International Journal of Multidisciplinary Research and Development 2015; 2(3): 513-518

International Journal of Multidisciplinary Research and Development

IJMRD 2015; 2(3): 513-518
www.allsubjectjournal.com
Impact factor: 3.672
Received: 05-03-2015
Accepted: 23-03-2015
E-ISSN: 2349-4182
P-ISSN: 2349-5979

Supratim Pal
Department of Zoology, University of Gour Banga, Mokdumpur, Malda, West Bengal, 732103.

Debashis Das
Department of Zoology, Tufanganj Mahavidyalaya,Tufanganj, West Bengal, 736160.

Kaushik Chakraborty
Department of Zoology, University of Gour Banga, Mokdumpur, Malda, West Bengal, 732103.

Correspondence:
Supratim Pal
Department of Zoology, University of Gour Banga, Mokdumpur, Malda, West Bengal, 732103.

Colour optimization of the secchi disk and assessment of the water quality in consideration of light extinction co-efficient of some selected water bodies at Cooch Behar, West Bengal

Supratim Pal, Debashis Das, Kaushik Chakraborty

Abstract
The District Cooch Behar of West Bengal, India embodies water bodies of different physical and biological parameters. *Secchi disk* have played an important role in hydrologic optics in part because they allow an easy practicable and inexpensive measure of water transparency. Experiment to observe the efficacy of both different colour (three colours) of *Secchi disk* was carried out in some selected water bodies of the district Cooch Behar, West Bengal. Disk of yellow-white colour followed by red-white colour shows best efficiency in consideration of its visibility. The least efficiency was noted for the conventionally used black colour disk. Total dissolved solid (TDS) have very little or no impact on the visibility of the disk. Visibility of the disk is thus should mainly depends on the plankton abundance, suspended solids and the nature of light.

Keywords: Water Transparency; Turbidity; Secchi Disk, Plankton abundance.

1. Introduction

Assessment of light extinction coefficient is related to primary production of the water body. This can be done either by using a light meter or by using a *Secchi disk*. Though the light meter method is generally considered more accurate, but *Secchi disk* methods use less expensive equipment and only require one measurement versus many for the light meter method.

Secchi disks have played an important role in hydrologic optics (Preisendorfer, 1986), in part because they allow an easy and inexpensively determine the extent of water transparency. *Secchi depth* measurements have been used as a real-time assessment of water transparency during optical measurements and as a quality check during analysis of radiometric profiles (Mueller *et al*. 1992).

The *Secchi disk* is a device used to visually measure the clarity of natural waters. The *Secchi disk*, as created in 1865 by Angelo Secchi is usually a circular white disk of 30-cm diameter that is lowered perpendicularly into the water, disk plane parallel, until it disappears from sight. A smaller 20 cm diameter, black and white *Secchi disk* design is generally used to measure freshwater transparency. The depth of disappearance of the disk is inversely proportional to the average amount of organic and inorganic materials along the path of sight in the water. In gross to make a Secchi depth measurement, a white disk is lowered into the water on the sunny side of the ship; the Secchi Depth (SD) is the depth where the disk disappears from view (Secchi, circa 1866).

The *Secchi disk* procedure is valued by many aquatic biologists as a useful and informal visual index of the trophic activity of any kind of water body. The accumulated listings of the depth of disappearance of the disk, as a function of time and location within a given water body can over the years provide a readily understood and quite useful record of the growth and decay of aquatic plant life in such condition. It is also useful in tracking visually the movements of suspended detritus and the migration of sediment influxes from tributary streams and rivers.

Turbidity is a measurement of the cloudiness in water and is caused by suspended sediments and plankton. Clarity for water body is measured with a *Secchi Disk*. The measurement is referred to as a *Secchi Disk Transparency*.

Changes in water transparency [*Secchi disk depth* (SD)] have often been related to single factors, e.g. dissolved and colloidal organic matter or color (Schindler 1971), turbidity from suspended inorganic particulates (Zettler *et al*. 1986), and phytoplankton (Ostrofsky *et al*. 1987).

In this contemplation present study was carried out in order to optimize the colour of the *Secchi Disk* and to assess the water quality of some selected water bodies of Cooch Behar.

