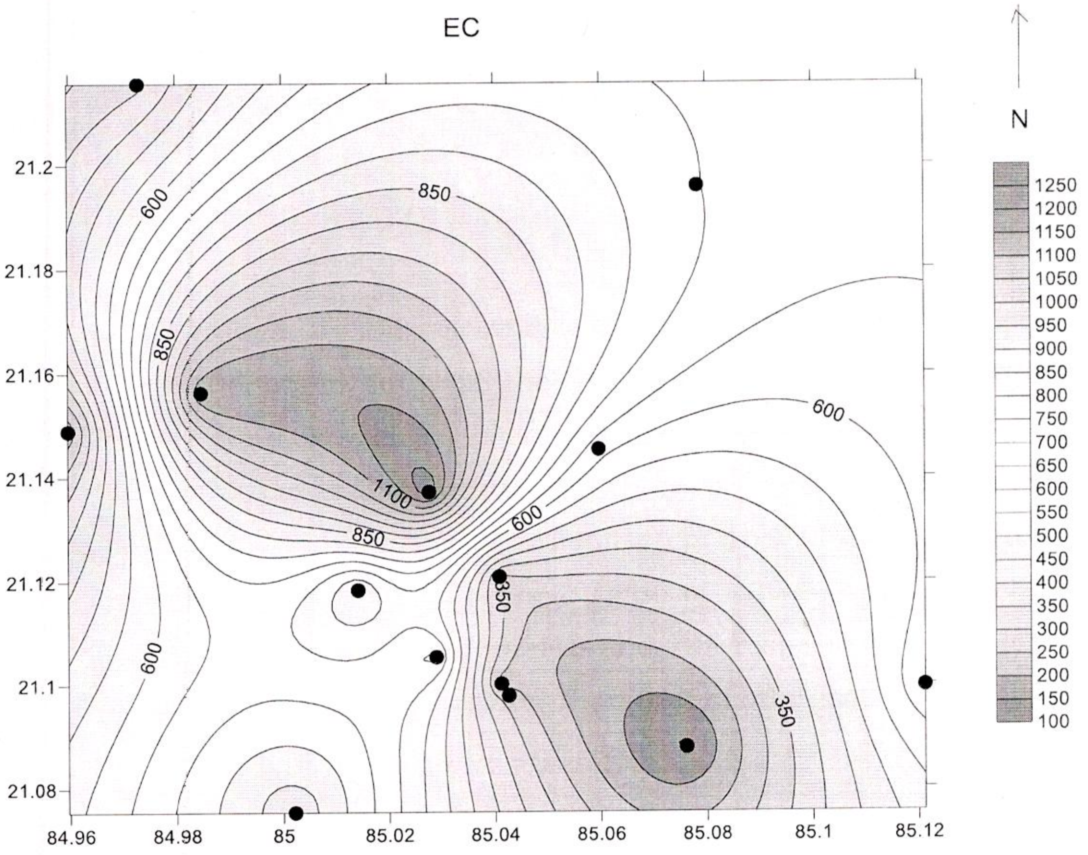


Figure 10: shows EC value of all water samples

4.1.3 Total Dissolved Solids (TDS)

Figure 11 show the ranges of the TDS were found in overall study area between 97mg/l to 811mg/l. Samples of water comprised of different sources such as river, ash pond and ground water. In the samples of River water, the value of TDS ranged from 97mg/l to 221mg/l, 98mg/l to 436mg/l in ash pond water and 211mg/l to 810.6mg/l in ground water. All the river samples show lower TDS content than pond samples. According to BIS (IS: 10500-1991) the agreeable value of TDS is 500mg/l and maximum is 2000 which is suitable for a drinking water. The samples that we have taken from different sites of our study area having a TDS less than its permissible value therefore it is quite visible that the water is suitable for drinking water purposes.

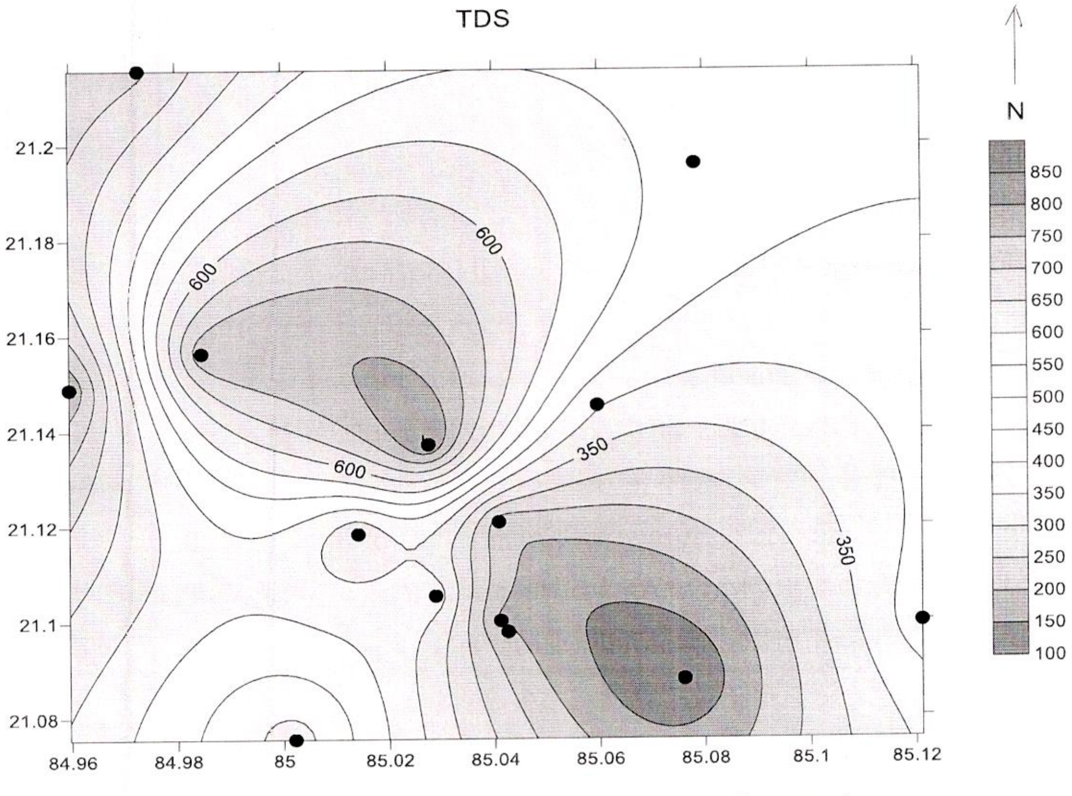


Figure 11: show TDS value of all samples

Table 6 Classification of water based on Total Dissolved Solids

TDS (mg/l)	Water Quality	% Samples
0-1,000	Fresh Water	100%
1,000-10,000	Brackish Water	Nil
10,000-100,000	Saline Water	Nil
>100,000	Brine	Nil

4.1.4 Total Hardness (TH)

Hardness in water is caused by a variety of dissolved polyvalent metallic ions, predominantly calcium and magnesium cations. It is usually expressed as milligrams of calcium carbonate per litre. The degree of hardness of drinking water is important for aesthetic acceptability by consumers. Hardness is the property of water which prevents the lather (foam) formation with the soap and increased the boiling point of water. Hardness is classified in four categories as soft water, hard water, moderately hard water and very hard water in table-6.

