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Impact of Urbanization on Yield and Water Quality of An Urban Tank of Chennai City: Rehabilitation Measures for Pisciculture Development

M. Krishnaveni*, A. Rajeswari

Centre for Water Resources, Anna University, Chennai – 600 025, Tamilnadu, India.

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ABSTRACT

Urbanization is a phenomenon affecting the tank eco-systems on the fringes of the cities. When tank rehabilitations are attempted, most of the times, the tank is desilted to increase the storage capacity without botheration of any attempt on the source of water and the means by which the water could be harnessed towards the tank through supply channels. Rehabilitation will be sustainable if the implementations are backed by a hydrological study of any tank. Chetpet tank (major tank in the southern urban area of Chennai city) is highly contaminated because of letting sullage and sewage water by neighborhood residents into the tank through storm water inlets in various locations of tanks. The main objective of this study is to understand the hydrology of Chetpet tank. Runoff yield was estimated by SCS-CN method and from the analysis it was found that the capacity of the tank is not sufficient to store the excess runoff water. The water quality analysis results are compared with the recommendation of the Central Institute of Freshwater Aquaculture (CIFA, India) standards for fish culture suitability and suggested possible rehabilitation measures for the sustainability of the tank ecosystem.

1. Introduction

Chennai, capital city of Tamilnadu in India was surrounded by many tanks that not only served for agricultural needs but also acted as ground water recharging sources. Tanks are low earthen bund which is constructed along slope of a valley or terrain to store the rain water. They are interlinked with several ecological and social elements forming an eco-system [1]. Over the years, with rapid expansion of Chennai city, the tanks have deteriorating due to encroachments by people inhabiting the nearby areas, promoters of residential / commercial properties in the vicinity and are highly contaminated due to letting sullage and sewage water by neighborhood residents into the tank through storm water inlets in various locations of tanks. Sakthivadivel [2] had indicated that the present scenario of tanks degeneration is due to lack of community involvement in tanks management and maintenance, inadequate and unreliable water supply to the tank, absence of local institutions for management and large-scale infestation of weeds and loss of grazing land in the tank bed. Rodrigues [3] has highlighted the changes in the basin due to anthropogenic activities, considering types of erosion, channel changes and urban problems. Tratalas [4] studied the relationship between urban density and decline of tank performance etc. Shankari [5] points out that poor management of the tanks is primarily responsible for their decline. This is evident in the non-participation of farmers in cleaning channels, encroachment of the tank bed, inadequate repairs, weed infestation and siltation.

Tank should be considered as a multiple use of water where various communities can be benefited if tanks are rehabilitated [6]. The protection and sustainable use of water resources plays a decisive role for the future of humankind and it needs an integrated management approach of the entire eco-system to reach sustainability. Integrated and sustainable rehabilitation of tanks will improve the storage capacity of incoming water into the tank and thereby increasing the ground water level. Palanisami [7] developed a framework to assess the socio-cultural issues in tank management and measures to mitigate negative issues and enhance positive issues. During the urbanization process, most of the natural features of the tank environment are getting modified; mainly the run-off to the tank may increase/ decrease [8]. Impact of urbanisation in water resources aims at refining a definition of urban water conflict [9]. In order to recommend measures for rehabilitation of any tank involves a thorough study of its hydrological process and estimation of runoff yield from its catchment is essential. The yield of catchments is the net quantity of water available for storage, after all loses, for the purposes of water resources utilization. Pandey [10] adopted SCS model for estimating runoff and validated the results with measured runoff during the monsoon period. A remote sensing technique through visual interpretation of satellite imagery in conjunction with ground truth has been used extensively in the assessment of runoff in a small watershed [11]. And GIS is also a powerful tool for developing solutions for water resources such as assessing water quality and managing water resources on a local or regional scale [12, 13]. This study is aimed to assess the surface water yield of the tank and to suggest the possible rehabilitation measures for pisciculture development with social and institutional perspective in order to achieve sustainability.