Materials and Methods

Source of water body and location:

The district of Cooch Behar is geographically a part of the *Himalayan Terai* of West Bengal, India. It lies between the parallels of 25° 57´ 56″ and 26° 32´ 46″ North latitude and the longitude of the eastern most point which beings 89° 52´ 00″ East and the longitude of the western most point beings 88° 45´02″ East. All the water sources are located in this district. *Mali dighi* (S1) is located beside *Magazine road*, *Bairagi dighi* (S2) is a temple pond, *Sagar dighi* (S3) is situated at the heart of town, *Narasingha dighi* (S4) is nearer to the *Sunity road* and *Panishala Beel* (S5) is a natural wetland situated 12 kilometer away from Cooch Behar town towards Dinhata subdivision.

Determination of water transparency:

By *Seechi disc*:

The ***Secchi disk***, as created in 1865 by Angelo Secchi, is a plain white, circular disk (30 cm in diameter or approximately 12 inches) used to measure water transparency in bodies of water. The disc is mounted on a pole or line, and lowered slowly down in the water. The depth at which the disk is no longer visible is taken as a measure of the transparency of the water. This measure is known as the **Secchi depth** and is related to water turbidity. Since its invention the disk has also been used in a modified, smaller 20 cm diameter, black and white design to measure freshwater transparency. The Secchi depth depends on four parameters, a radiation source (sunlight), a medium that the radiation travels through (water), an object (the *Secchi disk*), and a sensor (our eye). The *Secchi* models are based on the visibility theory. The theory is based on determining the brightness contrast of the *Secchi disk* with respect to the background.

The Disc (Fig.1, 2, 3a and 3b):

Shape and Size: The disk is circular (r=10 cm) with four coloured zone radiating from the centre. Each zone occupies 25% of the disc.

Materials (Fig.1): The disks are made up of aluminium sheet as water has no effect on aluminium. Nuts and washers are used as accessories. Compass, scale, pencil, scissor, colour paint, brush and thread are adopted to make it functional.

Colour (Fig.2): Three colours namely red, yellow and green were selected. Disc zones were painted either by red, yellow or green colour having an alternative intermediate white colour. The conventionally used black-white colour disc is considered as control.

Operational principle (Fig.3)*:*

a. Lower the *Secchi Disk* into thewater body until it just disappears (extinction depth).
b. Depth of disappearance (in cm.) was estimated from the calibrated line.
c. Raise *Secchi Disk* until it just appears. Read depth from calibrated line or for an unmarked line mark with another clothespin. Add readings from Steps 1 and 2. Divide by the unmarked line, and clothespins measure from the disk to the halfway mark between the two clothespins.
d. Data of *Secchi Disk Transparency* was accordingly recorded.
e. With the sun at your back and with the *Secchi disk* near its extinction depth.

Fig.1: Materials and instruments for *Secchi Disk* making. a) aluminium sheet, b) nuts, c) washers, d) scale, e) compass, f) scissor, g) pencil, h) brush, i) colour paint, and j)thread.

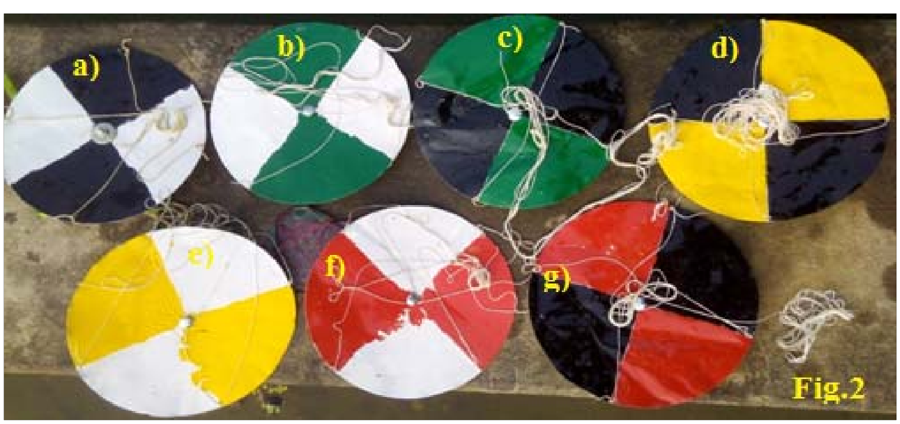

Fig.2: *Secchi Disks* of different colours. a) Black-White, b) Green-White, c) Black-Green, d) Black-Yellow, e) Yellow-White, f) Red-White, g)Black-Red.