Drinking water can be contributor to calcium and magnesium intake and could important for those who are marginal for calcium and magnesium. Consumers are likely to notice changes in hardness. Public acceptability of degree of hardness of water may vary considerably from one community to another. The taste threshold for the calcium ion is in the range of 100-300mg/l, depending on the associated anion, and the taste threshold for magnesium is probably lower than that for calcium. In some instances, consumers tolerate water hardness in excess of 500mg/l. BIS (2012) has prescribed 200mh/l as acceptable limit and 600 mg/l as permissible limit in absence of alternate source for drinking and other domestic usage. No health-based guideline value is proposed for hardness in drinking-water (WHO, 2011). Total hardness of the surface water samples, ash pond water samples and ground water samples of the study area, vary from 45 to 130mg/l, 42 to 367 mg/l and 109 to 556mg/l respectively. The average value of TH of surface water, ash pond water and ground water samples is85, 178 and 298 respectively.

Table 7 Hardness Classification of Water

Hardness (mg/l)	Water class	%Sample
0-75	Soft	0.00%
75-150	Moderately hard	20%
150-300	Hard	26.67%
>300	Very hard	50.33%

Table7 reveals that 13.34% of the analysed samples were falling in soft water class and 20% samples are moderately hard. While 33.3% analysed samples were falling in hard class and 20% of analysed water samples indicating very hard.

4.2 Major Anions (Alkalinity, F^-, Cl^-, SO_4^{2-} and NO_3^-

The anion chemistry of the analysed samples shows that HCO_3^-, Cl^-, SO_4^{2-}, NO_3^- and fluoride (F^-) are the dominant anions in water samples. The ash pond water and surface water samples follows the abundance order of HCO_3^- > SO_4^{-2-} > Cl^- >NO_3^->F^- in the study area, while the sample from ground water follows the abundance order of HCO_3^- > Cl^- >- SO_4^{2-} >NO_3^->F^-.

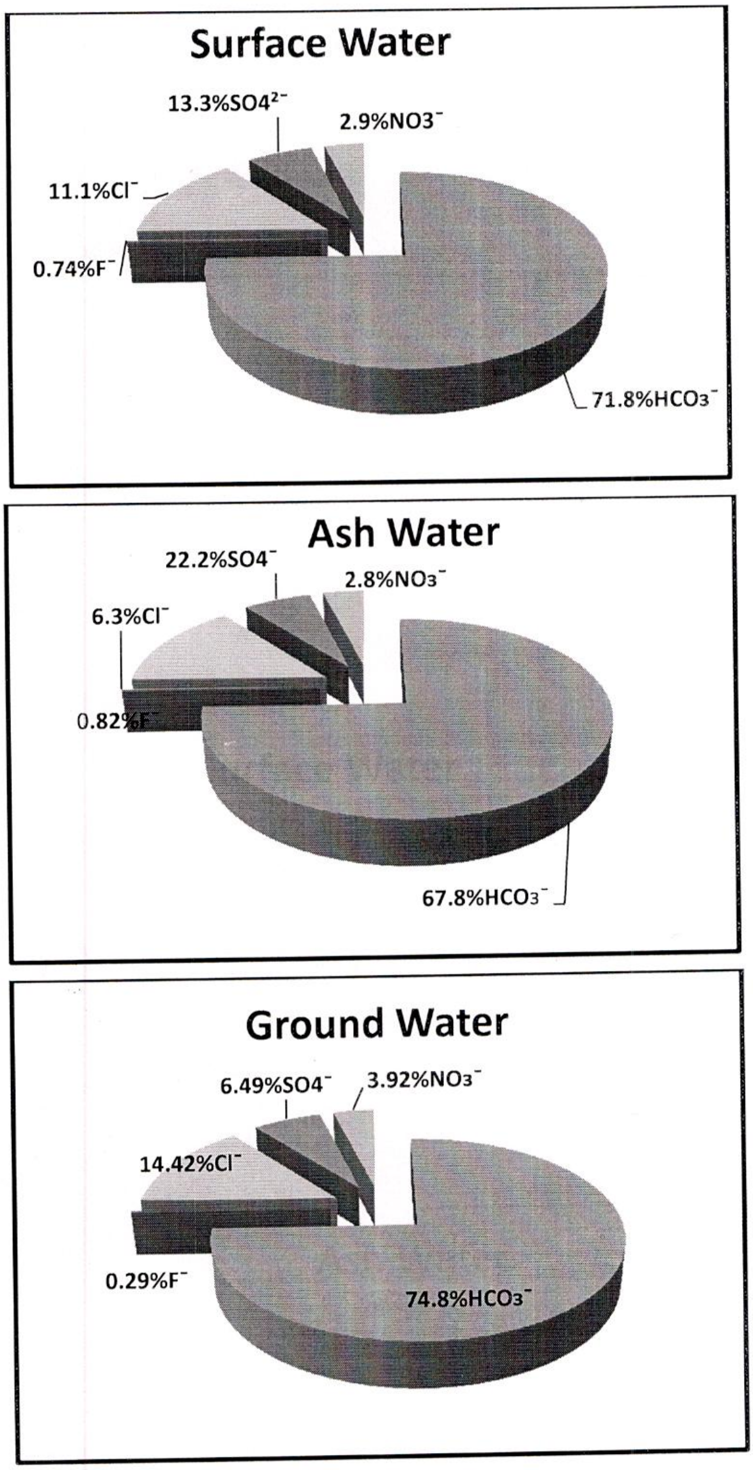


Figure 12: Contribution of Anions towards the total anionic charge balance

4.2.1 Alkalinity (Bicarbonate)

The bicarbonates & carbonate are derived mainly from the soil zone CO_2 and at the time of weathering of parent minerals. The soil zone in the subsurface environment contains elevated CO_2 pressure (produce as result of decay of organic matter and root respiration), which in turn combines with rainwater to form bicarbonate. Bicarbonate may also be derived from the dissolution of carbonates and-or silicate minerals by the carbonic acid. BIS (2012) have prescribed 200 mg/l as acceptable limit and 600 mg/l as permissible limit in absence of alternate source for drinking and other domestic usage. Alkalinity of the groundwater samples of the study area and surrounding area of Kaniha TSTPS varies between 236.1 to 375mg/l (average 320.2mg/l). The average Alkalinity of the surface water samples analysed was found as 87.3mg/l and varied between59.0 to 103.0mg/l, while ash water sample having Alkalinity (HCO_3^-) range from 65.12 to 303.0mg/l with an average of 171.03mg/l. The alkalinity (HCO_3^-) concentration of Groundwater, Surface water and Ash pond samples is contributing 74.9%, 71.89% and 67.8% to the total anions (TZ^-) respectively. Though Alkalinity concentration in all the water samples analysed from the study area were well within the permissible limit (600 mg/l) even >80% surface water and Ash pond water sample have HCO_3^- concentration within desirable limit (200mg/l) and were found suitable for drinking and irrigation purpose.

4.2.2 Chloride (Cl^-)

The chloride (Cl^-) concentration in the groundwater samples of the study area, surrounding the area of Kaniha TSTPS, varies between 6.01 to 140.53mg/l (average 61.66mg/l). The average chloride (Cl^-) in the surface water (River-Pond) samples analysed was found as 13.49mg/l and varied between 5.56 to 20.1mg/l.Ash water sample having chloride (Cl^-) average concentration (15.97mg/l) ranging between 4.07 to 29.13mg/l. BIS (2012) has prescribed chloride (Cl^-) concentration 250 mg/l as acceptable limit and 1000 mg/l as permissible limit in absence of alternate source for drinking and other domestic usage. Chloride concentrations in all the analysed samples were within the acceptable limit prescribed by BIS. No health-based guideline value is proposed for chloride in drinking-water. Chloride is present in lower concentrations in common rock types, than any of the other major constituents of natural water and it is assumed that bulk of the chloride in ground water is primarily either from atmospheric source, sea water contamination or from anthropogenic sources. Abnormal concentration of chloride may result from pollution by sewage wastes.