2. Experimental Methods

2.1 Study Area

Chetpet tank, a major tank in the southern urban area of Chennai city is taken for the study. The storage capacity of the tank is 0.28275 Mm^3. The source of water for the tank is storm water from the adjoining areas through the storm water inlets. The water spread area of the tank is 15 acres. It experiences a tropical climate. The maximum average temperature is about 33.4 °C during summer and the minimum average temperature is about 24.4 °C during winter. The normal rainfall of the region is 1200 mm. About 40% of the annual rainfall is received during southwest monsoon and about 57% of the annual rainfall is received during northeast monsoon. The study area map of Chetpet tank was prepared using GIS and is shown in Fig. 1. Chetpet tank in Chennai had been acting as a garbage dump for the people located in the outskirts and in periphery of the water body. This tank is highly contaminated due to letting sullage and sewage water by neighborhood residents into the tank through storm water inlets in various locations of tanks [14]. The entire tank is polluted by plastic paper and other solid waste disposed by residential people around it and they are frequently trespassed the premises and used it to attend to their nature calls. The tank is surrounded by a thick vegetation and covered with water hyacinth and in certain areas it is not accessible and totally covered by weed growth as the resultant of all the above, the water in the tank is entirely contaminated and it has

*Corresponding Author
Email Address: mkveni@annauniv.edu (M. Krishnaveni)

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become a breeding place for the mosquitoes and further to that the dumping of the solid waste inside the tank prevents the recharge of the ground water and the tank is overflowing in the rainy season inundating the low lying areas in the neighbourhood. The photos taken depicting the status of tank before rehabilitation is given in Fig. 2.

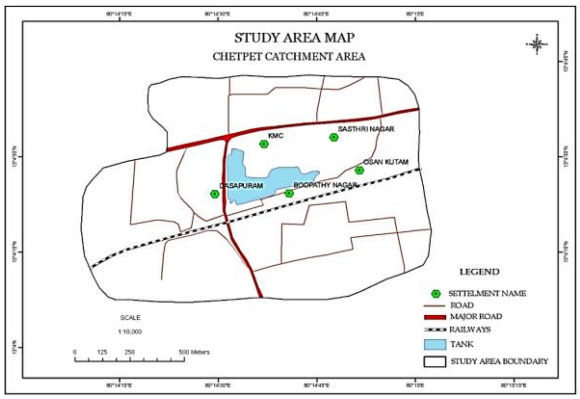

Fig. 1 Study area map of Chetpet Tank (Major urban Tank)

Fig. 2 Photos taken at different inlet and water spread areas of the tank before rehabilitation

2.2 Methodology

Methodology developed in the present study is to assess the surface water potential using SCS-CN method and water quality analysis for possible rehabilitation measures for pisciculture development. In addition, field reconnaissance study was done to identify the various factors causing the water quality deterioration. The Schematic diagram for Chetpet tank rehabilitation plan is given in Fig. 3.

