Chapter - II

LIMONOLOGICAL ANALYSIS
OF THE COMMUNITY
2.1 INTRODUCTION

Professors F.A. Forel described the biological status of the fresh water bodies and coined the term 'Limnology' which is derived from the Greek word 'limn' meaning 'marsh' (Mahapatra, 2001). Limnology is defined as the study of functional relationship and productivity of fresh water bodies (Wetzel, 1975). The most important goal of limnology is the study and circulation of organic and inorganic materials in water (Sisodia, 2002).

2.2 MATERIALS AND METHODS

Experimentation needs a methodology. A research work is a set of experimentation. In general on the basis of versatile land use pattern, the biogeographical sites are classified (Mahapatra, 2001; Mahapatra et al., 2003) as follows

1. Foothill (FH),
2. Central table (CT) and
3. River bank (RB) area.

These three-mega divisions of community ecosystem are subdivided into six micro divisions such as sagar, kata, ghaghra, bundh, muda and chahla (Mahapatra & Mishra 2003). Samples were collected from these micro WHS seasonally i.e. in pre monsoon [Feb, Mar, Apr, May], monsoon [Jun, July, Aug, Sept] and post monsoon [Oct, Nov, Dec, Jan] from 2002 to 2004 accordingly.

The Western part of Orissa, also known as Koshal, lying between 14° - 22° 34" N latitudes and 82° - 88° E longitudes is equipped with various traditional water harvesting structures (WHS) i.e. Muda, Kata, Bundh, Chahla, Sagar and Ghaghra etc. (Local Name). Two districts of western Orissa i.e. Subarnapur and Nawapara were chosen as study site. Subarnapur district was taken as control site, as fluoride pollution was not reported there while Nawapara district was chosen as F-exposed site due to reported case of fluorosis (Mahapatra et al., 2005). In Subarnapur district, Survey of India toposheet No 73(D/1), 64 (P/13), 64 (0/16) and 73 (C/9) were used for the sample study while
in Nawapara. 20° to 20° 5' North latitude and 82° 5' to 85° East longitude was taken as sample study. While sampling the water bodies annual (A) and perennial (P) ponds of versatile traditional WHS are properly and randomly selected. The studied traditional WHS are depicted in table no 2.1.

**Table No. 2.1**

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<th>Sl No</th>
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**Water sampling procedure:**

Water was collected from the WHS by a plastic bottle. It was done by lowering a closed polythene bottle to the bottom, opening and closing it there, by hands and taking it out. But for collecting the subsurface samples, water sampler was used. In this work Ruttner water sampler was used. Ruttner water sampler is made up of a cylinder of Plexiglas having two open ends and the lids interconnected by a central shaft. The two lids are held upon with the help of a trap mechanism provided on the upper part of the shaft. The sampler was lowered in water to the desired depth with the help of a graduated rope; a messenger weight was released along the rope to open the trap and to allow two lids to close the sampler. It was taken out of water and the sample was drained through a tap provided in the lower lid. The sample was immediately fixed by adding manganous sulphate and alkaline potassium iodide solution to estimate the dissolved oxygen content and other parameters in the laboratory.

2.2.1 Depth of water

Depth of a WHS has an important bearing on the physical, chemical and biological properties of water. The depth of water also determines the perennial [P] and annual [A] nature of the WHS. Water depth is the vertical distance between the surface and underlying bottom. Depth of water was measured with a straight and pointed bamboo pool marked with cm and meter. The bamboo pool was taken into the WHS by the help of supporting villagers and desired depth was measured (Devi and Sharma, 2003).

2.2.2 Temperature of water

Temperature is basically an important factor for its effects on chemical and biological reactions in water. A rise in temperature of water accelerates chemical reactions, reduces solubility of gases, amplifies taste and odour and elevates metabolic activities of organism.

**Material**

A mercury thermometer of 0°C to 50°C range and with 0.2°C least count was used
**Method**

The surface water was taken in a plastic container. Its temperature was recorded immediately by dipping the thermometer for about one minute (Saxena, 1990).

### 2.2.3 Hydrogen Ion Concentration (pH)

pH is defined as the "negative logarithm (base 10) of the hydrogen ion concentration". The concentration of the hydrogen ion is expressed in molecular weights (mols) per liter. pH is a scale of intensity of acidity and alkalinity which measures the concentration of Hydrogen ion in water.

**Material**

(i) pH meter with glass and a combined electrode, (Spectrum model)
(ii) Buffer solutions, preferably of pH 4.0 and 9.2.
(iii) Thermometer

**Method**

The electrodes were washed with distilled water and connected to the pH meter. The electrode was dipped in buffer of pH 4.0 and moved to the temperature compensation knob to the temperature of the buffer. Then the electrode was removed from buffer, washed with distilled water and again dipped into buffer of pH 9.2. In doing so, the meter is calibrated for pH ranges from 0 to 7 and from 7 to 14. The pH meter reading will be giving the correct pH of the sample (APHA, 1995).

### 2.2.4 Free Carbon Dioxide (CO₂)

Carbon dioxide is one of the causes of instability of water. Water having a pH above 8.34 does not contain appreciable amount of Carbon Dioxide.

**Material**

(i) Phenolphthalein indicator - It was prepared by dissolving 0.5 gm of Phenolphthalein in 50ml of 95% ethyl alcohol and adding 50ml of Carbon Dioxide free distilled water.
(ii) Standard sodium carbonate (N/44) Na2CO3 - It was prepared by dissolving 1.205gm of anhydrous Na2CO3 in 1 liter of Carbon Dioxide free distilled water.

Method

Immediately after sample collection analysis was made. To a 50 ml sample of water 2-3 drops of Phenolphthalein indicator was added and was titrated against N/44 sodium carbonate solution till the colour turns pink.

For calculation the following formula was used (Saxena, 1990)

Free CO₂ (in ppm) = ml of (N/44) Na₂ CO₃ × 1000/sample volume in ml.

2.2.5 Total Alkalinity

The amount of acid required to neutralize bases in water is a measure of the alkalinity of water. Carbonate and bicarbonate are considered to be the prominent bases in natural water while hydroxyl occurs at higher water pH. Water samples, which turn yellow upon addition of methyl orange indicators, were considered to be alkaline and usually alkalinity is expressed as mg/liter of calcium carbonate.

Material

a) Methyl orange indicator – It was prepared by dissolving 0.05 gm of methyl orange in 100 ml of distilled water.

b) Sulphuric acid 0.02 (N) – It was prepared by diluting conc. H₂SO₄ (36N Sp.gr. 1.84) with100 ml of distilled water to get approximately 1 (N) stock solution. 20 ml of (N) H₂SO₄ was diluted to 100 ml and standardized against standard 0.02 (N) sodium carbonate solution using methyl orange indicator to determine the exact strength of the solution.

c) Sodium carbonate solution 0.02 (N)- It was prepared by dissolving 1.06 gm of anhydrous sodium carbonate in 100 ml of distilled water.
Method

2 to 4 drops of methyl orange indicator solution was added to 50ml sample and titrated with 0.02 (N) Sulphuric acid until the colour of the solution changes from yellow to faint orange. Calculation was done by the following formula (Saxena, 1990):

\[
\text{Total alkalinity (ppm) } \approx \text{ ml of } 0.02 \text{ (N) } H_2SO_4 \text{ required } \times \frac{100}{\text{sample volume in ml}}
\]

2.2.6 Dissolved Oxygen (DO₂)

Dissolved oxygen (DO₂) is an essential component to maintain the metabolic processes of aquatic life. Oxygen concentration in water depends on its temperature and the degree of pollution. DO₂ is a very important parameter of water quality index and ecobiological processes going in water. Low DO₂ may prove lethal for many organism of the community ecosystem.

Winkler's Method

Oxygen combines with Mn(OH)₂ to form higher hydroxides which is an acidification in presence of iodine (I) to liberate an equivalent amount of iodine corresponding to the dissolved oxygen content of the sample. The liberated iodine is determined by titration with Na₂S₂O₃ using starch as an indicator. The solution remains blue till iodine is present and become colourless later on.

Material

(i) Manganous sulphate solution – It was prepared with 364 gms of Mn₃SO₄ dissolved in 1lt of distilled water.

