MATERIALS AND METHODS

Of the several water-bodies observed during field survey conducted almost in all parts of the district since 2007 following the District Planning Map procured from Survey of India Anon, 1994) as many as 38 wetlands were selected each having an area exceeding 3 acres. These water bodies are in possession of important wetland characteristics as laid down by United States Fish and Wildlife Services through their Circular 39, viz. (i) presence of water for at least seven successive days during growing season, (ii) the habitat supports aquatic macrophytes growing in water, soil and some other substrate that is periodically deficient in oxygen due to water logging in some parts of the year and (iii) the substrate is predominantly of hydric soils that are saturated or flooded for a sufficiently long period to become anaerobic in their upper layers. Cook’s (1996) consideration of wetland as a place where inundation must occur for about 14 days and saturation for at least about 60 consecutive days has also been adopted as a basis for identification of these wetlands.

The present work covers four major aspects, viz. Study of wetlands, Study of macrophytes and Resolution of remedial measures to restore and optimize wetland use. The methodology concerning these aspects has been dealt with separately in the following.

3.1. STUDY OF WETLANDS

3.1.1. Preparation of inventory of wetlands, their characterization and classification:

3.1.1.1. A brief resume of wetlands studied.

The 38 wetlands which are all static, i.e. non-tidal, inland and freshwater were selected covering the 19 Blocks of the district which. Each of these wetlands was with an area greater than or equal to 3 acres. Their names, wherever available, place of occurrence were recorded in the field note book and enumerated. A brief description of each of these was prepared subsequent to initial field survey.

3.1.1.2. Block wise distribution of wetlands studied:

The inventory has been prepared in such a way as to constitute a basic information system giving a precise account of location of each wetland in terms of latitude and longitude, nearest village or town, Block etc.).

3.1.2. General characteristics of wetlands and their classification:

These wetlands were periodically visited in different seasons for recording field observations on their hydrological features, biodiversity (mainly macrophytes), threat perceptions use pattern including annual fish production, existing mode of management etc. in the information collecting sheet. An information collecting sheet used in this context which
was designed more or less adopting the ones used by Zalidis and Mantzavelas (1996) while studying the Greek wetlands. The information collecting sheets thus used included such aspects as location, area, uses, the pressures threatening the wetland, the legal status and the positive actions. During field work eco-sucessional characteristics of wetlands as determined by their macrophytes were also observed and recorded. The names and address of local informants (wetland users, representative of the Local Self Govt. i.e. Gram Panchayat or Municipality and other officials, teachers, students etc.) who were used as primary data sources have also been documented (Table 19). The information thus recorded was used for characterization and classification of the concerned wetlands.

According to Zalidis et al., (1997) the choice of classification system is the main consideration when an inventory effort begins and it comprises the infrastructure for distinction of different wetland units and types of data collected. As such, 38 wetlands have thus been classified in this work using the different parameters, viz. location, ownership pattern, size, hydrological features, source of pollution, plant and animal diversities, use pattern, sucessional characteristics, problems faced by wetlands and ongoing management programmes recorded against each wetland. The results have been expressed in pie-charts.

### SURVEY OF WETLANDS

**INFORMATION COLLECTING SHEET**

**General Information:**

- **District:**
- **Block:**
- **Police Station:**
- **Mouza:**
- **Nearest Village/Town:**

**About the person interrogated:**

- **Name:**
- **Sex:**
- **Age:**
- **Occupation:**
- **Religion/caste**
- **Educational qualification:**

**About the wetland:**

1. What is the local name of the wetland?
2. What is the ownership pattern of the wetland?
   - [Private(singlerjoinownership)/Government/Panchayat/Cooperative]
3. What is the nature of wetland?
   - [Natural/Man-made]
4. What is the approximate area of the wetland(in acres)? (5-10; 10-15; 15-25; 25-50; 50-100; 100-200; 200-500; 500 acres and more)
5. What type of wetland is it? (Perennial/Seasonal)
   a) If seasonal, in which part of the year there is water scarcity or total dryness?
b) Maximum depth (ft.)  [month]  Minimum depth (ft.)  [month]
Average depth (ft.)  [Annual]

6. What is the source of water?  (River/canal/spring/runoff from adjacent high land/rain water)

7. Type of water: (fresh/brackish/saline)

8. What type of land forms the adjacent scenario?  
   (Grassland/forest/wasteland/agricultural land/mined land etc.)

9. Type of soil  (Laterite/alluvial)

10. Type of aquatic plant (Macrophytes only/microphytes only/both micro- and macrophytes/none)

11. Types of macrophytes  
   [free floating on surface/rooted submerged/rooted with floating leaves/freefloatingandsubmerged/ emergent/ hydrophilous/ combination of _____ types (to be mentioned) or all types]

12. Aquatic macrophytes to be enumerated

13. Avi-fauna, if any (local and migratory birds/local birds only)  Names to be written, if identified. Other relevant information like approximate number of migratory birds visiting the wetland every year and the tenure of such visits etc.

14. Are the people of the locality aware of the functions and values of the wetland?  (Yes/No)

15. In what way(s) is (are) the wetland used?  
   (Pisciculture/domesticuse/juteretting/irrigation/directly for agriculture/tourism and recreation /other uses/not used)

16. How are the plants of the wetland used?  
   (Plant species of the wetland to be enumerated along with their local uses)

17. Whether used as a source of  
   (Food/fodder/thatching material/medicines/ mat preparation etc. for own use/commerce/both personal use and commerce)

18. How are the aquatic animals used?  
   (Animal species to be enumerated along with their local uses)

19. If pisciculture is in vogue then:  
   i) What is the method practised?  (Scientific/traditional)
   ii) What types of fishes are cultured?
   iii) What is the annual fish production?.
   iv) How many families/persons are benefited from pisciculture.
   v) Is there any society formed by the people for pisciculture?
   vi) How is the society functioning?
   vii) Has it stopped functioning?

What are the reasons for their success/failure?
20. Domestic use:
How is the water used?
   [for drinking purpose/bathing/cleaning utensil and laundering/cattle
bathing/car and other vehicle washing/different purposes (to be specified)]

21. In case of use of the wetland for irrigation:
   i) What is the total area irrigated?
   ii) In which part of the year is it used for irrigation?
   iii) What are the different crops that receive water from it?
22. In case of direct use of the wetland in agriculture.
   i) Is the wetland totally/partly converted to agricultural field in dry season?
   ii) Is it partly/totally used for agriculture in wet seasons?
   iii) What are the crops/vegetables raised in wetland?
   iv) To what extent has there been shrinkage of the wetland due to agriculture?

23. Is the wetland used in jute retting? (Yes/No)

24. What are the problems faced by the wetland?
   (Shrinkage/dehydration/depletion of plant and animal resources/pollution/eutrophication
    /siltation/salinity/local dispute/overuse etc.)

25. The reason(s) for shrinkage of wetland, if any:
   (human colonization/road construction/silviculture/agriculture/other reasons)

26. If the wetland is polluted, what is its source?
   (Pesticide/biocides/industrial effluents/retting of jute/input of sewage/washing of auto
    mobiles/washing of clothes and bathing of cattle/other sources/composite reason as
    mentioned/none)

27. Specify the reason for eutrophication, if any:
   [industrial effluents/agricultural run-off/domestic sewage/combination of these (to be
    specified)]

28. Status of plant diversity (Poor/moderate/rich)

29. Status of animal diversity (Poor/moderate/rich)

30. What steps have the people of the locality taken for sustainable use and conservation of
    water as well as plant and animal diversities?

31. Are the people aware of:
   i) Wildlife Protection Act?
   ii) Town and country Planning Act, West Bengal, 1979.
   iii) Inland Fisheries Act, 1984 and Indian Fisheries Act (Amendment, 1993):

32. Is there any problem in implementation of legislation?

33. Has the Govt/Panchayat/NGO/local people taken any step towards mitigation of
    pollution, proper use and conservation of water and bio-resources? (A brief account to be
    prepared)

34. What Govt. Projects were/are in operation on this wetland?
   (to be specified whether the Project is for growth of awareness, restoration or pisciculture or
   development of a tourist spot)
35. What are the problems associated with implementation of the Project(s) (Non-cooperation/illiteracy/lack of awareness etc.).