4.2.3 Sulphate (SO_4^{2-})

Sulphate in drinking-water can cause noticeable taste, and very high levels might cause a laxative effect in unaccustomed consumers. Taste impairment varies with the nature of the associated cation; taste thresholds have been found to range from 250 mg/l for sodium sulphate to 1000 mg/l for calcium sulphate. High sulphate levels in drinking water results in gastro-intestinal disorders, and hence, it is recommended that health authorities be notified of sources of drinking water that contain sulphate concentrations in excess of 500 mg/l (WHO, 2011). BIS (2012) have prescribed 200 mg/l as acceptable limit and 400 mg/l as permissible limit for sulphate in absence of alternate source for drinking and other domestic usage. Sulphate (SO_4^{2-}) concentration in groundwater varies between 2.1 mg/l to 65.1mg/l with an average 27.7 mg/l and is contributing 6.5% to the total anions (TZ^-). Similarly, Sulphate (SO_4^{2-}) concentration in surface water was also observed well within BIS (2012) limit and varies between 1.54 to 40.1mg/l and accounting for 13.29% to the total anions. Though average SO_4^{2-} concentration in ash pond water was observed high (104.6mg/l) in compare to ground water & surface water samples but still it was under BIS prescribed limit (200 mg/l) and varies between 6.36 to 104.6 mg/l (AWTL-5@ Ash pond-2 seepage water). Sulphate concentrations were well within the acceptable limit in 100% samples of the total analysed samples. The high-SO_4 concentration was noticed in ground water samples GWTL-13, GWTL-14, which are all Indian Mark II hand pumps, and surface water sample and located closely of the existing ash ponds. The high SO_4 in groundwater samples can be attributed to the bottom ash, which is subsequently mixed with water and disposed in the ash pond in slurry form. The sulphate is usually derived from the oxidative weathering of sulphide bearing minerals like pyrite, gypsum or anhydrite. Apart from these natural sources, sulphate may be introduced through the application of sulphatic soil conditioners and fertilizers. The observed high concentration of (SO_4^{2-}) in some samples indicates the effects of industrial and anthropogenic activities in the area.

4.2.4 Nitrate (NO_3^-)

Nitrate is highly soluble in water. Nitrate ($NO3^-$) is found naturally in the environment and is an important plant nutrient. It is present at varying concentrations in all plants and is a part of the nitrogen cycle. Nitrate can reach both surface water and groundwater as a consequence of agricultural activity (including excess application of inorganic nitrogenous fertilizers and manures), from wastewater disposal and from oxidation of nitrogenous waste products in human and animal excreta, including septic tanks. Surface water nitrate concentrations can change rapidly owing to surface runoff of fertilizer, uptake by phytoplankton and denitrification by bacteria, but groundwater concentrations generally show relatively slow changes. Some ground waters may also have nitrate contamination as a consequence of leaching from natural vegetation. The anthropogenic sources of nitrogen include (i) point source including industrial sewage, refuse dumps etc. discharged directly in to the surface water, (ii) diffuse source including runoff and leaching from rural and urban land and (iii) precipitation. The presence of nitrate in drinking water is a potential health hazard when present in large quantities. Nitrites are formed by reduction of nitrate in the human body, which combines with haemoglobin in the blood to form methemoglobin that leads to methaemoglobinaemia (blue baby syndrome) in infants. The combination of nitrates with amines, amides, or other nitrogenous compounds through the action of bacteria in the digestive tract results in the formation of nitrosamines, which are potentially carcinogenic. According to the Indian Standard for drinking water (IS 10500:2012), the maximum allowable nitrate concentration in drinking water is 45 mg/l as NO_3. Concentration of nitrate in the study area groundwater, surface water and ash pond water ranges from 0.21 to 52.18mg/l, 3.3to 4.1mg/l and 0.31 to 17.1mg/l respectively. Nitrate concentrations were well within the acceptable limit (45.0 mg/l) in all the analysed water samples except one groundwater sample (GWTL-14). Nitrate is contribution in surface water sample, ash pond water sample and ground water sample 2.9%, 2.8% and 3.9% respectively.

4.2.5 Fluoride (F^-)

Fluoride is found in all natural waters at some concentration. Seawater typically contains about 1 mg/l while rivers and lakes generally exhibit concentrations of less than 0.5 mg/l. In groundwater, however, low or high concentrations of fluoride can occur, depending on the nature of the rocks and the occurrence of fluoride-bearing minerals. Fluoride occurs as fluorspar (fluorite), rock phosphate, and phosphorite minerals etc. in nature. Among the factors, which control the concentration of fluoride includes climate of the area and the presence of accessory minerals in the rock mineral assemblage through which the groundwater is circulating. Concentrations in water are limited by fluorite solubility. It is the absence of calcium in solution which allows higher concentrations to be stable. High fluoride concentrations may therefore be expected in groundwater from calcium-poor aquifers and in areas where fluoride-bearing minerals are common (Nanyaro et al., 1984; Gaciri and Davis, 1993; Kundu et al., 2001). Many epidemiological studies have shown that fluoride in drinking water has a narrow range between intakes that cause beneficial and detrimental health effects. Fluoride intake to humans is necessary as long as it does not exceed the limits. The WHO (2011) and BIS (2012) estimates the maximum allowable limit for fluoride uptake to human's in drinking water as 1.5 mg/l. Excess fluoride intake causes different types of fluorosis, primarily dental and skeletal fluorosis.

Concentration of fluoride in groundwater, surface water and ash pond water samples of existing and proposed ash pond area of TSTPS Kaniha varies between 031 to 2.06 mg/l, 0.21 to 2.1 mg/l and 0.39 to 3.57mg/l (Ash Pond Effluent L-I STAGE II) respectively. The average concentration was found in groundwater, surface water and ash pond water samples as 1.23, 0.89 and 2.07 mg/l respectively. In all these water samples on an average fluoride is contributing 0.2% to 3.57% of the total anionic balance and concentration of fluoride exceeds the prescribed permissible limit (1.5 mg/l) in drinking water requirement is about 6.6%, 20% & 13.3% of the total analysed surface water, ash pond water and ground water samples respectively. The fluoride in groundwater can be derived from various sources. The weathering of rocks containing fluoride-rich minerals such as fluorite, fluoroapatite, and mica is reported as the main source of fluoride in groundwater (Kim, 2011). However, high concentration of fluoride in surface and ground water is reported in various places around the fly ash pond. The highest concentration of fluoride was observed in ash pond discharge water

(2.76mg/l @ AWTL-5, 3.57mg/l @ AWTL-6) at existing and proposed ash pond area of TSTPS Kaniha and also groundwater (2.1mg/l @Mandua) was observed in the vicinity of ash pond in area of TSTPS Kaniha. Fly ash is a by-product of the coal combustion process. Coal contains 20-500 mg-kg of fluoride (Swaine, 1990), and during its combustion, elements are enriched as a result of loss of carbon as carbon dioxide. Fluoride concentration in coal fly ash varies from 0.4 to 610 mg-kg (Rai, 1987). Under the natural leaching condition, fluoride likely to release and contaminate the water body. The fluoride concentration in the ash pond water (3.57mg/l @ AWTL-6) is much higher than the maximum permissible limit (1.5 mg/l) at most of the locations. As the pond water has been discharged to nearby water body therefore proper care needs to adopt for limiting the possible fluoride related health hazard.

