**Poll Res. 39 (4) : 985-996 (2020)**

ISSN 0257–8050

# A RIVER WATER QUALITY MONITORING, ASSESSING AND DEVELOPING A COMMUNITY BASED ECO-HEART INDEX TOOL KIT FOR CAUVERY RIVER

**C. RAMPRASAD*[1], KARTHIK SONA[2], MOHAMMED AFRIDHI[2] AND RAM KUMAR[2]**

*School of Civil Engineering, SASTRA Deemed to be University, Thanjavur, India*

(Received 2 February, 2020; Accepted 3 April, 2020)

## ABSTRACT

**The present study aims to analyze the quality of River Cauvery in two distinct places (Mettur and Mayanur) at the upstream and downstream sides and also to prepare a community-based tool kit an "eco-heart" map. The Eco-heart index has the great potential to be a community-friendly water quality indicator that can be easily recognized by common public through the universal symbol of peace and love. It was drawn based on the 6 vital water quality parameters, pH, dissolved oxygen, chlorides, sulfates, hardness, and total dissolved solids. The study concludes that the water quality map at Mettur upstream clearly visualized a slightly tilted heart shape that indicates it is clean compared to Mayanur. As the stream progresses towards the drain, the water quality gets deteriorated due to various anthropogenic activities. The study concludes that River Cauvery is unfit for drinking purpose directly, and proper treatment needs to be adopted before distribution.**

**KEY WORDS :** Cauvery basin, Community tool kit, Chlorides, Eco-heart index, Heavy metals, Ion-exchanger

## INTRODUCTION

The majority of the world population hinges on the surface water or the groundwater or combination as the sources of drinking water for their thriving demand. Unfortunately, many of the watersheds in the world (including both surface and subsurface) are found to be highly contaminated due to various anthropogenic factors like untreated or partially treated wastewater discharges, improper management of solid waste and improper sanitation etc., (Kumarasamy *et al.*, 2009; Solaraj *et al.*, 2010; Dhanakumar *et al.*, 2013; Sidek *et al.*, 2016; Ramprasad *et al.*, 2017; Sakai *et al.*, 2018). India, the scenario remains the same as many of the perennial and non-perennial rivers in South and North India are labeled as unfit for portable applications directly (Kim *et al.*, 2007; Sakai *et al.*, 2018; Philip *et al.*, 2019). The Central Pollution Control Board (CPCB), GoI reported that the river bodies are getting depleted in both quality and quantity year by year and the depletion rate follows the logarithmic growth phases. The GoI along with CPCB and Bureau of Indian Standards (BIS) adopted Water Quality Index (WQI) as one of the tool for assessing surface water quality and conveying it to the people. The WQI consists of 8 physicochemical parameters like pH, dissolved oxygen (DO), sulfate, nitrate, magnesium, calcium, total hardness, and total dissolved solids (TDS). The WQI value is calculated by aggregating the quality rating with the unit weight linearly and value lies in the range 0 d"WQId" 100 (Yogendra and Puttaiah, 2008). The WQI is a number that denotes the quality and status of the river stream (clean, moderate or not safe) higher the WQI it denotes that water is of poor quality (Chatterji and Raziuddin, 2002).

The water quality index (WQI) is the basic indicator followed by various developed and developing nations to confess the river health to the local authorities and communities. Nevertheless, the WQI from the community point of view has following disadvantages like the analysis of water quality parameters requires high quality laboratories with the sophisticated instruments facilities (Sidek *et al.,* 2016). Subsequently, the WQI is an integrated value and weighted average that never infer the exact quality of river. Additionally, the WQI values are difficult to read and appealing to the local communities. Hence, it is necessary to develop a tool that complement to the WQI as well as easily comprehensible and attractive to local communities and most importantly the local authorities can spontaneously monitor and assess the water quality at the local scale with cost effective techniques. In the present study, the authors evaluated a novel community based water quality tool kit the "Eco-Heart" index that depicts the universal peace and love symbol "The heart" shape (Sakai *et al.,* 2018). The Eco-heart index depicts the proper heart shape if the river water quality is very clean, while the broken heart represents polluted or unclean water.

The present study focuses on checking the quality of one of the most important river in South India "The Cauvery River". The river has its applications for drinking, agricultural and industrial and in the recent past the expanding human population, industrialization, intensive agricultural practices has degraded the quality (Kumarasamy *et al.,* 2009; Solaraj *et al.,* 2010; Dhanakumar *et al.,* 2013; Suriya *et al.,* 2017; Vijayan *et al.,* 2018). The organic and nutrient levels in the Cauvery River were much higher than the permissible drinking water values and it was concluded that the water quality was close enough with the secondary wastewater values (Solaraj *et al.,* 2010). The literature support shows that the pathogenic bacteria level at 16 different locations was in the range of 2 to 4 log counts (Kumarasamy *et al.,* 2009). The heavy metal pollution and other emerging pollutants (like pharmaceuticals and personal care products) were also analyzed by Begum *et al.,* 2009 and Dhanakumar *et al.,* 2013. The emerging pollution level was varying spatially and the researchers concluded that in the upstream side (near the Coorg) the water quality was good and fit for drinking because of no human interventions or anthropogenic activities. As the river approaches the drain (near Trichy and Chidambaram) the pollution levels are much higher (Suriya *et al.,* 2017; Vijayan *et al.,* 2018). There are reports stating that tributaries like Noyyal and Amaravathi has more anthropogenic activities like industrial effluents and municipal effluents discharge are more without treatment or partial treatment into main stream (Devarajan *et al.,* 2015; Jayakumar *et al.,* 2015; Kumar *et al.,* 2019). Overall the authors conclude that the river is slowly declining in its quality as well as quantity and there is an urgent need for a community friendly tool to educate /inform the local authorities and communities about the pollution scenario. Therefore, in the present study monitoring and assessing the quality of River Cauvery at two vital cities / towns and to develop the community based tool kit "Eco-Heart index" was coined. The scope of the present work was to check and compare the quality at upstream side and downstream side. An eco-heart indexed water quality map for the Cauvery River basin was generated using the standard values and the pollution trend in the river basin for the two selected towns / cities assessed accordingly. Additionally, the paper also suggests a suitable treatment options for the contaminated river water.