Table 19: List of persons from whom information regarding wetlands and their uses were recorded:

<table>
<thead>
<tr>
<th>Name of the Wetland</th>
<th>Place</th>
<th>Name of the person from whom information was procured</th>
<th>Address of the concerned person</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adra Sahebbundh</td>
<td>Adra</td>
<td>S. Sengupta</td>
<td>D.C. Water supply Office, Adra, Puruliya</td>
</tr>
<tr>
<td>Angarkhuri</td>
<td>Chharra</td>
<td>Jabbar Bauri</td>
<td>Labourer, Chharra, Puruliya</td>
</tr>
<tr>
<td>Babirbundh/Sabirbundh</td>
<td>Babiddi</td>
<td>Sibu Dutta, Gopal Chandra Hazra</td>
<td>Moneylender, Babiddi, Puruliya; Worshiper, Gourangadi Junior High School, Gourangadi, Puruliya</td>
</tr>
<tr>
<td>Barikbundh</td>
<td>Raghunathpur</td>
<td>Bimal Mandal</td>
<td>Raghunathpur, Puruliya</td>
</tr>
<tr>
<td>Benabundh</td>
<td>Manbazar</td>
<td>Srikanta Paoria</td>
<td>Mason, Male, 32+</td>
</tr>
<tr>
<td>Benagora</td>
<td>Sankra</td>
<td>Samir Maji</td>
<td>Student, Sankra, Para, Puruliya</td>
</tr>
<tr>
<td>Burosayar</td>
<td>Mangalda</td>
<td>Rabilal Murmu</td>
<td>Aamaidi, Guniyara, Puruliya</td>
</tr>
<tr>
<td>Desh bundh</td>
<td>Kharbar</td>
<td>Shyamal Mandal</td>
<td>Tiyashi, Santuri, Puruliya</td>
</tr>
<tr>
<td>Dewanbundh</td>
<td>Kalidaha</td>
<td>Sudhir Bauri</td>
<td>Jagannathdi, Gourangadi, Puruliya</td>
</tr>
<tr>
<td>Dhanarbundh</td>
<td>Akunga, Raghunathpur</td>
<td>Bimal Mandal; Rabilal Murmu</td>
<td>Raghunathpur, Puruliya; Aamaidi, Guniyara, Puruliya, Asst. Teacher, Maldanga R. M. institution Burdwan</td>
</tr>
<tr>
<td>Ganakbundh</td>
<td>Damda</td>
<td>Baru Bauri</td>
<td>Damda, Puruliya; Railway Staff, Engineering Department, S. E. Railway, Puruliya</td>
</tr>
<tr>
<td>Gayerbundh</td>
<td>Tiyashi</td>
<td>Shyamal Mandal</td>
<td>Tiyashi, Santuri, Puruliya</td>
</tr>
<tr>
<td>Gaylabundh</td>
<td>Lalpur</td>
<td>Dipankar Kundu</td>
<td>Trader, Lalpur market, Hura, Puruliya</td>
</tr>
<tr>
<td>Ghoshalpukur</td>
<td>Puncha</td>
<td>Shakti Pada Modak</td>
<td>Trader, Puncha market, Puncha, Puruliya</td>
</tr>
<tr>
<td>Gobindasayar</td>
<td>Patharmura</td>
<td>Debasis Narayandeub</td>
<td>Patharmura, Puruliya</td>
</tr>
<tr>
<td>Gorsailbundh/ Namobundh</td>
<td>Gorsai</td>
<td>Ram Jiban Mahanti</td>
<td>Gorsai, Barabazar, Puruliya</td>
</tr>
<tr>
<td>Guniyara Bara Bundh</td>
<td>Guniyara</td>
<td>Rabilal Murmu</td>
<td>Aamaidi, Guniyara, Puruliya</td>
</tr>
<tr>
<td>Hanumata Dam</td>
<td>Mudidi, Dumari, Khairadi</td>
<td>Sadhu Charan Mandal</td>
<td>Ex-panchayet Pradhan, Balarampur, Puruliya</td>
</tr>
</tbody>
</table>

Materials & methods
### Materials & methods

Table 19: List of persons from whom information regarding wetlands and their uses were recorded:

<table>
<thead>
<tr>
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<th>Name of the person from whom information was procured</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Joypur Ranibundh</td>
<td>Joypur</td>
<td>Bhagbat Kumar; Surya Kumar</td>
<td>Barabenda, Joypur, Puruliya</td>
</tr>
<tr>
<td>Kalidaha Jore</td>
<td>Kalidaha</td>
<td>Sagar Das; Sudhir Bauri</td>
<td>Herbalist, Rampur, Puruliya</td>
</tr>
<tr>
<td>Kamalabundh</td>
<td>Baghmundi</td>
<td>Bhabani Singhadeb; Jagannath Singha Deb</td>
<td>Baghmundi, Puruliya, Baghmundi, Puruliya</td>
</tr>
<tr>
<td>Ketankiyari Jore</td>
<td>Ketankiyari</td>
<td>Sudhir Bauri</td>
<td>Jagannathdi, Gourangadi, Puruliya</td>
</tr>
<tr>
<td>Khagerbundh</td>
<td>Puncha</td>
<td>Shakti Pada Modak</td>
<td>Trader, Puncha market, Puncha, Puruliya</td>
</tr>
<tr>
<td>Kumaridam</td>
<td>Baraurma, Dubraj pur, Panjanbera</td>
<td>Malay Choudhury</td>
<td>Puruliya Jellar, Nadnadi</td>
</tr>
<tr>
<td>Lihirbundh</td>
<td>Jhalda</td>
<td>Sarat Chatterjee</td>
<td>Ex-sanity Inspector, Municipality Office, Jhalda, Puruliya</td>
</tr>
<tr>
<td>Mahatobundh</td>
<td>Pithati, Kantadi</td>
<td>Chandra Mohan Mahato; Ajit Mahato</td>
<td>Korang, Arsha, Puruliya, Korang, Arsha, Puruliya</td>
</tr>
<tr>
<td>Maidhara</td>
<td>Patharmura</td>
<td>Debasis Narayan Deb</td>
<td>Patharmura, Puruliya</td>
</tr>
<tr>
<td>Nutanbundh</td>
<td>Puruliya</td>
<td>Bishwanath Chattoraj</td>
<td>Head Clerk, Puruliya Municipality Office, Puruliya</td>
</tr>
<tr>
<td>Pokabundh</td>
<td>Banduan</td>
<td>Rabindranath Kar</td>
<td>Sabhadhipati, Puruliya Zilla Parisshad, Puruliya</td>
</tr>
<tr>
<td>Purano Sayar</td>
<td>Chharra</td>
<td>Jabbar Bauri</td>
<td>Labourer, chharra, Puruliya</td>
</tr>
<tr>
<td>Rajabundh</td>
<td>Puruliya</td>
<td>Bishwanath Chattoraj; Puruliya Darpan</td>
<td>Head Clerk, Puruliya Municipality Office, Puruliya, Thursday</td>
</tr>
<tr>
<td>Rampur Barabundh</td>
<td>Rampur</td>
<td>Ambuj Mandal</td>
<td>Farmer, Rampur, Puruliya</td>
</tr>
<tr>
<td>Ranibundh</td>
<td>Baghmundi</td>
<td>Bhabani Singhadeb; Jagannath Singha Deb</td>
<td>Baghmundi, Puruliya, Baghmundi, Puruliya</td>
</tr>
<tr>
<td>Ruknibundh</td>
<td>Guniyara</td>
<td>Rabilal Murmu</td>
<td>Aamaidi, Guniyara, Puruliya</td>
</tr>
<tr>
<td>Sahebbundh/ Nibaransayar</td>
<td>Puruliya</td>
<td>Bishwanath Chattoraj; Shyamal Kishore Teowary</td>
<td>Head Clerk, Puruliya Municipality Office, Puruliya, Rukshya Buje Jaller Ban, Sahebbundh</td>
</tr>
<tr>
<td>Sankra Barabundh</td>
<td>Sankra</td>
<td>Samir Maji</td>
<td>Student, Sankra, Para, Puruliya</td>
</tr>
</tbody>
</table>

