APPENDIX – A

Part-A

Questionnaire to Determine the Wetland Services and Land Use Pattern of the Wetland Surroundings

Section I

Interview no: 64 date 20.11.16

Name of respondent: Dhurjadhan Barman

Sex: Male [✓] Female [ ] age: 65

Present occupation: fisherman

Previous occupation (before 10-15 years): fisherman

Reasons for changing theoccupation: N.A.

Educational Qualification: V

Name of the village: Dhakhin changtimari

Name of the block: Tufanganj - I

Name of the wetland in vicinity: Rasik Beel Wetland complex (Raichan mari)

Location: latitude: 26°24'30" N longitude: 89°43'15" E

Section II

1. How long have you been staying in the village? From birth [✓] year [ ]
2. Do you derive any benefit from the wetland? Yes [✓] No [ ]
3. **Which of the following activities sums up your utilization of wetland resources?**

[X] Crop cultivation
[X] Grazing
[X] Edible plant collection
[X] Medicinal plant collection
[X] Animal remains for medicinal use
[X] Collection of building materials
[✓] Fuel wood collection
[✓] Fishing
[X] Hunting
[X] Drinking water
[X] Water for cooking

[✓] Bathing
[✓] Washing household utensils
[✗] Washing vehicles
[✗] Irrigation
[✗] Jute retting
[✗] Release of sewage
[✗] Release of effluents
[✓] Garbage disposal → Small amount.
[✓] Disposal of festival generated wastes Small amount.
[✓] Surroundings used as toilets
[✗] Urban development

4. What other benefit [redacted] derive from the wetland?

[✓] Religious use
[✓] Aesthetic value
[✓] Cultural value
[✓] Tourism
[✓] Education and awareness
[✓] Recreation (swimming, bathing, boating, other)
[✓] Livelihood dependence

5. Human Induced Activities

1. Disposal of religious waste: [✓] Yes [ ] No
   If yes, mention the occasion.. Durga puja & Kali puja.....
2. Rubble and construction material: [ ] Yes [✗] No
   If yes, mention the type..... N.A.....
3. Washing vehicles & clothes: [✓] Yes [ ] No
4. Surroundings used as toilets: [✓] Yes [ ] No
5. Catching fish &Prawns: [✓] Yes [ ] No
6. Collection of Reeds, grasses for thatch
   (a roof covering of straw) or fodder : [✓] Yes [ ] No
   If yes, provide the details.. Small amount of kashiya & some fodder.

Section III

A. AGRICULTURE

1. Do you have cultivable land? [ ] Yes [✓] No ✓

If yes, mention the total area and type of land (in Bigha) N.A.

Years	In wetland	Around Wetland
<5		
5-10		
10-20	N.A	
20-30		
>30		

2. If your cultivable land is in wetland, how many years have been farming there?

Indicate total amount of cultivable land (in bigha) in wetland N.A.

years ago_____10years ago_____20years ago_____30years ago_____

3. How many house-holds do you know to be involved in farming activity in the wetland? 20

4. Reasons for cultivation in wetland:scarcity of land [✓] more production [✓]

If other, provide the details govt. was give cultivable land to 20s S.T. People.

5. Crops cultivated in the last 3 years (fulfill the table with production amount per bigha)

year	Year 2013-14		Year 2014-15		Year 2015-16		Year 2016-17	
Season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season
crop			N.A					
Production/ bigha								

6. How will you describe benefits from cultivation in the wetland during the last five years?

Increasing [ ] Decreasing [ ] No change [ ]

7. If changes have occurred explain the causes: scarcity of water [ ]

Decline in the water quality [ ] Decline in the soil fertility [ ]

If other, mention the cause_____

8. Fertilizer Used

Fertilizer & pesticide used in the last year/ throughout the year							
Summer crop Aus, amon, jute, chilli, greens, vegetables, others. Winter crop Greens, chilli, ground creep, potato, wheat, vegetables, maize, oil seeds, tobacco, boro, ginger, garlic, onion, others				Chemical fertilizer: npk(10/26, 15/15) = i, urea = ii, phosphorus(ssp)= iii Potash= iv, dap =v, magnesium=vi, zinc=vii Boron= viii ,dolomite =ix ,potassium humate =x Bio- fertilizer: cow dung-a, others organic-b			
Season	Name of the crop	Fertilizer(সার)		Pesticideকীটনাশক		Herbicideউদ্ভিদনাশক	Irrigation from wetland (if yes, mention amount of withdrawal)
		Chemical fertilizer	Bio-fertilizer	Chemical	Bio-pesticide		
Summer							
			N.A.				
Winter							
Jute retting		Mention the amount of land/ coverage					
Seed-bed							

9. Determining the level of awareness on the effect of farming activities in the wetlands based on the typical five-level Likerts cale:

Statement /scale	(put √ on his response) farmers in the wetlands [ ] farmers around the wetlands[ ]				
	Strongly disagree	Disagree	Don't know	Agree	Strongly agree
Use of chemical fertilizers affects the wetlands.		✓			
Use of pesticides affects the wetland.				✓	
Use of herbicides affects the wetland.		✓			
Runoff from agricultural fields degrades the wetlands.	✓				
Deep tillage in wetlands affect the Wetland ecosystem.	✓				
Water quality is affected by agriculture.		✓			
Soil quality is affected by agriculture.	✓				
Wildlife is affected by agriculture.		✓			
Landscape change due to agriculture			✓		
Advantages of using bio-fertilizers& bio-pesticides?			✓		

B) PISCICULTURE

i. Are you engaged in pisciculture? yes[✓] no[ ]

ii. If yes, mention the type: own [✓] co-operative [ ]

iii. Particulars of pisciculture:

Chemical fertilizer: NPK(10/26, 15/15) = I, Urea = ii, Phosphorus(ssp)= iii Potash= iv, DAP =V, Magnesium=vi, Zinc=vii Boron= viii ,Dolomite =ix ,Potassium Humate =x
Bio- fertilizer: Cow dung-A, Others organic-B

Name Of The Fish Collected	Name Of Fish Spray	Fertilizer Use In Pisciculture		Pesticide Use In Pisciculture		Threatened Fish Species
		Chemical fertilizer	Bio-fertilizer	Chemical	Bio	
Bengal eel(বানমাছ), Long whiskered catfish(আইড়), Bacha (বাচা),Dwarf goonch(বাগাইর/বাঘাইর),Sind danio(বাঁশপাতা),Awaousguamensis(বাইলা),Zig-Zag eel/Tire track eel(বাইম),Balitora minnow (বালিচুরা) ,Barred baril (বারালি / বোরালি), Indian Batasi (বাতাসি), Bogalabeo (ভাঙন/ভাঙ্গন), Indian Jewfish (ভেটকী), Wallago (বোয়াল), Bengal loach (বৌমাছ/রানি), Ganges River Gizzard Shad(চাপিলা), Squarehead catfish (চেকা), Silver razor belly minnow (চেলা), Flying barb, Slender rasbora, Gangetic scissortail	Indian carp. বাটা, রুই.	X	A.	X	X	Indian catfish, Long wish-Kered cat fish, Wallago

rasbora (দারকিনা), Sucker head(ঘরপোয়া), Clown knifefish (চিতল/ চেতল),Gogangraviridescens, Nangranangra (গংটেংরা), Gray eel-catfish (গংমাগুর), Largescale archerfish (গোটিপোয়া), Gangeticailia, Jamunsailia (কাজুলি), Freshwater garfish (কাকিলা), Orange-fin labeo (কালিবাউস/ কালবোশ), Butter catfish (কানিপাবদা), Glyptothoraxcavia (কানিটেংরা), Indian Carp (কাতলা), Banded gourami (লশে,/খৌলশা), Grass Carp (গ্রাসকার্প), Scribbled goby (বেলে), Burmese loach (পুয়াকই) ,Rita (রিটা), Indian glassy fish (রাঙ্গাচান্দা / রাঙাচাঁদা), Java barb (রাজপুঁটি), ফলি, Gangetichairfin anchovy (ফাশা/ ফাঁসা), Swamp barb (পুঁটি), Green pufferfish (পটকা), Mango fish/Cichlid (তপসে/তপস্বী),Olive barb (সরপুঁটি) , Ocellatedpufferfish (ট্যাঁপা), Tyangra (টেংরা), Indian Tilapia(তেলাপিয়া), Stinging catfish (শিঙি/শিঙ্গাঘি), Snakehead murrel (শৌল/শোল), Spotted snakehead (টাকি), Climbing perch(কৈ),Swamp eel (কুঁচে/কুচিয়া/কুইচ্চা/কুইচা),Kalabans (কুরসা),Dwarf gourami (লালখোলিশা/ খলশে),Elongate glass-perchlet (লম্বাচাঁদা), Tor Tor (মহাশোল), Bombay duck (লোটে/ল্যাটা), Walking catfish (মাগুর), Barred spiny eel (পনকালবাইম / পাঁকালবাম), Mrigal(মৃগেল/মিরগেল), GaruaBachcha (মুরিবাচা), MolaCarplet (মলা), Indian Carplet (মৌরলা), Indian catfish(পাবদা), Pomfret (চাঁদা/পমফ্রেট), Pama croaker (পোয়া), Bengal Parshey (পারশে), Yellowtail catfish (পাঙ্গাস / পাঙাশ), Indian mottled eel, Any other.....						Ras bora, Clown Knifefish, Climbing Jamunsailia, Perch,

10. Determining the level of awareness on the effect of fisheries or related activities in the wetlands based on typical five-level Likert scale

Statement /scale	(put √ on his response) farmers in the wetlands [ ] farmers around the wetlands[ ]				
	Strongly disagree	Disagree	Don't know	Agree	Strongly agree
Chemical fertilizers affect wetland			✓		

Pesticides use affect wetlands.	✓				
Herbicides affect wetlands.			✓		
Removal of weeds affects wetlands.		✓			
Water quality is affected by fish-farming				✓	
soil quality affect by fish-farming		✓			
wildlife affect by fish-farming		✓			
Landscape change			✓		
Advantages of using bio-fertilizer & bio-pesticides?			✓		

C) FISHING

i. Involvement in fishing: Yes[✓] no [ ] If yes,

ii. Duration of fishing in the wetland 35 years. (months/years)

iii. Is fishing your main occupation? Yes [✓] no[ ]

iv. If yes mention how much you earn daily Rs. 250/- 300/-

v. Indicate the type of fishing in different time.

Indian mottled eel, Bengal eel (বানমাছ), Long whiskered catfish (আইড়), Bacha (বাচা), Dwarf goonch (বাগাইর/বাঘাইর), Sind danio (বাঁশপাতা), Awaousguamensis (বাইলা), Zig-Zag eel/Tire track eel (বাইম), Balitora minnow (বালিচুরা) ,Barred baril (বারালি / বোরালি), Indian Batasi (বাতাসি), Bogalabeo (ভাঙন/ভাঙ্গন), Indian Jewfish (ভেটকী), Wallago (বোয়াল), Bengal loach (বৌমাছ/রানি), Ganges River Gizzard Shad (চাপিলা), Squarehead catfish (চেকা), Silver razorbelly minnow (চেলা), Flying barb, Slender rasbora, Gangetic scissortail rasbora (দারকিনা), Sucker head(ঘরপোয়া), Clown knifefish (চিতল/ চেতল), Gogangraviridescens, Nangranangra (গংটেংরা), Gray eel-catfish (গংমাগুর), Largescale archerfish (গোটিপোয়া), Gangeticailia, Jamunsailia (কাজুলি), Freshwater garfish (কাকিলা), Orange-fin labeo (কালিবাউস/ কালবোশ), Butter catfish (কানিপাবদা), Glyptothoraxcavia (কানিটেংরা), Indian Carp (কাতলা), Banded gourami (লশে,/খৌলশা), Grass Carp (গ্রাসকার্প), Scribbled goby (বেলে), Burmese loach (পুয়ারুই) ,Rita (রিটা), Indian glassy fish (রাঙ্গাচান্দা / রাঙাচাঁদা), Java barb (রাজপুঁটি), ফলি, Gangetichairfin anchovy (ফাশা/ ফ্যাঁসা), Swamp barb (পুঁটি), Green pufferfish (পটকা), Mango fish/Cichlid (তপসে/তপস্বী), Olive barb (সরপুঁটি) , Ocellatedpufferfish (টাঁপা), Tyangra (টেংরা), Indian Tilapia (তেলাপিয়া), Stinging catfish (শিঙি /শিঙ্গি), Snakehead murrel (শৌল/শোল), Spotted snakehead (টাকি), Climbing perch(কৈ), Swamp eel (কুঁচে/কুচিয়া/ কুইচ্চা/কুইচা), Kalabans (কুরসা), Dwarf gourami (লালখোলিশা/ খলশে), Elongate glass-perchlet (লম্বাচাঁদা), Tor Tor (মহাশোল), Bombay duck (লোটে/ল্যাটা), Walking catfish (মাগুর), Barred spiny eel (পনকালবাইম / পাঁকালবাম), Mrigal (মৃগেল/মিরগেল), GaruaBachcha (মুরিবাচা), MolaCarplet (মলা), Indian Carplet (মৌরলা), Indian catfish (পাবদা), Pomfret (চাঁদা/পমফ্রেট), Pama croaker (পোয়া), Bengal Parshey (পারশে), Yellowtail catfish (পাঙ্গাস / পাঙাশ)

Major fish collected in summer season	Major fish collected in monsoon season	Major fish collected in post-monsoon season	Major fish collected in winter season

Pama croaker, climbing perch, etc.	Mola carplet, Swamp barb.	Snakehead Murrel, Stinging catfish, Walking catfish.	Snakehead Murrel, Spotted Snakehead,

VI. How will you describe the fishing productivity in the wetlands during the past five years? [ ] increasing [✓] Decreasing [ ] No change

If change has occurred explain the cause Excessive fishing, water polution, water from Khamakhaser Municipality.