## MATERIALS AND METHODS

### Study area

This study was carried out in Cauvery River, which is considered as one of the major peninsular rivers in South India. The Cauvery River catchment area is a widespread one and lies between latitude 10°7′ N to 13°28′ N and longitude 75°28′ E to 79°52′ E. In the current study, water samples were collected from two distinct places Mettur and Mayanur towns that lie in the Cauvery basin. The Mettur town is situated in Tamil Nadu with the GPS coordinates as 11°48′02.1"N 77°48′26.1"E and it is entry point of River Cauvery into the Tamil Nadu. The Mayanur town is situated in Tamil Nadu with the following GPS coordinates 10°57′16.6"N 78°13′44.7"E and it is located very closer to the drain point. The water samples were collected during post monsoon season from the locations in the upstream and downstream point of the towns, the water samples were collected at three different locations in the upstream and downstream side (Figure 1).

### Physico-chemical analysis

The water samples from the rivers were collected in fresh polystyrene bottles of 2 L capacity and were washed with distilled water thoroughly before sampling. Another set of samples were collected in a 500 mL polystyrene bottles and were preserved with Boric acid and Hydrochloric acid (1:1 ratio) for

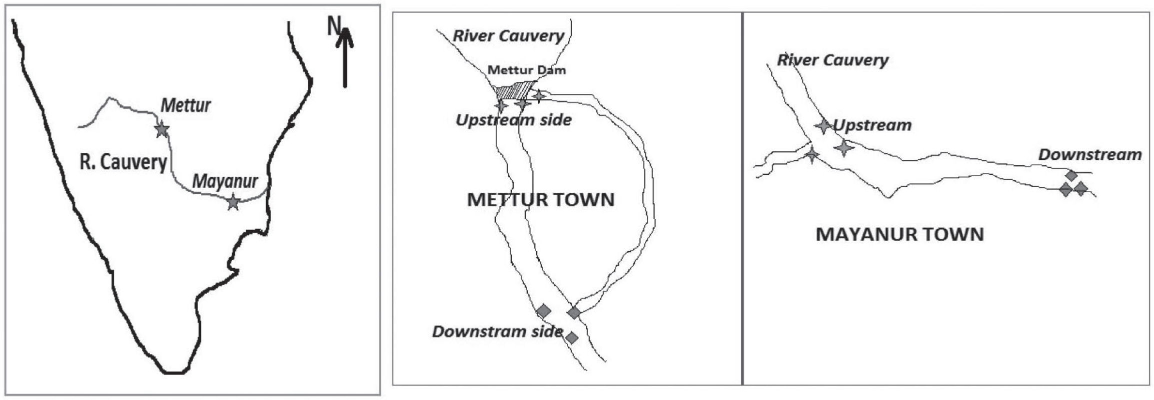


**Fig. 1.** Line map showing the study locations

the measurements of trace elements. The sample bottles were stored in an ice box filled with gel ice and transported to laboratory and preserved in refrigeration at 4 °C before analysis. The physic chemical parameters were analyzed by the standard methods for water and wastewater as prescribed in APHA, 2012. The trace elements like sodium, calcium, iron, manganese, zinc etc., were measured. The water samples were first lyophilized and were measured using X-ray fluorescence diffraction and elemental analyzer (XRF, Bruker S8 Tiger, USA). The analyzed values are used for the preparation of the community based tool "The Eco-Heart" index.

**Community based Eco-heart index: Development and Assessment**

The concept of eco-heart index was developed by selecting 6 parameters that are easily measurable and essential as per Bureau of Indian Standards. The six parameters that were chosen for eco-heart mapping are pH, dissolved oxygen, hardness, chlorides, dissolved solids and sulphates. The Eco-heart was developed by following the three steps: marking, connecting and assessing (Sakai *et al.*, 2018). The selected six parameters were classified into different levels based on the Bureau of Indian Standard (BIS) IS: 10500-2012 standards and were tabulated in Table 1 with little refinement. The selected six water quality parameters were able to capture the overall water quality of the rivers, as well as to identify major pollution loads such as dissolved solids, sulphates, chlorides and dissolved oxygen level. The five levels of classification for each of the six parameters are marked in graphical forms as shown in Figure 2. The each five levels of the water quality parameter (except pH) were placed in an order from level I (clean) at the edges through level V (heavily polluted) at the center, while the pH was plotted in reverse order. The inverse order placement of levels for pH was mainly to get a proper heart shape (Figure 2).

## RESULTS AND DISCUSSION

### Water quality of Cauvery River

#### At Mettur

The river water samples from the upstream side and downstream side of the Mettur town were collected at three different locations across the width of the

**Table 1.** Water quality levels classification for platting in Eco-Heart index

| Parameter (Unit) | Level I – Clean | Level II – Moderate | Level III – Slightly polluted | Level IV – Polluted | Level V – Heavily polluted |
|---|---|---|---|---|---|
| pH | 6.5 – 7.5 | 7.6 – 8.5 or 5.5 – 6.4 | 8.6 – 9.5 or 4.5 – 5.4 | 9.6 – 10.5 or 3.5 – 4.4 | >10.6 or < 3.4 |
| Dissolved Oxygen (mg/L) | >4 | 3.0 – 4.0 | 2.0 – 3.0 | 1.0 – 2.0 | <1.0 |
| Total dissolved solids (mg/L) | < 500 | 501 – 1000 | 1001 – 1500 | 1501 – 2000 | >2000 |
| Hardness (mg/L) | < 200 | 201 – 300 | 301 – 400 | 401 - 600 | >600 |
| Sulphates (mg/L) | < 200 | 201 - 300 | 301 - 400 | 401 - 500 | >500 |
| Chlorides (mg/L) | < 250 | 251 – 500 | 501 – 750 | 751 - 1000 | >1000 |