(ii) Sodium Thiosulphate solution (0.025 N) – It was prepared by dissolving 6.205 gm of Sodium Thiosulphate (Na₂S₂O₃ · 5H₂O) in 1lt of distilled water. 5 drops of chloroform was added as preservative.
(iii) Alkaline Potassium Iodine solution – It was prepared by dissolving 100g of Potassium Hydroxide (KOH) and 50g of Potassium iodide (KI) in
200ml of previously boiled distilled water.

(iv) Starch indicator – It was prepared with 1 g of starch powder in 5ml cool
water, then the suspension was dissolved in 100ml boiled distilled water. 3 g of Boric Acid was added as preservative.

**Method**

100ml of filtered sample was taken without any bubbling. 1ml of
Manganese Sulphate and 1ml of alkaline Potassium Iodide was added which
formed a precipitate. Then the stopper was placed and the bottle was shaked
thoroughly. 2ml of conc. H₂SO₄ was added to dissolve the precipitate. From the
solution 10ml samples were taken into conical flasks and 1ml of starch indicator
was added to them. Then the samples were titrated against sodium thiosulphate
solution. There was an immediate reaction resulting in the initial blue colour
turning colourless.

Calculation:

\[ 1\text{ml of } 0.025 \text{ N } \text{Na}_2\text{S}_2\text{O}_3 = 0.2\text{mg } \text{O}_2 \]

Hence DO₂/Lit = m₁ Na₂S₂O₃ consumed × 0.2/ml of water (ppm)

This modification of Winkler's method is also known as
Alsterberg Azine modification (APHA, 1995).

**2.2.7 Inorganic Phosphorus (Ortho Phosphate)**

Presence of phosphates in water has a great significance. Presence of phosphate in large quantities in fresh waters indicates pollution. In
strongly acid solutions Ortho Phosphate forms a yellow complex with molybdate
ions, which is reduced to a highly blue coloured complex in the presence of
reducing agents. A number of reducing agents may be employed, but Stannous
Chloride has been widely used for this purpose.

The intensity of the blue colour is measured
spectrophotometrically, for which the concentration of orthophosphate in a
sample is determined with reference to a standard calibration graph prepared from known concentration of orthophosphate.

Materials

a) 2.5% sulphomolybdic acid - 2.5gms of pure Ammonium Molybdate \((\text{NH}_4)_6\text{Mo}_7\text{O}_{24}\cdot\text{H}_2\text{O}\) was dissolved in 200ml of distilled water by warming at 60°C. In another container, 275ml of concentrated \(\text{H}_2\text{SO}_4\) was diluted to 750ml of distilled water. After both the solutions have cooled down Ammonium Molybdate solution was added to the dilute \(\text{H}_2\text{SO}_4\) slowly by constant stirring. The volume was made up to 1lt and stored.

b) 2.5% Stannous Chloride: - 2.5% Stannous Chloride solution was prepared with 2.5gm of \(\text{SnCl}_2\cdot2\text{H}_2\text{O}\) dissolved in about 5ml of conc. \(\text{HCl}\) with warming. 50ml of boiled distilled water was diluted and ultimately made up to the volume to 100ml with about 1.2 (N) \(\text{HCl}\). The reagent was kept in a dark coloured bottle under a thin layer of liquid Paraffin.

c) Standard Phosphorous solution - It was prepared with 0.2195gm of Potassium dihydrogen Phosphate dissolved in 400ml of distilled water. 25ml mixture of \(\text{H}_2\text{SO}_4\) distilled water in the ratio of 1:5 and make up the volume to 100ml with distilled water added to it. This gave a stock solution of 50 ppm of Phosphorous (P). 20ml of this solution was diluted to 500ml to prepare 2-ppm solution of P.

Method

25ml of sample was taken in a flask. 1ml of Ammonium Molybdate solution was added to it. 3 drop of Stannous Chloride solution was mixed with it. A blue colour appeared. The complete colour intensity developed within 3-4 minutes and began to fade after 10-12 minutes. The transmission was measured using a spectrophotometer at 660nm and a standard curve was prepared by plotting concentration along X-axis and transmission along Y-axis in a semi-logarithmic paper (Saxena, 1990).
2.2.8 Fluoride

Fluoride ions have dual significance in water supplies. Excess concentration of F causes dental fluorosis. At the same time, a concentration less than 0.8mg/l results in 'dental caries'.

Material

1. Spectrophotometer

2. Alizarin red solution (Reagent A)- 0.75g of 3-alizarin sulphuric acid salt was dissolved in 1 liter of distilled water to prepare the solution.

3. Zirconyl acid solution (Reagent B)- 0.354g of Zirconyl chloride octahydrate was dissolved in 600 ml of distilled water. 33.3ml of conc. H₂SO₄ was added slowly followed by a 10.1 ml of conc. HCl. It was cooled and the volume was adjusted to 1 liter.

4. Standard fluoride solution - 0.221g of sodium fluoride (NaF) was dissolved in distilled water to make the volume 1 liter. 100 ml of this solution was diluted to make 1 liter by adding distilled water. This stock solution contains 10 mg F/l it. A series of standard fluoride solution was prepared from 0.0 to 5.0 F/l it at intervals of 0.5 F/l it by dilution of the stock solution with distilled water.

Method

100 ml of the sample solution was taken in a flask and 5 ml of each Alizarin red solution and Zirconyl acid solution was added. The solution was left for one hour and the absorbance was noted on the spectrophotometer at 520 nm. Distilled water was taken as blank, standard fluoride solutions of different concentration were taken and ran in similar manner and each absorbance was noted. Then a standard graph was plotted between concentration and absorbance of standard solution. Then the fluoride concentration of the desired sample was calculated out by comparing its absorbance with standard curve and the result was expressed in mg/l (Megregian, 1954).
Soil sampling procedures:

Soil is the biological substratum. It has a profound influence on the maintenance of natural equilibrium. Its productivity can be judged by taking into consideration the "integral effect of all its characteristics".

Several random samples were collected from the homogenous part of study area and taken in polythene bags. On reaching the laboratory the samples are spread on brown papers and air-dried. Large lumps or clods are broken to facilitate air-drying and the sample was grounded in a mortar by a wooden pestle taking the precaution not to breakdown ultimate particles of soil or stones and Pebbles.

2.2.9 Soil pH

pH of soil is the most important single property identifying the chemical nature of soil. It greatly influences the nature and determines the diversity of soil fauna and flora, physical properties of the soil and availability of certain essential nutrients. The air-dried soil sample was sieved in 0.2mm sieve. A few drops of distilled water were added to it. After standardizing the apparatus by means of a set of buffer (pH 4.0, 9.0), the electrodes were dipped into the soil suspension and the pH value was noted down directly on the pH meter. The essential apparatus includes

i) Spectrum Model pH meter

ii) Buffer solution (4.0 and 9.0) (Saxena, 1990).

2.2.10 Organic Carbon

The amount of organic carbon greatly influences soil quality, soil texture, water holding capacity, availability and abundance of nutrients and biological population and their activity including productivity. Walkley and Black (1947) rapid titration method was adopted for organic carbon determination.

Materials

a) Potassium Dichromate 1 (N) – Exactly 49.04gms of K₂Cr₂O₇ was dissolved in 100 ml distilled water and the volume made up to 1000ml
b) Ferrous Ammonium Sulphate 1 (N) – 352.2gm of Fe(NH₄)₂(SO₄)6H₂O was dissolved in distilled water 15ml of conc. H₂SO₄ was added and diluted to 1 liter.

c) Diphenylamine indicator – 0.5g diphenylamine was dissolve in a mixture of 20 ml of water and 1000ml of concentration H₂SO₄.

d) Concentrated H₂SO₄ (Sp.Gr 1.84)

e) Ortho Phosphoric Acid (85%)

**Methods**

The air-dried soil was passed through 0.2mm sieve and 1.00g soil was placed at the bottom of a dry 500ml conical flask. It was moistened with a few ml of distilled water. 10ml of (N) Potassium Dichromate solution followed by 20ml of conc. H₂SO₄ was added to it. The flask was allowed to stand for 30 minutes and thereafter 20ml of distilled water was added. After incorporation of 10ml of Ortho Phosphoric Acid and 1ml of Diphenylamine indicator, the contents were titrated with Ferrous Ammonium Sulphate solution till the colour flashes from purple to green. 0.5ml of Potassium Dichromate solution was added accurately and the titration was continued till the colour changes to green. In the same way a blank experiment was carried out without soil.