4.3 Major Cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+})

The major cations include Ca, Mg, Na and K. On an average Ca^{++} and Na^{+} are the major cations and both constitute 80.2 % of the total cations (TZ^{+}) in the analysed groundwater, surface water and ash pond water samples of existing and proposed ash pond area of TSTPS Kaniha. Figure10 shows that the groundwater is dominated by Ca, Mg, Na, and K. The dominance of these ions in groundwater and ash water and surface water is in the order Ca> Na > Mg > K, Alkali cations dominate over alkaline earths (Ca and Mg) in many samples and on average Ca alone constitute 51.63% of the total cations (TZ^{+}) in the groundwater of the area.

4.3.1Calcium (Ca++)

Calcium ion and calcium salt are among the most commonly encountered substances in water. Calcium in water arising mostly from dissolution of Ca bearing minerals of the aquifer formation and often it is the most abundant cation in aquatic water. Weathering and dissolution of calcium carbonate (limestone and dolomite) and calc-silicate minerals (amphiboles, pyroxenes, olivine, biotite etc.) are the most common source of calcium is aquatic system. Calcium is exceeding sodium, magnesium and potassium concentration in majority of analysed water samples of the area. Concentration of Calcium in groundwater, surface water and ash pond water samples of existing and proposed ash pond area of TSTPS Kaniha varies between 55.12 to 145.9mg/l, 11.68 to 42.24mg/l and 13.5 to 144.32mg/l respectively. The average concentration was found in groundwater, surface water and ash pond water samples as 89.1, 26.40 and 62.08mg/l respectively.

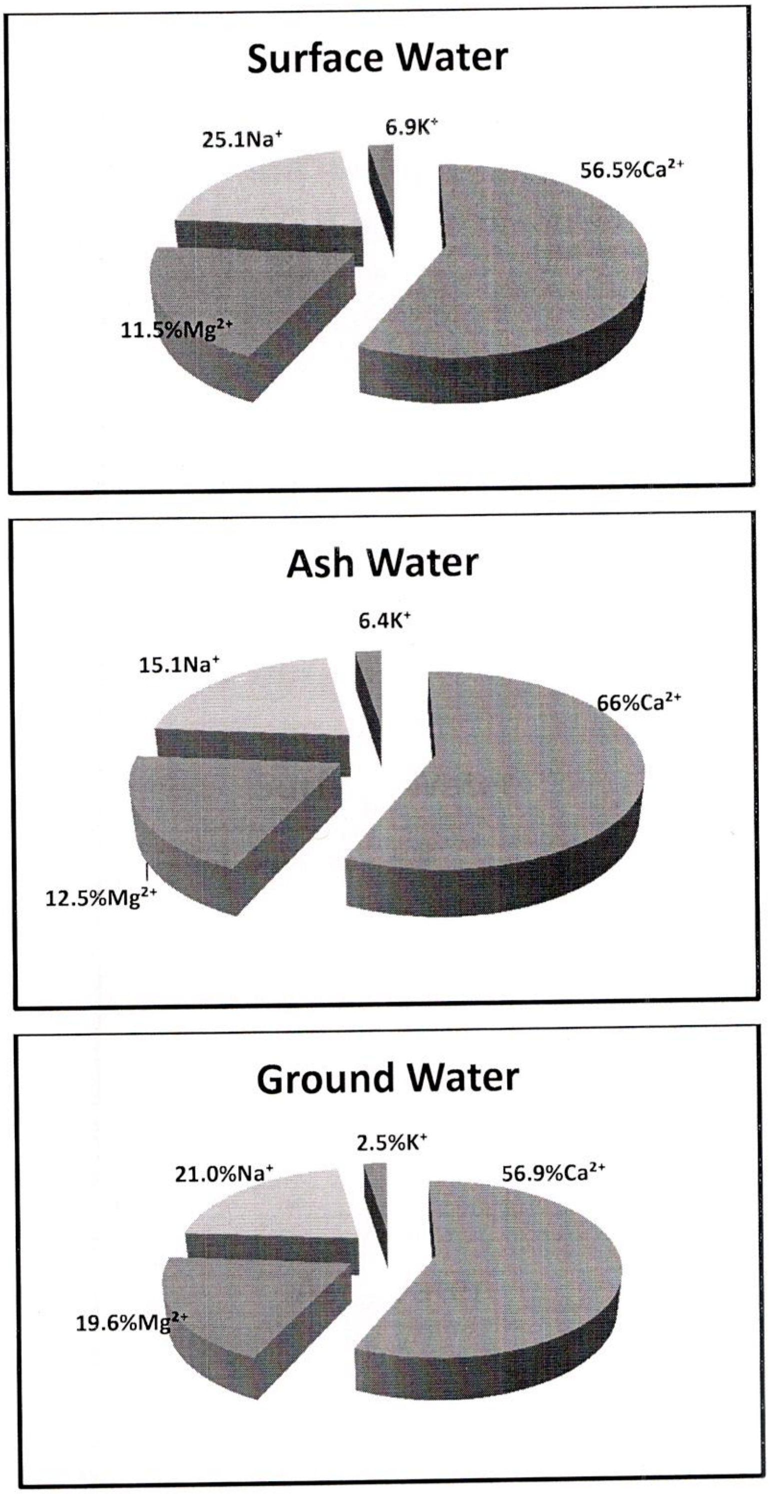


Figure 13: Contribution of cations towards the total cationic charge balance

BIS (2012) have prescribed 75 mg/l as acceptable limit and 200 mg/l as permissible limit for calcium in absence of alternate source for drinking and other domestic usage. Only in 33.3% samples (ground water and ash water samples) exceeded the acceptable limit of calcium while no samples exceeded the permissible limit for drinking water and this water seems safe for drinking purpose and for other uses.

4.3.2 Sodium (Na)

The sodium (Na) in the aquatic system is derived from the atmospheric deposition, evaporate dissolution and silicate weathering. The evaporate encrustations of sodium-potassium salts may also be developed due to cyclic wetting and drying periods causes the formation of alkaline-saline soils, which may also serve as a source of sodium and potassium. The weathering of Na and K silicate minerals like albite, anorthite, orthoclase and microcline are the major source of the Na and K in the aquatic system. Na^+ constitutes 28.6%, of the total cationic charge balance. Concentration of Sodium in groundwater, surface water and ash pond water samples of existing and proposed ash pond area of TSTPS Kaniha varies between 6.94 to94.12mg/l, 6.1 0 to 15.1mg/l and 6.5 to 22.72mg/l respectively. The average concentration was found in groundwater, surface water and ash pond water samples as 32.87, 11.7 and 14.16mg/l respectively. No health-based guideline value has been derived, as the contribution from drinking-water to daily intake is small (WHO, 2011). Based on taste threshold, the recommended concentration of sodium in the water should be less than 200 mg/l and 100% of the total analysed sample was well within this category. The taste threshold concentration of sodium in water depends on the associated anion and the temperature of the solution.

4.3.3 Magnesium

Magnesium (Mg^{2+}) is abundant in earth crust and is a common constituent of natural water. Olivine, clay minerals, dolomite, pyroxenes are the common source minerals for magnesium in the waters. The carbonate, chlorides, hydroxides, oxides and sulphate of the magnesium are used in the production of magnesium metal, refractories, fertilizers, ceramics, and explosives and medicinal. Magnesium compounds are more soluble than their counterparts. As a result, large amount of magnesium is rarely precipitated. Magnesium carbonate and hydroxide precipitate at pH>10.