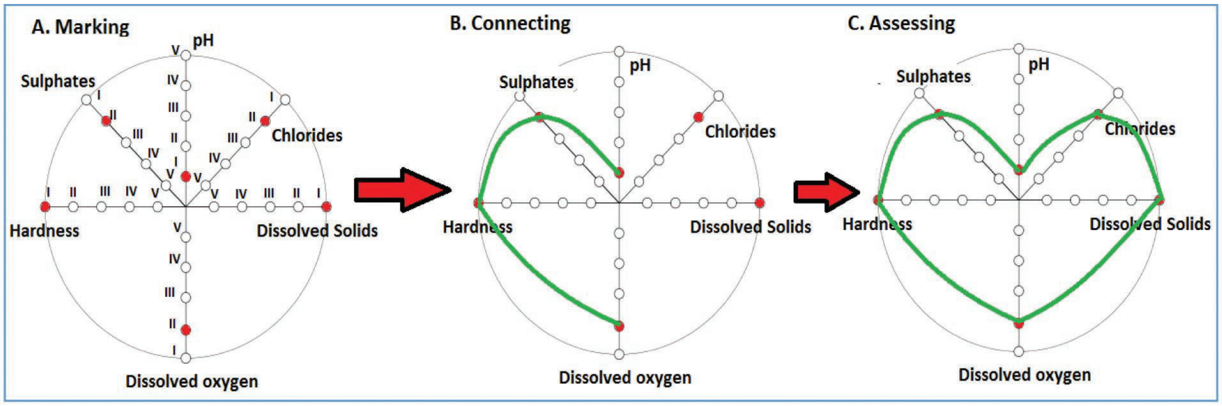


**Fig. 2.** Overall concept of Eco-Heart index (a) Marking (b) Connecting (c) Assessing

river. The sampling site was selected in such a way that it is very close to the intake structure and from where the water for the public uses drinking and bathing as well as industrial uses are taken. It was observed that the sampling site in the upstream side looks clean and there were no wastewater streams or discharges close-by (Figure 3(a), while in the downstream side the wastewater discharges were observed (Figure 3(b)). The river water characteristics at Mettur in the upstream and downstream side were tabulated in Table 2 with the BIS drinking water standards. The pH value of the river sample in the upstream side was found to be 7.97±0.23 and in the downstream side it was 8.16 ± 0.38, and the values are within the permissible level (6.5-8.5). The dissolved oxygen level of the river water is much higher (7.5±0.2 mg/L in upstream side and 7.2 ± 2.3 mg/L in downstream side), than the IS: 10500-2012 permissible (4.0 mg/L) and very close to DO saturation level 8 mg/L (Khan *et al.*, 2003). The electrical conductivity of the river water in upstream side (0.82±0.3 mS/cm) and in downstream side (1.24 ± 0.25 mS/cm) was found to be higher than the permissible value (0.5 mS/ cm). The reason for higher EC may be due to higher anthropogenic activities happening in the stream

**Fig. 3(a).** Photographs of sampling points in upstream of the Mettur, River Cauvery

**Fig. 3(b).** Photographs of sampling points in downstream of the Mettur, River Cauvery

(Shah and Joshi, 2017); especially in downstream side the industrial effluents as well as domestic effluents were found to be discharged. The high EC of water samples corresponded to the presence of ions ($HCO^{3-}$, $SO_4^{2-}$, $Ca^{2+}$ and $Mg^{2+}$) in higher concentrations which resulted from the solubility of rocks and ion exchange process happening in aquifers (Shahab *et al.*, 2018).There is a positive correlation between the EC and total dissolved solids (TDS) value, as EC is higher TDS value was also found to be higher.

The turbidity of the river was found to be higher than the permissible value; the turbidity value was 12±3 NTU in upstream side and 38±7 NTU, which is higher than 1-5 NTU. Turbidity in water is caused by suspended and colloidal matter such as clay; silt and finely divided organic and inorganic matter; plankton and other microscopic organisms. Turbidity has positive correlation with suspended solids. The reason for turbidity is due to the erosion of sand and silt from the boulders causing the suspension of particles (Venkatesharaju *et al.*, 2010) as well as domestic discharges. The dissolved solids concentration was in the range of 1250 ± 30 mg/L in the upstream and 1550 ± 50 mg/L in the downstream side, much higher than the acceptable value (500 mg/L).

The suitability of the river water for drinking and industrial applications highly depends on the hardness of the water. The hardness in water are caused by multivalent cations and anions like calcium, magnesium, strontium, iron, etc. (Batabyal and Chakraborty, 2015). The total hardness in the present study was found to be 475±30.2 mg/L in the upstream side and 565±52.5 mg/L in the downstream side, which is much higher than the standard values 200mg/L. Another important parameter that contributes to river water quality is total alkalinity. The alkalinities in the natural streams are primarily due to the salts of weak acids, bases, carbonates, bicarbonates and hydroxides (Venkatesharaju *et al.*, 2010). The levels of alkalinity in the upstream and downstream sides were 425±25 mg/L and 520±23.5 mg/L respectively. All the above mentioned parameters were found to be higher in downstream side than upstream side due to higher anthropogenic activities happening closer to downstream of Mettur town, similar results were obtained (Kumarasamy *et al.*, 2009; Venkatesharaju *et al.*, 2010; Batabyal and Chakraborty, 2015).

The calcium and magnesium levels in the River Cauvery are much lesser than the permissible values. The chlorides are the natural occurring salt in the form of rocks and they are present in all the river water streams. The high concentrations of chlorides are considered to be the indicators of the pollution from anthropogenic activities like organic waste disposal or industrial effluents discharge. The chlorides in a higher concentration in rivers are harmful to irrigation, drinking and affects plants and aquatic/human life (Venkatesharaju *et al.*, 2010). The levels of chlorides in the River Cauvery at

**Table 2.** River water characteristics in Mettur of River Cauvery

| Sl. No | Parameter | Unit | Upstream side | Downstream side | Drinking water standards (IS:10500-2012) |
|---|---|---|---|---|---|
| 1. | pH | | 7.97 ± 0.23 | 8.16 ± 0.38 | 6.5 – 8.5 |
| 2. | Dissolved Oxygen | mg/L | 7.5 ± 0.2 | 7.2 ± 2.3 | >4.0 |
| 3. | Turbidity | NTU | 12 ± 3 | 38 ± 7 | <5.0 |
| 4. | Electrical Conductivity | mS/cm | 0.822 ± 0.31 | 1.24 ± 0.25 | <0.5 |
| 5. | Total Hardness | mg/L | 475 ± 30.2 | 565±52.5 | 200 – 600 |
| 6. | Total Alkalinity | mg/L | 425 ± 25 | 520±23.5 | 200 – 600 |
| 7. | Chlorides | mg/L | 1631 ± 56 | 2111.5 ± 32 | 250 – 1000 |
| 8. | Sulphates | mg/L | 394 ± 17.5 | 512.8 ± 11.2 | 200 – 400 |
| 9. | Total Suspended Solids | mg/L | 72 ± 2.8 | 155 ± 30 | NA |
| 10. | Total Dissolved Solids | mg/L | 1250 ± 30 | 1550 ± 50 | 500 – 2000 |
| 11. | Total Solids | mg/L | 1322 ± 27 | 1705 ± 20 | NA |
| 12. | Calcium | mg/L | 7.2 ± 3.8 | 12.8 ± 5.5 | 75 – 200 |
| 13. | Sodium | mg/L | 27.33 ± 5.27 | 35.2 ± 10.8 | NA |
| 14. | Magnesium | mg/L | 3.79 ± 1.22 | 3.98 ± 2.4 | 30 – 100 |
| 15. | Potassium | mg/L | 4.24 ± 2.88 | 8.12±5.2 | NA |