**Calculation**

\[ \text{Organic carbon (\%) = } 10(B-T)/B \times 0.003 \times 100/\text{wt.of soil} \]

Where,

\[ B = \text{Titration value of blank} \]

\[ T = \text{Titration value of soil} \]

**2.2.11 Available Nitrogen**

**Alkaline Permanganate Method**

A known weight of soil was mixed with excess of alkaline KMnO₄ and liberated Ammonia was absorbed in a known volume of standard acid and the excess acid was titrated with standard alkaline using Methyl red as the indicator.
Materials

a) Potassium Permanganate solution (0.32%) - 3.2 gms of KMnO₄ was dissolved in distilled water and the volume was made to 100ml.

b) Sodium Hydroxide solution (2.5%)- 25gms of NaOH was dissolved in 100ml of distilled water.

c) Sulphuric Acid (0.02 N) - 28ml conc. H₂SO₄ was diluted to 1000ml with distilled water to get approximately 1 (N) stock solution. 200ml of this stock solution was dissolved in 1000 ml distilled water to prepare 0.02 N sulphuric acid titrant.

d) Sodium hydroxide 0.02 (N) – 4 gms of NaOH soil was dissolved in 100ml of distilled water to get 0.1 N solutions. 50ml of this stock solution was diluted to 250ml to get 0.02 (N) NaOH.

e) Methyl red indicator – 0.1gm of Methyl red indicator powder was mixed in 25ml of ethyl alcohol was made up to 50ml with distilled water.

Methods

1gm of soil was taken in a 100ml Kjeldahl flask and equal volume of 10ml each of 0.32% KMnO₄ and 2.5% NaOH were added to it. The mixture was distilled after adding 2ml of liquid paraffin and few glass bids to the flasks. 50ml of the distillate was collected in the receiving flask containing 25ml of 0.02 (N) H₂SO₄ with a few drops of methyl red indicator and titrated against the excess acid with 0.02 (N) NaOH till the colour changes from red to yellow (APHA,1995).

Calculation:

Available Nitrogen (Mg/100 gm soil) = \frac{ml of 0.02(N) \ H₂SO₄ - ml of 0.02 (N) \ NaOH \ required \ to \ neutralization}{0.28 \times 100/weight \ of \ the \ sample}
2.2.12 Available Phosphorous

Phosphates played a substantial role in the metabolism of biota. Phosphorous in soil occurs as orthophosphate in several forms and in combination.

Troug's Method

In this method the soil was extracted with a buffer solution (pH 3.0) containing Sulphuric Acid and Ammonium Sulphate under specific conditions. The Phosphate thus dissolved is determined spectrophotometrically by Troug's method, where in the blue colour of heteropoly complex was developed by reducing Phosphomolybdate complex with Stannous Chloride.

Materials

a) Sulphuric Acid solution (0.002 N): - 100ml of 0.02 n H₂SO₄ was diluted with 1lt of distilled water and 3g of Ammonium Sulphate was added to it.

b) Sulphomolybdic acid solution 2.5% - 2.5g of pure ammonium molybdate was dissolved in 2.0ml of distilled water by warming at 60°C. In another container 275ml of conc. H₂SO₄ was diluted to 750ml with distilled water. After both the solutions have cooled down Ammonium Molybdate solution was added to the dilute H₂SO₄ slowly.

c) Stannous Chloride solution (2.5%): - 2.5gm of SnCl₂, 2H₂O was dissolved in about 5ml of conc. HCl with warming. 50ml of boiled distilled water was diluted and ultimately made up to 100ml with about 1.2 (N) HCl.

d) Standard Phosphorus solution - 0.2195gm of Potassium Dihydrogen phosphate was dissolved in 400ml of distilled water. 250ml mixture of H₂SO₄ in distilled water in the ratio of 1:5 and made up the volume to 100ml with distilled water added to it. This gave a stock solution of 50 ppm of Phosphorous (P). 20ml of this solution was diluted to 500ml to prepare 2-ppm standard Phosphorus solution.
**Method**

1. Preparation of standard curve – It was prepared by plotting concentration along X-axis and transmission along Y-axis on a semi-logarithmic paper.

   i) Extraction of available phosphorous – About 1 g of soil taken in a stopped glass bottle 200ml of 0.002 N H₂SO₄ was added and was shaked for 30 minutes in a mechanical shaker. The suspension was filtered immediately through filter paper discarding the first few ml of filtrate. The concentration of phosphorous in 25-75 ml of the filtrate depending on the phosphorus content was determined spectrophotometrically (APHA, 1995).

Calculation:

   i) **Available P₂O₅ (mg/100gm soil) = Disc reading few 100ml x 0.01 x 20**

   ii) **Available P (mg/100gm of soil) = ppm of P in soil x 202.2.13**

2.2.13 Available Potassium

   This cation plays a vital role in the metabolism of fresh water environments and considered to be an important macronutrient.

**Materials**

i) Flame photometer

ii) Whatman filter paper and reagents

iii) Standard potassium solutions: 1.9064 g of Potassium chloride was dissolved in distilled water to make the volume 1 litre. This stock solution contains 1g K⁺. Various standard potassium solutions of different strengths by diluting this stock solution with distilled water were prepared

**Method**

The filter of flame photometer was set at 769 nm. The compressor set start and the burner was lighted. The air pressure was kept at 5 lbs and gas feeder was adjusted to give a blue sharp flame. The standard
...potassium solution was fed and the emission was read on the scale. It was adjusted to zero volume by feeding with distilled water. Now potassium solution of different concentration was fed and the emission value for each was recorded.

A standard graph was plotted between concentration and emission of standard potassium solution. The result was expressed in mg/100g soil.

2.3 RESULTS

2.3.1 Depth of Water:

In control community highest water depth was observed in RB during M. It was nil in FH during PreM and found lowest during PreM of CT (Table 2.2).

In F-community, highest water depth was observed during M of CT region while the lowest value was observed during PreM of FH and CT region (Table 2.2).

The results obtained from two way ANOVA indicated that, the effects of season and site on water depth were significant at $P \leq 0.001$ level. In addition, the interaction effect of both the factor was statistically significant at $P \leq 0.01$ level.

Further, results of Duncan's multiple range test depicted that, the highest level of water depth was observed during M while the lowest was found during PreM (Fig. 2.1.a). It also indicated that, in RB site highest water depth was present while the FH witnessed less water depth (Fig. 2.1.b). The differences in season obtained statistical validation while the RB site was statistically significant from FH and CT. The FH and CT were not significant to each other.

The depth of water was positively correlated with free CO$_2$, DO$_2$, fluoride, and inorganic phosphorous and available potassium content while it was negatively correlated with water temperature, water pH, total alkalinity, organic carbon, available nitrogen and available phosphorus content (Table 2.3)
2.3.2 Temperature of Water:

In control community, the temperature of water was found maximum in CT during PreM and minimum also in CT but during M (Table 2.2).
In F community, it was found maximum in FH during PreM while the minimum water temperature was observed in RB during PoM (Table 2.2).

Results obtained from two way ANOVA indicated that, the effect of different season was significant to each other at $P \leq 0.01$ level while the effect of different sites was significant at $P \leq 0.05$ level. The season and site dependent effect was not obtained statistical validation.

Further, the results of Duncan's multiple range test indicated that, the water temperature was more during PreM and less during M. It was more in FH and less in RB. The different seasons were significant to each other. The site FH obtained statistical validation from CT and RB while the CT and RB were not obtained statistical validation (Fig. 2.2.a, 2.2.b).

The temperature of water was positively correlated with water pH, total alkalinity, organic carbon, available nitrogen and available phosphorus while it was negatively correlated with free $\text{CO}_2$, $\text{DO}_2$, fluoride and inorganic phosphorus (Table 2.3).

![Fig.2.2](image-url)

**Temperature of water**

Please see legend to Fig 2.1
2.3.3 pH of Water:

In control community, pH of water was found more in CT during Pre M and less in RB during M. It was found absent in FH during Pre M (Table 2.2). In F-community, highest water pH was observed in FH during PreM while the lowest water pH was observed in RB during PoM (Table 2.2).

