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Water Quality Studies of Cooum Sub Basin, Chennai

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ABSTRACT

Cooum is one of the degraded sub basins in Tamil Nadu. Surface water, groundwater in and around the basin is polluted by factors such as industries and domestic waste etc. This paper highlights the importance of sewage inflow through Cooum inlets and assess quality of the surface water and groundwater influenced by the discharges in Cooum basin. Sewage inflow was highest in Elephant Gate Bridge (3039 Cum/day) and Annai Kasthuriba Nagar (2651 Cum/day). Surface water results exhibited higher pH, BOD, COD, chloride and zinc content. Groundwater quality of the study area has a higher pH of alkaline in nature and total dissolved solids in the range of 859-1611 mg/L. Sodium concentration was much higher than permissible limits (110-357 mg/L), and sulphate concentration was about 672 mg/L in Avadi region. Investigation was taken up for groundwater quality assessment through Water Quality Index, for drinking purpose, of open well in Cooum basin. Groundwater variables such as electrical conductivity values vary from 1760 to 2540 µS/cm. Analysis was taken for the parameters such as pH, electrical conductivity, total dissolved solids (TDS), calcium, magnesium, sodium, potassium, bicarbonates, chlorides, sulphates and nitrates. WQI ranges from 221 (very poor water) for Govindampadi to 321 for Avadi (unsuitable for drinking).

INTRODUCTION

Development activities of metropolitan cities like Chennai are rapid due to industrialization. Therefore the availability and quality of surface and groundwater are deteriorating due to factors like increasing industrialization and population growth due to urbanization etc. (Shweta Tyagi et al. 2013). Among the urban setup, horizontal space within municipalities shrink and vertical space expands in an exponential manner. Disposal of sewage, sludge and domestic waste is a concern in the recent times. Unusual sewage sludge called 'biosolids', is the solid fraction of this waste disposal that occurs along the banks of Coolum river within the city limits causes: i) contamination of water, land and air, ii) harbor more pathogens which ultimately spurt new diseases among humans (Ramana Dhara et al. 2013, Cabral 2010 and Chapman 1996), iii) shrinking of river course. At times, devastating floods occur during monsoons, so the river has to be treated before sewage is disposed on land (Maureen Reilly 2001). Surface water contamination may slowly recharge and enter the sub surface layer, and they become subject to variety of physical, chemical and biological processes that operate below the ground and end up in aquifer systems (Committee on Ground Water Cleanup Alternatives 1994). Thus, groundwater quality depends on the quality of recharged water, atmospheric precipitation, inland surface water and subsurface geochemical processes (Reza & Singh 2010). Geographical Information System (GIS) has the capability of mapping the chemical parameters spatially, to understand the distribution of variables within the study region. Therefore, a study has been taken to investigate sewage inflow into inlets, and assess surface water and groundwater quality of the Cooum River by employing water quality index (WQI). Major anthropogenic activities like solid waste dumping along the banks of Cooum (Bhuvana & Ramesh 2012) and its consequent results as sedimentation and sand formation, have been covered in this study.

STUDY AREA

The Cooum river originates from the Cooum tank in Thiruvallur district of Tamil Nadu, has a sub basin area of 682 sq.km, flows towards east for a distance of 65 km, and confluences with Bay of Bengal adjoining Chennai City. It is situated between latitude 12°54' and 13°9' and longitude 79°36' and 80°19'. Cooum is bounded by Kosasthaliyar sub basin in the north, Palar basin and Adayar sub basin in the south and Bay of Bengal in the eastern side. The boundary of the study area and corresponding image are shown in Fig. 1a and 1b. The sub basin is underlain by formation of Archaean to the recent age. Crystalline rocks of Archaean age comprising granite gneises, charnockite and associated basic and ultra basic igneous and metamor-

phic rocks cover the west. Sedimentary formations of Gondwana, tertiary, quaternary and alluvial deposits covers the east. They contain shale, clay, sandy clay, gravels, pebbles and fine to coarse sand. Groundwater occurs under confined and unconfined conditions. There are two significant storm water streams that link Cooum within Chennai i.e., Otteri nalla and Arumbakkam odai. Otteri nulla starts as a small drain from the surplus water of Padi and Villivakkam tanks and runs through north Chennai City for a distance about 10.8 km and discharges into Buckingham canal near Basin Bridge power house. The Arumbakkam odai starts at Virugambakkam area and joins Cooum river at Metha Nagar (6.4 km) in the south. The Trustpuram odai, the branch of Arumpakkam odai joins just before entry into Cooum. Mean maximum temperature and mean minimum temperature are 33.4°C and 24.4°C respectively. Maximum and minimum wind velocity was in the range of 3.7-9.1 (km/hr). Average annual evaporation was 2161 mm. Once a freshwater source, it is today a drainage course in the city of Chennai, collecting surpluses of 75 small tanks of a minor basin. The total catchment area of the river is about 400 km^2 and the bed width ranges from 40 to 120 m.

MATERIALS AND METHODS

Cooum river is more complex where the stream movement towards the confluence of the sea is almost nil due to levelled gradient along this stretch. Additional factors also include the accumulation of sewage, sludge, industrial and domestic waste that is dumped directly or let out through the inlets. Monsoon rain plays a vital role in cleaning of the river, the surplus water from the tank networks is let out into Cooum, thereby, the sewage/sludge load is discharged into the sea. This study was taken up to identify the boundary of Cooum with channel network that is linked to Cooum from point of origin to the tail end, identify sewage inflow points across the Cooum river using Geographic Information System and to assess the sewage inflow to Cooum and to collect surface water samples from most of the inlet points, and to analyse it for water quality and heavy metal characteristics.