VII. How many house hold do you know have involved in fishing in the wetland?

At present 150-160 2 years ago 150-160 5years ago 250 10years ago 300

In the last 2-3 years has any community/organization taken any action to mitigate the problem? If yes, explain NO

VIII. To test the extent of knowledge on the negative effects of fishing in the wetlands based on a typical five-level Likert scale

Statement /scale	(put √ on his response) Farmers in the wetlands [ ] Farmers around the wetlands[ ]				
	Strongly disagree	Disagree	Don't know	Agree	Strongly agree
Excessive fishing affects wetland.				✓	
Catching tench affect thefish population & fishing productivity.				✓	
Catching brooding fish affect the fish population.				✓	
Removal of weeds affect the wetland	✓				

IX. **List of endangered and protected flora and fauna of wetland (fishermen)**

Name of species		Endangered	Protected
fauna	fish	Tinkata · Gili Putki, Koi, Bam	Sati, Shol,
		Pakal, Khosa, Kuchiya	Changa.
flora		Ulu, Khagra, Binna,	Zanglikachu.

Overall fish yield during the last 5-10 years

No Change [ ] Decreased (%) [✓] Increased (%) [ ]

Any incidence of mortality of fish or birds in the wetland in the recent past? If so yes.

provide details fish.

Mention the flora which is less seen during the last 5 years —

Do you think conservation of wetland is necessary? No Answer.

D. EDIBLE PLANT COLLECTION

I. Involvement in the collection of edible plant: Yes [ ] No [✓] if yes,

II. Duration of collection of edible plants from the wetland: N.A. (months/years)

III. How many house hold do you know to be involved in this activity in the wetland? 10-15

Indicate the type of Edible plant collected in different time

Edible Plant	Niche of Plant	Summer Season	Monsoon Season	Winter Season
Water spinach(Kulmi)				
Buffalo Spinach (Hincha)				
Suluk				
Fiddleheads (Dhekisak)				
Colocasiaesculenta (Kachusak)		NA		
Water caltrop (Jalsingara)				
zongasak				
Others.....				

IV. Is the collection of wild plant your main occupation? Yes [ ] No [ ]

If yes mention the daily income _____

V. How will you describe the prospect of collection of wild plants as an income source in the past five years? [ ] Increasing [ ] Decreasing [ ] No change

If change has occurred explain the cause _____

VI. Are you aware of the impact of edible plant collection on the wetland?

Yes [ ] No [ ]

E. LIVESTOCK

I. Does your livestock graze in the wetlands? Yes [ ] No [ ]

II. Livestock has been grazing the wetland since _____(months/years)

III. How many household you know to be involved in grazing the livestock in the wetland?

Mention the data of total livestock grazing in the wetlands during different times of the year

Livestock	No.	Summer Season	Monsoon Season	Post Monsoon Season	Winter Season
Cattle					
Goat					
Sheep					
duck					
Other.....					

IV. Do you cut grass or bushes to feed your livestock? Yes [ ] No [ ]

V. If yes mention time.....why.....

VI. Is the animal husbandry and fodder collection your main occupation?

Yes [ ] No [ ]

VII. How will you describe the changes in fodder collection during the past five years?

[ ] Increasing [ ] Decreasing [ ] No change

VIII. If there is a change explain the cause _____

IX. Are you aware about impact of collection of grazing on wetland?

Yes [ ] No [ ]

F. COLLECTION OF BUILDING MATERIALS

I. Do you in in collection of building material?

Yes [ ] No [ ] If yes

II. How long have you been involved in the collection of building materials from the wetland? N.A.

III. How many house hold do you know to be involved in collection of building materials the wetland? NO

IV. Indicate the type of building material extracted from the wetlands at different times of the year:

Building material (mention name)	Area of collection	Summer Season	Monsoon Season	Post Monsoon Season	Winter Season
Plant			N.A		
Grass					
Mud					
Sand					
Stone					

V. Is the collection of building material your main occupation? Yes [ ] no[✓]

VI. If yes mention your daily earnings N.A.

VII. How will you describe the changes in building material extraction from the wetland in the past five years?

Increasing [ ] Decreasing [ ] No Change [ ] N.A.

VIII. If change has occurred explain the causes N.A.

IX. Are you aware of the impact of collection of building materials on wetland?

Yes [ ] No[✓]

G. COLLECTION OF FIRE WOOD

I. Do you involved in collection of collection fire wood? yes[✓] no [ ] if yes

II. How long have you been involved in collection of fire wood from the wetland? Very long

III. How many house hold do you know to be involved in this activity in the wetland? 35-50

Indicate the collection pattern of fire wood at different times of the year.

Fire wood(mention plant name)	Niche of plant	**Summer Season**	**Monsoon Season**	**Post Monsoon Season**	**Winter Season**
Baro Kalmi'	edge	X	X	✓	✓

Branch of Tree	edgs.	✓	✗	✗	✓

V. Is the collection of fire wood your main occupation? Yes [ ] No [✗]

V. If yes, mention your daily earnings ✗

VI. How will you describe the changes in the firewood collection in the wetland during the past five years?

Increasing [ ] Decreasing [✓] No change [ ]

VII. If change has occurred explain the causes _____

VIII. Are you aware of the impact of firewood collection on wetland?

Yes [ ] No [✓]

H. **HUNTING**

I. Are you involved in hunting? Yes [ ] No [✓]

If yes, How long have you been involved in hunting in the wetland? _____ (month/year)

II. How many house hold do you know to be involved in hunting in the wetland?

Indicate the type of hunting at different times.

Hunting(mention bird/animal name)	Niche of animal	Summer Season	Monsoon Season	Post Monsoon Season	Winter Season
		N.A			

III. Hunting your main occupation? Yes [ ] No [ ] N.A.

IV. If yes mention how much you daily earnings

V. How will you describe the monetary returns from hunting in the wetlands during the past five years?

[ ] Increasing [ ] Decreasing [ ] No change N.A.

If change has occurred explain the causes

VI. Are you aware of the negative impacts of hunting on wetland? Yes ✓ no ____

I. WATER USE

J. Mention the quantity of water for the following activities:

Water for	Quantity of collection per day/season	Frequency of collection	Number of people/other	Cause of use
Irrigation	For Boro Production	one.	20-25	More Production
Drinking water supply	X	—	—	—
Water for cooking	X	—	—	—
Bathing	yes.	whole year.	—	—
Washing household utensils	yes.	All over the year.	—	—
Washing of cloths & vehicles	yes.	All over the year.	—	—
Other	—	—	—	—

II. How will you describe the changes in the water use in the past five years?

Increasing [✓] Decreasing [ ] No change [ ]

III. If change has occurred explain the causes Boro cultivation, Population expoitation.

IV. Are you aware about the negative impact of excessing pressure on water resources of wetland? Yes [ ] No [✓]

দুর্যোধন বর্মন
Signature of Respondent

Abdul Miraj 20.11.16
Signature of Researcher

Part-B

Questionnaire for Assessment of wetlands

GENERAL

1. Name of the Wetland: Rasik Beel wetland complex.
2. Location: Latitude: 26°24' 30"N Longitude: 89°43' 15" E
3. Lake Type: Natural Lake ✓ Man-made (Reservoir) X
4. Constriction/stricture (if any) for the purpose of

a) Fishery development X

b) Flood control ✓

c) Irrigation X

d) Settlement ✓

e) Road ✓

f) Other –

6. Number of roads and railways nearby the wetland: Road - 6 Railways - NIL
7. Roads and railways passing through the wetland: Road - 2
8. How many villages/ settlements are located near or on the periphery of wetland? 5
9. Land use (%):

Urban [ ] Rural [✓] Agricultural [ ] Forest [✓] Grazing [✓] Fallow [ ]

10. Fishing: Non-commercial fishing [✓] Pisciculture [✓]
11. If Urban Catchment: N.A.

Has Sewerage been provided? Yes [ ] No [ ]

13. Sewage treatment: Yes [ ] No [✓]
14. Solid waste disposal in lake (if any) [ ] yes. But small amount.

HYDROLOGY

1. Source of water(inflow): Rainfall ✓ Runoff ✓ River Drainage [ ] Wastewater drainage [✓]
2. Outflow. if any (describe): yes. But Blocked by Sui gate [ ]
3. Name of the feeder channel (with the time of connection) Burha Raidak & Ghoramara River.
4. Water level changes (annual) in Meters 2-4 ft. [ ]
5. Does the lake dry out completely? Every year [✓] occasionally [ ] Rarely [ ] But Purly *
6. Name of the nearby river with distance from the Beel Burha Raidak ½ km.
7. Approximate area of the Wetland 180 ha. [ ]
8. Water spread area of the Beel in rainy season all over wetland [ ]

* Chotojan & Barojan wetland are dried completly every year.

BIODIVERSITY

a. Inhabiting Flora

Population Status		
Very common	Fairly common	Rare
Kochuri pana Topa Pana Zongli kachu Kalmi	Saluk Kalmi Helencha Dheki sak Bhet Dandokalas	Zonga Sak/kachu- Pani pkal Nalkhagra Pundi Hogla Binna kash ulu Khagra Khes.

b. Inhabiting Fauna

Population Status		
Very common	Fairly common	Rare
Chang, Shel, Soti Lesser whistling-Duck cattle Egret, Stated Dove, Block Drongo Jungle Myna	Bata, Kalbows, Koi, Chanda, Ruhi Kacho chinni, common Kingfisher, Asian Koel, Gaso Bang, Daraos, Beji. Mitho idur.	Sing, Pabda Paia, Kuchia Bam, Baal, Darikina, Water Beetle, Black Kite Jhinuk, Googhi Sona Bang. Goshap Bador ud.