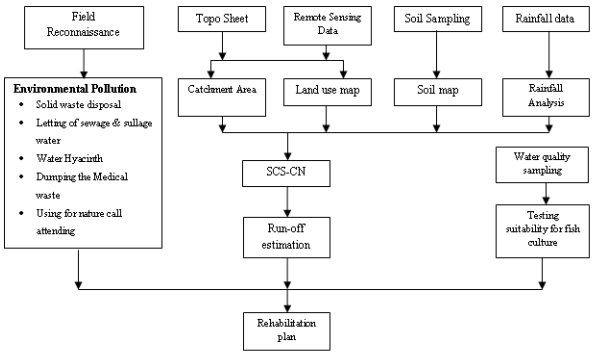

Fig. 3 The Schematic diagram for Chetpet tank Rehabilitation plan

2.2.1 Field Reconnaissance Survey

The field reconnaissance survey was carried out in order to know how the tank ecological and social aspects varied in the present and the past scenario. From the field visit it was observed that, there is reduction in tank water spread area due to dumping of solid waste material, cow dung, nature calls and weed growth. The 25% of water spread area encroached by the building, vegetation and embankment. Birds are reduced due to pollution, no trees around the bund and population has increased near the tank and houses are constructed. Due to noise pollution also migratory birds decreases. Large- scale infestation of weeds is notified in major portion of the tank area. These weeds are mostly juliflora and water hyacinth ipomea cornea. Cornea is the one of the main succulent weeds growing in the water spread areas of tanks and on the feeder channels. They spread very fast and chokes up the entire water spread. It reduces the storage capacity of the tank and affects the quality of water. Encroachment is an illegal occupation of tank beds, banks, and supply and drainage channel. In Chetpet tank the foreshore tank area is widely encroached by various people from different area. In Chetpet tank water is polluted directly due to mixing of drainage from various households. Supply channels are converted as drainage carrier. It gives foul smell and breeding place for mosquito.

2.2.2 Generation of Thematic Maps of the Tank Catchment

The process of getting the land-cover information involve following steps i) Extracting the study area image, ii) Correcting geometrical distortion of the study area image and iii) Obtaining land-cover information of the study area. In general, the satellite data will have geometric distortion which is not suitable for obtaining the true information. Therefore, the geometrical distortion of IRS IC and IRS ID satellite data of Chennai city is corrected using ERDAS Image processing software. The image rectification is performed by means of registration with the planimetric precision. The land use map of the study area as shown in Fig. 4 has been prepared using Remote Sensing data. Soil samples were collected from various locations of the tank bed. The samples are tested in the soil lab by Robinson Pipette Method. The soil analysis gave the result as sand of 54.6%, silt of 3.3% and clay of 42.1% indicating the type as sandy clay in tank bed. The digital elevation model was developed for the surface level of the Chetpet tank catchment area with respect to Mean Sea Level (MSL) with the help of ASTER data and GPS survey using ArcGIS as shown in Fig. 5.

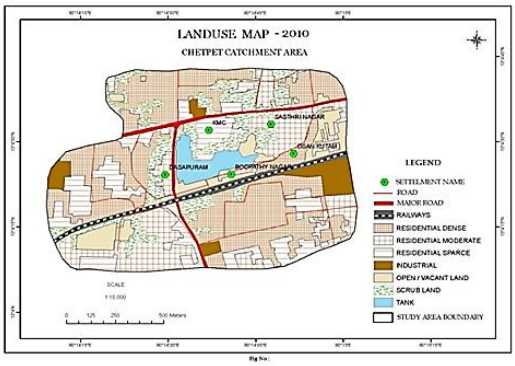

Fig. 4 Land use map of the study area

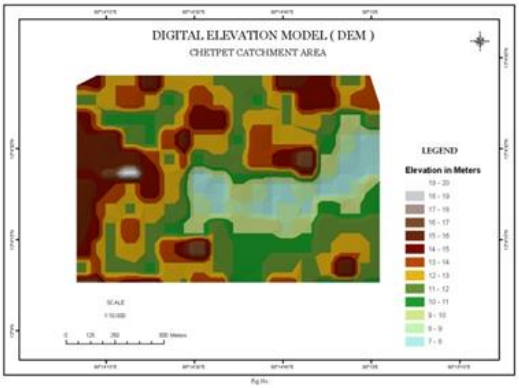

Fig. 5 Digital elevation model of the tank catchment area

2.2.3 Yield Estimation using SCS-CN Method

Rainfall analysis is significant and fundamental for rainfall runoff computation. Rainfall data is the driving force in the relationship. Frequency analysis of the rainfall data was done to determine the probability of occurrence of a particular extreme event. The purpose of the frequency analysis is to obtain a relation between the magnitude of the event and its probability of exceedence. In hydrological modelling the runoff estimation is the most important aspect [4]. A numbers of empirical methods are available for the surface runoff estimation. The most commonly used one is the Soil Conservation Service – Curve Number

Method developed by United States Department of Agriculture and Soil Conservation Service. The curve Number (CN) is used for the computation of runoff.