Results obtained from two way ANOVA indicated that, the effects of season and site were significant at $P \leq 0.001$ level while the season and site dependent effect was significant at $P \leq 0.05$ level.

Further, the results of Duncan's multiple range test indicated that, the highest pH of water was observed during PreM while the lowest value was observed in M. The PreM was statistically significant to M and PoM while PoM and M were not obtained statistical validation (Fig. 2.3.a).

The FH site contained highest pH while the RB contained lowest pH of water. The sites FH and CT were not significant with each other but were found significant with the RB (Fig. 2.3.b).

The pH of water was positively correlated with the total alkalinity, organic carbon, available nitrogen and available phosphorus content while it was negatively correlated with free CO$_2$, DO$_2$, fluoride and available phosphorus (Table 2 3).
Fig. 2.3

Effect of Season on Water pH

Effect of Site on Water pH

2.3.4 Free Carbon Dioxide of Water:

In control community, free CO₂ content was found absent in FH during PreM and M while in CT it was found absent during Pre M. Highest amount of free CO₂ was found in CT during M while lowest amount was present in RB during Pre M (Table 2.1).
In F-community, it was also absent in FH and CT during PreM period. The highest value was obtained in RB during M while the lowest value was obtained during the PreM period of RB site (Table 2.1).

The results of two way ANOVA indicated that, the effect of site was significant at $P \leq 0.001$ level while the effect of season and dependent effect of both the factors were not obtained statistical validation.

The results of Duncan's multiple range test indicated that, the highest value was observed in M while the lowest value was obtained in PreM (Fig. 2.4.a). It further indicated that, the CT possessed highest free CO$_2$ content (Fig. 2.4.b). All seasons were statistically significant with each other. The CT was significant with FH and RB while they were not obtained statistical validation.

The free CO$_2$ content was positively correlated with DO$_2$, fluoride and inorganic phosphorus while it was negatively correlated with a total alkalinity, available nitrogen and available phosphorus (Table 2.3).
Effect of Season on free CO$_2$

Please see legend to Fig 2.1.
Bar having similar alphabet are not significant to each other.

2.3.5 Total Alkalinity of Water:

In control community, highest total alkalinity was observed in RB during PreM and lowest was obtained in FH during PoM (Table 2.1).

In F-community, it was also found more in RB during PreM and less in FH during PoM (Table 2.1).

The results of two way ANOVA indicated that, the effect of season was significant at $P \leq 0.01$ level, the effect of site was significant at $P \leq 0.001$ level while the dependent effect of both the factors was significant at $P \leq 0.05$ level.

The results obtained from Duncan's multiple range test indicated that, the highest value was obtained in PoM while the lowest amount was obtained in PreM. The PreM and M were not significant to each other while the PoM obtained statistical validation with PreM and M (Fig. 2.5.a).

It further indicated that, the highest total alkalinity content was present in RB and lowest was present in FH. The RB was significant with FH and CT while they were not significant to each other (Fig. 2.5.b).

Total alkalinity was positively correlated with soil pH, carbon, nitrogen and available phosphorous while it was negatively correlated with DO$_2$ and fluoride (Table 2.3)
Total Alkalinity of water

Please see legend to Fig 2.1.

Effect of Season on total alkalinity

Effect of Site on total alkalinity

Please see legend to Fig 2.1.
Bar having similar alphabet are not significant to each other.

2.3.6 Dissolved Oxygen of Water:

In control community, highest DO$_2$ was found in RB during M and lowest was found in FH during PoM (Table 2.1). In F-community, it was found more in FH during M and less in RB during PreM (Table 2.1).
Results obtained from two way ANOVA indicated that, the effect of season was not obtained statistical validation. The effect of site was significant at $P \leq 0.001$ level while the interaction effect of both the factors was found statistically significant at $P \leq 0.05$ level.

Further, results of Duncan's multiple range test depicted that the highest amount of DO$_2$ was observed during M and lowest was during PreM. All the seasons were significant to each other (Fig. 2.6.a).

It also indicated that, the highest DO$_2$ was present in FH and lowest was present in RB. FH was found significant with CT and RB while CT and RB were not significant to each other (Fig. 2.6.b).

The correlation coefficient matrix indicated that, the DO$_2$ was positively correlated with the water depth, free CO$_2$, fluoride, inorganic phosphorous, soil pH and available potassium while it was negatively correlated with the water temperature, water pH, total alkalinity, organic carbon, available nitrogen and available phosphorus (Table 2.3).
Effect of Season on DO2

Please see legend to Fig 2.1. Bar having similar alphabet are not significant to each other.

2.3.7 Fluoride:

In control community, highest F was observed in RB during M and lowest was observed in FH during PoM (Table 2.2).

In F-community, it was found more in CT during M and observed less in FH during PreM (Table 2.2). In F-community, tube well contained highest amount of fluoride than bore well and WHS. The highest amount of fluoride (11.74 mg/l) was found in a tube well of F-community (Karlkote village) (Table 2.5; Fig. 2.7.1).

In F-community, Kata contained highest amount of F during PreM. Sagar contained highest amount of F during M while muda contained highest amount of F during PoM. During PreM and PoM less amount of F-content was observed in Sagar while during M, Chahla contained the same (Table 2.6; Fig. 2.7.2).

The results of ANOVA indicated that, the F-content in bore well, tube well and WHS were statistically significant. The effect of site and dependent effect of both the factors were significant at $P \leq 0.001$ level while the effect of season was statistically validated at $P \leq 0.05$ level.
The results of Duncan's multiple range test indicated that, the highest amount of fluoride was observed during M and less amount was observed during PreM. The PreM season was significant with PoM and M while they were not significant with each other (Fig. 2.7.a). It further indicated that, the F-content was found more in RB and less in FH. The different sites were obtained statistical validation with each other (Fig. 2.7.b).

The F-content of bore well, tube well and WHS were positively correlated with each other. The F-content of Sagar was positively correlated with the F-content of Muda while negatively correlated with the F-content of Bundh and Kata. The F-content of Bundh was positively correlated with the F-content of Kata. The correlation analysis indicated that, fluoride was positively correlated with depth of water, free CO₂, DO₂, inorganic phosphorus and available potassium while it was negatively correlated with temperature of water, pH of water and soil, total alkalinity, available phosphorus, organic carbon and available nitrogen (Table 2.4).

![Fig. 2.7](image)

**Fluoride content of water**

Please see legend to Fig 2.1
Fig. 2.7.1

Effect of Season on Fluoride

Please see legend to Fig 2.1.

Bar having similar alphabet are not significant to each other.

Sample sites

F-content in different sample sites of F-community

Fig 2.7.2

F-content in different water sources of F-community

Please see legend to Fig 2.1
F-contents in annual and perennial WHS of F- community

Please see legend to Fig 2.1; A : Annual ; P : Perennial

2.3.8 Inorganic Phosphorus:

In control community, highest amount of inorganic phosphorus was obtained in RB during M and lowest amount was obtained in CT during PoM (Table 2.2).

In F-community, inorganic phosphorus was observed more in RB during M while less amount was observed in FH during PreM (Table 2.2).

Results obtained from two way ANOVA indicated that, the effects of season site and the interaction effect of both the factors were found significant at $P \leq 0.001$ level.

Further, results of Duncan’s multiple range test depicted that, the highest amount of inorganic phosphorus was obtained in M and lowest amount
was observed in PoM. All the seasons were significant with each other (Fig. 2.8.a).

It also indicated that, the RB site contained more inorganic phosphorus while FH contained less. RB was statistically significant with FH and CT while FH and CT were not obtained statistical validation (Fig. 2.8.b). Inorganic phosphorus was positively correlated with pH of soil while negatively correlated with the organic carbon (Table 2.4).

**Fig.2.8**

![Inorganic phosphorous](image)

Please see legend to Fig. 2.1

**Fig.2.8.a**

![Effect of season on Inorganic phosphorous](image)

Please see legend to Fig 2.1

Bar having similar alphabets are not significant to each other
2.3.9 PH of Soil:

In control community, the pH of soil was found more in RB during PreM while it was less in FH during PoM (Table 2.3). In F-community it was more in CT during PreM and less in FH during PoM (Table 2.3). Table 2.3 also indicated the presence of slightly alkaline soil in PreM and M while it was slightly acidic in PoM.