MAJOR PROBLEMS

I. Thickness of organic & Inorganic Bottom Deposits(Mud): (Bachannon Beel)

II. Edges of the wetland [✓], 1.5 feet

III. middle of the wetland [✓], 2.5 feet

IV. Blockage of Feeder Channel by road [✓], railways [ ], embankment [ ] house

V. Encroachment and Areal Shrinkage by agriculture [✓], Local Residents [ ], Builders [ ], Government [ ],

VI. Fragmentation of wetland by road [✓], railways [ ], creation of pond [ ]

VII. Garbage Dumping

i. No. of garbage dumping points [✗]

ii. Material: organic [ ], inorganic [ ]

VIII. Major dumped materials ✗

Amount: small [ ] Moderate [ ] Huge[ ]

IX. Pollutants Inflow from market: municipality [ ] agricultural fields [✓] N.A [ ],

X. Eutrophication: vegetation cover of wetland: 100% [ ] 75% [✓] 50% [ ] 25% [ ],

XI. Indiscriminate Fishing: All throughout the year [✓], only rainy season [ ],

Only dry season [ ], fishing by dried up

XII. Every year flood affects the wetland: Yes [✓] No [ ]

XIII. Weed Clearance: every year [ ] Alternative years [ ] No [✓]

Once a year [ ], Twice a year [ ], Thrice a year [ ], four times a year [ ]

XIV. Jute retting: Yes [✓] No [ ]

XV. Approximate amount of jute retting in bigha [120],

XVI. Socio-cultural activities in and around the wetland:

Puja [ ], Fairs [ ], Crematory grounds [ ], Immersion of idols [✓]

XVII. Depth of water in feet:

In rainy season

i. Edges of the wetland [ ], 2 feet

ii. Middle of the wetland [ ], 12 feet

In summer season

i. Edges of the wetland [ ], 1 feet

ii. Middle of the wetland[ ], 6 feet

XVIII.Other information:

Reduction in area (shrinkage) [✓], Reduction in depth (Siltation) [✓], Encroachments [✓],

Algal blooms [✗], Aquatic weeds [✓], Decline or Loss of fisheries [✓],

Eutrophication [✓], Organic Pollution [✓], Toxic pollution [✗],

XIX. Total area of the wetland: Increased [✗], Decreased [✓], Unchanged [✗],

MONITORING &CONSERVATION

1. What is the present legal conservation status of the wetland?

Protected fully [ ] Protected partially [✓]

Unprotected [ ] Proposed for protection [ ]

2. If protected, please mention -

(a) The Year since when the wetland is being protected ..... 91 included in wetland development Project in 2005.

(b) Protecting agency:

Forest department [✓] Irrigation department [ ]

Municipal Corporation [ ] Any other Agency [ ]

(c) Protection Status:

Fishing Prohibited or regulated [✗] Hunting prohibition [✓] other [✗]

Abdul Miraj 20.11.12

Signature of Researcher

Appendix – B

List of Abbreviations

ANOVA= Analysis of Variance

BIS= Bureau of Indian Standard

BLRO= Block Level Revenue Officer

BOD= Biological Oxygen Demand

CGWB= Central Ground Water Board

CGWB= Central Ground Water Board

DFO= District Forest Officer

DSH= District Statistical Handbook

DO= Dissolve Oxygen

EC= Electrical Conductivity

FAO= Food and Agricultural Organization

GSI= Geological Survey of India

GSI= Geological Survey of India

IFS=Indian Forest Service

IMD= Indian Meteorological Department

ISRO= Indian Space Research Organization

NWCP=National Wetland Conservation Programme

OC= Organic Carbon

PFCS= Primary Fishermen Co-operative Society

RLI= River Lift Irrigation

RSC= Sodium Residue Carbonate

TA= Total Alkalinity

TS= Total Solid

TSS= Total Suspended Solid

WCMC= World Conservation Monitoring Centre

WHO= World Health Organization

WQI=Water Quality Index

PPM= Parts Per Million

Appendix – C

Glossary of the terms

Annoprason = First feeding Ceremony

Chhara', 'Dara', 'Doba', 'Jheel', 'Beel', and 'Kura'= Marshy or swamp generally created by remnant channel or ox bow lake in plain region.

Dighi= Pond

Fish hunting=fish catching from wetland without fish culture.

Jampoi =Minor natural Canal from which water has been withdrawal for irrigation purpose in dry season.

Kalbaishakhi= Thunder storm accompanied by hail

Kalmi, Hincha, Sushni= Edible Plant

Koch =An indigenous mongoloid race who lived in the area from pre- historic time

patkathi= Jute sticks

Rajbanshis, Oraon, Rabha, Munda, Santal, Bedia and Garo=The native people of Koch Bihar district.

APPENDIX-D

List of Publications

1. Miraj, A. & Bhattacharya, S., K. (2017). "Changing Trends Of Some Bio –Physico-Chemical Characteristics of Sagar Dighi of Cooch Behar, West Bengal, India, Journal of Indian Research (ISSN: 2321-4155), 5(3), pp. 79-94**. (Included in the Thesis)**

2. Miraj, A. & Bhattacharya, S., K. (2017). "Assessment of Water Quality Index (WQI) and Suitability of Sagar Dighi, Koch Bihar, West Bengal, India", International Journal of Pharmaceutics & Drug Analysis, (ISSN: 2348-8948), 5 (12), pp. 467-474. **(Included in the Thesis)**

3. Miraj, A., Pal, S., Bhattacharya, S., K. & Chakrborty, K. (2017). "Observation on the TDS and EC Values of Different Water Bodies at Cooch Behar, West Bengal, India" International Journal of Theoretical & Applied Sciences, 9(2),106-113.

4. Bhattyacharya. S., K., & Miraj. A. (2017), "Application of Remote Sensing and G.I.S in Wetland management: A Case study of Koch Bihar District, West Bengal" (Mandal. D.K. Ed), Remote Sensing and G.I.S in Environmental Management, 28-39.

Appendix – E

Copy of the Publications

Journal of Indian Research (ISSN: 2321-4155)
Vol.5, No.3, July-September, 2017, 79-94

Geography

CHANGING TRENDS OF SOME BIO-PHYSICO-CHEMICAL CHARACTERISTICS OF SAGARDIGHI OF COOCH BEHAR, WEST BENGAL, INDIA

Abdul Miraj*
Sudip Kumar Bhattacharya**

ABSTRACT

Present work was designed to study the changing trends of some important bio-physico-chemical characteristics of Sagardighi of Cooch Behar, West Bengal, India. To evaluate the water quality of the lake, bio-physico-chemical parameters (tested by West Bengal Pollution Control Board, Siliguri laboratory) were studied on the monthly basis for a period of five years between June 2011 to May 2016. There were seven physical parameters , interalia, Temperature, pH, Total Dissolved Solid (TDS), Total Suspended Solid (TSS), Total Fixed Solids (TFS), Turbidity, and Electrical Conductivity (EC); thirteen chemical parameters, interalia, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Alkalinity (TA), calcium, magnesium, chloride, sulphate, sodium, phosphate, nitrate-N, potassium, Total Hardness (TH) and two bacteriological parameters, Total Coliform(TC) and Fecal Coliform(FC). The present work provides baseline information on changing trends of bio-physico-chemical status of Sagardighi. This would facilitate sustainable management and conservation of ecosystem of this lake. The data obtained from this study reveals that the bio-physico-chemical parameters of Sagardighi of Cooch Behar are comparatively in moderate condition but almost all the parameters are prone to cross the critical pollution level, if necessary action is not taken in time.

Keywords: Bacteriological Parameters, Changing Trends, Chemical Parameters, Physical Parameters, Sagardighi.

INTRODUCTION

Ponds are useful wetlands located in and around human settlement. Ponds are generally semi-natural ecosystems constructed by man. The ponds are subjected to a range of physical,

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chemical and biological problems caused by human activities and climate change due to which a major concern has aroused as it can diminish their aesthetic beauty, recreational value, water quality and habitat suitability. Most of the ponds or lakes, especially near residential, commercial and administrative areas are polluted because of anthropogenic activities. The physical and chemical characteristics of water are important parameters as they directly or indirectly affect its quality and consequently its suitability for the distribution and production of fish and other aquatic animals (Swingle 1969).

Increased anthropogenic activities in and around the water bodies damage the aquatic ecosystems and ultimately the physico-chemical properties of water (Upadhyay *et al.* 2010). It is well established that domestic sewage and industrial effluents falling into natural water bodies change the water quality and lead to eutrophication (Shaw *et al.* 1991). The monitoring of physico-chemical parameters of a water body is vital for both long term and short term study (Wood 1995). Good water quality resources depends on a large number of physico-chemical parameters and the magnitude and source of any pollution load; and to assess that, monitoring of these parameters are essential (Reddi *et al.* 1993).

MATERIALS AND METHODS

Description of Study Area

Sagardighi has been selected for study. It is the most important freshwater body which is situated in the heart of Cooch Behar town. It extends between 26°19’12”N to 26°19’21”N and 89°26’21”E to 89°26’28”E and the total surface area of this lake is 14.60 hectare. The lake was excavated by Maharaja Harendra Narayan in 1807 AD. It attracts various migratory

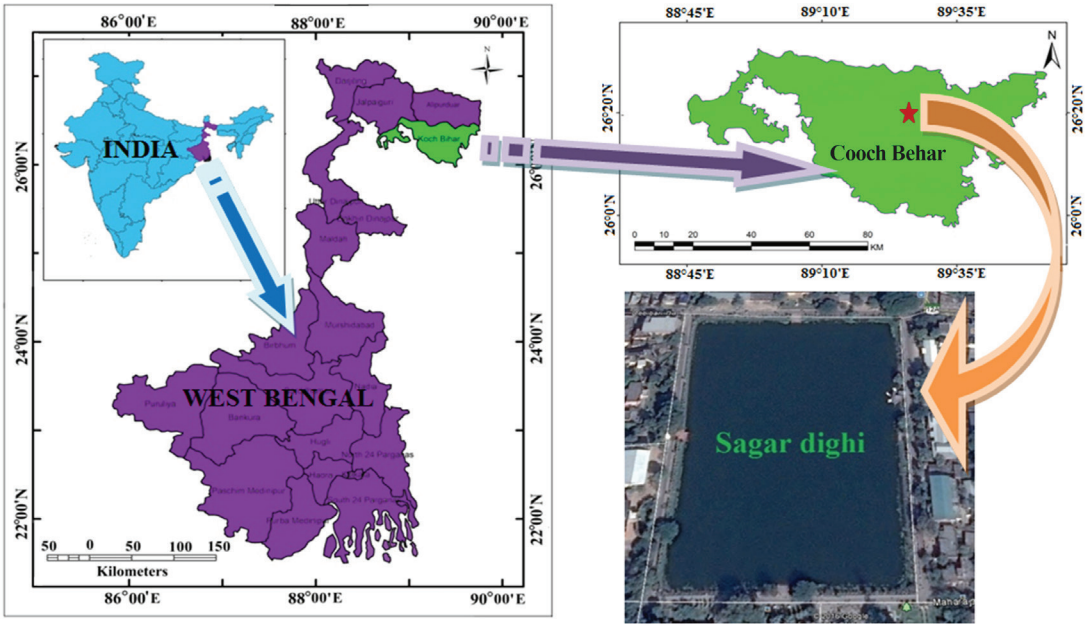

Figure 1: Locational Map of Sagardighi.

birds during the winter season. Among all ponds in Cooch Behar town the most spectacular is Sagardighi, with grand structures arrayed all around it. These buildings, built mostly between 1880 to 1920, are now offices of the district administration like Office of the District Magistrate, Administrative Building of North Bengal State Transport Corporation, BSNL Office on the West; Office of the Superintendent of Police, District Library, Municipality Building on the South, Office of the BLRO, Sate Bank of India (Cooch Behar Main Branch) and numerous other on the east and RTO office, Foreigner's enrollment office, District Court in the north. Although this lake was excavated for drinking water supply control, now it is used for bathing, swimming, washing clothes, fishing, morning and evening walk around the lake, resting or gossiping place, boating etc.

Collection of Water Parameters Data:

The study of Cooch Behar Lake or Sagardighi was conducted using secondary data of five year duration between June 2011 to May 2016 of West Bengal Pollution Control Board, Siliguri Laboratory, Siliguri in Darjeeling.

Statistical Analysis:

Statistical analysis like mean, standard deviation and correlation coefficient, correlation matrix etc. and some graphical representation have been made using Microsoft Excel (Version Windows 2007), a computer based programmer for windows.

Preparation of maps:

The locational map was prepared by using Google Earth, Global Mapper 2011 and Arc GIS v-9.3.

RESULTS AND DISCUSSION

Physical Parameters:

Temperature: It is one of the most important parameters for aquatic environment because it governs the physical, chemical and biological properties of water. The maximum water temperature (35°C) was recorded in September, 2011 and minimum (18°C) in January, 2013(Table 1). The mean temperature is gradually high from 28.58°C (2011-12) with SD 4.54 to 29.83°C (2015-16) with SD 3.59 in (Table 1 & 2).

pH: pH is an important parameter because it indicates more or less overall water environment. The intensity of acidity or alkalinity of water can be measured by taking the value of pH of water. Natural water is usually alkaline due to the presence of sufficient quantities of carbonate. Here, it ranged from 6.63 (July, 2011) to 9.54 (April, 2016) during 2011-16(Table 1). Sometime pH value exceeds the permissible limit i.e. 6.5 to 8.5.