The equation for surface runoff computation is given by Eq. (1)

$$Q = (P - Ia)^2 / (P - Ia + S) \quad (1)$$

where Q = Accumulated runoff or rainfall excess in mm
P = Rainfall depth in mm
Ia = Initial abstraction in mm, For Indian Conditions Ia = 0.3S
S = Potential maximum retention in mm

Eq. (1) can also be written in terms of S as in Eq. (2),

$$Q = (P - 0.3S)^2 / (P + 0.7S) \quad (2)$$

The term S is given by Eq. (3)

$$S = (25400 / CN) - 254 \quad (3)$$

where CN is the Curve Number.

Knowing the value of CN, the runoff from the watershed is computed by using the above equations. The SCS curve number is a function of the ability of soils to allow infiltration of water, land use and the antecedent soil moisture condition. According to the U.S. Soil Conservation Service soils are divided into four hydrologic soil groups such as Group A, Group B, Group C and Group D with respect to the rate of runoff potential and final infiltration rate. The curve number CN depends upon soil type, land use and AMC. The volume of runoff from watersheds with different land uses can be obtained by determining the volume of runoff from each land use and then summing them [3].

2.2.4 Water Quality Analysis

In general, the quality of water is determined by physical parameters, chemical parameters. Physical parameters define those characteristics of water that respond to the senses of sight, touch, taste and smell. Physical impurities are due to the presence of inorganic substances like clay, sand, silt, and organic substances, algae, fungi etc. These are not serious and can be easily detected and removed. Suspended solids, turbidity, colour, taste and odour and temperature fall into this category. Chemical impurities may be either organic or inorganic. These may be present in dissolved form in the ground water. The organic impurities are due to the presence of algae, fungi, minerals etc. They impart colour, acidity and taste to water. Some of the dissolved chemical impurities are create carbonates, bicarbonates calcium and manganese, sulphates, chlorates, sodium, chlorates, sodium, fluorides, and nitrates in the ground water. In this study, the following physical and chemical parameters were chosen for analysis. They are pH, EC, TDS, chloride, sodium, and potassium. Samples were also analysed for the BOD and COD, as these parameters can be used to analyse the contamination due to organic waste sources. Samples were collected in 1 L pre-washed polythene plastic bottles, appropriate labels and numbering is done to identify at the laboratory. Temperature, pH and Electrical Conductivity were measured. All the collected samples were preserved as per APHA (1998) and further analyses for pisciculture suitability were done.

3. Results and Discussion

Frequency analysis of rainfall was carried out from 1971 to 2008 as given in Table 1. From the frequency analysis it was observed that 50% dependable rainfall of 1402 mm was received with a return period of 2.05 year, 75% dependable rainfall of 1082mm was received with a return period of 1.34 years and 90% dependable rainfall of 957 mm was received with a return period of 1.11 years for the study area. The prominent rainfall occurring in the area is in the month of October and November. 75% of the dependable rain fall was received in the year 2000. Runoff estimation was found out by using SCS – CN method. Runoff from the 75% dependability rainfall for November month estimation is given in Table 2 and for all the months of the dependable year is given in Table 3. Depending on the rainfall, yield of the tank is also increased. It was found that the holding capacity of the soil is considerably moderate because the soil type is sandy clay. And as the capacity of the tank 0.28275 Mm^3, it is not sufficient to store the excess water. So the surplus water is going as runoff. To store the precious excess water, the capacity of the tank to be increased. Water sample testing was done during the month of March 2012 as it was the period the tank yield is found to be very low and seems to be highly contaminated. The water samples are analyzed for fish culture suitability. The results are shown in Table 4 and compared with the recommendation of the Central Institute of Freshwater Aquaculture (CIFA) water quality standards.