n = 3; NA – Not Applicable

Mettur upstream and downstream sides were 1631±56 mg/L and 2111.5±32 mg/L respectively. The values are much higher than the prescribed limit for drinking 250 mg/L. The sulphate content of the river water samples was; 394±17.5 mg/L in upstream side and 512.8±11.2 mg/L in downstream side, well above the prescribed Bureau of Indian standards limit (400 mg/L), and hence before using the river water for drinking or non-potable applications an appropriate treatment is required.

**At Mayanur**

In the Mayanur town, the river water samples were collected from three points in upstream side and three points in downstream side across the width of the river (Figure 1). The chosen sampling sites were selected closer to the intake structure in the upstream side and wastewater discharge point in the downstream side (Figure 4). The pH value in the upstream was 7.56±0.32 and in the downstream was 7.72±0.81, which are well within the permissible limit (6.5-8.5), except the downstream side. The dissolved oxygen (DO) levels in the upstream of the river were found to be 4.2±2.4 mg/L and in the downstream the level was 3.8±3.1 mg/L. The reason for lesser DO level is due to the anthropogenic activities like domestic wastewater discharge and industrial effluents mixing with river. Similar kind of results were obtained, the DO level reduced to <1.0 mg/L in the river (Venkatesharaju *et al.*, 2010) due to domestic and small scale industrial effluents.

The electrical conductivity (EC) values in the upstream side were 1.53±0.38 mS/cm and in the downstream side was 2.18±0.56 mS/cm, which is much higher than the permissible value (0.5 mS/cm). The higher EC content in the rivers are affected by illegal domestic and industrial discharges (Shahab *et al.*, 2018). The EC have a positive correlation with dissolved solids, as the EC value increases the dissolved solids concentration was also increased. The turbidity in the river is caused by the colloidal and suspended particles due to anthropogenic or natural activities. The levels are much higher than the permissible limit (<5 NTU) as tabulated in Table 3. The turbidity value was lower in upstream and similarly the suspended concentration was also lower showing positive correlation compared to downstream. The hardness, chlorides, sulphate, alkalinity, calcium and magnesium were much higher than the permissible values (Table 3). Hence, there should be a proper treatment is required before using for drinking / irrigation/industrial applications.

**Heavy metals concentration**

Generally, the heavy metals concentrations in the river water sample is higher than the permissible level, it cause's lot of problems to humans, plants and animals (Begum *et al.,* 2009). The contamination level of Cauvery River (India) by heavy metals such as Pb, Cr, Zn, Cu and Fe was reported and it was attributed to agricultural, industrial and anthropogenic activities happening around the river (Begum *et al.*, 2009; Dan'Azumi and Bichi, 2010; Venkatramanan *et al.,* 2015). In the present study, it was seen from the Figure 5(a) & (b) that all the heavy metals concentrations are much higher than the BIS-10500:2012 standard limit. The study results are in good agreement with earlier researches (Begum *et al.,* 2009; Shang *et al.,* 2015; Chen *et al.,* 2016; Sim *et al.,* 2016; Wong *et al.,* 2017), as the heavy metals concentrations in the upstream are much lower than the downstream values

**Eco-heart index mapping and pollution trend characterization**

The Eco-Heart index value and the WQ index values were been correlated to elucidate that both are

**Fig. 4.** Photographs of sampling points in upstream and downstream of the Mayanur, River Cauvery

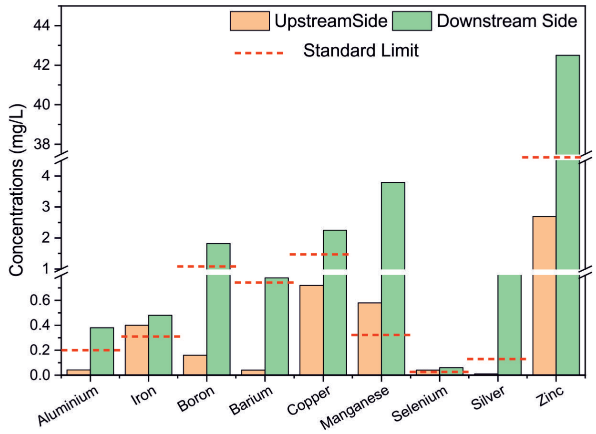


**Fig. 5(a).** Heavy metal concentration profile of upstream and downstream of Mettur, River Cauvery

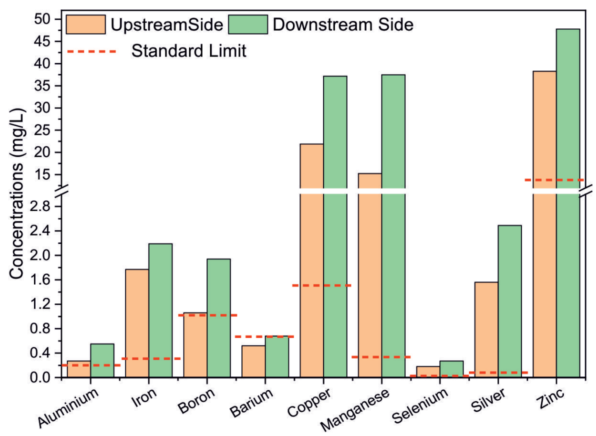


**Fig. 5(b).** Heavy metal concentration profile of upstream and downstream of Mayanur, River Cauvery

similar by Sakai *et al.*, 2018. They found that the there is a negative correlation between the two indices and the regression coefficient ($R^2$) was found to be 0.853. Hence, the author concludes that the Eco-Heart Index could be numerically used as an alternative tool for the water quality categorization. The amount and scattering of the pollution levels in the River Cauvery at two locations (Mettur and Mayanur) and at upstream and downstream sides were shown in the Figures 6(a) & (b) and 7(a) & (b) respectively. It was observed that the quality of water in River Cauvery is not at all clean at any place in the present study, as a proper heart shape was not formed at any of the 4 locations. The river water quality of the upstream of Mettur looks moderately clean, as there was an uneven and "skewed heart" shapes (Figure 6(a)) and characterized as hard water. It represents hard water containing higher amount of calcium or magnesium chloride salts. There are studies showing that drinking hard water leads to eczema diseases in children and cardiovascular problems (Marque *et al.*, 2003; Arnedo-Pena *et al.*, 2007; Perkin *et al.*, 2016).