Total Dissolved Solid (TDS): TDS consequently may have an influence on the acceptability of water in general. Water with a very low TDS concentration may be corrosive and corrosive water may lead to toxicity in water. The variation of TDS in water may occur due to ionic composition of water. The highest TDS (271 mg/l) was recorded in August, 2012 and lowest one was 22 mg/l in November 2011(Table 1).

Total Suspended Solid (TSS): The TSS is a direct measurement of the concentration of suspended material present in a water sample. TSS value varied due to ionic composition of water and the factors like rainfall and biota cause changes in their concentrations. The maximum TSS (158 mg/l) was recorded in October, 2013 and minimum (4 mg/l) in January, 2011 (Table 1).

Total Fixed Solids (TFS): Total Solids are dried, weighed, and then ignited at 500 ± 50ºC. The loss of weight by ignition at 500 ± 50ºC is a measure of the volatile solids, which are classed as organic material. The remaining solids are the total fixed solids, which are considered as inorganic (mineral) matter. In other word, the Total Solids associated with the mineral fraction are termed Total Fixed Solids (TFS). It ranged from 4 mg/l (June, 2015) to 160 mg/l (September, 2015) during 2011-16 (Table 1).

Turbidity: It is another important physical parameter which is responsible for scattering and absorption of light by water. As the turbidity obstructs light penetration, it limits production of phytoplankton growth, which in turn leads to a decrease in photosynthetic activity and depletion of oxygen content. The maximum turbidity (39.1/NUT) was recorded in May, 2013 and minimum (3.11/NUT) in February, 2016 (Table 1), whereas the permissible limit (BIS standard) of turbidity is 5/NUT.

Electrical Conductivity (EC): EC value is an index to represent the total concentrations of soluble salt in surface water. The highest EC (98.8 µS/cm) was recorded in August, 2012 and lowest one was (42 µS/cm) in November 2011(Table 1). EC showed a positive correlation with Total Alkalinity (r=0.686) (Table 2).

Chemical Parameters:

Dissolved Oxygen (DO**):** DO indicate the health of the ecosystem and refers to the volume of oxygen present in water body. It is an important water quality parameter to be measured because it prevails over biological and physicochemical attributes of surrounding water. Oxygen enters into water by aerial diffusion and as a photosynthetic byproduct of aquatic plants and algae. The DO depends upon the temperature, salinity and pressure of water. The DO value indicates the degree of pollution in the water bodies (Gopalkrushna, 2011).It ranged from 5.2 mg/l in July 2011 to 9.9 mg/l in February, 2012 during 2011-16 (Table 1).

Biochemical Oxygen Demand (BOD): It is one of the most important components for the aquatic community. It is the amount of dissolved oxygen needed (i.e., demanded) by aerobic biological organisms to break down organic material present in a given water sample at certain temperature over a specific time period. The maximum BOD (7.1 mg/l) was recorded in May, 2012 and minimum (0.85 mg/l) in July, 2011(Table 1). The mean BOD is gradually low from 3.42 mg/l with SD 2.14 in 2011-12 to 2.28 mg/l with SD 0.72 in 2015-16(Table 1 & 2).

Chemical Oxygen Demand (COD): The oxygen required by the organic matters in water to be oxidized by a strong chemical oxidant which is known as Chemical Oxygen Demand (COD). Sometimes BOD cannot be determined accurately due to the presence of toxins and other such unfavorable conditions. Under such circumstances, COD plays an important role for assessment of organic matters in water. It ranged from 14.4 mg/l (October, 2011) to 78 mg/l

(July, 2011) during 2011-16 (Table 1), whereas the permissible limit (WHO standard) of COD is 10 mg/l. It showed a positive correlation with turbidity (r=0.647) (Table 2).

Total Alkalinity (TA): TA of water is an important parameter, which determines the amount of chemical needed to be added in water treatment. Alkalinity is an anionic phenomenon. The highest alkalinity value (68mg/l) was recorded in December 2012 and the lowest (15.2 mg/l) in March 2013. This shows a positive correlation with calcium (r=0.686, Table 1 and 2) and conductivity(r=0.748, Table 1 and 2).

Calcium: Calcium content is present in hard water as well as soft water. Calcium in wetland water is most essential for the growth of aquatic vegetation and lives. It ranged from 2.83mg/l (April, 2013,) to 27.25 mg/l (August, 2015) during 2011-16 (Table 1).

Magnesium: It is an important chemical component of water. It is essential for the chlorophyll bearing bacteria, algae and plants. Magnesium concentration ranged from 0.54 mg/1 to 8.75mg/l.

Chloride: It is one of the major inorganic anions in water and waste water. Chloride content increases in water bodies due to organic matter decomposition. The important source of chloride in the water is the discharge of domestic and industrial sewage. Hence, the chloride concentration serves as an indicator of pollution by sewage disposal and industrial wastes. The maximum chloride (17.61mg/l) was recorded in November, 2016 and minimum (1.96 mg/l) in May, 2016 (Table 1).

Sulphate: Sulphate is naturally occurring anions in all kinds of natural water. Industrial waste and domestic sewage are responsible for increase of its concentrations in water. The tolerance limit of sulphate in water is 200 mg/1 while, excessive limit considered is 400mg/l. Sulphate concentration ranged from 0.055mg/l in January, 2011 to 16.33 mg/l in June, 2013

Sodium: Sodium content in water is essential chemical component. The maximum sodium (1 mg/l) was recorded in March, 2013 and minimum (6mg/l) in September, 2011 (Table 1).

Phosphate: In natural water, phosphorous occurs as phosphate. It is essential for the growth of organisms and act as nutrient that limits the primary productivity of water body that stimulates the growth of photosynthesis of aquatic micro and macro organisms. The maximum phosphate (0.587mg/l) concentration was recorded in July, 2014 and minimum (0.007 mg/l) in February, 2014 (Table 1).

Nitrate-N: Nitrate-N concentration enters fresh water through discharge of sewage, industrial wastes and runoff from agricultural fields, the concentration and rate of supply of nitrate in the land use practices of the surrounding watershed. In present study, Nitrate-N concentration ranged from 0.003 mg/1 to 0.68mg/l (Table 1).

Potassium: Potassium concentration is very low (<10 mg/l) in natural waters since rocks, which contain potassium, are relatively resistant to weathering. It is usually found in ionic form and the salts are highly soluble. Though found in small quantities it plays a vital role in the metabolism of fresh water environment (Ramachandra *et al*., 2012). The maximum potassium (3 mg/l) was recorded in January, 2013 and minimum (0.78 mg/l) in September, 2013 (Table 1).

Total Hardness (TH): Total Hardness normally indicates the total calcium and magnesium salts present in water along with some other polyvalent metals such as iron, aluminum, manganese etc. It determines the suitability of water for domestic, industrial and drinking purposes. The total hardness of the water body was in the range between 14.14 mg/l in June, 2011 to 84 mg/l in December, 2011(Table 1).Total Hardness showed a positive correlation with calcium (r=0.883, Table 1 and 2) and magnesium (r=0.698, Table 1 and 2).

Bacteriological Parameters

Total Coliform and Fecal Coliform are the two bacteriological parameters considered here which indicate the presence of pathogens in water of the lake. The maximum Total Coliform (170000 MPN/100ml) was recorded in August, 2011 and minimum (1700 MPN/100ml) in April, 2013(Table 1). The maximum Fecal Coliform (27000 MPN/100ml) was recorded in August, 2011 and minimum (500 MPN/100ml) in April, 2013(Table 1), whereas the permissible limit of Total Coliform and Fecal Coliform is 500 MPN/100ml(CPCB standard) and 10-100 MPN/100ml(Malaysia standard) respectively. Total Coliform showed a positive correlation with Fecal Coliform (r=0.877) (Table 2).

Table 1a: Monthly Fluctuation of Different Bio-Physico-Chemical Parameters in Sagardighi of Cooch Behar, West Bengal

Year		2011							2012					Range	Mean	Standard Deviation
Parameters	**Unit**	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May			
BOD	mg/l	3.35	0.85	1.5	3.6	1.1	1.7	3.2	4	2.2	5.5	6.9	7.1	0.85-7.1	3.42	2.14
Calcium	mg/l	4.12	6.59	6.6	4.9	5.6	9.6	19.2	7.2	6.4	4	7.69	8	4-19.2	7.49	4.03
Chloride	mg/l	2.99	2.94	2.99	4	6.6	6.6	4.86	6.8	5.83	4.89	4.89	3.91	2.94-6.8	4.78	1.45
COD	mg/l	30	78	33.6	17.2	14.4	24.96	39.6	40	58.41	43.68	55.44	45	14.4-78	40.02	18.10
Conductivity	µS/cm	50.6	57.3	48.9	46.7	47.7	51.8	49.3	51.4	58.3	57.5	66	60	46.7-66	53.79	5.92
Dissolved O_2 (DO)	mg/l	7.8	5.2	8.2	8.1	9.8	9.2	9.8	9.8	9.9	9	9.1	8.8	5.2-9.9	8.73	1.32
Fecal Coliform	MPN/ 100ml	22000	9000	27, 000	9000	22000	7000	11000	8000	8000	1300	1700	3000	1300-27000	10750.00	8441.40
Magnesium	mg/l	0.98	1.96	0.99	1.45	4.37	1.94	8.75	1.46	4.37	1.73	3.88	2.3	0.98-8.75	2.85	2.23
Nitrate-N	mg/l	0.15	0.04	0.27	0.17	0.12	BDL	0.02	BDL	0.04	BDL	BDL	0.18	0.02-0.27	0.12	0.09
pH	Unit	7.25	6.63	7.01	7.94	6.93	7.24	7.63	7.31	6.95	7.92	6.66	7.89	6.63-7.94	7.28	0.47
Phosphate-P	mg/l	0.037	0.044	0.014	0.02	0.03	0.23	0.02	0.05	0.01	0.087	0.027	0.011	0.01-0.23	0.05	0.06
Potassium	mg/l	2	1	1	1	1	1	1	1	1	1	1	1	1-2	1.08	0.29
Sodium	mg/l	2.5	1.46	4.03	6	2.35	2.35	3.73	5.69	3.36	4.71	4.71	2.75	1.46-6	3.64	1.43
Sulphate	mg/l	0.055	0.16	NT	2.95	2.65	2.75	6.38	2.78	1.63	2.02	0.62	2.42	0.055-6.38	2.22	1.75
Temperature	^{0}C	32	33	31	35	32	25	25	20	23	27	30	30	20-35	28.58	4.54
Total Alkalinity	mg/l	18	20	22	20	22	24	68	30	24	32	28.5	24.7	18-68	27.77	13.36
Total Coliform	MPN/ 100ml	70000	17000	1, 70, 000	17, 000	50000	11000	14000	11000	13000	5000	2700	5000	2700-170000	32141.67	47811.42
Total Dissolved Solids(TDS)	mg/l	154	36	30	36	40	22	26	84	46	83	54	64	22-154	56.25	37.02
Total Fixed Solids(TFS)	mg/l	16	8	10	10	30	6	10	40	26	30	22	16	6-40	18.67	10.83
Total Hardness as $CaCO_3$	mg/l	14.14	24.24	20.2	18	32	32	84	24	34	16	32.69	28	14.14-84	29.94	18.36
Total Suspended Solids(TSS)	mg/l	48	42	18	38	28	4	6	4	92	30	16	142	4-142	39.00	40.70
Turbidity	NTU	17.4	28.6	7.11	8.57	17.2	10.2	13.9	9.25	22.4	12.5	19.6	10.7	7.11-28.6	14.79	6.44

Source: West Bengal Pollution Control Board. BDL= Below Detectable Level

Table 1b: Monthly Fluctuation of Different Bio-Physico-Chemical Parameters in Sagardighi of Cooch Behar, West Bengal