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Survey of Wetlands in Puruliya District
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<thead>
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<th>Name of the person from whom information was procured</th>
<th>Address of the concerned person</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sayerbundh</td>
<td>Khariduara</td>
<td>Bhaskar Chandra Mahato</td>
<td>Khariduara, Manbazar-2, Puruliya</td>
</tr>
<tr>
<td>Sindripathar</td>
<td>Karangberiya</td>
<td>Sagar Das</td>
<td>Herbalist, Rampur, Puruliya</td>
</tr>
</tbody>
</table>

3.1.3. Phenetic Classification (Cluster analysis):

For phenetic classification or cluster analysis of the 38 wetlands studied as many as 34-two state unit characters each of which exists in two alternative forms or states i.e. either present [or ‘Yes’] or absent [or ‘No’] (Table 20). Responses of each wetland to each of these characters were coded in a data matrix as ‘1’ and ‘0’ respectively for two alternative states i.e. presence [Yes] or absence [No]. The data thus recorded were further utilized in finding the overall similarities or rather the natural relationship (distance between wetlands) and putting them in clusters using the concept of ‘Euclidean Distance’ for measuring distance and ‘Complete Linkage’ for amalgamation or linkage. The software Statistica version 5.0 was used for the purpose which provides a common technique for data analysis to assign a set of observations into subsets (clusters) so that observations in the same cluster are similar in some sense. Of the different linkage or amalgamation rules to determine when two clusters are sufficiently similar to be linked together, the complete linkage (furthest neighbor) rule has been used. In this method the distances between clusters are determined by the greatest distance between any two objects in the different clusters i.e., by the "furthest neighbors"(Hill and Lewicki, 2007; Electronic Version: Stat Soft, Inc., 2011).

The Euclidean distance was determined by using the following formula:

\[
\text{Distance (X, Y)} = \left( \sum_{i=1}^{n} (V_{xi} - V_{yi})^2 \right)^{\frac{1}{2}}
\]

Where, \(d (X, Y)\) is the distance between the units X and Y, \(n\) is total number of characters, \(V_{xi}\) the character-state value of X for character ‘I’ and \(V_{yi}\) is the character-state value of Y for character ‘I’. A vertical ‘Hierarchical Tree Plot’ was obtained where the vertical axis denotes the linkage distance and the horizontal axis denotes the objects, i.e. the wetlands. In the graph, at each node where a new cluster was formed, the criterion distance at which the respective elements were linked together into the new single cluster, was read out and recorded.
Table 20. The unit characters used in phenetic classification of the wetlands

<table>
<thead>
<tr>
<th>CHARACTERS</th>
<th>CHARACTER STATES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location in rural setting</td>
<td>Yes</td>
</tr>
<tr>
<td>Ownership under Government</td>
<td>Yes</td>
</tr>
<tr>
<td>Wetland of natural origin</td>
<td>Yes</td>
</tr>
<tr>
<td>Area within 10 acres</td>
<td>Yes</td>
</tr>
<tr>
<td>Wetland with water throughout the year</td>
<td>Yes</td>
</tr>
<tr>
<td>River water as the main water source</td>
<td>Yes</td>
</tr>
<tr>
<td>Rain water as the main water source</td>
<td>Yes</td>
</tr>
<tr>
<td>Agricultural fields in the vicinity</td>
<td>Yes</td>
</tr>
<tr>
<td>Forests in the vicinity</td>
<td>Yes</td>
</tr>
<tr>
<td>Wetland used exclusively for pisciculture</td>
<td>Yes</td>
</tr>
<tr>
<td>Wetland used for domestic purposes</td>
<td>Yes</td>
</tr>
<tr>
<td>Wetland used excessively in irrigation</td>
<td>Yes</td>
</tr>
</tbody>
</table>

3.1.4. Physico-chemical characterization of water samples:

Out of the 38 wetlands studied, three, viz. Adra Sahebbundh, Joypur Ranibundh and Sahebbundh or Nibaran Sayar (‘Bundh’ is a vernacular term applied to the wetlands by the local people) were selected for studying the physico-chemical properties of their water and sediments. Water and soil samples (five in each case) were collected during the post-monsoon season of the years 2010 and 2011 and the minimum, maximum and the mean were
tabulated. The post-monsoon season was selected for this study since the wetlands overflow in monsoon and often many of them receive debris from the vicinity and in the dry pre-monsoon period dehydration leads to much contraction of water-bodies. The post-monsoon season especially the months of November and December, was thus considered ideal.

The physico-chemical parameters studied (Table 21) were pH, Transparency (Tran), Turbidity (Turb), Total Dissolved Solids (TDS), Electrical Conductivity (EC), Total Hardness (TH), Acidity (Acd), Alkalinity (Alk), Dissolved Oxygen (DO), and Biological Oxygen Demand (BOD).

**Table 21: Methods used for studying different physico-chemical parameters of water samples.**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Studied by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ph</td>
<td>Electronic method using pH meter</td>
</tr>
<tr>
<td>Tran (Cm)</td>
<td>Secchi disc method</td>
</tr>
<tr>
<td>Turb (NTU)</td>
<td>Nephelometric method</td>
</tr>
<tr>
<td>TDS (mg/l)</td>
<td>Gravimetric method</td>
</tr>
<tr>
<td>EC (µmho/cm)</td>
<td>Conductimetric method</td>
</tr>
<tr>
<td>TH (mg/l)</td>
<td>Titrimetric method (EDTA)</td>
</tr>
<tr>
<td>Acd (mg/l)</td>
<td>Colour indicator Titrimetric method</td>
</tr>
<tr>
<td>Alk (mg/l)</td>
<td>Colour indicator Titrimetric method</td>
</tr>
<tr>
<td>DO (mg/l)</td>
<td>Iodometric method</td>
</tr>
<tr>
<td>BOD (mg/l)</td>
<td>Dilution method</td>
</tr>
</tbody>
</table>

The sensitive water parameters like Turbidity, Suspended Solids, pH, Acidity, Alkalinity, and Dissolved Oxygen were analyzed on the spot with the help of a ‘Surface Water Testing Kit’ containing essential reagents and glass wares, whereas water samples for estimation of Specific Conductance, Total Hardness, and Biological Oxygen Demand, were brought to the laboratory for analysis.

For collection of water sample, water was filled in 500 ml plastic bottles from three portions separately (from periphery to middle) of each of the three wetlands selected. The plastic bottles were washed with source water before filling them up. Four readings of each parameter were taken with each water sample and the values thus obtained with all the sets of collections made from each wetland were added to find out the mean value. The tests were performed by following standard methods given by American Public Health Association (APHA, 1998), Jadav and Jogdan (1993), Central Pollution Control Board (CPCB, 1978) and Tribedi and Goel (1992). The significance of different water quality parameters, reagent preparation and the principles of their measurement are described in the following.
i. Transparency (Tran):
Solids including dissolved materials (calcium, nitrogen, phosphorus, iron, sulphur and other ions) and particulate matters that are suspended in the water (silt and organic solids) determine directly turbidity and indirectly transparency of water. Transparency is inversely proportional to dissolved solids and suspended particle. It may also have adverse effect on the aquatic life. Lower value is aesthetically unsatisfactory and may produce distress in human and live-stock. Transparency of a water body is recorded with a Secchi disc. Secchi disc is immersed in water till it is invisible. The Secchi depth from water surface is recorded in cm.

ii. Turbidity (Turb):
Suspension of particles in water interfering with passage of light is called turbidity. Turbidity in water is caused by suspended and colloidal matter such as clay, silt, finely divided organic matter, plankton and other microscopic organisms. Besides their unacceptability on aesthetic grounds, turbid water causes difficulties in filtration and disinfections. The permissible range (BIS, 2003) for turbidity is 5-10 NTU. Higher turbidity is reported to cause gastrointestinal irritation and hampers photosynthesis of aquatic plants, phytoplankton etc., thereby decreasing the dissolved oxygen (DO) level.