The water from Mettur upstream are taken by few industries near-by, and the hard water for the industries are not acceptable as it may form scaling and corrosion (Emerson and Traver, 2008). Hence, the water from the upstream side has to undergo a small treatment like water softening or ion-exchanger before using. The quality of river in the downstream side also looks similar to the upstream

**Table 3.** River water characteristics in Mayanur of River Cauvery

| Sl. No | Parameter | Unit | Upstream side | Downstream side | Drinking water standards (IS:10500-2012) |
|---|---|---|---|---|---|
| 1. | pH | | 7.56±0.32 | 7.72±0.81 | 6.5 – 8.5 |
| 2. | Dissolved Oxygen | mg/L | 4.2±2.4 | 3.8±3.1 | >4.0 |
| 3. | Turbidity | NTU | 23±12 | 52±8 | <5.0 |
| 4. | Electrical Conductivity | mS/cm | 1.53±0.38 | 2.18±0.56 | <0.5 |
| 5. | Total Hardness | mg/L | 515 ± 15.5 | 625±25 | 200 – 600 |
| 6. | Total Alkalinity | mg/L | 305 ±5 | 620±20 | 200 – 600 |
| 7. | Chlorides | mg/L | 1885 ± 35 | 2255 ± 15 | 250 – 1000 |
| 8. | Sulphate | mg/L | 512 ± 27 | 588 ± 35 | 200 – 400 |
| 9. | Total Suspended Solids | mg/L | 125±22 | 205±18 | NA |
| 10. | Total Dissolved Solids | mg/L | 1825±45 | 2830±120 | 500 – 2000 |
| 11. | Total Solids | mg/L | 1950±67 | 3035±102 | NA |
| 12. | Calcium | mg/L | 72.4 ± 13.1 | 89.5 ± 7.2 | 75 – 200 |
| 13. | Sodium | mg/L | 39.1 ± 2.4 | 40.4 ± 3.8 | NA |
| 14. | Magnesium | mg/L | 179.2 ± 12.8 | 188.7 ± 15 | 30 – 100 |
| 15. | Potassium | mg/L | 12.2 ± 1.8 | 18.72±3.79 | NA |

n = 3; NA – Not Applicable

side with slight deterioration in the quality parameters like sulphate, hardness and dissolved solids. The Eco-heart formed in the downstream side of Mettur looks like a narrow concave conical "shell shape" structure. The river water here is highly hard and containing higher amount of sulphate and chloride salts and also looks slightly turbid. Hence, the form represented in Figure 6(b) is characterized as hard and turbid water. More importantly the reason for higher concentration of solids, salts and turbidity is due to anthropogenic activities like uncontrolled domestic wastewater discharges and industrial effluents from small to large scale in the vicinity of Mettur (Jain *et al.,* 2011; Anbazhagan, 2018). Therefore, a treatment for such type of water is to be adoptedwith sequential processes containing

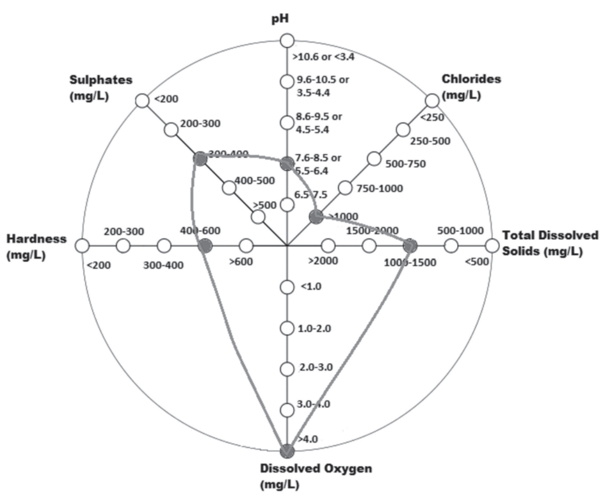


**Fig. 6(a).** The Eco-heart map for the upstream side of the Mettur, River Cauvery

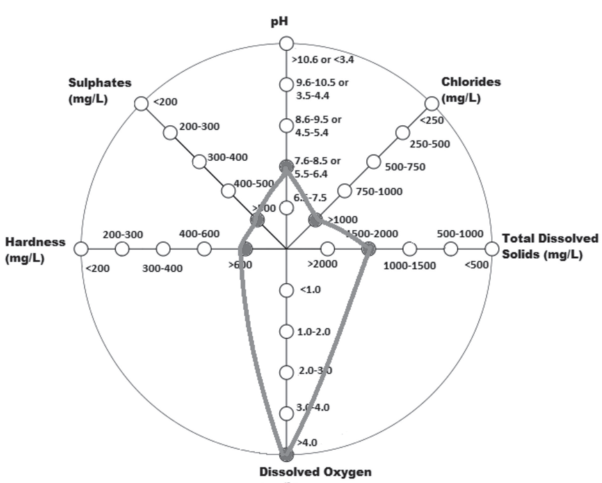


**Fig. 6(b).** The Eco-heart map for the downstream side of the Mettur, River Cauvery

a filtration followed by ion-exchanger before using the water.

In the Mayanur town the water from the upstream side and downstream side were collected and the Eco-heart index map was prepared for the two sites (Figure 7(a) & (b)). The contamination level in Mayanur is much higher than the Mettur town, due to more human settlements and other anthropogenic activities happening in the Cauvery River stretch as it passes through various cities/ towns. It was observed that at upstream of Mayanur the Eco-heart index map shape looks like a "round cut diamond" shape (Figure 7(a)). It symbolizes that it has low DO content, high salt content including chlorides and sulphate. The reason for the higher concentration of various pollutants in river water is due to discharges from industrial belts in Karur and Tirupur. The River Cauvery tributaries like River Amaravati and River Noyyal carry the textile effluents and small scale industrial effluents and sinking the quality of river. There are various studies showing that both tributaries are highly contaminated (Usharani *et al.,* 2010; Prasath *et al.,* 2013; Hema and Subramani, 2017). Therefore, the river Cauvery at upstream of Mayanur is found to carry predominantly of industrial effluents and little of domestic effluents and classified as unfit for direct drinking purposes. A proper treatment is required for the water and the illegal discharges have to be stopped.