Year		2012							2013							
Parameters	**Unit**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Range**	**Mean**	**Standard Deviation**
BOD	mg/l	6.3	5.35	3.2	3.8	4.8	4.1	4.3	4.2	3.6	6.3	4.3	2.8	2.8-6.3	4.42	1.10
Calcium	mg/l	5.82	5.6	5.6	7.2	5.6	8	8	5.66	9.2	5.66	2.83	9.82	2.83-9.82	6.58	1.93
Chloride	mg/l	3.91	3.74	4.78	2.87	3.83	3.83	5.74	6.7	2.87	7.66	3.82	7.78	2.87-7.78	4.79	1.75
COD	mg/l	21.12	37.44	32.64	19.32	27.04	37.44	39.12	41.6	66.56	73	61	69	19.32-73	43.77	18.90
Conductivity	µs/cm	56	50	47	47	42	50	52	53	56	58	57	53	42-58	51.75	4.79
Dissolved O_2 (DO)	mg/l	8.6	8.6	6.4	6.5	8	8.3	8.2	8.9	8.8	8.6	7.9	7.6	6.4-8.9	8.03	0.83
Fecal Coliform	MPN/ 100ml	2300	1300	1100	3300	2700	1700	2100	2200	1300	1100	500	1400	500-3300	1750.00	790.28
Magnesium	mg/l	1.79	1.73	2.3	1.73	2.3	2.3	1.152	2.55	5.61	1.02	1.53	5.05	1.02-5.61	2.42	1.44
Nitrate-N	mg/l	0.1	0.01	0.008	0.01	0.007	0.01	BDL	BDL	BDL	0.01	0.006	0.01	0.006-0.1	0.02	0.03
pH	Unit	8.02	8	7.21	7.65	8.5	8.27	7.57	8.1	8.35	7.3	7.96	7.63	7.21-8.5	7.88	0.41
Phosphate-P	mg/l	0.026	0.021	0.019	0.021	0.034	0.049	0.063	0.058	0.075	0.061	0.083	0.062	0.019-0.083	0.05	0.02
Potassium	mg/l	1	<1.00	1	<1.00	1	<1.00	<1.00	3	1	<1.00		<1.00	1-3	1.40	0.89
Sodium	mg/l	4.71	3.36	2.75	2.35	2.75	1.88	2.85	5	2.38	1		1.13	1-5	2.74	1.27
Sulphate	mg/l	1.5	7.19	5	0.29	0.468	5.37	0.075	4.29	2.22	2.24	3.17	3.33	0.075-7.19	2.93	2.23
Temperature	^{0}C	29	32	32	29	28	30	26	18	26	28	34	31	18-34	28.58	4.12
Total Alkalinity	mg/l	20.9	19	20.9	22.8	22.8	24.7	26.6	28.5	26.6	15.2	20.9	26.1	15.2-28.5	22.92	3.80
Total Coliform	MPN/ 100ml	8000	14000	8000	22000	17000	13000	17000	14000	8000	5000	1700	8000	1700-22000	11308.33	5818.07
Total Dissolved Solids(TDS)	mg/l	88	271	115	33	43	62	74	75	26	68	64	52	26-271	80.92	64.54
Total Fixed Solids(TFS)	mg/l	16	10	10	20	28	60	88	40	24	30	18	44	10-88	32.33	22.91
Total Hardness as $CaCO_3$	mg/l	20.8	20	22	24	22	28	24	23.1	21.47	17.7	12.39	42.09	12.39-42.09	23.13	7.07
Total Suspended Solids(TSS)	mg/l	40	40	26	98	24	12	28	42	44	44	44	60	12-98	41.83	21.65
Turbidity	NTU	9.56	7.89	5.26	4.18	5.14	6.64	8.84	7.36	17.4	31.7	14.8	39.1	4.18-39.1	13.16	11.20

Source: West Bengal Pollution Control Board. BDL= Below Detectable Level

Table 1c: Monthly Fluctuation of Different Bio-Physico-Chemical Parameters in Sagardighi of Cooch Behar, West Bengal

Year		2013							2014							
Parameters	**Unit**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Range**	**Mean**	**Standard Deviation**
BOD	mg/l	2.2	3	3.1	3.6	2.4	1.9	2.1	3.4	3.4	2.8	1.8	4.5	1.8-4.5	2.85	0.81
Calcium	mg/l	5.6	6.4	8.8	13.6	7.2	6.4	7.2	6.4	7.2	8	9.6	12	5.6-13.6	8.20	2.44
Chloride	mg/l	6.84	10.76	10.53	8.81	2.94	3.91	6.85	4.89	5.87	4.87	7.83	15.65	2.94-15.65	7.48	3.55
COD	mg/l	53	28.52	15.84	46.72	49.28	31	26.88	24.84	42.32	31.2	36.48	49	15.84-53	36.26	11.70
Conductivity	µs/cm	51	56	50	53	50	51	51	53	56	70	74	85	50-85	58.33	11.52
Dissolved O_2 (DO)	mg/l	7.2	7.8	6.9	8.2	7.8	8.2	7.8	6.8	7.8	6.9	6.9	6.8	6.8-8.2	7.43	0.56
Fecal Coliform	MPN/ 100ml	2700	9000	8000	2200	2600	5000	2600	2200	2200	2100	1100	1700	1100-9000	3450.00	2540.76
Magnesium	mg/l	3.46	3.46	2.88	1.73	0.58	1.15	1.73	1.73	2.3	1.15	2.3	4.61	0.58-4.61	2.26	1.16
Nitrate-N	mg/l	0.008	0.02	0.008	0.05	0.02	0.007	0.007	0.02	0.008	0.005	0.19	0.68	0.005-0.68	0.09	0.19
pH	Unit	7.35	7.16	7.2	7.32	7.28	7.38	7.2	7.22	7.23	7.13	7.22	7.58	7.13-7.58	7.27	0.12
Phosphate-P	mg/l	0.055	0.051	0.042	0.031	0.039	0.033	0.035	0.057	0.007	0.041	0.029	0.123	0.007-0.123	0.05	0.03
Potassium	mg/l	<1.0	<1.0	<1.00	0.78	<1.00	<1.00	1	1	1	1	2	1	0.78-2	1.11	0.40
Sodium	mg/l	1.813	2.86	2.35	4.43	<1.00	1.35	2.75	2.75	1.34	2.35	3.29	4.37	1.34-4.43	2.70	1.04
Sulphate	mg/l	16.33	2.54	3.49	1.41	0.74	1.74	1.82	0.75	0.92	0.94	0.79	0.45	0.45-16.33	2.66	4.39
Temperature	^{0}C	30	31	34	35	28	26	26	22	24	30	29	30	22-35	28.75	3.82
Total Alkalinity	mg/l	20	24	24	28	24	24	26	18	22	42	36	30	18-42	26.50	6.78
Total Coliform	MPN/ 100ml	13000	16000	14000	8000	11000	11000	8000	6000	5000	6000	5000	7000	5000-16000	9166.67	3737.61
Total Dissolved Solids(TDS)	mg/l	63	92	90	65	82	64	78	48	75	75	111	47	47-111	74.17	18.43
Total Fixed Solids(TFS)	mg/l	68	32	16	16	32	16	22	12	54	20	16	30	12-68	27.83	17.17
Total Hardness as $CaCO_3$	mg/l	26	28	32	40	20	20	24	22	26	24	32	46	20-46	28.33	7.99
Total Suspended Solids(TSS)	mg/l	42	54	88	78	158	42	24	16	44	44	22	146	16-158	63.17	46.57
Turbidity	NTU	13.8	10.4	5.24	3.46	3.65	3.75	4.34	6.28	4.27	6.12	5.61	22.3	3.46-22.3	7.44	5.60

Source: West Bengal Pollution Control Board. BDL= Below Detectable Level

Table 1d: Monthly Fluctuation of Different Bio-Physico-Chemical Parameters in Sagardighi of Cooch Behar, West Bengal

Year		2014							2015					Range	Mean	Standard Deviation
Parameters	**Unit**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**			
BOD	mg/l	4.5	1.7	2.8	2.1	2.6	2.2	2.4	2.6	1.6	3	1.8	2.4	1.6-4.5	2.48	0.77
Calcium	mg/l	9.6	10.92	6.72	10.08	8.4	6.72	5.92	11.2	12	11.16	11.21	10.42	5.92-12	9.53	2.08
Chloride	mg/l	3.91	4.89	10.76	7.82	3.91	7.83	6.85	4.99	7.83	4.89	16.75	4.89	3.91-16.75	7.11	3.66
COD	mg/l	41	35.36	24	22.08	44.16	28.56	18.32	24	41.28	33.16	37.44	55.12	18.32-55.12	33.71	10.80
Conductivity	µs/cm	67	69	70	66	60	71	62.7	65			92	98.8	60-98.8	72.15	12.79
Dissolved O_2 (DO)	mg/l	6.8	7.4	7.5	7.2	7.4	7.4	8.7	7.2	6.8	8.2	7.4	7.9	6.8-8.7	7.49	0.55
Fecal Coliform	MPN/ 100ml	1300	1700	9000	5000	1700	1400	2600	2700	1400	1700	1300	1700	1300-9000	2625.00	2260.78
Magnesium	mg/l	1.73	2.42	3.63	2.27	3.02	1.81	4.26	0.58	1.15	0.54	0.96	4.32	0.54-4.32	2.22	1.34
Nitrate-N	mg/l	0.05	0.02	BDL	NT	0.09	0.006	NT	0.007	0.004	NT	0.003	0.02	0.003-0.09	0.03	0.03
pH	Unit	7.6	7.12	6.96	7.57	7.33	7.89	7.75	7.56	7.49	8.8	8.5	8.73	6.96-8.8	7.78	0.60
Phosphate-P	mg/l	0.239	0.587	0.019	0.013	0.027	0.027	0.056	0.038	0.027	0.029	0.025	0.045	0.013-0.587	0.09	0.17
Potassium	mg/l			1	1	1	1	1	1	1	1	1	BDL	1-1	1.00	0.00
Sodium	mg/l		2.86	2	3	3	2.75	3	3	3.36	3	3.36	2.35	2-3.36	2.88	0.40
Sulphate	mg/l	0.68	2.17	3.38	2.5	3.71	0.14	0.66	0.97	1.94	0.95	1.67	1.09	0.14-3.71	1.66	1.12
Temperature	^{0}C	32	32	33	30	28	29	27	24	29	28	32	32	24-33	29.67	2.67
Total Alkalinity	mg/l	36	38	44	34	40	31.5	38	36	34	40	42	44	31.5-44	38.13	4.02
Total Coliform	MPN/ 100ml	8000	4000	14000	11000	7000	5000	7000	9000	8000	9000	7000	8000	4000-14000	8083.33	2609.71
Total Dissolved Solids(TDS)	mg/l	49	49	91	93	44	84	61	37	61	77	45	84	37-93	64.58	20.21
Total Fixed Solids(TFS)	mg/l	18	20	14	10	8	8	12	10			6	68	6-68	17.40	18.33
Total Hardness as $CaCO_3$	mg/l	30	35.7	29.4	23.1	31.5	23.1	29.6	30	34	30	32	44	23.1-44	31.03	5.51
Total Suspended Solids(TSS)	mg/l	24	57	46	56	16	38	56	22	24	28	64	25	16-64	38.00	16.92
Turbidity	NTU	4.57	10.2	3.44	6.16	8.27	4.67	8.76	7.07	6.58	6.14	9.12	14.1	3.44-14.1	7.42	2.91

Source: West Bengal Pollution Control Board. BDL= Below Detectable Level

Table 1e: Monthly Fluctuation of Different Bio-Physico-Chemical Parameters in Sagardighi of Cooch Behar, West Bengal