Principle of measurement: A Secchi disc was progressively dipped into water till the disc disappeared. This depth was measured (d1). Then the set was carefully lifted upward to note the level where the disc reappeared (d2). The turbidity was then determined from the value of \((d1+d2)/2\) in cm.

The readings obtained in metric unit (cm) were converted to Naphlometric Turbidity Unit (NTU). This conversion is based on the fact that the turbidity of the mixture containing 5 ml of 10% hexamethelene tetramine, 1% hydrazine sulphate and distilled water up to a final volume of 100 ml and representing 400 NTU standard is effective to disappear a cross mark down in a white paper at a height of 2.3 cm when observed vertically from the open end of a graduated nessler tube placing it on the marked paper. The average value of turbidity was finally calculated.

iii. Total Dissolved Solids (TDS):
TDS indicates the general nature of water quality related salinity. Determination of TDS is necessary to evaluate the fitness of water because it signifies the inorganic pollution load in the water. High values of TDS influence taste, hardness and corrosive property of the water, disturb the ecological balance and cause imbalance in osmotic regulation and suffocation in aquatic fauna even in the presence of fair amount of DO. Drinking water with TDS indicates its inferior potability and induces an unfavourable physiological reaction in transient consumers.
**Principle of measurement:** A well-mixed sample was filtered through a standard glass fiber filter paper, and the filtrate was evaporated to dryness in a weighted dish and dried to constant weight at 180ºC. The increase in dish weight represents the total dissolved solids which is measured by the formula: $\text{TDS (ml/l)} = \{(A-B) \times 1000\}/ \text{Sample volume (ml)}$ Where, $A$ = weight of dried residue + Dish (gm) $B$ = weight of dish (gm) 1000 is multiplied to convert it to mg/l since A minus B is in decimal value of gram.

**iv. Electrical Conductivity (EC):**

Conductivity is of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions; on their total concentration, mobility, valence and also on temperature during measurement. Conductivity value, an excellent indicator of TDS, is also a measure of salinity that affects the taste of potable water. Solutions of most inorganic compounds are relatively good conductors.

**Principle of measurement:** Conductance, $G$, is defined as reciprocal of resistance, $R$; i.e. $G=1/R$ where, unit of $R$ is ohm and $G$ is ohm$^{-1}$ (mho). Electrical conductance of a solution, $G$, is directly proportional to the electrode surface area, and inversely proportional to the distance between the electrodes, $L$. So $G = k(A/L)$ where, $k$ is the constant of proportionality known as the conductivity, which is expressed in mho/cm. The conductivity meter used in the measurement is calibrated in $\mu$mho/cm.

**v. pH:**

$\text{pH}$, the negative logarithm of hydrogen ion concentration, is one of the most important water quality parameters. It is the measure of acidity. At a given temperature the intensity of the acidic or basic character of a solution is indicated by its pH value. The determination of pH is an important factor because the solubility of carbon and the concentration of various carbonate species depend on the pH of water. The recommended range of pH for drinking and other human use is 6.5-8.5. Water of low pH has the ability to dissolve many metals and carry their toxicity. Besides, highly acidic or alkaline nature of water may be detrimental to vital biological process. A higher value of pH hastens the scale formation in water heating apparatus and reduces the germicidal potential of chlorine. Water with pH value below 6.5 is likely to start corrosion in pipes carrying it.
Reagent preparation:

**Standard buffer solution**: Standard buffer solution of known pH value were prepared by mixing commercially available PH tablets was PH value 4.01, 7.0 and 9.2 respectively. Each buffer solution was a volume of 100 ml with a single tablet into it.

**Principle of measurement**: The basic principle of electrometric pH measurement is determination of the activity of hydrogen ions by potentiometric measurement using a standard hydrogen electrode (glass electrode) and a reference electrode. The electromotive force (emf) produced in the glass electrode system varies linearly with pH. The linear relationship is described by plotting the measurement emf against the pH of different buffers. pH value of the samples is determined by extrapolation.

The pH-measuring instrument is calibrated using buffer of the National Institute of Standards and Technology (NIST) having assigned value:

\[ \text{pHB} = -\log_{10} aH^+ \]

where, \( \text{pHB} \) = assigned pH of NIST buffer

\( aH^+ \) = denotes single ion activity.

The operational pH scale is used to measure sample pH which is defined as

\[ \text{pHS} = \text{pHB} \pm \frac{F(\text{EX}-\text{ES})}{2.303\text{RT}} \]

where, \( \text{pHS} \) = potentiometrically measured sample pH

\( F = \) Faraday: 9.649x104 Coulomb/mole,

\( \text{EX} = \) Sample emf. (V),

\( \text{ES} = \) buffer emf (v),

\( R = \) gas constant: 8.314 J/ (mole 0K) and

\( T = \) absolute temperature. (0K) of the solution

vi. Total Hardness (TH):

It is a measure of the capacity of water to precipitate soap. Soap is precipitated chiefly by the calcium and magnesium ions present in water. Hardness is caused due to the presence of certain divalent cat ions like calcium, magnesium and strontium etc. In conformity with current practice, total hardness refers to the sum of calcium and magnesium concentrations, both expressed as calcium carbonate (CaCO3) in milligrams per liter. The hardness may range from zero to hundred of milligrams per liter, depending on the source and treatment to which the water has been subjected. Hardness of water when more than 100 ml/l is termed as hard water and it is as congenial as soft water for human consumption. Measurement of hardness is done by ethylene diamine-tetra-acitic acid (EDTA) titrimetric method.
Reagent preparation:

a) **EDTA solution 0.01 (N):** 3.723gm of disodium salt of EDTA was dissolved in distilled water to made volume to 1 litre. Stored in polyethylene or pyrex bottle.

b) **Buffer solution:** a) 16.9 gm NH4Cl was dissolved in 1.43 ml of concentrated NH4OH 1.179 gm of disodium EDTA and 0.780 gm of MgSO4.7H2O were dissolved in 50 ml of distilled water. Mixed both (a) and (b) solutions and diluted to 250 ml with distilled water.

c) **Eriochrome Black T indicator:** 0.40 gm of Eriochrome Black T were grinded with 100 gm of NaCl (AR).

d) **Sodium Sulphide solution:** 5.0 gm of Na2S. 9H2O or 3.7 gm of Na2S. 5H2O was dissolved in 100ml of distilled water and stored in tightly closed bottles.

e) **Principle of measurement:** Sodium salt of ethylene-di-aminetetra-acetic acid forms a chelated soluble complex when added to a solution containing calcium and magnesium ions at a pH of 10.0 ± 0.1. Calcium and magnesium ions develop wine red colour with erichrome black-T under alkaline condition. When it is titrated with EDTA, calcium and magnesium ions form the soluble complex and the colour gets changed from wine red to blue indicating the end point of the reaction. This shows the total hardness which is calculated with reference to a blank as: TH as CaCO3 (mg/l) = \(((A-B) \times 1000 \times 100 \times 0.01M)/ml \text{ sample})\) Where, A= volume of EDTA required B = volume of EDTA required by sample consumed for blank 100 is the molecular weight of CaCO3 and 0.01 is the molarity of EDTA and 1000 is multiplied to convert it to mg/l. When pH of the sample is raised to 12.0, only calcium ions precipitate out and magnesium ions remain in the solution. For determination of calcium hardness murex indicator is added to form a pink coloured complex with calcium ions which is then titrated with EDTA resulting in a change of colour from pink to violet indicating the end point of the reaction i.e. all the calcium ions get in the complex with EDTA. Calcium hardness is calculated like total hardness and the magnesium hardness of water is obtained by subtracting the calcium hardness from total hardness.

vii. **Acidity (Acd):** The acidity of water is a measure of its capacity to neutralize acid. The acidity of water is mainly due to the presence of various salts of acid. The major portion of acidity in natural water is caused by increase of hydrogen ion concentration. Acidic water has a low PH value. The determination of acidity is very significant due to:

a) The purpose of water use.

b) The healthy of water body.

c) Acidic water easily harmful for aquatic flora and fauna.
d) Water acidity increases.