Results obtained from two way ANOVA depicted that, the effect of site was significant at $P \leq 0.01$ level while effect of season and interacting effect of both the factors were not obtained statistical validation. Further the results of Duncan's multiple range test indicated that, the pH of soil was found more in M and less in PoM. The PoM season was significant with PreM and M while they were not obtained statistical validation with other (Fig. 2.9.a).

It also informed that, the soil pH was observed more in RB and less in FH. FH was significant with CT and RB while CT and RB were not significant to each other (Fig. 2.9.b).

The pH of soil was positively correlated with the organic carbon and available phosphorous while it was negatively correlated with available potassium (Table 2.3).
2.3.10 Organic Carbon of Soil:

In control community, the organic carbon of soil was observed highest in RB during PreM and lowest in FH during PoM. In F-community also it was found more in RB during PreM and less in FH during PoM (Table 2.3).

Results obtained from two way ANOVA indicated that, the effect of site was significant at $P < 0.001$ level while the effect of season and dependent effect of both the factors were not obtained statistical validation.

Further, the results obtained from Duncan's multiple range test depicted that, the highest value was noticed in PreM while the lowest was observed in PoM. The M and PoM were not obtained statistical validation while PreM was significant with M and PoM (Fig. 2.10.a).

It also indicated that, the organic carbon content was found more in CT regions and less in RB region. The RB was found significant to FH and CT while they were not obtained statistical validation with each other (Fig. 2.10.b).

It was positively correlated with water temperature, total alkalinity, pH of water of soil, inorganic phosphorous, available nitrogen and available phosphorous while it was negatively correlated with the water depth, free CO$_2$, DO$_2$, fluoride and available potassium (Table 2.3).
Fig. 2.10

Organic Carbon in Soil

Please see legend to Fig. 2.1
Bar having similar alphabets are not significant to each other.

Effect of Season on Organic Carbon

Please see legend to Fig. 2.1
Bar having similar alphabets are not significant to each other.

Effect of Site on Organic Carbon

2.3.11 Available Nitrogen:

In control community highest amount of available nitrogen was found in CT during PreM and less was observed in RB during PoM.
community also the similar result has been obtained (Table 2.3). The C/N ratio of soil was found more in M and less in PoM (Fig. 2.11.1).

Results obtained from two way ANOVA deciphered that, the effect of site was significant at $P \leq 0.01$ level while the effect of season and the interaction effect of both the factors were not obtained statistical validation.

Further, the results obtained from Duncan's multiple range test indicated that, the PreM witnessed highest amount of available nitrogen while the lesser amount was present during M. The PreM was found significant with M and PoM while the M and PoM were not significant with each other (Fig. 2.11.a).

It also indicated that, the CT contained highest amount of available nitrogen while the lesser amount was present in FH. The FH was found significant with CT and RB while they were not significant with each other (Fig. 2.11.b).

The available nitrogen was positively correlated with the water temperature, pH of water and soil, total alkalinity, organic carbon and available phosphorus while it was negatively correlated with the water depth, free CO$_2$, DO$_2$, fluoride, inorganic phosphorus and available potassium (Table 2.4).
Fig. 2.11.1

Bivariate analysis of fluoride with C/N ratio in soil

Please see legend to Fig.2.1; C/N : Carbon and Nitrogen ratio of soil

2.3.12 Available Phosphorus:

In control community, the available phosphorous was found more in RB during PoM and less in FH during PreM (Table 2.3).

In F-community, highest amount was obtained in CT during PoM while the lowest amount was obtained in FH during PreM (Table 2.3).
Results obtained from two way ANOVA indicated that, the effect of season was significant at $P \leq 0.05$ level, effect of site was significant at $P \leq 0.01$ level and the interacting effect of both the factors was not obtained statistical validation.

The results obtained from Duncan's multiple range test deciphered that, the highest amount was present in PreM while the lowest amount was present in PoM. All the seasons were statistically significant to each other (Fig.2.12.a).

Further, it also indicated that, the RB site contained highest amount of available phosphorous while FH site contained lowest amount. RB was statistically significant to FH and CT while FH and CT were not statistically significant to each other (Fig. 2.12.b).

Available phosphorous was positively correlated with the water temperature, pH of water and soil, total alkalinity, inorganic phosphorous, organic carbon and available nitrogen while it was negatively correlated with the water depth, free CO$_2$, DO$_2$ and fluoride content of water (Table 2.4).

![Available Phosphorous of soil](image)
2.3.13 Available Potassium:

In control community, it was found more in RB during PoM and less in CT during PreM. The same trend was also found in the F-community (Table 2.3).

Results obtained from two way ANOVA indicated that, the effect of site was significant at $P \leq 0.001$ level while the effect of season and interacting effect of both the factors were not obtained statistical validation.

Results obtained from Duncan's multiple range test informed that, the highest amount of available potassium was obtained in PoM while the lowest was found in PreM. All seasons were found statistically significant to each other (Fig. 2.13.a). It also indicated that, the maximum amount of available potassium was abundant in RB while lesser amount was found in FH. Effect of FH was statistically significant to CT and RB while they were not significant to each other (Fig. 2.13.b).

It was found positively correlated with the water depth, free $\text{CO}_2$, $\text{DO}_2$ and fluoride content while it was negatively correlated with the water temperature, $\text{pH}$ of water and soil, total alkalinity, inorganic phosphorous, organic carbon, available nitrogen and available phosphorous (Table 2.4).
Available Potassium in soil

Please see legend to Fig. 2.1

Effect of Season on Available Potassium in soil

Effect of Site on Available Potassium in soil

Bar having similar alphabets are not significant to each other.
Bivariate analysis of fluoride with NPK value in soil

Please see legend to Fig. 2.13.1; NPK: Nitrogen, potassium and Phosphorous (soil fertility) quality of soil in a proportionate ratio of 4:1:2.
### Table No. 2.2

**Physicochemical properties of water**

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Parameter</th>
<th>Site</th>
<th>Control community</th>
<th>F-community</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>PreM</td>
<td>M</td>
</tr>
<tr>
<td>1</td>
<td>Water Depth (in mt.)</td>
<td>FH</td>
<td>1.32 ± 0.34</td>
<td>0.52 ± 0.13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CT</td>
<td>0.40 ± 0.11</td>
<td>4.35 ± 0.77</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RB</td>
<td>2.03 ± 1.8</td>
<td>6.01 ± 1.32</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PreM</td>
<td>M</td>
</tr>
<tr>
<td>2</td>
<td>Water Temperature (in °C)</td>
<td>FH</td>
<td>37.45 ± 34.47</td>
<td>39.86 ± 31.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CT</td>
<td>8.72 ± 0.43</td>
<td>7.84 ± 0.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RB</td>
<td>7.99 ± 0.48</td>
<td>7.51 ± 0.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PreM</td>
<td>M</td>
</tr>
<tr>
<td>3</td>
<td>pH of water</td>
<td>FH</td>
<td>8.71 ± 0.3</td>
<td>7.8 ± 0.23</td>
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<td></td>
<td></td>
<td>CT</td>
<td>8.78 ± 0.43</td>
<td>7.84 ± 0.05</td>
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<td></td>
<td></td>
<td>RB</td>
<td>7.99 ± 0.48</td>
<td>7.51 ± 0.07</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>PreM</td>
<td>M</td>
</tr>
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<td>4</td>
<td>Free CO₂ (in ppm)</td>
<td>FH</td>
<td>8.95 ± 0.44</td>
<td>12.56 ± 0.00</td>
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<td></td>
<td></td>
<td>CT</td>
<td>15.46 ± 1.59</td>
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<td>RB</td>
<td>15.53 ± 0.97</td>
<td>8.42 ± 0.38</td>
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<td></td>
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<td>PreM</td>
<td>M</td>
</tr>
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<td>5</td>
<td>Total Alkalinity (in ppm)</td>
<td>FH</td>
<td>168.50 ± 8.25</td>
<td>114.66 ± 4.93</td>
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<tr>
<td></td>
<td></td>
<td>CT</td>
<td>304.25 ± 25.60</td>
<td>166.50 ± 30.5</td>
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<tr>
<td></td>
<td></td>
<td>RB</td>
<td>449.66 ± 33.75</td>
<td>273.25 ± 25.2</td>
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<td></td>
<td></td>
<td>PreM</td>
<td>M</td>
</tr>
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<td>Dissolved Oxygen (in mg/l)</td>
<td>FH</td>
<td>24.51 ± 1.53</td>
<td>10.79 ± 0.30</td>
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<tr>
<td></td>
<td></td>
<td>CT</td>
<td>8.08 ± 0.37</td>
<td>14.37 ± 0.53</td>
</tr>
<tr>
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<td></td>
<td>RB</td>
<td>5.39 ± 0.34</td>
<td>12.77 ± 0.49</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>PreM</td>
<td>M</td>
</tr>
<tr>
<td>7</td>
<td>Fluoride (in mg/l)</td>
<td>FH</td>
<td>0.69 ± 0.17</td>
<td>0.67 ± 0.31</td>
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<td>0.69 ± 0.20</td>
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<td>RB</td>
<td>1.06 ± 0.23</td>
<td>1.41 ± 0.28</td>
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<td></td>
<td></td>
<td>PreM</td>
<td>M</td>
</tr>
<tr>
<td>8</td>
<td>Inorganic phosphorous (in mg/l)</td>
<td>FH</td>
<td>3.19 ± 0.03</td>
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<td></td>
<td>CT</td>
<td>2.56 ± 0.21</td>
<td>3.40 ± 0.02</td>
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<tr>
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<td></td>
<td>RB</td>
<td>3.27 ± 0.14</td>
<td>3.50 ± 0.03</td>
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</table>