Year		2015							2016					Range	Mean	Standard Deviation
Parameters	**Unit**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**			
BOD	mg/l	2.4	1.7	2	2.5	2.8	3.9	3.1	1.7	1.6	2	2.3	1.4	1.4-3.9	2.28	0.72
Calcium	mg/l	9.62	12.83	27.25	10.42	16.03	15.23	16.83	11.22	12.02	15.23	10.42	12.02	9.62-27.25	14.09	4.79
Chloride	mg/l	6.84	10.76	4.89	13.69	7.83	17.61	13.69	12.72	9.78	9.78	2.93	1.96	1.96-17.61	9.37	4.71
COD	mg/l	46.8	19.76	25	33	22	27.84	34.56	31	23	39	60.48	62.4	19.76-62.4	35.40	14.37
Conductivity	µs/cm	86.6	87.18	86.6	79.81	87.74	77.12	68.89	66.97	73.42	84.51	85.19	80.1	66.97-87.74	80.34	7.32
Dissolved O_2 (DO)	mg/l	7.1	7.9	6.8	8	8.6	8.8	8.7	7.3	7	8	8.7	7.9	6.8-8.8	7.90	0.71
Fecal Coliform	MPN/ 100ml	2200	800	2200	2700	3300	14000	2600	2100	6000	1200	1100	800	800-14000	3250.00	3670.65
Magnesium	mg/l	3.84	0.56	2.8	4.48	6.16	1.73	5.18	5.76	1.73	5.18	4.03	5.18	0.56-6.16	3.89	1.80
Nitrate-N	mg/l	BDL	0.01	0.02	0.04	0.07	0.1	0.05	0.09	0.13	0.06	0.1	0.12	0.01-0.13	0.07	0.04
pH	Unit	8.79	8.73	7.31	8.33	7.86	7.6	8.6	7.7	8.45	8.62	9.54	8.75	7.31-9.54	8.36	0.63
Phosphate-P	mg/l	0.139	0.029	0.027	0.089	0.114	0.083	0.184	0.023	0.055	0.047	0.12	0.015	0.015-0.184	0.08	0.05
Potassium	mg/l	2	2	1	1	1	BDL	BDL	2	1	2	BDL	BDL	1-2	1.50	0.53
Sodium	mg/l	3	5	3	3	3	BDL	1	4	3.36	3.36	3	5	1-5	3.34	1.10
Sulphate	mg/l	2.96	2.13	4.29	4.38	5.49	4.08	5.16	6.56	BDL	6.12	0.88	2.38	0.88-6.56	4.04	1.78
Temperature	^{0}C	32	34	30	33	31	30	26	22	26	30	34	30	22-34	29.83	3.59
Total Alkalinity	mg/l	46	42	52	46	60	46	48	34	62	48	40	44	34-62	47.33	7.83
Total Coliform	MPN/ 100ml	11000	3000	5000	7000	5000	33000	7000	6000	17000	3300	2600	3300	2600-33000	8600.00	8702.25
Total Dissolved Solids(TDS)	mg/l	70	49	35	59	84	41	64	73	91	93	90	23	23-93	64.33	23.48
Total Fixed Solids(TFS)	mg/l	4	30	20	160	10	12	26		54	86	18	6	4-160	38.73	46.92
Total Hardness as $CaCO_3$	mg/l	48	34	78	42	62	36	60	48	36	56	40	48	34-78	49.00	13.06
Total Suspended Solids(TSS)	mg/l	48	22	24	38	52	20	84	28	26	94	22	20	20-94	39.83	25.42
Turbidity	NTU	24.3	6.28	10.2	11.4	4.18	11.5	7.18	5.04	3.11	10.2	8.39	10.4	3.11-24.3	9.35	5.51

Source: West Bengal Pollution Control Board. BDL= Below Detectable Level

Table 2: Correlation Matrix of Bio-Physico-Chemical Parameters of Sagardighi of Cooch Behar, West Bengal

Parameters	BOD	Calcium	Chloride	COD	Conductivity	Dissolved O2(DO)	Fecal Coliform	Magnesium	Nitrate-N	pH	Phosphate-P	Potassium	Sodium	Sulphate	Temperature	Total Alkalinity	Total Coliform	Total Dissolved Solids(TDS)	Total Fixed Solids(TFS)	Total Hardness as CaCo3	Total Suspended Solids(TSS)	Turbidity
BOD	1	-0.273	-0.142	0.148	-0.271	0.319	-0.212	-0.120	0.122	0.002	-0.075	-0.098	0.160	-0.082	-0.063	-0.318	-0.062	0.208	0.000	-0.273	0.151	0.136
Calcium		1	0.340	-0.098	0.563	-0.049	-0.133	0.378	0.041	0.229	0.130	-0.023	0.043	0.172	0.029	0.748	-0.215	-0.247	0.029	0.883	-0.013	-0.087
Chloride			1	-0.219	0.440	-0.042	-0.014	0.166	0.219	0.084	0.047	0.142	0.013	0.184	0.040	0.339	-0.028	-0.030	0.232	0.305	0.187	-0.002
COD				1	0.069	0.025	-0.264	0.191	0.027	0.063	0.034	0.011	-0.152	0.009	0.031	-0.158	-0.264	-0.098	0.098	-0.009	0.120	0.647
Conductivity					1	-0.178	-0.303	0.247	0.189	0.484	0.165	0.195	0.106	-0.054	0.259	0.686	-0.328	-0.056	0.121	0.527	0.038	0.028
Dissolved O_2 (DO)						1	0.229	0.269	-0.012	0.133	-0.023	-0.036	0.251	0.092	-0.295	0.027	0.114	-0.008	0.075	0.071	-0.099	0.093
Fecal Coliform							1	-0.024	0.252	-0.382	-0.128	-0.042	0.011	-0.017	0.097	-0.131	0.877	-0.067	-0.151	-0.091	-0.112	0.092
Magnesium								1	0.142	0.171	0.057	0.057	-0.045	0.370	-0.057	0.448	-0.109	-0.161	0.151	0.698	0.060	0.277
Nitrate-N									1	-0.015	0.028	0.051	0.392	-0.155	0.082	-0.004	0.112	-0.084	-0.073	0.081	0.322	0.167
pH										1	0.019	0.297	0.157	0.057	0.107	0.404	-0.229	0.060	0.215	0.232	-0.035	-0.113
Phosphate-P											1	0.067	-0.116	-0.010	0.088	0.143	-0.123	-0.137	-0.006	0.125	0.028	0.062
Potassium												1	0.218	0.257	-0.197	0.053	0.166	0.348	0.127	0.048	0.011	0.043
Sodium													1	-0.071	-0.062	0.128	-0.132	-0.025	-0.102	0.031	-0.132	-0.205
Sulphate														1	0.006	0.146	-0.049	0.152	0.240	0.286	-0.085	0.001
Temperature															1	0.017	0.090	0.127	-0.049	0.016	0.141	0.115
Total Alkalinity																1	-0.215	-0.138	0.093	0.763	-0.143	-0.185
Total Coliform																	1	0.164	-0.040	-0.198	-0.034	0.127
Total Dissolved Solids(TDS)																		1	0.033	-0.232	0.060	-0.167
Total Fixed Solids(TFS)																			1	0.087	0.030	0.060
Total Hardness as $CaCO_3$																				1	0.010	0.074
Total Suspended Solids(TSS)																					1	0.104
Turbidity																						1.000

(Values are shown as r = coefficient correlation)

CONCLUSION

The bio-physico-chemical parameters of Sagardighi are within the tolerance limits except pH, COD, Turbidity, Total Coliform and Fecal Coliform. Among them, value of COD, Total Coliform and Fecal Coliform were always above permissible limit. Therefore, we generally say that the water quality of Sagardighi is moderately suitable for bathing and swimming as well as for the growth of aquatic fauna and flora. However, fluctuations in bio-physico-chemical parameters, if they continue, would result in imbalance in the ecosystem in long run. After detailed study of bio-physico-chemical data of Sagardighi for five years (2011-2016), it is revealed that water quality is comparatively in moderate condition but almost all the parameters are prone to cross their critical pollution level. Therefore an urgent effort must be taken to develop ecosystem-based management strategies with inputs from scientists, resource managers, policy makers, government and non-government organizations and environmentalist to save this heritage water-body.

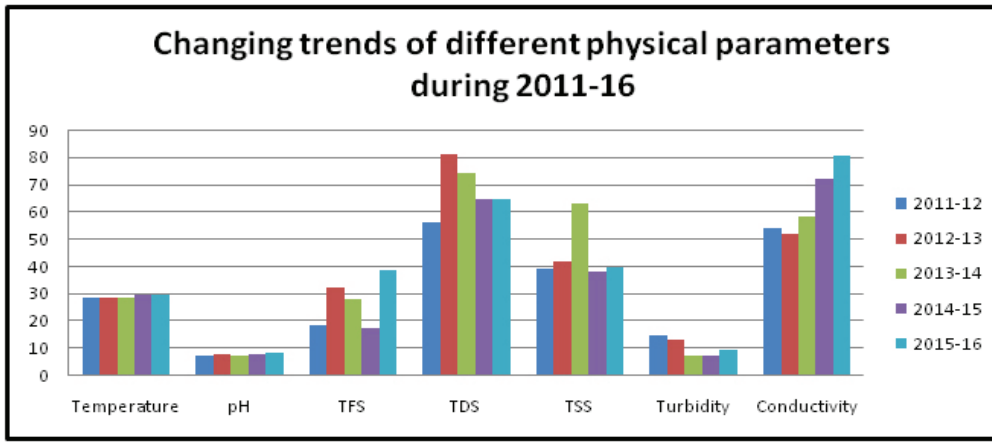

Figure 2: Changing Trends of Different Physical Parameters (Yearly Mean) of Sagardighi of Cooch Behar, West Bengal (2011-16)

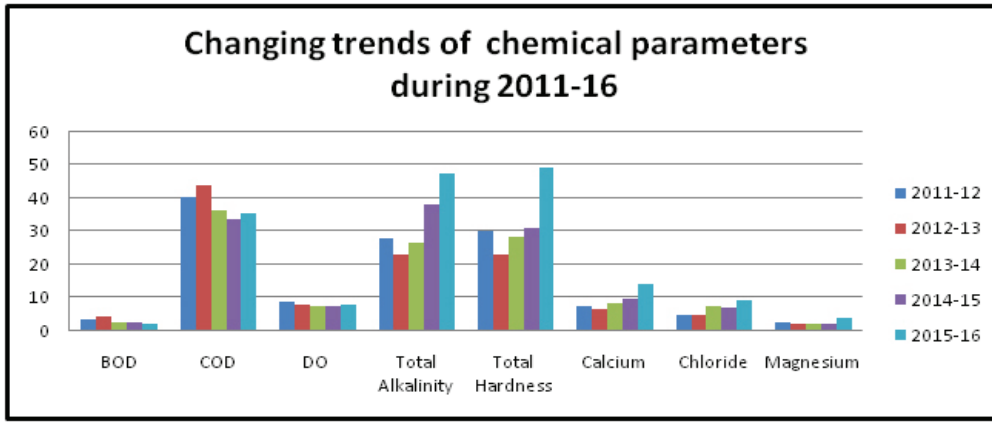

Figure 3: Changing Trends of Different Chemical Parameters (Yearly Mean) of Sagardighi of Cooch Behar, West Bengal (2011-16)

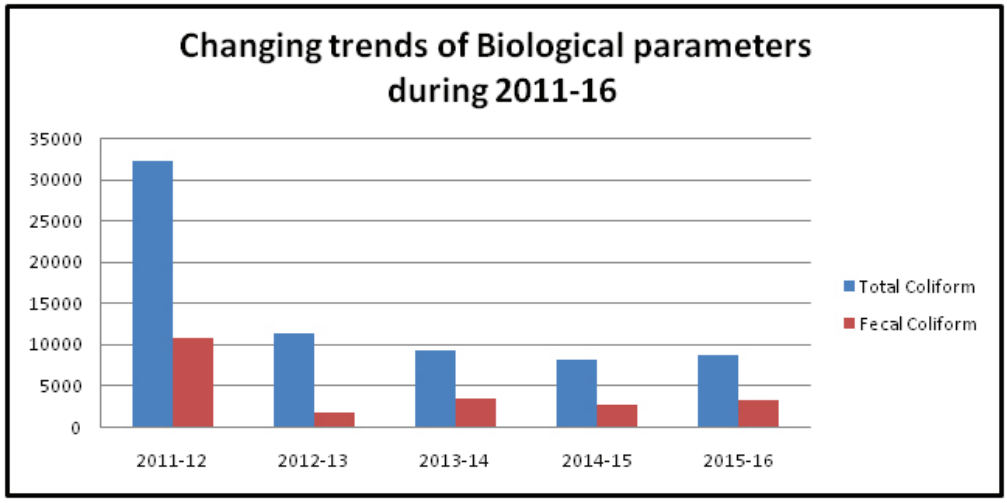

Figure 4: Changing Trends of Different Biological Parameters (Yearly Mean) of Sagardighi of Cooch Behar, West Bengal (2011-16)