**Reagent preparation:**

a) **Methyl orange indicator:** 0.5gm dry methyl orange powder was dissolved in 100ml of 95% alcohol.

b) **Phenolphthalein indicator:** 0.5gm of phenolphthalein was dissolved in 50 ml of 95% Ethanol and were added 50 ml of distilled water and 0.05 (N) CO2 free NaOH solution

Drop-wise until the solution turns faintly pink.

**Principle of measurement:** 100 ml of water sample was taken in a conical flask. A few drops of phenolphthalein was added to it. After adding phenolphthalein the colour of the solution was not change, the solution remains colour. 2-3 drops of methyl orange was added to the sample and continue to titrate against NaOH solution till the colour changes from pink to yellow.

Acidity of water was calculated as follows:

Acidity of water=(BxN) of HCL x 1000 x 50 mg/litre

Where B= ml of NaOH; N=0.1 ml of sample.

viii. Alkalinity (Alk):

It is a measure of an aggregate property of water and is primarily a function of carbonate, bicarbonate and hydroxide content. Phosphates, borates and silicates, if present, also contribute to alkalinity value. Alkalinity of water is its acid-neutralizing capacity. It is the sum of all the titrable bases. Colour indicator titration method has been adopted for determination of alkalinity.

**Reagent preparation:**

a) **HCl solution 0.1 (N):** 12 (N) concentration HCl was diluted to 12 times to have 1.0 (N) HCl, diluted it further 10 times to prepared 0.1 (N) HCl. Standardised it against Na2CO3 solution.

b) **Na2CO3 solution 0.1 (N):** 5.30gm of Na2CO3 (predried 250° C for 4 hours) was dissolved in distilled water to prepared 1 litre of solution.

c) **Phenolphthalein indicator:** 0.5 gm of phenolphthalein was dissolved in 50ml of 95% ethanol, and were added 50 ml of distilled water and 0.05 (N) Co2 free NaOH solution drop-wise until the solution turns faintly pink.
d) **Methyl orange indicator**: 0.5 gm dry methyl orange powder was dissolved in 100ml of 95% alcohol.

**Principle of measurement**: Hydroxyl ions present in a sample as a result of dissociation or hydrolysis of solutes react with the standard acid, which is added to it. Alkalinity thus depends on the end-point pH used and it is calculated as:

\[
\text{Alk, (mg CaCO}_3/\text{l}) = \frac{A \times N \times 50 \times 1000}{\text{ml sample}}
\]

Where, 
- \(A\) = total acid (H2SO4) consumed
- \(N\) = normality of the acid
- 50 = equivalent weight of CaCO3 and
- 1000 is multiplied to convert alkalinity value to mg/l.

ix. **Dissolved Oxygen (DO)**:

All living organisms are dependent upon oxygen to maintain the metabolic processes that produce energy for growth and production. In natural and wastewater, DO levels depend on the physical, chemical and biological activities in the water-body. Less amount of DO in water bodies causes anaerobic decomposition of many organic materials present, which ultimately tends to cause the formation of noxious gases such as hydrogen sulphide and methane in addition to carbon dioxide. The analysis of DO plays a key role in water-pollution control activities and waste-water treatment process. Iodometric method has been adopted for DO analysis.

**Reagent preparation**:

a) **Sodium thiosulphate solution 0.025(N)**: 24.82gm of Na2S2O3.5H2O was dissolved in a pre-boiled distilled water and made up the volume to 1 litre. A pellet of NaOH or 0.4 gm of borax were added as stabilizer. This was 0.1 (N) stock solution. Diluted it four times to have 0.025 (N) solution (250-1000ml). Stored in a brown glass bottle.

b) **Alkaline potassium iodide solution**: 100gm of KOH and 50gm of KI were dissolved in 200ml of pre-boiled distilled water.

c) **Manganous sulphate solution**: 100gm of MnSO4.4H2O was dissolved in 200ml of distilled water and heated to dissolve maximum salt, filtered when it was cool.

d) **Starch solution**: 1gm of starch was dissolved in 100ml of distilled water, and warmed for complete dissolution.
Principle of measurement:

The iodometric method is based on addition of divalent manganese solution, followed by strong alkali to the sample in a specified glass-stoppered bottle. DO rapidly oxidizes an equivalent amount of the dispersed divalent manganous hydroxide to precipitate hydroxides of higher valence states. In the presence of iodide ions in an acidic solution, the oxidized manganese reverts to the divalent state with the liberation of iodine equivalent to the original DO content.

The basis of calculation is as follows:

For titration of 200ml of sample,

1ml of 0.025 sodium thiosulphate (Na2S2O3) = 1mg DO/l

x. Biological Oxygen Demand (BOD):

Biological oxygen demand (BOD) is a measure of the quantity of oxygen required by a definite volume of the liquid effluent for oxidizing the organic matter contained in it by micro-organisms under specific conditions. The dissolved oxygen content of the sample with or without dilution is measured before and after incubation at 27°C for 5 days.

Reagent preparation:

a) Manganese sulphate solution: 100gm of MnSO4.4H2O was dissolved in 200ml of distilled water and heated to dissolve maximum salt, filtered when it was cool.

b) Alkaline potassium iodide solution: 100gm of KOH and 50 gm of KI were dissolved in 200ml of pre-boiled distilled water.

c) Starch solution: 1 gm of starch was dissolved in 100 ml of distilled water, warmed for complete dissolution.

d) Sodium thiosulphate solution 0.025 (N): 24.82 gm of Na2S2O3.5H2O was dissolved in a pre-boiled distilled water and made up the volume to 1 litre. A pellet of NaOH or 0.4gm of borax were added as stabiliser. This was 0.1 (N) stock solution. Diluted it four times to have 0.025(N) solution (250-1000ml). Stored in a
brown glass bottle.

**Principle of measurement:**
The BOD of the sample is measured by the formula:

\[
\text{BOD mg/l} = \frac{(\text{DO}-\text{D1}) - (\text{BO}-\text{B1})}{P}
\]

Where, DO = DO of the diluted sample immediately after preparation  
D1 = DO of the sample after 5 days of incubation at 27 °C.  
BO = DO of the blank (With dilution water) immediately after preparation.  
B1 = DO of the blank after 5 days of incubation at 27 °C  
P = Decimal volumetric fraction of sample used.

3.1.5. Physico-chemical characterization of sediment samples (soils):

In the present study eight chemical properties viz. pH, specific conductance, acidity, alkalinity, organic carbon, total nitrogen, available nitrogen, available phosphorus and available potassium in the sediment sample were analyzed following the methods prescribed by Piper (1966), Nath *et al.* (1994) and Behera (2006).

The samples were collected from different locations (from periphery to centre) of each of three selected wetlands and then composite samples were prepared for respective water body. Composite samples were then dried in air and powdered with a wooden hammer, strained initially through a 2mm and finally through an 80 mesh sieve respectively. Four readings of each of the following parameters were noted with each composite sample and their mean value was determined.

i. **pH:**

Hydrogen ion concentration or pH in a soil at a given time is the reflection of the status of biogeochemical processes because the temporal changes in pH are presumably due to change in primary production, respiration, mineralization and decomposition of organic matter in the soil.