Magnesium concentration can be extremely high in certain closed saline lakes. Natural sources contribute more magnesium to the environment than all anthropogenic sources. The principle source of magnesium in natural water is ferromagnesian mineral in igneous rock and magnesium carbonate in sedimentary rock. The sulphate and chloride of magnesium are very soluble. In the analyzed groundwater samples, surface water and ash pond water samples; Mg constitutes 19.6 %, 8.4 % and 12.4 % of the total cationic charge balance respectively (Fig.4.5). Concentration of magnesium in groundwater, surface water and ash pond water samples of existing and proposed ash pond area of TSTPS Kaniha varies between 10.98 to 47.31 mg/l, 3.82 to 7.91mg/l and 4.97 to 11.78mg/l respectively. The presence of calcium and magnesium make the water hard. BIS (2012) have prescribed 30 mg/l as acceptable limit and 100 mg/l as permissible limit for magnesium in absence of alternate source for drinking and other domestic usage. Though 25% of ground water samples exceeded the acceptable limit (30 mg/l) while not any analysed samples exceeded the permissible limit for drinking water and therefore it seems that the water is suitable for drinking purposes.

4.3.4 Potassium (K^+)

Although potassium (K^+) is nearly as abundant as sodium in igneous rocks and metamorphic rocks, its concentration in groundwater is one-tenth or even one-hundredth that of sodium. Parity in concentration of sodium and potassium is found only in waters with low mineral contents. Two factors are responsible for the scarcity of potassium in groundwater, one being the resistance of potassium minerals to decomposition by weathering and the other the fixation of potassium in clay minerals formed due to weathering. Concentration of K^+ in groundwater, surface water and ash pond water samples of existing and proposed ash pond area of TSTPS Kaniha varies between 2.89 to 4.56mg/l, 2.2 to 4.65mg/l (Baudapeda pond) and 1.56 to 13.25mg/l respectively. K^+ contribution in groundwater, surface water and ash pond water samples of the study area was found 2.5%, 9.5% and 6.4% of the total cationic charge balance respectively (Fig.4.5).

4.3.5 Silica (SiO_2)

Silica in river and ground water is present largely as H_4SiO_4or SiO_2 derived from the weathering of silicate minerals. The dissolved silica concentrations in study area (TSTPS) waters samples collected during post-monsoon are tabulated in Table (4a). Concentration of Silica in groundwater, surface water and ash pond water samples of existing and proposed ash pond area of TSTPS Kaniha varies between 1.23 to 2.91mg/l, 1.54 to 1.81mg/l and 1.21 to 2.56 mg/l respectively.

4.3.6 Oil and Grease

In this study oil and grease pollution levels were determined in groundwater, surface water and ash pond water samples of existing and

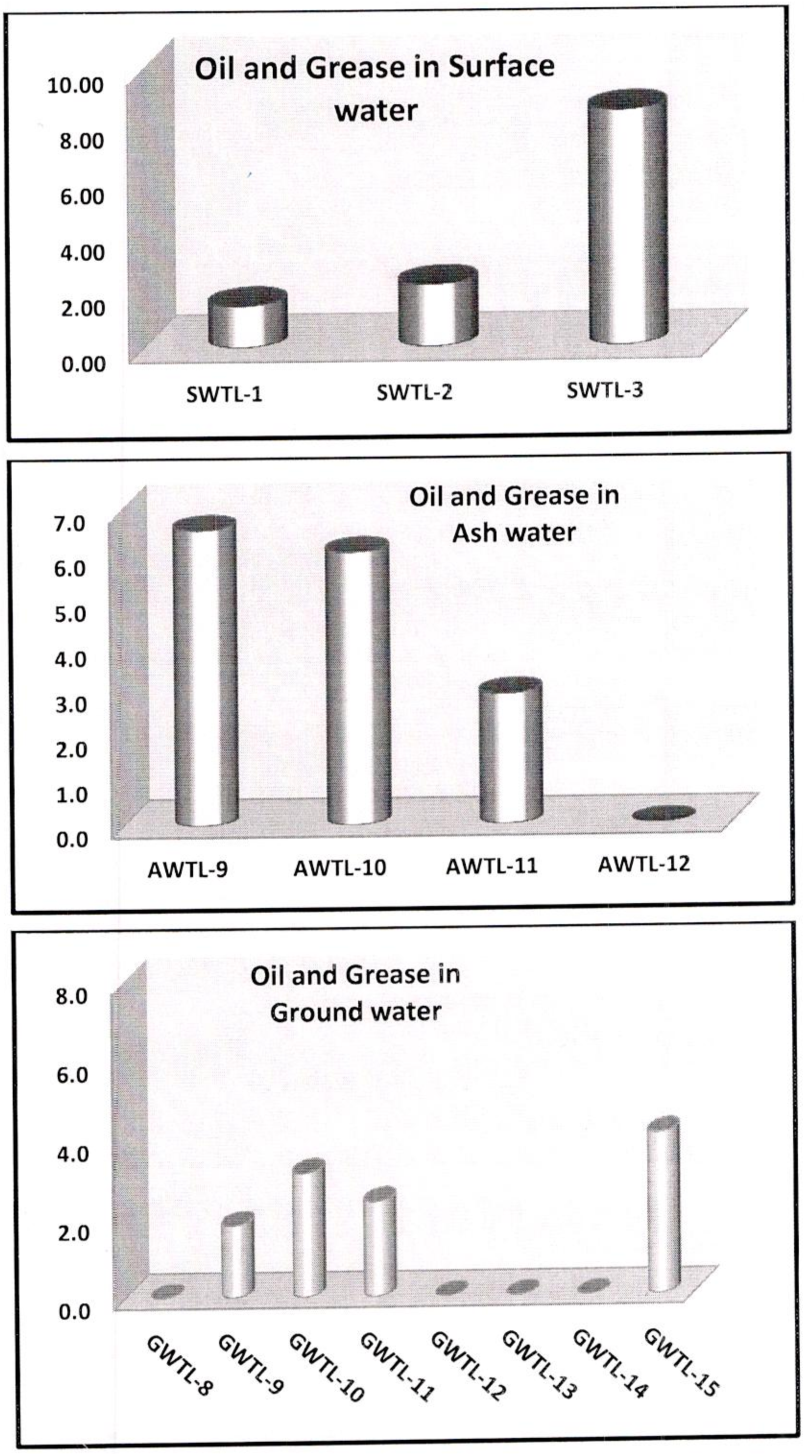


Figure 14: Contribution of Oil and Grease in water samples

Proposed ash pond area of TSTPS Kaniha Thermal power plant. Fifteen Samples were examined for oil and grease in the area. The highest level found in Tikira (DNS) water near thermal power plant and Oil and grease concentration varies from BDL to 8.44mg/L (SWTL-3) in surface water.