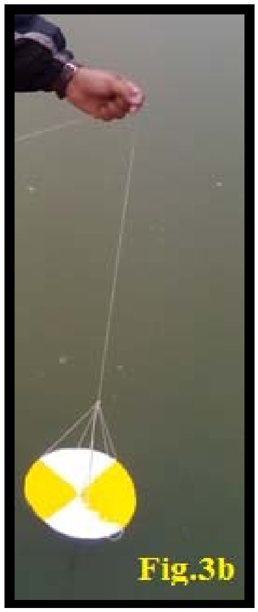

Fig.3a and 3b: Operation with *Secchi Disk*.

By sprectophotmeter:
Water sample of about 500 ml from each of the selected area was taken in the plastic bottle container separately and was analysed by using Semi-auto analyzer (Ebra CHEM – 7 of Transasia Biomedical Limited).

By TDS meter:
The TDS value of each Water sample of each selected area was estimated by using HM Digitals AquaPro digital water tester (model AP-1).

Interpretation of *Secchi disk* visibility (Table 1):
Interpretation of the result was done following the gradation and the characterization of the water body in consideration of the *Secchi disk* reading by the Auburn University Fisheries Research Unit.

Calculation:
Determination of light extinction coefficients: Using Secchi depth data, *light extinction coefficients* can be calculated by adopting suitable equation. Generally Poole and Atkins equation (Poole and Atkins, 1929; Isdo and Gilbert, 1974) was applied to assess the water transparency:

$$K = \frac{1.7}{z_S}$$

Where, Z_S = Secchi depth, K=extinction coefficient (m^{-1})

Table 1: Interpretation of *Secchi disk* visibility

Secchi Disk Reading (cm)	Comments
Less than 20 cm	Pond too turbid. If pond is turbid with phytoplankton, there are likely to be problems with low dissolved oxygen concentrations in the early morning. When turbidity is from suspended soil particles, productivity will be low.
20-30 cm	Turbidity becoming excessive.
30-45 cm	If turbidity is from phytoplankton, pond is in good condition.
45-60 cm	Phytoplankton becoming scarce.
More than 60 cm	Water is too clear. Inadequate productivity and danger of aquatic weed problems.

This can also be measured after following CE-QUAL-W2 manual as given by Williams *et al.* (1980).

$$K = \frac{1.1}{z_S^{0.73}}$$

Determination of correlation value: Correlation between the SD reading for the disappearance of the disc and TDS value of the water was calculated and accordingly R value was determined.

Results and Discussion

Observation on the efficacy of the colour of the disc (Fig 4):
The wave length range of Red, yellow and green colour are 620-740 nm, 570-590 nm and 495-570 nm respectively. The frequencies of red, yellow and green colour are 480-400 Tetrahartz (Thz), 525-505 Thz, 526-606 Thz respectively. The scattering power increases from red to yellow to green respectively. The visibility of any colour depends on some other factors also like emission, reflection, transmission, interference, dispersion etc. In our present study out of the three colour tested, the best result in consideration of the extent of visibility was noted for yellow coloured disc. This was followed by red coloured disc. The least efficiency was noted for the conventionally used black colour disc.

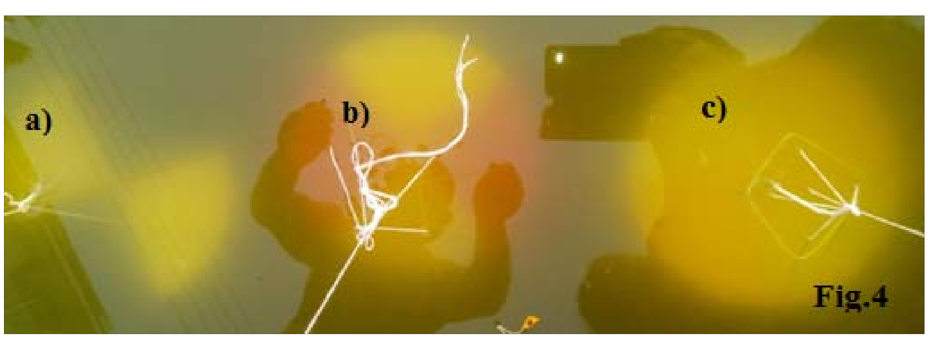

Fig 4: Visibility of *Secchi Disks*. a) Black-White *Secchi Disk*, b) Red-White *Secchi Disk*, c) Yellow-White *Secchi Disk*.