The pH depends largely on relative amounts of the adsorbed hydrogen and metallic ions in sediment. So, it is a good measure of acidity and alkalinity of a soil water suspension and provides a good identification of the soil chemical nature. The adsorption and distribution of the various cations on soil particles, release of bases and the solubility of many soil constituents are controlled by pH of the soil. The pH of soil is correlated with the amount of calcium and magnesium, solubility of iron, aluminum, manganese, phosphorous and metabolic activity of micro-organisms.
ii. Specific Conductance

Reagent preparation:

Buffer solution: Standard buffer solutions of known pH value were prepared by mixing commercially available pH tablets with values 4.01, 7.0, and 9.2 with water. Each buffer solution was given a volume of 100ml using a single tablet.

Principle of measurement: Electrometric method

Procedure: 10 g of soil was taken in 50 ml beaker to which 25 ml of distilled water was added which needed shaking for half an hour. The electrode of pH meter was dipped in the suspension and the pH reading was taken. The optimum range is near neutral (7.0-7.5)

Since ions are the carriers of electricity, the electrical conductivity (EC) of soil system rises according to the content of soluble salt in the soil giving rise to more of ion pairs on dissociation as it happens in case of a dilute solution. Thus the measurement of EC can be directly related to the soluble salt concentration of the soil at any particular temperature.

Principle of measurement: Conductimetric method

Procedure: Soils were finely dusted and sieved. Then 20 g of soil sample was taken in a 250ml conical flask and 100ml of distilled water was added to it. Then the conical flasks with soil samples were placed on electrical shaker for continuous shaking for about 30 minutes. Then it was left for 5 minutes and the supernatant was carefully filtered through filter paper. The filtrate was transferred to the conductivity cell. The electrode was first rinsed with the soil solution and then immersed into it. The conductivity of the filtrate was determined against the conductivity of distilled water (control).

iii. Acidity (Acd):

Soil acidity is associated with the presence of hydrogen and aluminium ions on the exchange complex and the existence of an equilibrium solution of hydrogen ions in the interstitial water of soil. Acid soils generally have a pH value less than 6.5. In the humid region, a continued washing or leaching of the soluble bases like Ca, Mg, K, and Na ions takes place. This leaves behind the insoluble acid residues to accumulate and make the soil acidic. Continual removal of lime and accumulation of acid contained in many manures and fertilizer like ammonium sulphate also make the soil acidic.

Reagent preparation:

a) Phenolphthalein indicator: 0.5 gm of phenolphthalein was dissolved in 50 ml of 95% ethanol and were added 50 ml of distilled water and 0.05 (N) CO$_2$ free NaOH solution drop-wise, until the solution turns faintly pink.

b) Methyl orange indicator: 0.5 gm dry methyl orange powder was dissolved in 100 ml of 95% alcohol.

Procedure: 20 gm of air dry soil was weighted into a 100 ml beaker. 40 ml of distilled water (1:2) was added and was stirred briskly at least 4 times over a 30 minutes period. Wait for precipitation of soil sample into the beaker and filtered the residual water for titration. A few
drops of phenolphthalein indicator was added to the filtered soil solution. The colour was not change. 2-3 drops of methyl orange indicator was added to the original sample. Titrate the solution against with sodium hydroxide solution till the colour change.

Acidity of soil was calculated as follows:

\[ \text{Acidity of soil} = (B \times N) \times 1000 \times 50 \text{ mg/litre} \]

Where, \( B = \text{ml of NaOH} \); \( N = 0.1 \text{ ml of sample} \).

iv. Alkalinity (Alk): Alkaline soils usually have a pH value higher than 7.5. These soils contain high concentration of either soluble salts like carbonates of sodium and potassium or chlorides, nitrates, and sulphates of sodium, potassium and magnesium. In the alkaline soil many essential elements like Zn, Cu, and Mn are precipitated and are no use of plants. Reclamation of alkaline soil can be done by adding gypsum (Calcium sulphate) which reacts with the carbonates of Na, and K to form insoluble calcium carbonate and sulphate of Na, K. Soil alkaline is also neutralized by the addition of sulphur.

Reagent preparation:

a) Methyl orange indicator: 0.5 gm dry methyl orange powder was dissolved in 100 ml of 95% alcohol.

b) Phenolphthalein indicator: 0.5 gm of phenolphthalein was dissolved in 50 ml of 95% ethanol and were added 50 ml of distilled water and 0.05 (N) CO2 free NaOH solution drop-wise until the solution turns faintly pink.

c) HCl solution 0.1 (N): 12 (N) concentration HCl was diluted to 12 times to have 1.0 (N) HCl. Diluted it further 10 times to prepare 0.1 (N) HCl. Standardised it against Na2CO3 solution.

Procedure: 50 gm of air dry soil was weighted into a 100 ml of beaker. 100 ml of distilled water was added and was stirred briskly at least 4 times over a 30 minutes period. Wait for precipitation of soil sample into the beaker and filtered the residual water for titration. The filtered soil solution was taken in a conical flask. A few drops of phenolphthalein was added to the sample solution. The colour of the solution was not change. So, 2-3 drops of methyl orange was added to the soil sample. Titrate the solution against HCl 0.1 (N) till the yellow colour changes to pink.

Calculation of total alkalinity (TA) was as follows:

\[ \text{TA (as CaCO3 mg/litre)} = (B \times N) \times 1000 \times 50 \text{ ml of sample} \]

Where, \( B = \text{ml of HCl used with phenolphthalein and methyl orange, i.e, total} \)

HCl used with both indicators.

v. Organic matter: (percentage of carbon):

Sediment organic matter is variable in composition with the remains of roots, plant material, remnant of dead aquatic animals, and soil organisms in various stages of
decomposition and synthesis. Organic matter (OM) has a major influence on soil aggregation, nutrient reserve and its availability, moisture retention and life-processes. The organic matter of soil was determined in terms of percentage of carbon present in it by Walkey’s method (1947). This method is based on the oxidation of carbon by nascent oxygen (O) liberated from the potassium dichromate in presence of H2SO4. The reaction is as follows:

$$K_2Cr_2O_7 + 4H_2SO_4 = K_2SO_4 + Cr_2 (SO_4)_3 + 4H_2O + 3 [O].$$

**Reagents**

- 1 (N) K2Cr2O7 solution
- Concentrated H2SO4 containing 1.25g AgSO4
- 85% Phosphoric acid
- 2% Sodium Fluoride (NaF)
- Diphenyl amine (0.5%) indicator
- Standard 1 (N) Ferrous ammonium sulphate

**Reagent preparation:**

1. **Potassium dichromate solution 1 (N):** 24.52 gm of potassium dichromate (K2Cr2O7) was taken into a 500 ml volumetric flask in the usual way. 200 ml water was added and shaked well. When all the K2Cr2O7 dissolved more water was added to make up the volume up to the mark of the flask and the solution (1(N) K2Cr2 O7) was prepared.

2. **Diphenyl amine solution (2 %):** 2 gm of solid diphenyl amine was taken into a beaker. Then 100ml strong sulphuric acid (H2SO4) was added. When the solid was completely dissolved the required solution was prepared.

**Procedure:**

1g of soil sample was taken in a 500 ml conical flask to which 10 ml of 1 (N) K2Cr2O7 solution and 20 ml concentrated H2SO4 were added and mixed thoroughly. The reaction was allowed to complete in dark for about 30 minutes and then diluted by adding 200ml of distilled water. To the diluted reaction mixture 10ml of 10% H3PO4 and 10ml of 2% NaF solutions were added to which 2 ml of diphenyl amine solution was added as an indicator. The solution was then titrated with Ferrous ammonium sulphate [1 (N)] till the greenish colour appeared and the corresponding burette reading was noted. A control set (without soil) was also titrated against 1(N) Ferrous ammonium sulphate.

**Calculation:**

Organic carbon of the soil sample was determined by using the following formula:

$$\text{Organic carbon(%) } = \frac{10 (S - T)}{S} \times \frac{0.003}{\text{Wt. of the soil}} \times 100$$
vi. **Total Nitrogen (%)**

The estimation of the amount of total nitrogen in the soil is essential to evaluate its fertility. Nitrogen in soil and sediment is present mostly in the organic form, together with small quantity of ammonium and nitrate.