Table 8 Calculated parameters for irrigation use

Sample Code	EC	Ca2+	Mg2+	Na+	SAR	Na%	TZ+
	(µS-cm)	meq/l	meq/l	meq/l			meq/l
SWTL-1	138	0.58	0.31	0.27	0.14	22.97	1.15
SWTL-2	209	1.26	0.35	0.66	0.26	28.90	2.27
SWTL-3	344	2.11	0.63	0.60	0.18	18.04	3.35
AWTL-4	276	1.65	0.76	0.40	0.13	14.07	2.81
AWTL-5	715	7.22	1.12	0.99	0.17	10.60	9.32
AWTL-6	539	2.87	1.49	0.80	0.19	15.44	5.16
AWTL-7	142	0.68	0.40	0.28	0.14	20.85	1.36
GWTL-8	387	3.36	0.88	0.30	0.07	6.65	4.54
GWTL-9	645	3.06	1.68	0.99	0.23	17.26	5.72
GWTL-10	702	3.41	1.81	1.86	0.41	26.28	7.08
GWTL-11	334	2.27	0.29	0.26	0.08	9.17	2.82
GWTL-12	621	2.76	2.43	0.50	0.11	8.86	5.69
GWTL-13	1234	6.76	2.40	4.09	0.68	30.89	13.25
GWTL-14	1148	7.30	3.78	1.74	0.26	13.57	12.82
GWTL-15	840	3.51	3.54	0.95	0.18	11.88	7.99

4.4 Electrical Conductivity (EC) and Sodium Percentage (Na %)

Electrical conductivity (EC) and sodium concentration are very important in classifying irrigation water. Water used for irrigation always contains measurable quantities of dissolved substances as salts. It includes relatively small but important amount of dissolved solids originating from the weathering of the rocks and soils and from the dissolving of lime, gypsum and other salt sources as water flows over or percolate through aquifer. The salts, besides affecting the growth of the plants directly, also affect soil structure, permeability and aeration, which indirectly affect plant growth. The sodium percentage (Na %) in the water samples of sub-surface water is calculated by the equation:

$$\mathbf{Na\% = Na/(Ca+Mg+Na+K)\times 100}$$

The sodium percentage (%Na) in the proposed study area ash pond ranges between 6.6 and 30.9% (Avg. 17%). As per the Indian Standard (ISI 1993), maximum sodium of 60% is recommended for irrigation water. Plot of analytical data on Wilcox (1955) diagram relating electrical conductivity (EC) to sodium percent (%Na) shows that Na% are within the recommended values, and in general majority of water samples of proposed ash pond area of the Kanhia district Orisha are falling in excellent to permissible quality region, which can be used for irrigation purposes **(Fig. 15)**

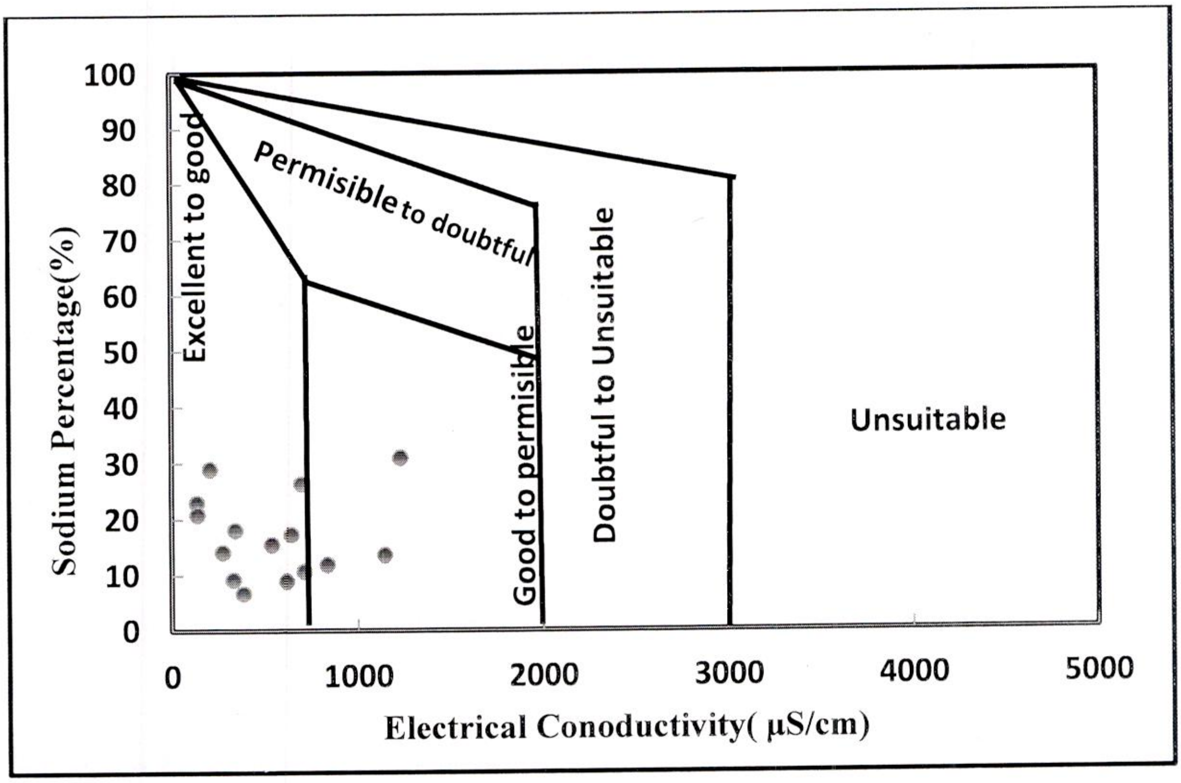


Figure 15: Plot of sodium percent (Na %) vs. electrical conductivity

4.5 Alkali and Salinity Hazard (SAR)

The total concentration of soluble salts in irrigation water can be expressed as low (EC =<250 µS cm^{-1}), medium (250-750 µS cm^{-1}), high (750-2250 µS cm^{-1}) and very high (2250-5000 µS cm^{-1}) salinity zone. While a high salt concentration (high EC) in water leads to formation of saline soil, a high sodium concentration leads to development of an alkaline soil. Excessive solutes in irrigation water are a common problem in semi-arid areas where water loss through evaporation is maximal. Salinity problem encountered in irrigated agriculture are most likely to arise where drainage is poor. This allows the water table to rise close to the root zone of plants, causing the accumulation of sodium salts in the soil solution through capillary rise following surface evaporation of water. The sodium or alkali hazard in the water for irrigation is determined by the absolute and relative concentration of cations and is expressed in terms of sodium adsorption ratio (SAR). It can be estimated by the formula:

$$\mathbf{SAR = Na/\ [(Ca+Mg)/2]^{0.5}}$$

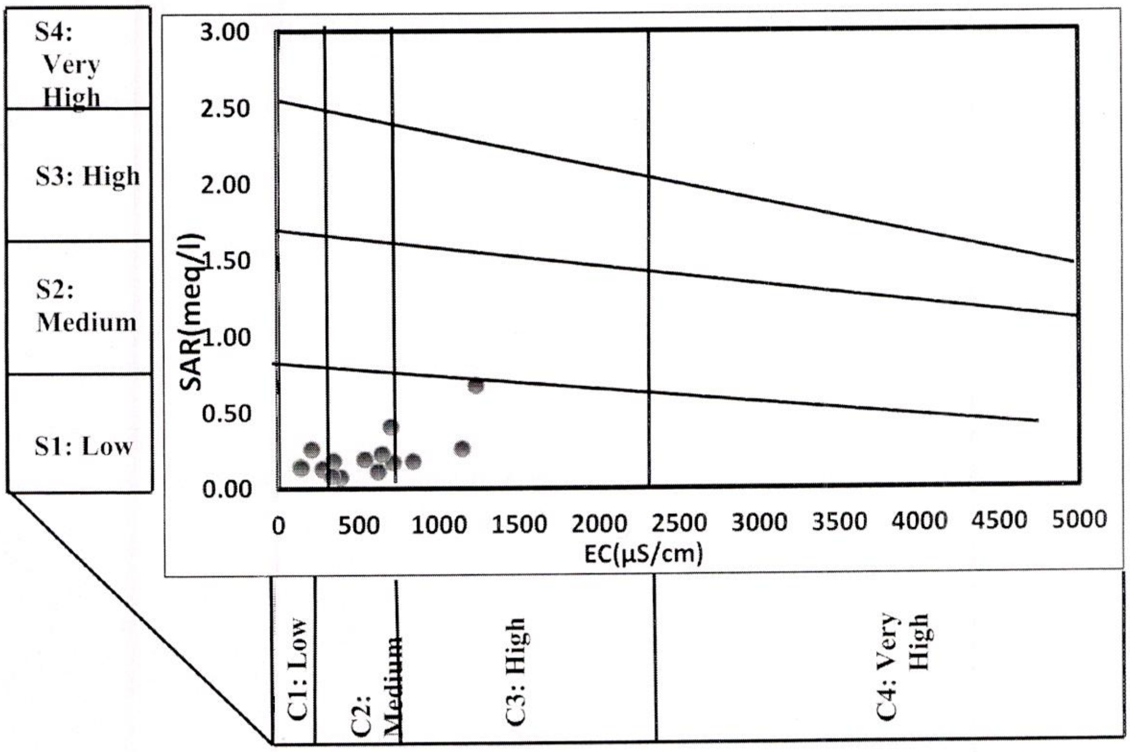


Figure 16: Salinity diagram for classification of irrigation water

Irrigation waters classified into four categories on the basis of sodium adsorption ratio (SAR) and EC:

SAR	*Water Category*	*% Sample*	*EC μS cm^{-1}*	*Water Category*	*%Sample*
0 – 10	Excellent (S-1)	100.0%	<250	Low (C-1)	20%
10 – 18	Good (S-2)	0.0%	250 – 750	Medium (C-2)	60%
18 – 26	Fair (S-3)	0.0%	750 - 2250	High (C-3)	20%
>26	Poor (S-4)	0.0%	>2250	Very High (C-4)	0%

There is a significant relationship between SAR values of irrigation water and the extent to which sodium is absorbed by the soils. If water used for irrigation is high in sodium and low in calcium, the cation-exchange complex may become saturated with sodium. This can destroy the soil structure due to dispersion of the clay particles. The calculated value of SAR in the study area ranged from 0.1 –0.7meq/l. The plot of data on the US salinity diagram, in which the EC is taken as salinity hazard and SAR as alkalinity hazard, shows that most of the water samples fall in the category C1S1, C2S1, C3S1 indicating medium to high salinity and low alkali water. This water can be used for plants with good salt tolerance **(Fig.16)**.

High saline water cannot be used on soils with restricted drainage and requires special management for salinity control. Plants with good salt tolerance should be selected for such areas. Very high saline water is not suitable for irrigation under ordinary conditions but may be used occasionally under very special circumstances. The soil must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching and salt tolerance crops/plants should be selected.

Low sodium (alkali) water can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. Medium sodium water will present an appreciable sodium hazard in fine textured soils having high cation exchange capacity especially under low leaching conditions. This water can be used on coarse textured or organic soils with good permeability.

4.6 Water Type and Hydro chemical Facies

The Hill and Piper plot is very useful in determining relationships of different dissolved constituents and classification of water on the basis of its chemical characters. The triangular cationic field of Piper diagram reveals that the groundwater samples fall into Ca type class, whereas in anionic triangle majority of the samples fall into bicarbonate field.

The plot of chemical data **(Fig. 17)**, on diamond shaped central field, which relates the cation and anion triangles revealed that the major water types in the studied locations wereCa-Mg-HCO_3, Na-Mg-HCO_3, Ca-Mg-SO_4-Cl and Na-K-HCO_3-Cl.In majority of the groundwater samples, alkaline earth metals (Ca+Mg) exceed alkali metal cations (Na+K). In general, the groundwater of the area exhibits the dominance of weak acid (HCO_3) over strong acid (SO_4+Cl). The facies mapping approach applied to the present study shows that Ca-Mg-HCO_3 is the dominant hydro geochemical facies in the all samples surface water, ash pond water and ground water of the Kanhia, district Angul, Orisha.