Please see legend to table 2.1, PreM Pre monsoon, PoM Post monsoon.
### Table No 2.3
Physicochemical properties of soil

<table>
<thead>
<tr>
<th>Sl. no</th>
<th>Parameter</th>
<th>Site</th>
<th>Control community</th>
<th>F-community</th>
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<tr>
<td></td>
<td></td>
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<td>PreM</td>
<td>M</td>
</tr>
<tr>
<td>1</td>
<td>pH of soil</td>
<td>FH</td>
<td>7.37 ± 0.06</td>
<td>7.14 ± 0.13</td>
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<tr>
<td></td>
<td></td>
<td>CT</td>
<td>7.4 ± 0.12</td>
<td>7.12 ± 0.21</td>
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<td></td>
<td></td>
<td>RB</td>
<td>8.08 ± 0.29</td>
<td>7.44 ± 0.12</td>
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<tr>
<td>2</td>
<td>Organic Carbon (in %)</td>
<td>FH</td>
<td>21.58 ± 0.04</td>
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<td>CT</td>
<td>22.81 ± 0.18</td>
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<td>RB</td>
<td>23.26 ± 0.12</td>
<td>22.28 ± 0.25</td>
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<td>Available Nitrogen (in mg/100g soil)</td>
<td>FH</td>
<td>22.72 ± 0.58</td>
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<td>CT</td>
<td>24.26 ± 0.67</td>
<td>26.42 ± 2.07</td>
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<td>RB</td>
<td>21.56 ± 0.11</td>
<td>23.86 ± 0.48</td>
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<td>Available Phosphorous (in mg/100g soil)</td>
<td>FH</td>
<td>2.24 ± 0.08</td>
<td>2.46 ± 0.02</td>
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<td>CT</td>
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<td>RB</td>
<td>2.93 ± 0.14</td>
<td>3.02 ± 0.07</td>
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<td>Available Potassium (in mg/100g soil)</td>
<td>FH</td>
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<td>CT</td>
<td>0.35 ± 0.07</td>
<td>0.65 ± 0.12</td>
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<td>RB</td>
<td>0.91 ± 0.03</td>
<td>1.16 ± 0.22</td>
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Please see legend to Table 2.1 and Table 2.2
Table No –2.4

F-content in different water sources of F-community

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Name of the village</th>
<th>Bore well</th>
<th>Tube well</th>
<th>WHS</th>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>Karlakote</td>
<td>7.59 ± 1.79</td>
<td>9.12 ± 2.62</td>
<td>1.24 ± 0.34</td>
</tr>
<tr>
<td>2.</td>
<td>Dargoan</td>
<td>3.51 ± 0.78</td>
<td>9.21 ± 1.67</td>
<td>2.03 ± 0.17</td>
</tr>
<tr>
<td>3.</td>
<td>Kotmal</td>
<td>4.12 ± 0.32</td>
<td>4.87 ± 0.87</td>
<td>1.34 ± 0.39</td>
</tr>
<tr>
<td>4.</td>
<td>Tangripara</td>
<td>3.59 ± 1.26</td>
<td>4.16 ± 0.69</td>
<td>0.96 ± 0.39</td>
</tr>
<tr>
<td>5.</td>
<td>Kurei johla</td>
<td>4.39 ± 0.93</td>
<td>2.98 ± 0.36</td>
<td>1.79 ± 0.36</td>
</tr>
<tr>
<td>6.</td>
<td>Sajumund</td>
<td>3.51 ± 0.28</td>
<td>3.17 ± 1.21</td>
<td>1.84 ± 0.51</td>
</tr>
<tr>
<td>7.</td>
<td>Kureikela</td>
<td>7.17 ± 0.57</td>
<td>5.87 ± 1.27</td>
<td>1.92 ± 0.89</td>
</tr>
<tr>
<td>8.</td>
<td>Dudkaibahal</td>
<td>6.92 ± 2.51</td>
<td>8.51 ± 1.03</td>
<td>3.12 ± 0.29</td>
</tr>
<tr>
<td>9.</td>
<td>Mandobirli</td>
<td>2.58 ± 1.32</td>
<td>3.41 ± 0.19</td>
<td>1.32 ± 0.24</td>
</tr>
</tbody>
</table>

WHS : Water Harvesting Structures

Table –2.5

F-content in the micro WHS of the F-community

<table>
<thead>
<tr>
<th>Sl no</th>
<th>Season</th>
<th>Sagar</th>
<th>Bundh</th>
<th>Kata</th>
<th>Muda</th>
<th>Chahla</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PreM</td>
<td>0.8 ± 0.4</td>
<td>1.41 ± 0.44</td>
<td>1.49 ± 0.00</td>
<td>0.99 ± 0.00</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>1.29 ± 0.38</td>
<td>1.36 ± 0.22</td>
<td>1.46 ± 0.66</td>
<td>1.35 ± 0.46</td>
<td>0.77 ± 0.31</td>
</tr>
<tr>
<td>3</td>
<td>PoM</td>
<td>1.12 ± 0.43</td>
<td>1.31 ± 0.23</td>
<td>1.48 ± 0.67</td>
<td>1.49 ± 0.00</td>
<td>-</td>
</tr>
</tbody>
</table>