**Reagents:**

a). Cone. H$_2$SO$_4$

b). Salicylic acid

c). Sodium thiosulphate

d). 12 N NaOH: 480g of NaOH was dissolved in 1 liter distilled water. It was kept in plastic or polythene bottle.

e). 0.1N NaOH: 4g of NaOH was dissolved in 1 liter distilled water and standardized against 0.1N H$_2$SO$_4$

f). 0.1N H$_2$SO$_4$: 100ml of N H$_2$SO$_4$ was diluted to one liter and standardized against 0.1N Na$_2$CO$_3$.

g). Potassium sulphate

h). Copper sulphate

i). **Methyl red Indicator:** 0.1 gm methyl red was dissolved in 25 ml of ethyl alcohol and made up volume to 50 ml with water.

**Procedure:** 10g of soil sample was taken in a Kjeldahl flask to which 20ml of conc. H$_2$SO$_4$ and 0.5g salicylic acid were added and kept for half an hour. Then 2g of sodium thiosulphate, 1g of copper sulphate and 5g of potassium sulphate were added and allowed to digest the mixture until a white or bluish coloured liquid was formed. It was allowed to cool and diluted with water. It was made alkaline with 80 ml 12N NaOH, a few beads of glass were added and distilled. The distillate was collected in a conical flask containing 20 ml of 0.1N H$_2$SO$_4$ and a few drops of methyl red indicator. About 120-150ml of distillate was collected and the excess of 0.1N H$_2$SO$_4$ was titrated with 0.1N NaOH till the solution became colourless.

**Calculation:** ($20$-ml of NaOH required) × 0.014 = Total nitrogen (%).

vii. **Available Nitrogen (mg/100g)**

Ammonium salts and nitrate constitute soil available nitrogen in soil. This is the inorganic nitrogen in available form which is actually utilized by plant.
**Reagent preparation:**

a). 0.02N H2SO4: The present author diluted 100 ml of 0.1N H2SO4 to 500 ml with distilled water.

b). 0.02N NaOH: 100 ml of 0.1N NaOH was diluted to 500 ml with distilled water. The reagent was standardised with 0.02N H2SO4 before use.

c). Methyl red indicator: 0.1g methyl red was dissolved in 25 ml of ethyl alcohol and made up volume to 50 ml with water.

d). 0.32% KMnO4: 3.2g of MnO4 was dissolved in 1 liter distilled water.

e). 2.5% NaOH: 25g NaOH was dissolved in 1 liter distilled water.

**Procedure:** 10g soil sample was taken in a 500 ml Kjeldahl flask to which were added 100 ml of 0.32% KMnO4 solution, 100ml of 2.5% NaOH, 2 ml of liquid paraffin and some glass beads. The mixture was distilled and the distillate was collected in a conical flask containing 20ml of 0.02N H2SO4 and a few drops of methyl red indicator. About 75-80ml of distillate was collected and the excess of 0.02 N H2SO4 was titrated with 0.02N NaOH to a colourless end point.

**Calculation:** \[(20-\text{No. of ml of 0.02N NaOH}) \times 2.8 = \text{Available nitrogen (mg/100g soil)}\]

Water-bodies with moderate to high production potential have available nitrogen in the range of 25-75 mg/100g of soil.

**viii. Available Phosphorous (P)[mg/100g]**

Phosphorus occurs in soil as orthophosphate (H3PO4, HPO42-- and PO43--). Phosphates in the soil are affected by organic matter, moisture content, temperature and soil reaction. The chief source of phosphorous for plants under natural conditions is orthophosphates. Phosphorus deficiency leads to retardation plant growth and delays maturation. When phosphorous is excessive, plants mature early and their yields are low.

**Reagent preparation:**

a). 0.002N H2SO4: 100ml of H2SO4 was diluted to 1 liter. Adjusted the pH to 3.0 with ammonium sulphate.

b). 50% H2SO4
c). 10% Ammonium molybdate
d). Acid ammonium molybdate reagent
e). Stannous chloride solution

f). **Standard phosphate solution 10 mg/l:** 4.390g KH2PO4 was dissolved in 1 liter distilled water. This stock solution was 1000 mg/l P. 10ml of this stock solution was diluted to 1 liter with distilled water. This was 10mg/l
Procedure: 1g of air dried soil sample was placed in a 250 ml bottle, then added 200ml 0.002N H2SO4 (pH 3) and shook the mixture for 30 minutes in a mechanical shaker. It was kept for 10 minutes and filtered. 50 ml of filtrate was taken in a Nessler tube and determined its phosphate as for water.

Calculation: mg/l of phosphate in solution × 20 = mg P/100mg soil.

ix. Available Potassium (K)[mg/100g]:

Potassium is an essential element in both plant and human nutrition and occurs in surface waters as a result of mineral dissolution from decomposing plant material, agricultural run-off, solid wastes etc. It helps plants to resist drought and water logging. It also activates enzyme system in plants. The deficiency of potassium causes margin of leaves to appear yellow and may develop spots and retard plant growth. Sediment’s available potassium was estimated by leaching it with 1N ammonium acetate and determining the potassium using flame photometer.

Reagent preparation:

a) Ammonium acetate 1N: As much as 77.08 g of ammonium acetate was dissolved in 1 liter of distilled water.

b) Standard K solution (1000mg/l): 1.907 g of dried KCl was taken which was dissolved in 1 liter. Pipetted 5ml and 10 ml of 1000ppm of K solution and diluted to 1 liter for getting 5 and 10 mg of K per liter respectively.

Procedure: 5g of air-dried and sieved soil was transferred to a 250 ml conical flask to which 100 ml 1N ammonium acetate was added. The contents were shaken for 30 minutes and then filtered. Then the flame photometer was started and adjusted 10 mg/l K solution to 100 reading on galvanometer. The extract was fed and the reading (R) was recorded.

Calculation: Available K mg/ 100g sample = (R/5) × 1.207. Where, factor 1.207 is used for conversion of K2O to K.

3.2. STUDY OF MACROPHYTES

3.2.1. Taxonomic study:

During periodic visit to the study sites (38 wetlands as shown in (Table 23) from time to time in different parts of the year since 2001 plant specimens of vascular macrophytes (large algae, pteridophytes and angiosperms) were collected and field observations on them were recorded in the note book. The collected plant specimens were properly dried and processed for herbarium preservation as well as taxonomic work out. Standard herbarium sheets measuring 41.5 – 42.0 x 28.0 cm were used for mounting specimens after proper pressing, drying and poisoning. Labels with all necessary information such as name of the plant, family, locality, and altitude, date of collection, collector’s name and field numbers and certain important phenotypic characters, which usually disappear on preservation, were affixed on the bottom right hand corner of the mounted sheets. Such specimens were
submitted to the Taxonomy Section of Botany Department of Burdwan University (B.U.) for preservation. The plant specimens used for working out the taxonomic characters were mostly dry preservations and in some cases, wherever possible, they were fresh. The samples (material) used for taxonomic descriptions were the whole plant, stem, leaves, flowers, fruits and seeds. Dry flowers and in some cases leaves collected from the dried specimens, were immersed in boiling water for a brief period for softening. Each material was placed on clean glass slide and dissected under binocular stereoscopic dissecting microscope (Olympus Model MS24). To the dissected part a few drops of aqueous glycerin solution (10%) were added and covered with cover slips for observation under microscope. Measurements of the plant organs were given in metric and decimal systems. The plants were identified accurately using pertinent literature and checking up with authentic herbarium specimens preserved in the Central National Herbarium (CAL) and in the Department of Botany of Burdwan University (BURD). Nomenclature of each species was checked with that given in the latest publications (Prain, 1963; Bennet, 1987; Guha Bakshi, 1984; Cook, 1996). The specimens, thus studied irrespective of each species have been referred to under ‘Specimens examined’. Artificial keys to the concerned families, genera and species were prepared to facilitate their identification. The arrangement of families followed in the present work is as given in Prain’s Bengal Plants (1903) which is the same as that of Bentham and Hooker in Genera Plantarum (1862-1883). However the circumscriptions of some families as given by Arthur Cronquist (1988) in his Evolution and Classification of Flowering Plants have been adopted. Genera under each family and species under each genus when in plural numbers were arranged in alphabetic order. The nomenclature which has been considered correct for a species is mentioned first with citation of the protologue. Other relevant publications consulted in original are also cited in order of priority of their publications. These citations are followed by basionyms wherever necessary, familiar synonyms and relevant publications. Local names, wherever available for different species are also mentioned. Life-span, Growth form, brief description, flowering and fruiting periods, field notes, status etc. are also recorded in case of each species. The abbreviation ‘MM’ used with each field number of the specimen examined stands for the surnames of SUJIT KUMAR MANDAL, the present author and AMBARISH MUKHERJEE, the supervisor of this work.