Table 1 Frequency Analysis of Rainfall of Chetpet tank catchment area

Year	Rank (m)	Rainfall (mm)	Probability in % P=m/n+1	Return Period T=1/P	Year	Rank (m)	Rainfall (mm)	Probability in % P=m/n+1	Return Period T=1/P
2005	1	2567.1	0.026	39.00	2002	20	1402.0	0.513	1.95
1996	2	2450.8	0.051	19.50	2006	21	1323.2	0.538	1.86
1997	3	2034.9	0.077	13.00	2007	22	1309.8	0.564	1.77
1985	4	1897.5	0.103	9.75	1972	23	1293.4	0.590	1.70
1976	5	1864.7	0.128	7.80	1987	24	1271.0	0.615	1.63
1990	6	1776.3	0.154	6.50	1993	25	1213.7	0.641	1.56
2001	7	1659.8	0.179	5.57	1971	26	1185.6	0.667	1.50
1995	8	1560.7	0.205	4.88	1981	27	1149.5	0.692	1.44
1994	9	1554.3	0.231	4.33	1999	28	1145.7	0.718	1.39
1977	10	1545.4	0.256	3.90	2000	29	1082.0	0.744	1.34
1984	11	1542.2	0.282	3.55	1998	30	1073.9	0.769	1.30
1983	12	1529.4	0.308	3.25	1992	31	1071.7	0.795	1.26
1980	13	1492.8	0.333	3.00	1973	32	1070.6	0.821	1.22
1975	14	1486.3	0.359	2.79	2004	33	979.8	0.846	1.18
1978	15	1484.2	0.385	2.60	1974	34	962.7	0.872	1.15
1979	16	1462.0	0.410	2.44	1986	35	957.7	0.897	1.11
1988	17	1434.3	0.436	2.29	1982	36	852.0	0.923	1.08
1991	18	1429.2	0.462	2.17	2003	37	727.0	0.949	1.05
1989	19	1402.9	0.487	2.05	2008	38	519.3	0.974	1.03

Table 2 Runoff for 75% dependability rainfall for Chetpet Tank Catchments (November 2000)

Month	Days	Rainfall (mm)	Prev 5Days Rainfall (mm)	AMC Type (I/II/ III)	Curve No.	Runoff (mm)	Area Sq.Km	in S	Q	Yield in Mm^3
November	1	1	1	1	78	0	3.7686	71.64	0.000	0.00000
	2	0	1	1	78	0	3.7686	71.64	0.000	0.00000
	3	20.1	21.1	2	90	6.56	3.7686	28.22	3.396	0.01280
	4	0	21.1	2	90	0	3.7686	28.22	0.000	0.00000
	5	0	21.1	2	90	0	3.7686	28.22	0.000	0.00000
	6	0	20.1	2	90	0	3.7686	28.22	0.000	0.00000
	7	0	20.1	2	90	0	3.7686	28.22	0.000	0.00000
	8	0	0	1	78	0	3.7686	71.64	0.000	0.00000
	9	0	0	1	78	0	3.7686	71.64	0.000	0.00000
	10	0	0	1	78	0	3.7686	71.64	0.000	0.00000
	11	19.3	19.3	2	90	6.07	3.7686	28.22	3.005	0.01133
	12	3.7	23	2	90	0.03	3.7686	28.22	0.000	0.00000
	13	2.6	25.6	2	90	0	3.7686	28.22	0.000	0.00000
	14	1.6	27.2	2	90	0	3.7686	28.22	0.000	0.00000
	15	1.3	28.5	3	96	0.01	3.7686	10.58	0.000	0.00000
	16	0	9.2	1	78	0	3.7686	71.64	0.000	0.00000
	17	0	5.5	1	78	0	3.7686	71.64	0.000	0.00000
	18	0	2.9	1	78	0	3.7686	71.64	0.000	0.00000
	19	54	55.3	3	96	44.12	3.7686	10.58	42.06	0.15853
	20	0	54	3	96	0	3.7686	10.58	0.000	0.00000
	21	0	54	3	96	0	3.7686	10.58	0.000	0.00000
	22	0	54	3	96	0	3.7686	10.58	0.000	0.00000
	23	8.5	62.5	3	96	3.07	3.7686	10.58	1.783	0.00672
	24	0	8.5	1	78	0	3.7686	71.64	0.000	0.00000
	25	0	8.5	1	78	0	3.7686	71.64	0.000	0.00000
	26	0	8.5	1	78	0	3.7686	71.64	0.000	0.00000
	27	0	8.5	1	78	0	3.7686	71.64	0.000	0.00000
	28	0	0	1	78	0	3.7686	71.64	0.000	0.00000
	29	34.4	34.4	3	96	25.31	3.7686	10.58	23.324	0.08790
	30	43.7	78.1	3	96	34.16	3.7686	10.58	32.136	0.12111