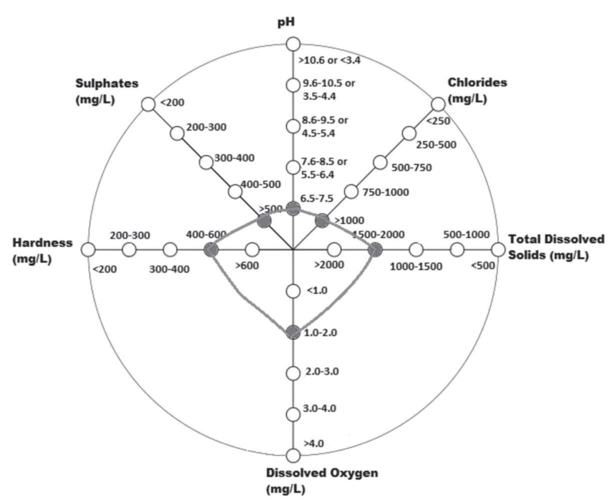


**Fig. 7(a).** The Eco-heart map for the upstream side of the Mayanur, River Cauvery

In the downstream side of Mayanur, the river quality is further deteriorated and contains all sorts of chemicals that exist in the world. The pH value is i alkaline in nature, and DO level has dropped down to <1 mg/L making it unfit for drinking. The salt concentration including, sulphate, chlorides and bicarbonates are very high than the permissible level. The water in the Mayanur downstream is characterized as dark brown water and the Eco-heart shape showed a unique pattern of "Rabbit ear" (Figure 7(b)). The shape symbolizes that the river carries only wastewater and not water, and it is unfit for drinking and non-potable applications also. If the water from the river is taken for drinking or other purposes, it has to be extensively treated using some membrane filtration or advanced filtration techniques (Skariyachan *et al.,* 2015). Henceforth, it was seen that the quality of river in the course of the flow from the source to drain was slowly deteriorating. The clear evidence for the increased pollution level in the river is due to anthropogenic activities like illegal domestic wastewater discharges, solid waste dumping, industrial effluents mixing and illegal accessing for spiritual activities.

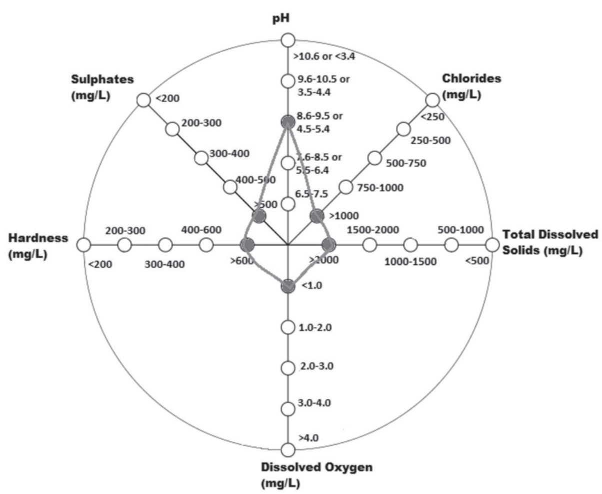


**Fig. 7(b).** The Eco-heart map for the downstream side of the Mayanur, River Cauvery

However, the developed eco-heart shapes as well as the source of pollution and its association has to be re-categorized for the other watershed structures, because the quality varies with respect to source, land use, population, geological condition, living standards and level of anthropogenic activities (Sakai *et al.,* 2018). The seasonal and spatial variation of the water quality also needs to be clarified as the pollutants concentration will vary from season to season and spatially. Therefore, the developed Eco-Heart categorization needs to be revised or modified including the seasonal and spatial variations. Additionally, the six parameters that were used for preparing the Eco-Heart was selected based on easiness and that can be analyzed by the field workers with lesser efforts. The analyzed 6 parameters can provide only the general water quality and not focused on specific pollutants like nutrients, fecal contamination, pharmaceuticals, heavy metals and emerging contaminants. If the parameters need to be changed in the re-categorization/modification process, the number of parameters must be fixed at 6 because heart shape only works with 6 parameters. If five parameters or 4 parameters were chosen to draw the index value, then it may represent a star shape or a diamond shape. In this sense, Eco-Heart Index should not be used beyond general water quality monitoring and assessment, but it will be helpful to indicate the necessity of further analyses for specific pollutants, based on the drawn figures.

The Eco-heart index developed based on the standard operating procedure has been validated with the community-based water quality monitoring kits (Results not shown), and the results were satisfactory. The developed kits have to be introduced into some villages or town peoples and educate them about the procedure for measurement and techniques or provide awareness among them with hands on training. Subsequently, the local government authorities or community representatives can be educated on the eco-heart mapping and preparation of management options. An instruction booklet or training module can be developed further, for the sake of correct mapping of eco-heart and measurement of water quality parameters, so that Eco-Heart Index will provide a best performance as a locally-adapted water quality indicator. Additionally, the research can be carried out further including the community engagement in testing the parameters and validation of results with standard methods and depiction an eco-heart index. Overall, the Eco-heart index is a very good tool for the understanding and easily recognition of river water quality by the local uneducated people or communities.

## CONCLUSION

This study developed an Eco-Heart Index for the community to easily understand the quality of river water. It is considered as user-friendly, economical, accurate and speedy measurement of river water quality by using lesser resources. The river water collected from the upstream and downstream sides were characterized using the standard test procedure and was checked for the accuracy with a commercially available water test kit. The values obtained by the monitoring kits are quite accurate and strongly correlated with those obtained by standard methods; results are not shown in this paper. The eco-heart index development by using a water test kit will be an economical option, as it cost approximately 60 Indian Rupee (0.86 USD). The 6 parameter (pH, DO, chlorides, sulphates, hardness and dissolved solids) values were plotted in a graphical form and the connected points represents a proper heart shape if the river is clean and if polluted it forms an irregular or corrugated shape.