Observation on the *Secchi disk* transparency (Table 2):

Our present study indicates that the White-Yellow *Secchi Disk* remains visible upto a greater distance (203 cm in S5) than other coloured disks (191 cm, 189 cm, 179 cm, 170 cm, 161 cm and 146 cm for white-red, black-yellow, white-green, white-black, black-red and black-green respectively) at different water bodies of Cooch Behar. Low SD value indicates large turbidity of that water body. The White-Yellow *Secchi Disk* with greater transparency and highest SD value should be more effective for comparing the turbidity of different water bodies.

Table 2: SD value (in cm.) at different water sources with different *Secchi Disks*.

Water Sources	SD value (in cm.) with different *Secchi Disks*						
	White-Green	White-Red	White-Yellow	White-Black	Black-Red	Black-Green	Black-Yellow
S1	30	35	36	26	29	27	37
S2	82	95	116	80	89	72	100
S3	84	91	97	81	76	69	91
S4	56	65	72	51	59	50	67
S5	179	191	203	170	161	146	189

'S1' = *Mali dighi*, 'S2' = *Bairagi dighi,* 'S3' = *Sagar dighi,* 'S4' = *Narasingha dighi,* 'S5' = *Panishala Beel* (a natural wetland).

Table 3: Relative performance of different disc colour grossly at different water body sources

Statistical Parameter	White-Green	White-Red	White-Yellow	White-Black	Black-Red	Black-Green	Black-Yellow
Mean	86	95	105	82	83	73	97
Standard Error	25	26	28	24	22	20	26
Median	82	91	97	80	76	69	91
Standard deviation	56	59	63	54	49	45	57
Sample Variance	3176	3433	3910	2961	2415	1998	3252
Kurtosis	3	2	2	2	2	2	2
Skewness	1	1	1	1	1	1	1
Range	149	156	167	144	132	119	152
Confidence Level (95.0%)	70	73	78	68	61	55	71

By the analysis of different statistical parameters the relative performance of differently coloured disks reveals also that the White-Yellow coloured disk shows highest performance value in comparison to other disks.

Table 4. Correlation (r) of the SD value of different colour disk and at different water sources

Disk Colour	White-Green	White-Red	White-Yellow	White-Black	Black-Red	Black-Green	Black-Yellow
White-Green	1						
White-Red	0.999059	1					
White-Yellow	0.988971	0.994296	1				
White-Black	0.999423	0.99917	0.991634	1			
Black-Red	0.991827	0.996426	0.999366	0.993383	1		
Black-Green	0.999148	0.999953	0.993645	0.998935	0.996083	1	
Black-Yellow	0.996912	0.999348	0.997441	0.997763	0.998688	0.999135	1

Correlation (r) values of different coloured disks are calculated and it shows that the differently coloured disks are highly correlated.

Table 5: Association coefficients of different colour disk and at different water

Coefficient	Value
Pearson's Phi	0.033
Contingency coefficient	0.032
Cramer's V	0.019
Tschuprow's T	0.017
Goodman and Kruskal tau (R/C)	0.000
Goodman and Kruskal tau (C/R)	0.000

Different association coefficients of different coloured disks are calculated. The Pearson's Phi value is 0.033,the Contingency coefficient value is 0.032, the Cramer's V value is 0.019, the Tschuprow's T value is 0.017 and the Goodman and Kruskal tau (R/C) and Goodman and Kruskal tau (C/R) values are 0.000 and 0.000 respectively.

Light extinction coefficients (Table 6):

Higher light extinction coefficients mean that there is less light transmitted or that the water is less transparent. A low light extinction coefficient allows light to penetrate into deeper water, and less heat is lost in surface exchange. With higher light extinction coefficients, surface water temperatures increase; deep waters stay cooler, the depth of the mixed layer decreases, and the total heat content of the standing water body decreases (Hocking and Straskraba, 1999). The light extinction coefficients are calculated on the basis of the SD values of different *Secchi Disks* at different water bodies.