Table 3: Changing Trends of Different Bio-Physio-chemical Parameters (Yearly Mean) of Sagardighi of Cooch Behar, West Bengal (2011-16)

Parameters	Mean						Standard Deviation
	Unit	2011-12	2012-13	2013-14	2014-15	2015-16	
BOD	mg/l	3.42	4.42	2.85	2.48	2.28	0.860755
Calcium	mg/l	7.49	6.58	8.2	9.53	14.09	2.949876
Chloride	mg/l	4.78	4.79	7.48	7.11	9.37	1.951904
COD	mg/l	40.02	43.77	36.26	33.71	35.4	4.044251
Conductivity	µs/cm	53.79	51.75	58.33	72.15	80.34	12.42199
Dissolved O_2 (DO)	mg/l	8.73	8.03	7.43	7.49	7.9	0.522858
Fecal Coliform	MPN/100ml	10750	1750	3450	2625	3250	3630.238
Magnesium	mg/l	2.85	2.42	2.26	2.22	3.89	0.695895
Nitrate-N	mg/l	0.12	0.02	0.09	0.03	0.07	0.041593
pH	Unit	7.28	7.88	7.27	7.78	8.36	0.456815
Phosphate-P	mg/l	0.05	0.05	0.05	0.09	0.08	0.019494
Potassium	mg/l	1.08	1.4	1.11	1	1.5	0.218449
Sodium	mg/l	3.64	2.74	2.7	2.88	3.34	0.412068
Sulphate	mg/l	2.22	2.93	2.66	1.66	4.04	0.889112
Temperature	^{0}C	28.58	28.58	28.75	29.67	29.83	0.616336
Total Alkalinity	mg/l	27.77	22.92	26.5	38.13	47.33	10.02211
Total Coliform	MPN/100ml	32141.67	11308.33	9166.67	8083.33	8600	10293.15
Total Dissolved Solids(TDS)	mg/l	56.25	80.92	74.17	64.58	64.33	9.594407

Total Fixed Solids(TFS)	mg/l	18.67	32.33	27.83	17.4	38.73	9.058688
Total Hardness as $CaCO_3$	mg/l	29.94	23.13	28.33	31.03	49	9.82244
Total Suspended Solids(TSS)	mg/l	39	41.83	63.17	38	39.83	10.60562
Turbidity	NTU	14.79	13.16	7.44	7.42	9.35	3.377465

FUTURE SCOPE

On the basis of our present observation and detailed data base of important bio-physico-chemical characteristics of Sagardighi of Cooch Behar, West Bengal, India, we feel that further time-series analysis of quality of water of this water body and a detailed study of these parameters should be conducted.

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Research Article

ASSESSMENT OF WATER QUALITY INDEX (WQI) AND SUITABILITY OF SAGAR DIGHI, KOCH BIHAR, WEST BENGAL, INDIA

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Abstract

The aim of the study was to find out the Water Quality Index (WQI) of Koch Bihar Lake or Sagar Dighi in order to assess its suitability for drinking, bathing and swimming purposes. Water sample were collected in three bottles, two glass bottles with the capacity of 100 ml each and one large PVC (1 litter capacity) bottle for laboratory analysis. Total 20 bio-physico-chemical parameters were used for WQI calculation for drinking purpose and six physico-chemical parameters were used for WQI calculation for bathing and swimming purposes. The calculation of the WQI was done using weighted arithmetic water quality index which was originally proposed by Horton (1965) and developed by Brown et al (1972). The WQI of Sagar Dighi obtained for drinking and Bathing/ recreational use indicates Unsuitable for drinking and poor quality for humans uses respectively. We therefore strongly recommend that an urgent effort must be taken to develop ecosystem-based management strategies.

Key words: Bio-Physico-Chemical Parameters, Weighted Arithmetic Index Method, Water Quality, Water Quality Index, Sagar Dighi.

INTRODUCTION

The district of Koch Bihar is situated in the Himalayan Tarai Region of West Bengal. A number of artificial wetlands (ponds) are present in Koch Bihar town, most of which were created at the time of 'Koch dynasty' for drinking water. The most important is Sagar Dighi which situated in the middle of the town. Now it is used by surrounding dwellers and daily workers of the town for bathing, swimming, washing and other domestic purposes. Runoff from surrounding, solid waste by the visitor and tourist directly disposes to this pond. As a result the Water quality of the pond water is gradually changing. So the monitoring of water quality is very essential. Water quality refers to the different physical, chemical and biological characteristics of water [13]. Evaluating the water quality from a large number of samples, each containing concentrations for many parameters is very difficult [2]. A water quality index (WQI) summarizes large amounts of water quality data into simple terms (e.g., excellent, good, bad, etc.) for reporting to managers and the public in a consistent manner [4]. A water quality index provides a single numerical value that expresses overall water quality at a certain location and time, based on several water quality parameters. In general WQI can give an indication of water health. The objective of the study therefore was to calculate the Water Quality Index (WQI) of Sagar Dighi in order to assess its suitability for drinking, bathing and swimming.

Materials and Methods:

Description of Study Area:

Koch Bihar Lake or Sagar Dighi is selected for study. It is the most important freshwater body which is situated in the heart of Koch Behar town. It extends between 26°19'12"N to 26°19'21"N and 89°26'21"E to 89°26'28"E and the total surface area of this lake is 14.60 hectare which was excavated by Maharaja Harendra Narayan in 1807 AD. It commonly attracts various migratory birds in the winter season. Among all ponds in Koch Bihar town the most spectacular is Sagar Dighi, with grand structures arrayed all around it. These buildings,

built mostly between 1880 to 1920, are now offices of the district administration like Office of the District Magistrate, Administrative Building of North Bengal State Transport Corporation, BSNL Office on the West; Office of the Superintendent of Police, District Library, Municipality Building on the South, Office of the BLRO, Sate Bank of India (Cooch Behar Main Branch) etc on the East and RTO office, Foreigner's enrollment office, District Court and so on the North. Although this lake was excavated for drinking water supply and flood control, now it is used for bathing, swimming, washing clothes, fishing, morning and evening walk around the lake, resting or gossiping place, boating etc.

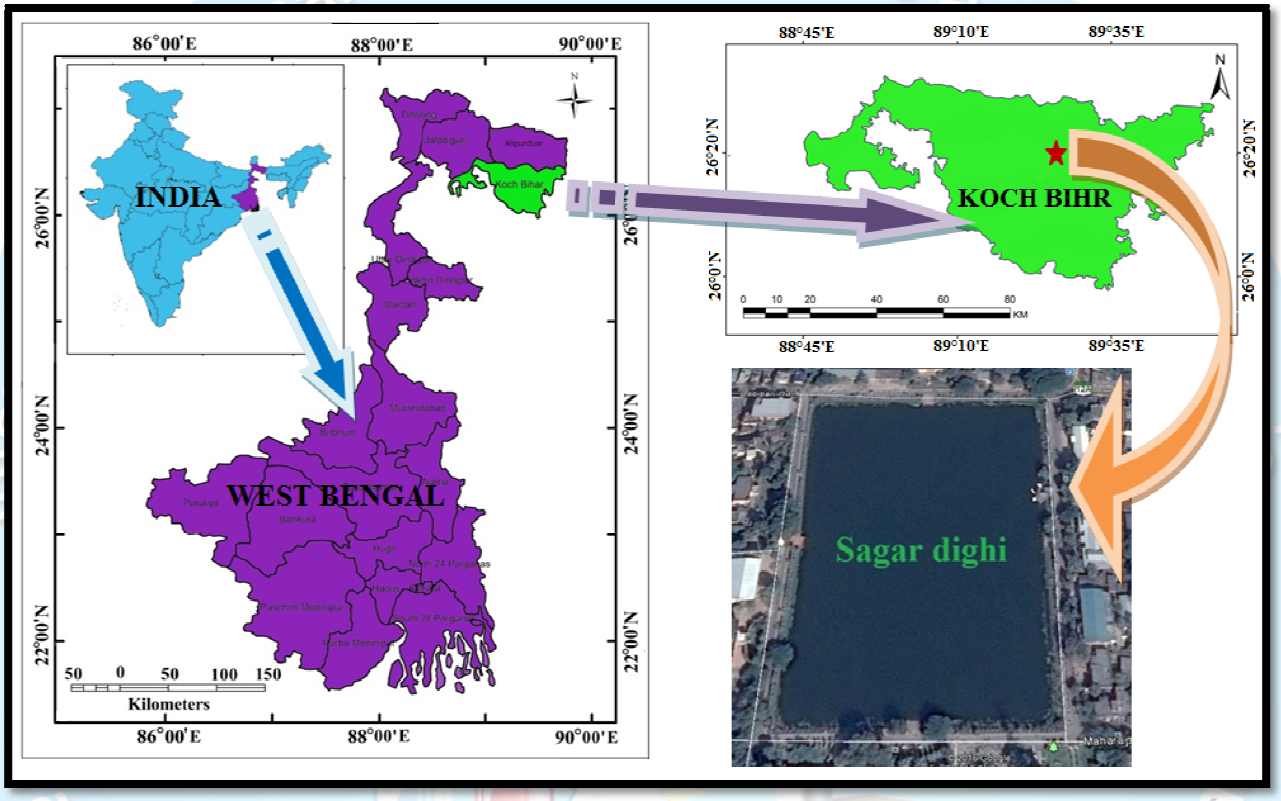

Fig1: locational map of sagar dighi.

Mode of Study:

Water Quality Parameter data is derived by three modes. Water PH, Total dissolved solids, Electrical Conductivity are measured in situ by digital instrument. Dissolved O2(DO) , BOD, FREE CO_2,Chloride ,Total Hardness , Bicarbonate, Total Alkalinity are analysed from collected water sample in laboratory and other Water Quality Parameter are collected from secondary source i.e. West Bengal Pollution Control Board. (Table-1).

Sample Collection: Water samples were collected in 2nd weak of pre-monsoon (June, 2017) and post-monsoon (September, 2017) period from selected site of the study area. Collection of samples took place within 9:30 am by dipping well labeled sterilized plastic and glass containers at the approximate depth of 1.00 ft. All water sample were collected in three bottles , two glass bottles sinking it in the water carefully and slowly so that no air bubbles were introduced with the capacity of 100 ml each (among them in one glass bottle 2ml of $MnSO_4$ followed by 2ml alkaline iodide solution is added)and one large PVC (1 litter capacity) bottle. Physicochemical parameters were analysed in the laboratory in the same day as early as possible except BOD.

Water Analysis Methods:

Physical and chemical analysis of the samples was

done according to Standard Methods as per APHA[3], 1995. Methods used and Source of Data for physical and chemical analyses of water are shown in below mentioned in Table 1.

Water quality Standards:

The values obtained were compared with standards prescribed by BIS[5], WHO[22] and CPCB[18]. The following table reveals the parameters, with their units which are evaluated, in water samples. The water quality index is calculated by using the standard of drinking water and Bathing/ Recreational Use of Water quality prescribed by the World Health Organization, Bureau of Indian Standards and Central Pollution Control Board(Table 2). In calculation BDL (Below Detectable Level) treated as zero(0)

Water Quality Index Calculation:

A Water Quality Index (WQI) is a compilation of a number of parameters that can be used to determine the overall quality. In order to keep the health of any aquaculture system at an optimal level, certain water quality indicators or parameters must be monitored and controlled. A numbers of water quality indices have been formulated all over the world which can easily judge out the overall water quality within a particular area promptly and efficiently. For example, US National Sanitation Foundation Water Quality Index (NSFWQI) [5], Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI) [5], British Columbia Water Quality Index (BCWQI), and Oregon Water Quality Index (OWQI)[12, 17, 1].

Brown et al. (1970) developed a paying great rigor in selecting parameters, developing a common scale, and assigning weights for which elaborate Delphic exercises were performed [5]. This effort was supported by the National Sanitation Foundation (NSF) and that is why also referred as NSFWQI. This work seems to be the most comprehensive and has been discussed in various papers [8]. It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose [10].