It was observed in the study that, at the upstream side of Mettur the river water is slightly clean except for chloride level (1631±56 mg/L) other parameters are well within the permissible limit as provided in IS: 10500-2012. Whereas, the river flows through the Mettur town, the river water quality was deteriorated due to anthropogenic activities. Hence, the water in the river at Mettur downstream was contaminated with high level of hardness (565±52.5 mg/L), chlorides (2111.5 ± 32 mg/L), turbidity (38 ± 7 NTU) and sulphates (512.8 ± 11.2 mg/L). Subsequently down the stream, at Mayanur the river water quality has further worsened, comparatively the upstream side has better quality water than the downstream side. At the downstream of Mayanur, the quality of river was: pH - 7.72±0.81, dissolved oxygen was 3.8±3.1 mg/L, the chlorides level was 2255 ± 15 mg/L, dissolved solids was 2830±120 mg/L and turbidity was 52±8 NTU. The heavy metal pollution levels in Mettur and Mayanur are much higher than the standard values; hence a proper treatment is required before using for drinking or other non-potable applications. The study concludes that amongst the two towns selected, Mettur was found to be comparatively cleaner than Mayanur. Additionally, the research also shows that among the upstream side and downstream side pollution levels, it was found that the level of pollution is higher in downstream side due to various human interventions and other anthropogenic activities. Overall, Eco-Heart Index is a multi-functional community-based water quality indicator; further research is required to make it universally accepted index value.

## REFERENCES


Anbazhagan, V. 2018. Analysis and assessment of heavy metals in soils around the industrial areas in Mettur, Tamilnadu, India. *Environmental Monitoring and Assessment*. 190(9) : 519. https://doi.org/10.1007/s10661-018-6899-5

APHA, A. W. W. A. 2012. WEF. (2012). *Standard Methods for the Examination of Water and Wastewater*. 22.

Arnedo-Pena, A., Bellido-Blasco, J., Puig-Barbera, J., Artero-Civera, A., Campos-Cruañes, J. B., Pac-Sa, M. R. and Felis-Dauder, C. 2007. Domestic water hardness and prevalence of atopic eczema in Castellon (Spain) schoolchildren. *Saludpublica de Mexico*. 49 (4) : 295-301.

Batabyal, A. K. and Chakraborty, S. 2015. Hydrogeochemistry and water quality index in the assessment of groundwater quality for drinking uses. *Water Environment Research*. 87(7) : 607-617. https://doi.org/10.2175/106143015X14212658613956

Begum, A., Ramaiah, M., Khan, I. and Veena, K. 2009. Heavy metal pollution and chemical profile of Cauvery River water. *Journal of Chemistry*. 6(1) : 47-52. ISSN: 0973-4945

Chatterjee, C. and Raziuddin, M. 2002. Determination of Water Quality Index (WQI) of a degraded river in Asansol industrial area (West Bengal). *Nature, Environment and Pollution Technology*. 1(2) : 181-189.

Chen, H., Chen, R., Teng, Y. and Wu, J. 2016. Contamination characteristics, ecological risk and source identification of trace metals in sediments of the Le'an River (China). *Ecotoxicology and Environmental Safety*. 125 : 85-92.https://doi.org/10.1016/j.ecoenv.2015.11.042

Dan'Azumi, S. and Bichi, M. H. 2010. Industrial pollution and heavy metals profile of Challawa River in Kano, Nigeria. *Journal of Applied Sciences in Environmental Sanitation*. 5(1).

Devarajan, N., Laffite, A., Ngelikoto, P., Elongo, V., Prabakar, K., Mubedi, J. I. and Poté, J. 2015. Hospital and urban effluent waters as a source of accumulation of toxic metals in the sediment receiving system of the Cauvery River, Tiruchirappalli, Tamil Nadu, India. *Environmental Science and Pollution Research*. 22(17) : 12941-12950.https://doi.org/10.1007/s11356-015-4457-z

Dhanakumar, S., Murthy, K. R., Solaraj, G. and Mohanraj, R. 2013. Heavy-metal fractionation in surface sediments of the Cauvery River Estuarine Region, Southeastern Coast of India. *Archives of Environmental Contamination and Toxicology*. 65(1) : 14-23.https://doi.org/10.1007/s00244-013-9886-4

Emerson, C. H. and Traver, R. G. 2008. Multiyear and seasonal variation of infiltration from storm-water best management practices. *Journal of Irrigation and Drainage Engineering*. 134(5) : 598-605.https://doi.org/10.1061/(ASCE)0733-9437(2008)134:5(598)

Hema, S. and Subramani, T. 2017. Scientific Methods of Assessing Groundwater for Irrigation Purpose-A Case Study in a Part of Cauvery River Basin, South India. *The Indian Ecological Society*. 44(2) : 185-191.

Jain, M. K., Dadhich, L. K. and Kalpana, S. 2011. Water quality assessment of Kishanpura Dam, Baran, Rajasthan, India. *Nature, Environment and Pollution Technology*. 10(3) : 405-408.

Jayakumar, R., Dhanakumar, S., Kalaiselvi, K. and Palanivel, M. 2015. Water pollution in the vicinity of stanley reservoir by point and non-point sources, Cauvery Basin, India. In: *Environmental Management of River Basin Ecosystems* (pp. 491-505). Springer, Cham.https://doi.org/10.1007/978-3-319-13425-3_23

Khan, F., Husain, T. and Lumb, A. 2003. Water quality evaluation and trend analysis in selected watersheds of the Atlantic region of Canada. *Environmental Monitoring and Assessment*. 88(1-3): 221-248.https://doi.org/10.1023/A:1025573108513

Kim, G., Chung, S. and Lee, C. 2007. Water quality of runoff from agricultural-forestry watersheds in the Geum River Basin, Korea. *Environmental Monitoring and Assessment*. 134(1-3) : 441.https://doi.org/10.1007/s10661-007-9635-0

Kumar, D., Kumar, R., Aakib, T. and Soni, V. K. 2019. Analysis on Water Quality of Cauvery and Bhavani River for its Seasonal Variation at Bhavani. *Journal of Water Pollution & Purification Research*. 3(2) : 24-29.

Kumarasamy, P., Vignesh, S., Arthur James, R., Muthukumar, K. and Rajendran, A. 2009. Enumeration and identification of pathogenic pollution indicators in Cauvery River, South India. *Research Journal of Microbiology*. 4(12) : 540-549.