Table 3 Runoff for 75% dependability for Chetpet Tank Catchments for the year 2000

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Yield in Mm^3	0.00	0.0	0.00	0.00	0.00	0.00	0.187	0.00	0.06	0.45	0.40	0.01

Table 4 Results of water quality analysis with CIFA (Central Institute of Freshwater Aquaculture) recommendation

S.No	Water quality parameter	Test results	As recommended by CIFA
1	Depth of water	1.30m (average)	2.00 -2.50m
2	BOD	3.40 mg per litre	<20mg per litre
3	Dissolved oxygen	3.8 mg per litre	>5 mg per litre
4	COD	20 mg per litre	<10mg per litre
5	Sulphate So_4	18mg per litre	1000 mg per litre
6	Chloride	103 mg per litre	>60 mg per litre
7	PH of water	6.11	6.5 to 9.5

Table 5 Problems and remedial measures for the study tank

Problem	Solution
Technical	*Technical*
1)Scale infestation of weeds. 2)Water depth has become lower due to silt accumulation and hyacinth growth. 3)Rain water inlets are used for discharging waste water from nearby residents and hospital. 4)In some inlet points it is completely choked by weed growth.	1)Removal of vegetation and hyacinth is the major aspect. It helps to maintain the DO, BOD and COD. 2)The depth of tank is not as per recommended level for fish growth. So desilting of the tank upto 2.5 m will helps in fish culture. 3)Preventive measure to be carried out to the entry of sewage, sullage and dumping of medical and solid waste in to the tank. 4)The tank is having 12 storm water inlets, in that some 4 or 5 inlets functioning moderately, thereby removing the vegetation bushes and clearing the mud deposited inside the inlets for effective functioning. The balance inlets are to be identified and made it for function.
Social	*Social*
1) The process of encroachment started as a small beginning for temples, petty shops and over a period it has emerged as a wholesale encroachment.	1)The encroachment area has to be cleared and it should be made as water spread area of the tank.
Ecology	*Ecology*
1) Migratory bird species such as pelican, flamingo and native birds such as myna, kingfisher, crow etc were regular visiting birds in earlier periods but now those species are completely vanished.	1) Awareness about the tank Eco system to be given to the surrounding people to maintain the quality of the tank.