Please see legend to Table 2.2
Table No.2.3.6

Correlation coefficient matrix of the limnological parameter

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>W.D</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W.T</td>
<td>-0.9882</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>W.pH</td>
<td>-0.8329</td>
<td>0.9077</td>
<td>1</td>
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<td></td>
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<td></td>
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</tr>
<tr>
<td>F.C</td>
<td>0.9931</td>
<td>-0.9993</td>
<td>-0.891</td>
<td>1</td>
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<td></td>
</tr>
<tr>
<td>T.A</td>
<td>-0.698</td>
<td>0.79934</td>
<td>0.9776</td>
<td>-0.176</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>D.O</td>
<td>0.9997</td>
<td>-0.9911</td>
<td>-0.843</td>
<td>0.952</td>
<td>-0.7122</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>0.9297</td>
<td>-0.9751</td>
<td>-0.978</td>
<td>0.9664</td>
<td>-0.9125</td>
<td>0.9369</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I.P</td>
<td>0.7983</td>
<td>-0.6986</td>
<td>-0.331</td>
<td>0.7224</td>
<td>-0.1261</td>
<td>0.7861</td>
<td>0.5206</td>
<td>1</td>
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<tr>
<td>S.pH</td>
<td>0.1091</td>
<td>0.04423</td>
<td>0.4591</td>
<td>-0.007</td>
<td>0.6356</td>
<td>0.08917</td>
<td>-0.2644</td>
<td>0.68568</td>
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</tr>
<tr>
<td>C</td>
<td>-0.4839</td>
<td>0.6121</td>
<td>0.8873</td>
<td>-0.582</td>
<td>0.9644</td>
<td>-0.5014</td>
<td>-0.772</td>
<td>0.1405</td>
<td>0.817</td>
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</tr>
<tr>
<td>N</td>
<td>-0.9749</td>
<td>0.9974</td>
<td>0.9352</td>
<td>-0.994</td>
<td>0.8398</td>
<td>-0.9791</td>
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<td>-0.6443</td>
<td>0.114</td>
<td>0.667</td>
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<tr>
<td>A.P</td>
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<td>-0.566</td>
<td>0.9590</td>
<td>-0.4814</td>
<td>-0.7593</td>
<td>0.1601</td>
<td>0.828</td>
<td>0.999</td>
<td>0.651</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>0.3285</td>
<td>-0.4692</td>
<td>-0.796</td>
<td>0.4368</td>
<td>-0.9056</td>
<td>0.3474</td>
<td>0.65318</td>
<td>-0.3063</td>
<td>-0.902</td>
<td>-0.98</td>
<td>-0.530</td>
<td>-0.98</td>
<td>1</td>
</tr>
</tbody>
</table>


2.4 DISCUSSION:

In aquatic community, the distribution of fluoride was studied in different water harvesting structures (WHS). In the present study five types of WHS were sampled such as; Sagar, Bundh, Kata, Muda and Chahla (Mahapatra and Mishra, 2003)

The Sagar is the WHS located in central table (CT) area and occupies 15-25 acres. It is perennial in nature and witnesses a high lentic biodiversity. It fulfills the peripheral irrigation demands.

Kata is the structure located in the foot hill (FH) area, it is a WHS having opening on one side which catches huge runoff water from forest and excessive water from paddy fields.
The *muda* is the traditional embankment structure located in the peripheral region of *kata*. It is annual in nature. It receives excess water of *kata* and stores it exclusively for irrigation purposes. *Chahla* is the minor WHS located in paddy fields, ponds etc. It is also annual in nature. It is located in all the FH, CT and river bank (RB) regions. The *bundhs* are bounded from four sides. Its belly is filled by the percolation of water. This is situated at the base of village land. It is mainly used for drinking purposes (Mahapatra, 2004). These traditional WHS have a stronger role in fresh water management (ENS, 1999). Besides these WHS, the community people are also dependant on tube well and bore well (Mahapatra et al., 2005)

In the communities studied, the distribution of fluoride varies from water bodies to water bodies; tube well to bore well and site-to-site, season-to-season and year-to-year. It indicates that, the F- content in the water bodies is not a stable parameter. *Kata* contains highest amount of fluoride that may be due to its vast catchment areas and large amount of runoff water which bleaches some soil fluoride in to this WHS. It also indicates that *chahla* contains less amount of fluoride may be due to the fact that the runoff catchment areas are small where the chances of bleaching is less. It may also be due to the minimum depth of the *chahla*. The depth of WHS is directly proportional to the amount of fluoride present (Naik & Samal, 1986). The *muda* contains comparatively less amount of F- content than *kata* because the channelised water of *kata* fills it. As the *kata* witness significant biodiversity, the flora and fauna may absorb considerable amount of fluoride for physiological process. This water having less amount of fluoride enters into the *muda*. It may also be due to the annual nature of *muda*. The water along with its fluoride is evaporated to the atmosphere and has negligible amount of fluoride in its belly due to scarcity of water in the PreM.

Next to *kata*, *bundh* contain highest amount of fluoride both in PreM and M. It may be due to source of water (percolation) enters to the *bundh* along with the soil carrying highest amount of fluoride in compound forms, which may be transported to the pond as it is located at the base of the village or mostly located in RB (Kessabi & Amouzigh, 1981). The *sagar* contains less amount of fluoride than *bundh*. It may also be due to rainwater that enters the *sagar*. *Sagar* has largest biodiversity, thus large amount of fluoride present may
be absorbed by the biotic community and lead to less amount of F-persistence (Ender, 1969).

2.4.1 Depth of water

The depth of water which were observed during M may be attributed to the supply of rain water while the minimum depth in PreM have resulted mainly due to very less rain fall during this period, substantiated by excessive loss of water due to high evapotranspiration rate (Devi and Sharma, 2003). The finding of present study supports this theory.

The depth of water (Table 2.2) was found more in RB and less in FH, may be due to the force of runoff and percolation to the ground water. Mishra et al., 1999, also support it.

2.4.2 Temperature of water

Temperature is the chief factor influencing the biotic as well as abiotic parameters of any aquatic ecosystem (Rawat and Jakhar, 2002). The temperature of water is high in PreM than PoM. The least temperature was recorded in M. This may be due to high solar radiation (Agrawal et al., 1976). The temperature of different sites are also greatly varies depending on the soil texture and the atmospheric conditions (Mosely, 1982). The WHS present in FH and RB area have difference in water temperature, may be due to the porosity of soil and composition of soil texture. High temperature during PreM can be attributed to grate intensity of light penetration and low water level (Brown, 1982). It is a most important single factor controlling many profound influences in the medium (Welch, 1952; Ruttner, 1953). The fluoride content is negatively correlated with water temperature. A similar trend in water temperature is reported by (Prakasam and Johnson, 1992; Kumar 2002). Temperature affects fluoride toxicity, in part because metabolic rates and uptake rates for every $10^0\text{C}$ rise in temperature.

2.4.3 pH of water and soil

pH is an important factor determining the biodiversity of the aquatic ecosystem (Huet, 1971; Jonnes, 1979, Brown, 1982). The lowest pH was reported during M (Dwivedi et al., 1977, Jefferies et al., 1979, Kant and Anand, 1979) Singh et al., 2002, reported higher pH during PreM Devi and Sharma, 2003 reported lowest pH during M In the present study, higher water
pH was reported during PreM while less was observed during M. This finding is similar with that of Dwivedi et al., 1977; Jefferies et al., 1979 and Kant & Anand, 1979, however it is not similar with the finding of Devi & Sharma, 2003. This may be due to higher photosynthetic activity or may be due to decrease in water level caused by evapotranspiration of water. Adoni, 1975; Verma, 1994; Raman, 1980 and Bose, 1968, also support this finding. The pH of soil is less in PoM. Absolutely similar soil pH was found during PreM and M. This may be due to heavy deposition of fluoride and phosphate during the M and high solar radiation, high temperature and less rain fall in PreM. pH of soil regulates the diversity and distribution of biotic component. Little fluctuations from the pH may cause large biological change in the ecosystem. In the present study it is observed that, fluoride is negatively correlated with pH of water and soil. pH of soil influences nutrient absorption and plant growth through its direct effect on the hydrogen ion and indirect influence on the nutrient availability (Arunprasad et al., 1990; Cole, 1940.) Samal 1989, observed negative correlation between pH and fluoride.

4.5.4 Free carbon dioxide (CO₂) of water

Carbonate and bicarbonate ions are primarily derived from the dissolved CO₂. Presence of carbonic acid is indicated, when pH is less than 4.5 and more than 8.4 (Mahapatra, 2004). Free CO₂ is absent in the WHS having pH more than 8 (Hutchinson, 1978). Sharma et al., 1979, reported increased free CO₂ in PreM. Verma, 1967 reported, decrease of free CO₂ content in PoM. However the present studies varies significantly from their findings. It may be due to positive correlation of fluoride with the free CO₂ content of water. It may also be due to the free CO₂ content of water from a F-controlled community has inverse relation with the free CO₂ content of F- community. It may probably due to the reason that, rapid decomposition and high temperatures in the WHS are negatively correlated with the F-content. The findings of this study is also supported by Backer, 1981; Joshi & Tyagi 1997; Rautham et al., 1992 & Behura, 1998) They reported that, free CO₂ is supplied from atmosphere and CO₂ evolving as a by-product of community respiration. The F-deposition, which affects the physiology of respiration, may be a reason due to why the free CO₂ content is more during M.
2.4.5. Total alkalinity content of water

The total alkalinity affects the primary production and other metabolic processes of aquatic organism (Singh et al., 2002). The presence of carbonates, bicarbonates and hydroxide are the three main factors determining the alkalinity of fresh water bodies. The desirable limit for total alkalinity is 200 mg/l and the maximum permissible limit is 600 mg/l. High alkalinity values may be attributed to the action of carbonates upon the basic material in the soil. Such water gave an unpleasant taste. The total alkalinity is more during PreM than PoM (Mishra et al., 1999). Balkhi et al., 1987, reported the increasing in total alkalinity during PoM. The finding of this study is similar with this finding. It may be due to the concentration of high nutrient load in reduced volume of water during PoM.