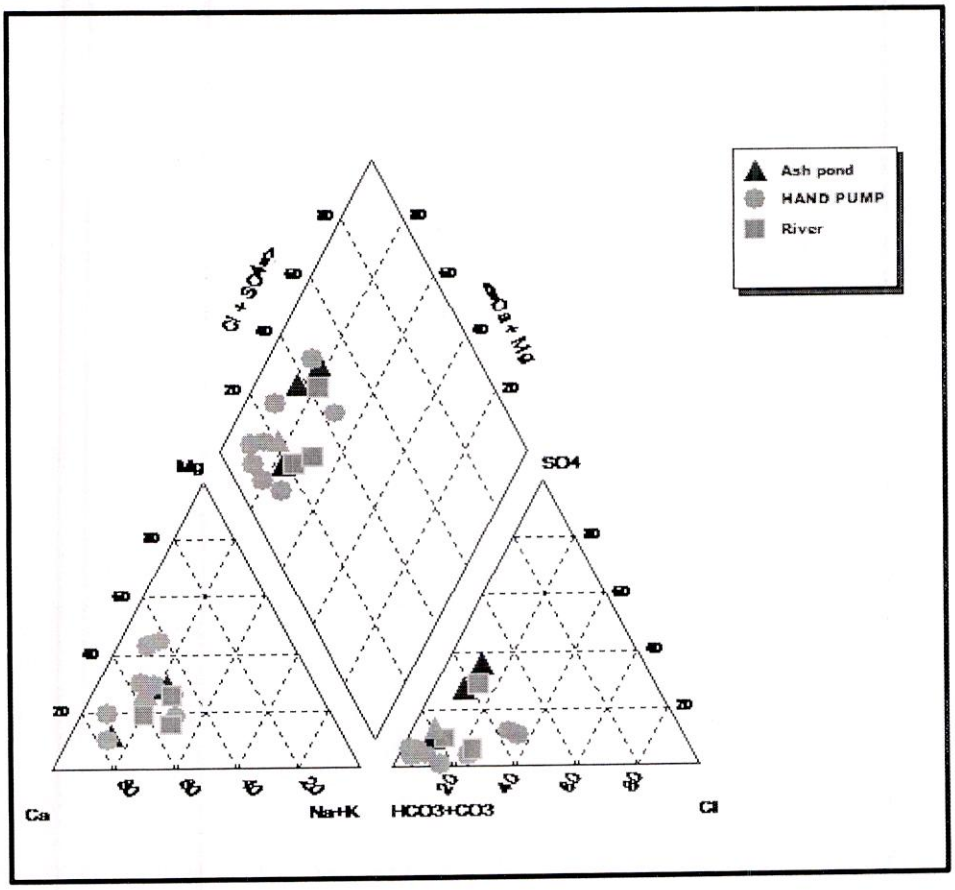


Figure 17: Hill and Piper plot showing water type and hydro chemical facies

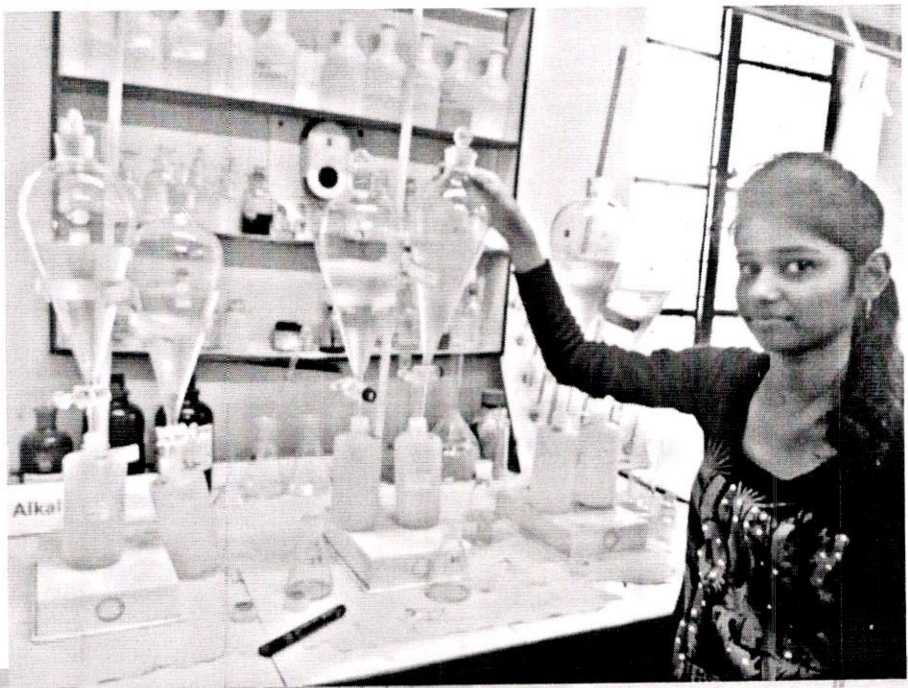
CONCLUSION

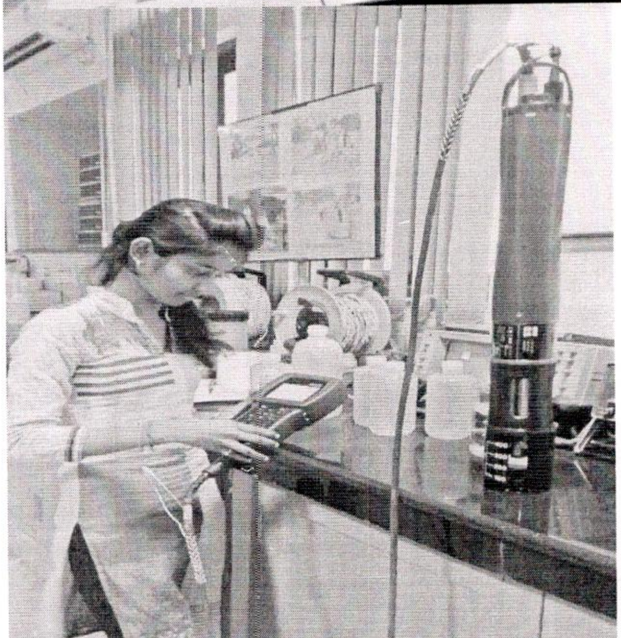
- The study area is located at Kanhia in Angul district of Odisha. The study area approximately extends from 21°N to 21°13' N latitudes and 84°54 ' E to 85°09 ´E longitudes. The fifteen samples of water are collected from the periphery of proposed ash pond area, in which three samples are collected from river and four samples from ash pond and eight samples from handpump for analysis of water chemistry.
- In the study area overall pH varied from 6.2 to 7.9. Among all the samples of water of different sources, average value of pH of the surface water, ash pond and ground water samples is 7.6, 7.6 and 7.3 respectively. Therefore, all the samples are in alkaline nature except sample no. 15 of ground water with pH value 6.2 is acidic in nature.
- TDS were found in overall study area between 97mg/l to 811mg/l. TDS average value of the surface water, ash pond and ground water samples is 155, 267 and 494mg/l respectively. Therefore, all the samples are under the permissible limit (2000mg/l). Hence water is suitable for drinking purpose and fall under category of fresh water.
- The cation chemistry of the study area is dominated by Ca^{2+}, Mg^{+}, Na^{+} and K^{+}. The dominance of these cations are in the order of Ca>Na>Mg>K in all sample of surface water, ash pond water and ground water.
- In the samples of the study area, Ca alone constitute 56.5%, 66% and 56.9% of the total cation in surface water, ash water and ground water respectively.
- The anion chemistry of the analyzed samples show that HCO_3^-, F^-, Cl^-, NO_3^- and SO_4^- are the dominant anions and the surface water and ash pond water samples follow the order of $HCO_3^- > SO_4^- > Cl^- >$

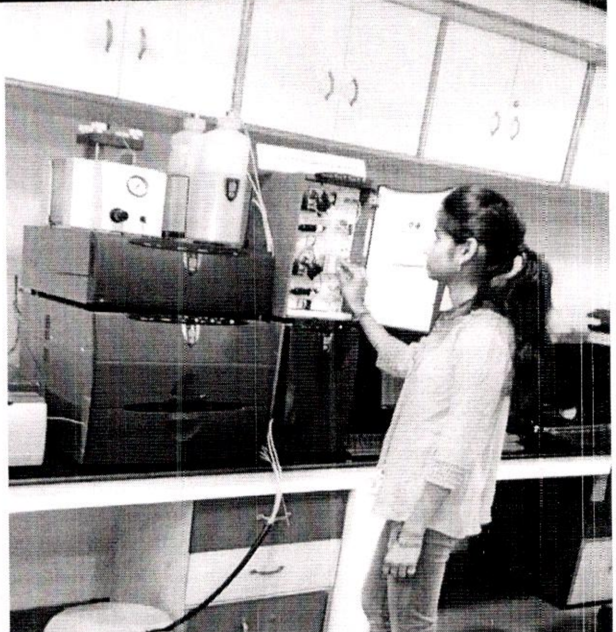
NO_3^- > F^- while ground water follows the abundance of HCO_3^- > Cl^- > SO_4^- > NO_3^- > F^-.

- In the study area bicarbonate (HCO_3^-) alone constitute 71.8%, 67.8%, and 74.8% in surface water, ash water and ground water respectively to the total anions.
- Oil and grease in surface water sample varies from 1.5 to 8.44 mg/l, in ash pond waater samples vary from BDL to 6.54 mg/l and in ground water samples vary from BDL to 4.1mg/l
- The highest amount of oil and grease (8.44 mg/l) is found in the SWTL-3 of Tikira river which is surrounded by Shale with coal and fire clay.
- AWTL-3 and AWTL-4 also contain the oil and grease in the amount of 6.54mg/l and 6.04mg/l respectively which are also surrounded by shale with coal and fire clay.
- Application of Wilcox plot relating electrical conductivity to sodium percent on the analysed samples, it was concluded that water of the Kanhia district is excellent to permissible quality, which can be used for irrigation purposes.
- Based on US salinity diagram, it can be concluded that most of the water samples fall in the category C1S1, C2S1, C3S1 indicating medium to high salinity and low alkalinity.
- The Hill and Piper plot of chemical data revealed that the major water types in the studied locations were Ca-Mg-HCO_3, Na-Mg-HCO_3, Ca-Mg-SO_4-Cl and Na-K-HCO_3-Cl. The facies mapping approach shows that Ca-Mg-HCO_3 is the dominant hydrochemical facies.

PHOTOGRAPHS







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