Here the calculation of the WQI was done using weighted arithmetic water quality index which was originally proposed by Horton (1965)[15] and developed by Brown et al (1972)[8] in the following form:

$WQI = \Sigma QiWi / \Sigma Wi$

Further, the quality rating scale (Qi) for each parameter is calculated according to Brown et al (1972)[8] by using the following equation:

$Qi = 100 \{(Va-Vi)/ (Vs-Vi)\}$

Where,

Va = actual value of the water quality parameter obtained from laboratory analysis.

Vi = ideal value of the water quality parameter can be obtained from the standard tables. All the ideal values (Vi) are taken as zero except pH and dissolved oxygen [16] For pH, the ideal value is 7.0 and for dissolved oxygen, the ideal value is 14.6 mg/l.

Vs = recommended standard value of ith parameter.

The unit weight for each water quality parameter is calculated by a value inversely proportional to recommended standard (Vs) for the corresponding parameter using the following expression.

$Wi = K / Vs$

Wi is Unit weight of factor

K is proportionality constant.

Table 3 shows a classification of water quality, based on its quality index due to Brown et al (1972)[8], Chatterji and Raziuddin (2002) [9]etc.

Results and Discussions

Table 4, 5, 6 & 7 deals with calculation of the water quality index (WQI) of the of Sagar Dighi for drinking and Bathing/ recreational use of water in pre-monsoon period (June, 2017) and post-monsoon period (september, 2017) using the weighted arithmetic index formula as follows: $WQI = \Sigma QiWi / \Sigma Wi$.

Table:1 Mode of Water Quality Analysis

Sl. No	Parameters	Method Adopted/Instrument/Source of Data
1	Ammonia-N	WBPCB
2	BOD	Titrimetric Method (five days incubation)
3	Boron	WBPCB
4	Calcium	WBPCB
5	Chloride	Argent metric Method
6	COD	WBPCB
7	Conductivity	HM Digitals Aquapro digital water tester (Model AP-2)
8	Bi-carbonate	Titration Method
9	Dissolved O2(DO)	Winkler's Method
10	Fluoride	WBPCB
11	Magnesium	WBPCB
12	Nitrate-N	WBPCB
13	pH	HM Digitals pH Hydrotester (Model pH-80)
14	Sodium	WBPCB
15	Sulphate	WBPCB
16	Total Alkalinity	Titration Method
17	Total Coliform	WBPCB
18	Total Dissolved Solids(TDS)	HM Digitals Aquapro digital water tester (Model AP-1)
19	Total Hardness as CaCO3	Conventional titration method.
20	Turbidity	WBPCB

N.B.:WBPCB= West Bengal Pollution Control Board

Table 2. Standard for drinking water and Bathing/ recreational use of water.

Sl. No	Parameters	Unit	Drinking Water		Bathing/ Recreational Use of Water	
			Standard	Recommended Agency	Standard	Recommended Agency
1	Ammonia-N	mg/l	0.3	WHO	--	
2	BOD	mg/l	2	CPCB	3	CPCB
3	Boron	mg/l	0.3	BIS	--	
4	Calcium	mg/l	75	BIS	--	
5	Chloride	mg/l	250	BIS	600	CPCB
6	COD	mg/l	10	WHO	--	
7	Conductivity	µs/cm	300	ICMR (1975)	--	
8	Bi-carbonate	mg/l	244	BIS	--	
9	Dissolved O_2(DO)	mg/l	6	CPCB	5	CPCB
10	Fluoride	mg/l	1	BIS	1.5	CPCB
11	Magnesium	mg/l	30	BIS	--	
12	Nitrate-N	mg/l	45	BIS	--	
13	pH	Unit	6.5 - 8.5	BIS	6.5 - 8.5	CPCB
14	Sodium	mg/l	180	BIS	--	
15	Sulphate	mg/l	200	BIS	--	
16	Total Alkalinity	mg/l	200	BIS	--	
17	Total Coliform	MPN/100ml	50	CPCB	500	CPCB
18	Total Dissolved Solids(TDS)	mg/l	500	BIS	--	
19	Total Hardness as $CaCO_3$	mg/l	300	BIS	--	
20	Turbidity	NTU	5	BIS	--	

N.B.: (--): *not indicated.*

Table 3. Classification of water quality based on weighted arithmetic WQI method

WQI	STATUS
0 - 25	Excellent
26 - 50	Good
51 - 75	Poor
76 - 100	Very Poor
Above 100	Unsuitable for use

Source: Brown et al (1972), Chatterji and Raziuddin (2002)

Table 4: Calculation of Water Quality Index (WQI) of Sagar Dighi for drinking water in pre- monsoon period (June, 2017).

Sl. No	Parameter	Unit	Standard values (Vs)	Observed Value (Va)	Unit Weights (Wi)	Quality Rating (Qi)	WiQi
1	Ammonia-N	mg/l	0.3	0.347	0.375705816	115.6666667	43.45663939
2	BOD	mg/l	2	4.4	0.056355872	220	12.39829193
3	Boron	mg/l	0.3	0.011	0.375705816	3.666666667	1.377587992
4	Calcium	mg/l	75	8.02	0.001502823	10.69333333	0.01607019
5	Chloride	mg/l	250	14	0.000450847	5.6	0.002524743
6	COD	mg/l	10	25	0.011271174	250	2.817793621
7	Electrical Conductivity	µs/cm	300	75	0.000375706	25	0.009392645
8	Bi-carbonate	mg/l	244	18	0.000461933	7.37704918	0.003407705
9	Dissolved O2(DO)	mg/l	6	7.6	0.018785291	81.39534884	1.529035298
10	Fluoride	mg/l	1	BDL	0.112711745	0	0
11	Magnesium	mg/l	30	1.73	0.003757058	5.766666667	0.021665702
12	Nitrate-N	mg/l	45	0.43	0.002504705	0.955555556	0.002393385
13	pH(6.5-8.5)	Unit	6.5-8.5	8.8	0.013260205	120	1.591224633
14	Sodium	mg/l	180	4	0.000626176	2.222222222	0.001391503
15	Sulphate	mg/l	200	0.32	0.000563559	0.16	9.01694E-05
16	Total Alkalinity	mg/l	200	28	0.000563559	14	0.007889822
17	Total Coliform	MPN/100ml	50	14000	0.002254235	28000	63.1185771
18	Total Dissolved Solids(TDS)	mg/l	500	34	0.000225423	6.8	0.00153288
19	Total Hardness as CaCO3	mg/l	300	28	0.000375706	9.333333333	0.003506588
20	Turbidity	NTU	5	9.6	0.022542349	192	4.328131001
					Σ Wi=1		**Σ** Wi-Qi=130.6871463
WQI = ΣQiWi /ΣWi=130.6871463							

N.B.: BDL= Below Detectable Level

Table 5 : Calculation of Water Quality Index (WQI) of Sagar Dighi for Bathing/ recreational use in pre-monsoon period (June, 2017).

SlNo	Parameter	Unit	Standard values (Vs)	Observed Value (Va)	Unit Weights (Wi)	Quality Rating (Qi)	WiQi
1	BOD	mg/l	3	4.4	0.252274178	146.6666667	37.0002127
2	Chloride	mg/l	600	14	0.001261371	2.333333333	0.002943199
3	Dissolved O_2(DO)	mg/l	5	7.6	0.151364507	72.91666667	11.03699527
4	Fluoride	mg/l	1.5	BDL	0.504548355	0	0
5	pH(6.5-8.5)	Unit	6.5-8.5	8.8	0.089037945	120	10.6845534
6	Total Coliform	MPN/100ml	500	14000	0.001513645	2800	4.238206182
					Σ Wi=1		**Σ** WiQi=62.96291075
WQI = **Σ**QiWi /**Σ**Wi=62.96291075							

N.B.: BDL= Below Detectable Level

Table 6: Calculation of Water Quality Index (WQI) of Sagar Dighi for drinking water in post-monsoon period (september, 2017).

Sl. No	Parameter	Unit	Standard values (Vs)	Observed Value (Va)	Unit Weights (Wi)	Quality Rating (Qi)	WiQi
1	Ammonia-N	mg/l	0.3	BDL	0.375705816	0	0
2	BOD	mg/l	2	4.3	0.056355872	215	12.11651257
3	Boron	mg/l	0.3	0.006	0.375705816	2	0.751411632
4	Calcium	mg/l	75	9.62	0.001502823	12.82666667	0.019276213
5	Chloride	mg/l	250	20	0.000450847	8	0.003606776
6	COD	mg/l	10	22	0.011271174	220	2.479658386
7	Electrical Conductivity	µs/cm	300	63	0.000375706	21	0.007889822
8	Bi-carbonate	mg/l	244	14	0.000461933	5.737704918	0.002650437
9	Dissolved O2(DO)	mg/l	6	6.2	0.018785291	97.6744186	1.834842358
10	Fluoride	mg/l	1	0.14	0.112711745	14	1.577964428
11	Magnesium	mg/l	30	1.15	0.003757058	3.833333333	0.014402056
12	Nitrate-N	mg/l	45	0.38	0.002504705	0.844444444	0.002115085
13	pH(6.5-8.5)	Unit	6.5-8.5	8.2	0.013260205	80	1.060816422
14	Sodium	mg/l	180	2.51	0.000626176	1.394444444	0.000873168
15	Sulphate	mg/l	200	1.18	0.000563559	0.59	0.0003325
16	Total Alkalinity	mg/l	200	22	0.000563559	11	0.006199146
17	Total Coliform	MPN/100ml	50	11000	0.002254235	22000	49.59316772
18	Total Dissolved Solids(TDS)	mg/l	500	28	0.000225423	5.6	0.001262372
19	Total Hardness as CaCO3	mg/l	300	22	0.000375706	7.333333333	0.002755176
20	Turbidity	NTU	5	13.1	0.022542349	262	5.906095429
					Σ Wi=1		**Σ** WiQi=75.3818317
WQI = ΣQiWi /ΣWi=75.3818317							

N.B.: BDL= Below Detectable Level

Table 7: Calculation of Water Quality Index (WQI) of Sagar Dighi for Bathing/ recreational use of water in post-monsoon period (september, 2017).

Sl. no	Parameter	Unit	Standard values (Vs)	Observed Value (Va)	Unit Weights (Wi)	Quality Rating (Qi)	WiQi
1	BOD	mg/l	3	4.3	0.252274178	143.3333333	36.15929878
2	Chloride	mg/l	600	20	0.001261371	3.333333333	0.00420457
3	Dissolved O_2(DO)	mg/l	5	6.2	0.151364507	87.5	13.24439432
4	Fluoride	mg/l	1.5	0.14	0.504548355	9.333333333	4.70911798
5	pH(6.5-8.5)	Unit	6.5-8.5	8.2	0.089037945	80	7.1230356
6	Total Coliform	MPN/100ml	500	11000	0.001513645	2200	3.330019143
					Σ Wi=1		**Σ**WiQi=64.57007039
WQI = **Σ**QiWi /**Σ**Wi=64.57007039							

N.B.: BDL= Below Detectable Level

The water quality Index for drinking obtained water in pre-monsoon (June, 2017) and post-monsoon (September, 2017) period are130.6871463 (Table 4) and 75.3818317 (Table 6) respectively. The water quality Index value (130.69) of June, 2017 indicates the Unsuitable for drinking and WQI (75.38) of September, 2017 indicate poor quality for human uses and must therefore be treated before use to avoid water related diseases.

The water quality Index for Bathing/ recreational use obtained in pre-monsoon (June, 2017) and post-monsoon (September, 2017) period are 62.96291075(Table 5) and 64.57007039(Table 7) respectively which indicate poor quality for humans uses.

Conclusion:

During the study, it is observed that the water quality of Sagar Dighi for drinking water in pre-monsoon period become unsuitable than post-monsoon period. We concluded that the water is not fit for drinking purpose without treatment (filtration, disinfection etc). Suitability of water quality for Bathing/ recreational use is become poor in post-monsoon period than pre-monsoon period. The Study show that the water of the Sagar Dighi is deteriorated very badly due to the addition of urban sewage, anthropogenic activities like washing, Bathing etc. Therefore an urgent effort must be taken to develop ecosystem-based management strategies with inputs from scientists, resource managers, policy makers, government and non-government organizations and environmentalist.

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