The present study also reported, during PreM and M the total alkalinity content is found in desirable limit and in the PoM, it is slightly less than the desirable limit. This may be due to the less nutrient load in huge water and may be due to the concentration of fluoride present in water because fluoride is negatively correlated with the total alkalinity content of water.

2.4.6. Dissolved oxygen of water (DO$_2$)

The quantity of DO$_2$ in water is of prime importance. It can be used as pulse of the aquatic system and the environmental reactions of the system can be determined (Baker, 1981). DO$_2$ content regulated, primarily by free diffusion of oxygen air to water, production through photosynthesis, consumption by biota, DO$_2$ affects the solubility and availability of many nutrients and therefore productivity of aquatic ecosystem (Kumar, 2002). Highest value of DO$_2$ was recorded in PoM (Panda and Dash 1993; Wetzel, 1983). However the present study does not support this finding. In the present study higher value of DO$_2$ is reported during M followed with PreM (Mahapatra & Mishra, 2003; Mahapatra, 2005a and Mahapatra 2004b). This may be due to huge run off catchments in M, which allows this conversion of atmospheric oxygen in to aquatic oxygen, while flowing from high land to low land. This may also be due to the variation of temperature. The difference of the DO$_2$ content form natural community to F-community may be due to the positive correlation of the F with that of the DO$_2$ content. Singh et al., 2002, reported that the DO$_2$ content was high in PoM and minimum during M findings of this study does not support this.
hypothesis, because it may be due to versatile solubility ranges of fluorides in water.

Devi and Sharma, 2003 reported that the DO$_2$ content is high in surface water and low in bottom water. Finding of this study support this finding, as the DO$_2$ in RB is more than that of CT and FH. This may be due to less water temperature and the positive correlation of pH with DO$_2$ of water in the F-communities.

2.4.7. Fluoride distribution in communities

The perennial water bodies of FH and RB have more F- content. In CT the annual WHS have more F- content than perennial WHS. This may be due to the force of run off, storage of water, depth of WHS. C/N ratio, K content and the biodiversity present. In FH the force of run off is more and depth of WHS is less. The chances of evaporation are maximum in annual WHS hence it contains less amount of F- than the perennial water bodies. In RB, the WHS are eutrophicated due to the maximum amount of phosphorous entry and prevalent weeds (Groth, 1975).

The F-content in annual WHS of RB may be less than that of the perennial WHS. In CT the F- content is more in annual WHS than the perennial WHS may be due to huge run off catchments from CT as well as FH enters to the annual WHS. The fluoride thus enters to the annual WHS in CT along with the runoff, but the perennial WHS does not allow any run off entry due to storage of water.

The fluoride levels in different WHS are increases steadily and gradually year after year. It may be due to the heavy concentration of fluoride in soil (Groth, 1975; Lavardo and Reinaudi, 1979; Kessabi and Amouzigh, 1981; Behera, 2004) bleached of more and more by soil erosion, siltation, and salinity. The deterioration of soil surfaces increases year after year. This may be a major cause of increasing F- content in WHS. This results in increasing total alkalinity of the WHS.

The F- content was more during M than other seasons, may be due to the interaction of rainwater and soil surface, which bleaches considerable amount of fluoride entry to the belly of WHS. During the PreM it was less, as the
aquatic flora, fauna, animal husbandary and human absorb the most amount of fluoride present in the WHS during the whole year and most of the water was evaporated to the atmosphere. The F-content of PoM was lesser than monsoon but was higher than PreM. It may be due to the gradual F- absorption by the livestock and aqua diversity.

F-content in bore well was more than that of the tube well. It may be due to heavy amount of fluoride deposition in earth crust (Kessabi and Amouzigh, 1981). The bore well was deeper than tube well and in the deepest the ground water more amount of fluoride is reported (Harvey, 1952; Jolly et al., 1977). May be due to this reason the bore well contains more amount of F- than tube well. Marier and Rose (1975) also supported this theory as most soil samples show lower fluoride content near the surface than at depths.

2.5.8 Phosphate of water and soil

Phosphorus in water is inorganic while that at soil is available phosphorous (Mahapatra, 2004; Mahapatra and Mishra 2005). Phosphorous is an important factor to determine the magnitude of eutrophication. The amount of phosphorous found in older silted pond is high due to eutrophication. (Mahapatra, 2001). The muda and kata have higher concentration of phosphorous due to excess of nutrients load in the WHS (Mahapatra, 2001). The increasing concentration of phosphorous from high land to low land is correlated with the run off entry, siltation, soil erosion and salinity. Thus with these parameters of soil a huge quantities of fluoride enters to the belly of the WHS. In the present study, inorganic phosphorous was more during M and the available phosphorous was more during PreM. This may be due to the phosphorous entry to the water in the form of agrochemicals, pesticides, fertilisers from the adjacent paddy fields. The phosphorous content of soil was more during PreM may be due to heavy amount of nutrient load and less amount of water in the WHS of F-community. The fluoride is positively correlated with the inorganic phosphorous and negatively correlated with the available phosphorous, this is also supported by Samal, 1989.
2.5.9. C/N ratio of soil

Carbon and nitrogen are two parameters affecting the fish diversity and soil fertility. Fish diversity was found positively correlated with the C/N and DO₂ content (Mahapatra & Mishra, 2003). In the present study, the C/N ratio was more during M, may be due to the enhancing fertility and productivity of the ecosystem (Schleisinger, 1997). Its chemical composition, distribution, concentration and movements with in the soil are of great pedogenetic and applied importance (Lavelle & Spain, 2001). In this study maximum amount of carbon is found in PreM. It may be due to the predominant deposition in the living biomass and dead organic matter in the soils in PreM. It is also supported by Lavelle & Spain, 2001.

Nitrogen is critical to all forms of life. As nitrogen is a component of nucleic acid, it has greater role in reproduction and evolution of the community. Its seasonal variation is may be due to the varieties of nitrogen compounds present in soil. In the present study, more amount of available nitrogen is present in PreM may be due to more nitrogen fixation in soil takes place in this season. The fluoride is negatively correlated with carbon and nitrogen.

2.5.10. Available potassium

All living organisms normally require potassium in relatively large amounts. It major roles in plants are pH stabilisation, osmoregulation, enzyme activation and membrane transport process at both cellular and physiological level (Masuda, 1969) Samal, 1989 observed available potassium decreases with increasing fluoride. The potassium has greater role in ecosystem. When it mixes with nitrogen and phosphorous in the ratio of 3-1-2 or 4-1-2 it forms NPK, (a chemical fertiliser), which is more abundant in M may be due to excessive use of fertiliser in adjacent paddy fields. It has positive correlation with the F-content. Along with the fluoride, NPK enhances the magnitude of oxygen and diversity of F-toxicity in the community ecosystem. Mahapatra, 2005, reported that the concentration of potassium ranges from 1 ppm or less to about 10 to 15 ppm in potable water. In this study we have observed only in PoM the potassium content is found in the range of potable water. Thus it may be concluded that in F- community the available potassium content in PreM and M are below the
desired limit for potable water, it may be due to the heavy deposition of fluoride in M and heavy phosphorus load in PreM.

2.5 CONCLUSION:

It could be concluded that, the fluoride was positively correlated with depth of water, free CO\textsubscript{2}, DO\textsubscript{2}, inorganic phosphorous and available potassium while it was negatively correlated with the temperature of water, pH of water and soil, total alkalinity available phosphorus, organic carbon and available nitrogen.

It was also concluded that, the concentration of fluoride was variable in different water sources in different seasons. It was found increasing with depth of soil and wits having eutrophication and vast catchments area. The year has no profound effect on the f-concentration of different water harvesting structures.