3.1 Suitability Analysis for Pisiculture

The average depth of water available in the tank is 1.30 m. But as per the CIFA recommendation the depth of tank should be 2.00 – 2.50 m for effective pisciculture. So the depth of the tank has to be increased to the recommended level to the effective yield of the fishes. Dissolved Oxygen (DO) is less compared to the CIFA recommendation. Fish are extracting oxygen from the very low concentrations found in water. The rate of oxygen consumption is closely related to the water temperature, the amount of oxygen available in the water also decreases with temperature. Water with an oxygen concentration of less than 3 mg/L will generally not support fish. When concentrations fall to about 3-4 mg/L, fish start gasping for air at the surface, whereas fishes are reasonably comfortable and healthy at 5-6 mg/L concentrations. So the tank water does not support the fish growth. The solution to increase the DO level of the Chetpet tank, removal of the vegetation and water hyacinth is to be done. Normal Chemical Oxygen Demand (COD) in a pond should be less than 10 mg/L. But the C.O.D was observed in the Chetpet tank is not within the prescribed standard limit i.e. 20 mg/L. COD measures organic and inorganic content as indicators of the amount of dissolved oxygen that will be removed from the water column due to bacterial and/or chemical activity. Sulphate (SO_4) a common compound found in water as a result of the dissolution of minerals from soil and rocks. Typical levels are between 0 and 1,000 mg/L. Fish tolerate a wide range of sulphate concentrations. It was observed within the prescribed standard limit i.e. 18 mg/L. Chloride (Cl) was observed within the prescribed standard limit i.e. 103 mg/L. Chloride is a common component of most waters and is beneficial to fish in maintaining their osmotic balance. High chloride levels are above 100 mg/L, the water is also used to irrigate sensitive land-based crops. The pH of water is a measure of how acid or basic it is, on a scale of 0 to 14 with 7 being neutral. In fish tanks, the time of day that a sample is taken often will influence the pH because of variations in the carbon dioxide (CO_2) concentration. As plants in the water remove carbon dioxide for photosynthesis, the pH will increase. At night, the pH will decrease as carbon dioxide accumulates. Increasing the total alkalinity concentration in water helps buffer against pH changes. Most fish species do well within the pH range of 6.5 to 9.5. Chronic pH levels below 6.5 may reduce fish reproduction. The solution to increase the pH level of the Chetpet tank, removal of the vegetation and water hyacinth is to be done.

3.2 Rehabilitation Plan

The Chennai city has started to lose its water bodies day by day due to urbanisation. Hence it is necessary to study the dynamic characteristics of the urban tank in terms of its tank yield and quality and suggested measures for Rehabilitation of the tank to increase the surface water quantity and quality for pisciculture development. The problems associated with the tank and its remedial measures during the study period are provided in Table 5 and are, (i) removal of vegetation and hyacinth is the major aspect. It helps to maintain the DO, BOD and COD. The hyacinth covered over the entire tank to be removed, (ii) preventive measure to be carried out to the entry of sewage, sullage and dumping of medical and solid waste in to the tank. Ultimately it will improve the water quality, (iii) the encroachment area to be cleared and it made to be water spread area of the tank. The depth of tank is not as per recommended level fish growth. So desilting of the tank upto 2.5 m will helps the growth for fishes, (iv) the tank is having 12 storm water inlets, in that some 4 or 5 inlets functioning moderately, thereby removing the vegetation bushes and clearing the mud deposited inside the inlets for effective functioning. The balance inlets are to be identified and made it for function, (v) to prevent the entry of trespassers to avoid nature call attending and strengthening of tank bund has to be done and (vi) awareness about the tank Eco system to be given to the surrounding peoples to maintain the quality of the tank.

4. Conclusion

Water bodies such as urban tank, temple tank are essential for city environment. They support multiple users and maintain ecosystem. Recent period due to urbanization, reduction in pervious surface and conversion of water bodies to build up areas, reduce natural recharge and surface storages. The suitable rehabilitation measures to improve the quantity and quality are necessary for sustainable use of the resources. The essential steps involved are, 1) delineating the source area and estimating the yield of urban tank using geospatial technology and 2) protecting the source area by implementing suitable measures in order to maintain the water quality of the tank. In 2013, Tamilnadu government sanctioned 420 million rupees for the restoration of this tank. Now the tank has become an ecological park with three angling decks, fishing equipment, a boat-riding option, a play area for children, a walking/jogging track, multi-level parking and have food facilities. Tank rehabilitation work with the detailed study of its hydrology helps in better planning of its restoration in an effective manner. There are 1400 urban and peri-urban tanks in and around Chennai city, if such restoration plans are developed for other such tanks then its ecosystem can be retrieved and preserved.

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