Marque, S., Jacqmin-Gadda, H., Dartigues, J. F. and Commenges, D. 2003. Cardiovascular mortality and calcium and magnesium in drinking water: an ecological study in elderly people. *European Journal of Epidemiology*. 18(4) : 305-309.https://doi.org/10.1023/A:1023618728056

Perkin, M. R., Craven, J., Logan, K., Strachan, D., Marrs, T., Radulovic, S. and Flohr, C. 2016. Association between domestic water hardness, chlorine, and atopic dermatitis risk in early life: a population-based cross-sectional study. *Journal of Allergy and Clinical Immunology*. 138(2) : 509-516.https://doi.org/10.1016/j.jaci.2016.03.031

Philip, L., Ramprasad, C. and Krithika, D. 2019. Sustainable Wastewater Management through Decentralized Systems: Case Studies. In: *Water Scarcity and Ways to Reduce the Impact* (pp. 15-45). Springer, Cham.https://doi.org/10.1007/978-3-319-75199-3_2

Prasath, B. B., Nandakumar, R., Kumar, S. D., Ananth, S., Devi, A. S., Jayalakshmi, T. and Santhanam, P. 2013. Seasonal variations in physico-chemical characteristics of pond and ground water of Tiruchirapalli, India. *Journal of Environmental Biology*. 34(3) : 529.

Ramprasad, C., Smith, C. S., Memon, F. A. and Philip, L. 2017. Removal of chemical and microbial contaminants from greywater using a novel constructed wetland: GROW. *Ecological Engineering*. 106 : 55-65.https://doi.org/10.1016/j.ecoleng.2017.05.022

Sakai, N., Mohamad, Z. F., Nasaruddin, A., Kadir, S. N. A., Salleh, M. S. A. M. and Sulaiman, A. H. 2018. Eco-Heart Index as a tool for community-based water quality monitoring and assessment. *Ecological Indicators*. 91 : 38-46.https://doi.org/10.1016/j.ecolind.2018.03.079

Shah, K. A. and Joshi, G. S. 2017. Evaluation of water quality index for River Sabarmati, Gujarat, India. *Applied Water Science*. 7(3) : 1349-1358.https://doi.org/10.1007/s13201-015-0318-7

Shahab, A., Qi, S., Zaheer, M., Rashid, A., Talib, M. A. and Ashraf, U. 2018. Hydrochemical characteristic and water quality assessment for drinking and agricultural purposes in District Jacobabad, Lower Indus Plain, Pakistan. *International Journal of Agricultural and Biological Engineering*. 11(2) : 115-121. DOI: 10.25165/j.ijabe.20181102.2747

Shang, Z., Ren, J., Tao, L. and Wang, X. 2015. Assessment of heavy metals in surface sediments from Gansu section of Yellow River, China. *Environmental Monitoring and Assessment*. 187(3): 79.https://doi.org/10.1007/s10661-015-4328-6

Sidek, L., Basri, H., Lee, L. K. and Foo, K. Y. 2016. The performance of gross pollutant trap for water quality preservation: a real practical application at the Klang Valley, Malaysia. *Desalination and Water Treatment*. 57(52) : 24733-24741. https://doi.org/10.1080/19443994.2016.1145599

Sim, S. F., Ling, T. Y., Nyanti, L., Gerunsin, N., Wong, Y. E. and Kho, L. P. 2016. Assessment of heavy metals in water, sediment, and fishes of a large tropical hydroelectric dam in Sarawak, Malaysia. *Journal of Chemistry*. *2016*. http://dx.doi.org/10.1155/2016/8923183

Skariyachan, S., Mahajanakatti, A. B., Grandhi, N. J., Prasanna, A., Sen, B., Sharma, N. and Narayanappa, R. 2015. Environmental monitoring of bacterial contamination and antibiotic resistance patterns of the fecal coliforms isolated from Cauvery River, a major drinking water source in

Karnataka, India. *Environmental Monitoring and Assessment*. 187(5) : 279.https://doi.org/10.1007/s10661-015-4488-4

Solaraj, G., Dhanakumar, S., Murthy, K. R. and Mohanraj, R. 2010. Water quality in select regions of Cauvery Delta River basin, southern India, with emphasis on monsoonal variation. *Environmental Monitoring and Assessment*. 166(1-4) : 435-444.https://doi.org/10.1007/s10661-009-1013-7

Suriya, J., Shekar, M. C., Nathani, N. M., Suganya, T., Bharathiraja, S. and Krishnan, M. 2017. Assessment of bacterial community composition in response to uranium levels in sediment samples of sacred Cauvery River. *Applied Microbiology and Biotechnology*. 101(2) : 831-841.https://doi.org/10.1007/s00253-016-7945-2

Usharani, K., Umarani, K., Ayyasamy, P. M., Shanthi, K., and Lakshmanaperumalsamy, P. 2010. Physico-chemical and bacteriological characteristics of Noyyal River and ground water quality of Perur, India. *Journal of Applied Sciences and Environmental Management*. 14(2). http://dx.doi.org/10.4314/jasem.v14i2.57830

Venkatesharaju, K., Ravikumar, P., Somashekar, R. K. and Prakash, K. L. 2010. Physico-chemical and bacteriological investigation on the river Cauvery of Kollegal stretch in Karnataka. *Kathmandu University Journal of Science, Engineering and Technology*. 6(1) : 50-59.

Venkatramanan, S., Chung, S. Y., Ramkumar, T. and Selvam, S. 2015. Environmental monitoring and assessment of heavy metals in surface sediments at Coleroon River Estuary in Tamil Nadu, India. *Environmental Monitoring and Assessment*. 187 (8): 505.https://doi.org/10.1007/s10661-015-4709-x

Vijayan, P., Senthilmurugan, S., Pugazhendy, K. and Tamizhazhagan, V. 2018. Analysis of physicochemical parameters water samples from Cauvery River in Thanjavur district, Tamil Nadu. *International Journal of Biology Research*. 3(1): 223-227.

Wong, K. W., Yap, C. K., Nulit, R., Hamzah, M. S., Chen, S. K., Cheng, W. H. and Al-Shami, S. A. 2017. Effects of anthropogenic activities on the heavy metal levels in the clams and sediments in a tropical river. *Environmental Science and Pollution Research*. 24 (1) : 116-134.https://doi.org/10.1007/s11356-016-7951-z

Yogendra, K. and Puttaiah, E. T. 2008. Determination of water quality index and suitability of an urban waterbody in Shimoga Town, Karnataka. In *Proceedings of Taal. 2007: The 12th world lake conference* (Vol. 342, pp. 346).