3.2.2. Form Study of Macrophytes

‘Form Study’ includes characterization of the concerned macrophytes on the basis of their characteristic Growth Forms, Life Forms and Ecophases or Ecoperiods or Ecocycles, each of which has been dealt with separately in the following.
3.2.2.1. Growth form category analysis of Macrophytes:

On the basis of the observation on the growth forms of the concerned macrophytes, they were assigned to different categories adopting Hutchinson’s (1975) system of classification, as mentioned hereunder.

**GROWTH FORMS**

**A. Pleustophytes:** Free-floating, roots absent or pendant in water

  i. **Acropleustophyta:** Floating at surface, upper part of plant dry
      a. **Lemnids:** Small, reduced plant body
      b. **Salviniiids.**
      c. **Eichhorniids.**

  ii. **Mesopleustophyta:** Entirely submerged, floating below water surface.
      a. **Utricularids.**

**B. Rhizophytes:** Rooted in sediments. Reproductive structures (inflorescences or flowers) always above water surface.

  i. **Hyperhydates:** Vegetative parts emergent for most of the year, commonly called helophytes.
     a. **Graminids.**
     b. **Herbids.**
     c. **Ipomeids:** Climbing emergent.
     d. **Decodontids:** Stem floating with emergent shoots bearing leaves.
     e. **Aeschynomenids:** Stem floating bearing shoots with compound leaves.
     f. **Sagittariids:** Petioles extending above water, leaves cordate, sagittate, lanceolate.
     g. **Nelumbids.**

  ii. **Ephydates:** Leaves floating but not emergent.
     a. **Nymphaeids:** Leaves cordate, circular, elongate oblong.
     b. **Natopotamids:** Leaves lanceolate.
     c. **Marsileids:** Leaves compound.
     d. **Batrachids:** Floating leaves simple or partly dissected.
     e. **Trapids:** Floating leaves in rosette.

  iii. **Hyphydates:** Plants except flower or inflorescence, submerged completely.

    1. **Vittate:** Long stems or creeping rhizomes with long flexible branches.
       a. **Parvopotamids:** Small leaves.
       b. **Myriophyllids:** Leaves greatly divided.

    2. **Rosulate:** Stems very short, leaves in rosette.
       a. **Vallisneriids:** Leaves elongate, ribbon-like.
       b. **Otteliids:** Leaves petiolate, broad.
       c. **Isoetids:** Leaves narrow, often stiff.
3.2.2.2. Life-form Categories (Hejny, 1971)

1. **Pleustophytes**: Plants occupying the water level, usually not rooted, temporarily rooted in limosal ecophase.

2. **Euhydatophytes**: Plants rooted in soil by roots, sporadically by rhizomes. Life cycle is confined to hydrophase and littoral phase. Only submerged leaves are formed. Reproductive organs develop in water or just above surface.

3. **Acrohydatophytes**: Plants rooted in the soil by rhizomes and roots, develop both submerged and floating leaves. Capable of passing their life-cycle in hydrophase, littoral and limosal ecophases but normally do not flower in the limosal ecophase.

4. **Tenagophytes**: Plants rooted in soil, capable of completing their lifecycle in both littoral and limosal ecophase. Reproductive organs are formed both in water and air.

5. **Ochthohydrophytes**: Rooted plants, growth-form with submerged, floating and aerial leaves, capable of completing their lifecycle in littoral, limosal and terrestrial ecophases, and partly also in the hydrophase. Flowering occurs normally in the littoral ecophase.

6. **Hydrochthophytes**: Rhizomatous plants capable of passing their lifecycle in all four ecophases. Flowering occurs normally in littoral ecophase.

7. **Pelopchthophytes**: Plants with caespituous root, capable of passing their lifecycle in limosal and terrestrial ecophases. Only aerial leaves develop. Plants occur on temporarily exposed substrata.

3.2.2.3. Ecophase or Ecoperiods or Ecocycles (Hejny, 1957, *Sensu* Lavania *et al.*, 1990)

1. Hydrophase (permanent deep water)
2. Littoral ecophase (shallow water)
3. Limosal ecophase (No standing water above soil)
4. Terrestrial ecophase (Soil wet to moist)

3.2.3. Utilitarian perspectives of Macrophytes:

Uses of the wetland macrophytes were recorded only from primary sources i.e. on the basis of interrogation with knowledgeable users, herbalists, businessmen, experts in rural technology (*Table 19*) and author’s own experience gained during field work. The concerned species were enumerated alphabetically with their local names, family names and uses.
Materials & methods

### Table 22: List of abbreviations used in taxonomic work

<table>
<thead>
<tr>
<th>Abbreviations</th>
<th>Full form</th>
</tr>
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<tbody>
<tr>
<td>auct. non</td>
<td>auctorum non</td>
</tr>
<tr>
<td>M</td>
<td>Meter</td>
</tr>
<tr>
<td>Cm</td>
<td>Centimeter</td>
</tr>
<tr>
<td>mm</td>
<td>Milimeter</td>
</tr>
<tr>
<td>Comb. nov.</td>
<td>New combination</td>
</tr>
<tr>
<td>Diam</td>
<td>Diameter</td>
</tr>
<tr>
<td>Dist.</td>
<td>District</td>
</tr>
<tr>
<td>et al.</td>
<td>et aliorum/and others</td>
</tr>
<tr>
<td>Excl.</td>
<td>Excluded</td>
</tr>
<tr>
<td>f.</td>
<td>form/ forma</td>
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<tr>
<td>Fig.</td>
<td>Figure</td>
</tr>
<tr>
<td>nom. cons. = nomen conservandum</td>
<td>Conserved name</td>
</tr>
<tr>
<td>nom. illegit.= nomen illegitimum</td>
<td>Illegitimate name</td>
</tr>
<tr>
<td>nom. nud.= nomen nudum</td>
<td>Nude name</td>
</tr>
<tr>
<td>nom. rejic.= nomen rejicienda</td>
<td>Rejected name</td>
</tr>
<tr>
<td>s. col.</td>
<td>sine collector</td>
</tr>
<tr>
<td>s. legit.</td>
<td>sine legitimate</td>
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<tr>
<td>s. loc.</td>
<td>sine loco</td>
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<tr>
<td>ssp.</td>
<td>Sub species</td>
</tr>
<tr>
<td>syn.</td>
<td>Synonym</td>
</tr>
<tr>
<td>var.</td>
<td>Variety</td>
</tr>
</tbody>
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3.3. RESOLUTION OF REMEDIAL MEASURES TO RESTORE WETLANDS AND OPTIMIZE THEIR USE:

3.3.1. Wetland Restoration:

The wetlands in Puruliya district have been facing with certain problems challenging their existence. Envisaging the need for a periodic surveillance of these wetlands for identification of their problems and mitigation, field surveys were undertaken at frequent intervals. Appropriate strategies for remediation were worked out for each of them.

3.3.2. Development from sustainable use of wetlands:

After thoroughly studying the wetlands the present author feels that certain developmental programmes may be launched based on sustainable use of their resources other than water. Strategies for sustainable development based on wetland -resources were formulated considering such perspectives as pisciculture, floriculture, duckery, cottage industry (mats/ sola, art and craft etc.), vermiculture, establishment of plants for production of biogas, dry anaerobic composting etc.