Table 6: Light extinction coefficients

Light Extinction Coefficients	Water Source	*Secchi Disk* Types						
		White-Green	**White-Red**	**White-Yellow**	**White-Black**	**Black-Red**	**Black-Green**	**Black-Yellow**
K value of Poole and Atkins equation	S1	0.057	0.049	0.047	0.065	0.059	0.063	0.046
	S2	0.021	0.018	0.015	0.021	0.019	0.024	0.017
	S3	0.020	0.019	0.018	0.021	0.022	0.024	0.019
	S4	0.030	0.026	0.024	0.033	0.029	0.034	0.025
	S5	0.009	0.009	0.008	0.010	0.011	0.012	0.009
K value following CE-QUAL-W2 manual	S1	0.092	0.082	0.080	0.102	0.094	0.099	0.079
	S2	0.044	0.040	0.034	0.045	0.042	0.048	0.038
	S3	0.043	0.041	0.039	0.044	0.047	0.050	0.040
	S4	0.059	0.052	0.048	0.062	0.056	0.063	0.051
	S5	0.025	0.024	0.023	0.026	0.027	0.029	0.024

Observation on the Reflectance by Spectrophotometer (Table 7):

Spectrophotometry is the quantitative measurement of the reflection or transmission properties of a material as a function of wavelength. A spectrophotometer is commonly used for the measurement of transmittance or reflectance of solutions, transparent or opaque solids, such as polished glass, or gases. However they can also be designed to measure the diffusivity on any of the listed light ranges that usually cover around 200 nm - 2500 nm using different controls and calibrations. For our study, filters of 550 nm, 578 nm, and 505 nm were used for red, green and yellow colour respectively to observe the reflectance of different water sources and the results are listed in table 4.

Table 7: Reflectance of Red, Green and Yellow colour of different water sources.

Water Sources	**Reflectance of Colours [in percent (%) or a factor between 0 and 1]**		
	Red	Green	Yellow
S1	0.0736	0.0703	0.0918
S2	0.0261	0.0210	0.0265
S3	0.0332	0.0323	0.0306
S4	0.0356	0.0305	0.0332
S5	0.0146	0.0125	0.0096

Observation on TDS value (Table 8):

Suspended solids affect physical (such as temperature), chemical (such as nutrients) and biological (such as habitat and photosynthesis) properties of aquatic ecosystems (Cordone *et al*. 1961; Kirk, 1994; Lloyd *et al*. 1987). The most obvious negative impact of suspended solids is their impairment of recreational use and aesthetic enjoyment of water bodies. Turbidity due to suspended solids has an impact on flora and fauna of the water body. Suspended particles absorb sunlight and then become warm, so the turbid water becomes warm. As water gets warmer the concentration of oxygen dissolved in water is reduced. Scattering of light by particulates impairs the photosynthetic activity of plants and algae, thus contributing to further reduction of dissolved oxygen in water and worsening conditions for aerobic life like fish and shell fish.

Excessive concentrations of suspended solids have several effects on aquatic organisms. Fish gills can be clogged, which hinders gas exchange, destroys protective mucous coverings on eyes and scales, and makes fish more susceptible to infection and disease. Filter-feeding systems can be fouled, hindering the ability of aquatic predators to pursue their prey. Suspended solids may settle to the stream bottom, where they bury and suffocate fish eggs and newly hatched larvae.

Our study reveals that Total dissolved solid (TDS) have very little or no impact on the visibility of the disc. Visibility of the disc is thus should mainly depends on the plankton abundance, suspended solids and nature of light.

Table 8: TDS values observed at different water bodies

Water Sources	**S1**	**S2**	**S3**	**S4**	**S5**
TDS values (in ppm.)	111	86	36	104	121

Organic matter dissolved in water varies greatly as to composition and concentration. Probably of greatest importance on a large scale is the macromolecular humic and fulvic acids and similar compounds which persist in the environment as degradation products of plant materials. These compounds can serve as chelating or complexing agents for metals and nutrients, and have been shown to be effective in solublizing chlorinated hydrocarbons (Wershaw *et al*. 1969; Blom *et al*. 1976). Dissolved organic compounds which exert a BOD are of serious local importance to aquatic life. Currently, great effort is being made to remove these compounds from waste water effluents. However, urban runoff often goes untreated even though it is a significant source of oxygen demanding organic matter (Whipple *et al*. 1974).

In consideration of SD value, spectrophotometric studies and TDS value the water source S5 seems to be least turbid and the water of S1 is highest turbid. Thus, S1 should contain highest plankton abundance, organic and inorganic materials and suspended solids. By the analysis of statistical parameters this can be concluded that the White-Yellow disk type shows more efficiency than the other coloured disks.

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