Water sample collection and analysis: The physical and chemical properties of a freshwater body are characteristic of the climatic, geochemical, geomorphological and pollution conditions prevailing upon the drainage basin and the underlying aquifer. Chemical quality of water bodies can be measured by suitable analytical methods. Sampling sites for the study area are selected to represent the water quality at different points to spatially understand the distribution of various chemical parameters in view of WHO standards. Generally, sampling sites are selected for monitoring inlets (the point where the principal feeder opens into the river) at four locations, namely Cooum, Buckingham North Canal, Buckingham South Canal and Otteri Nullah. Grab sampling was done at sides of the river, especially at the discharge points for most of the places to assess the chemical quality in the laboratory. Surface water samples were collected during the year 2011 for water quality along with sediments samples. Groundwater samples from open well and bore wells, which are near to the discharge points, were also collected to assess the water quality variables. The following parameters such as pH, total dissolved solids (TDS), dissolved oxygen (DO) biochemical oxygen demand (BOD), chemical oxygen demand (COD), chlorides, sulphates, total chromium, lead, zinc and copper were analysed using standard techniques.

Water quality index (WQI): WQI represents the quality of water that is fit for consumption purpose. WQI is derived through the following approach. The parameters responsible for the quality of water, such as eleven parameters that are analysed for this study, are expected to assign weight (wi) according to their relative importance in the overall quality of water for consumption purposes (Table 4). Assigning the relative weight (Wi) is calculated as per the established (Horton 1965, Gebrehiwot et al. 2011, Ishaku 2011) method as follows:

$$\text{Relative weight (Wi)} = \Sigma\, wi / \Sigma_{i=1}^{n}\, wi$$

Where 'Wi' is the relative weight, 'wi' is the weight of each parameter and 'n' is the number of parameters.

Further a quality rating scale (Qi) for each parameter is calculated by the following equation:

$$Qi = (Ci/Si) \times 100$$

Where 'Ci' is the concentration of each chemical parameter in each water sample in mg/L and 'Si' is the standard value according to the guidelines of WHO (Table 4). Finally, the sub index (Sli) of each chemical parameter is estimated by using the equation $Sli = Wi \times Qi$. Then, the overall water quality index is calculated by adding together each sub index value of each water sample as: $WQI = \Sigma\, Sli$.

RESULTS AND DISCUSSION

Sewage inflow in waterways: Urbanization is one of the causative factors for sewage disposal in the Cooum river. Domestic and industrial units, within the ambit of Cooum river, have the advantage of disposing or connecting their point of outflow to inlets of Cooum discharge. Unauthorized entry of sewage into the storm water drains from houses and slums as inflows are other source of pollution load dumped then and again in the Cooum sub basin. At times, excess overflow from the existing sewage system of Chennai city is let out into Cooum inflows beginning from

Table 1: Geo-coordinates, inlet locations and quantity inflow of Cooum sub basin.

Sl.No.	Coordinates		Inlet location	Quantity of inflow (Cum/day)
	Lat	Long		
1	13° 4'29.46"N	80°11'25.89"E	Thirumangalam causeway	428
2	13° 4'40.59"N	80°11'55.34"E	IRR Bridge	404
3	13° 4'40.64"N	80°12'43.39"E	Naduvankarai Bridge	481
4	13° 4'50.41"N	80°13'3.61"E	Annanagar Bridge	635
5	13° 4'26.29"N	80°13'19.52"E	Amingikarai Bridge	858
6	13° 3'40.70"N	80°12'42.75"E	Arumpakkam odai	530
7	13° 4'4.39"N	80°13'42.18"E	Arumpakkam odai inlet	1166
8	13° 4'5.50"N	80°13'53.74"E	Choolaimedu Bridge	295
9	13° 4'4.91"N	80°14'0.42"E	Chetput Mundro Bridge	194
10	13° 4'1.88"N	80°15'16.00"E	College Road Bridge	397
11	13° 3'48.99"N	80°15'37.31"E	Com.in chief Bridge	1026
12	13° 4'5.66"N	80°16'8.55"E	Harries Bridge	783
13	13° 4'35.16"N	80°15'56.92"E	Andrews Bridge	1338
14	13° 4'45.49"N	80°16'13.89"E	Laws Bridge	1235
15	13° 4'5.73"N	80°17'2.65"E	Napier- South arm	689
16	13° 4'9.59"N	80°17'5.33"E	Napier- North arm	317
17	13° 4'4.88"N	80°17'23.78"E	Cooum mouth	24
18	13° 5'52.48"N	80°12'6.30"E	I C F	1944
19	13° 5'38.32"N	80°13'6.64"E	Sathia nagar Bridge	346
20	13° 5'23.15"N	80°13'33.99"E	V O C Nagar Bridge	363
21	13° 5'11.25"N	80°14'3.68"E	New Avadi Road Bridge	1385
22	13° 5'52.70"N	80°15'4.05"E	Otteri Bridge	2471
23	13° 6'23.40"N	80°15'38.03"E	Dr. Ambedkar Bridge	1400
24	13° 7'30.13"N	80°16'24.34"E	Buchinham canal	600
25	13° 7'38.79"N	80°15'56.92"E	Captain Cotton canal	795
26	13° 2'35.66"N	80°16'34.35"E	Dr.Rhadakrisnan road	1271
27	13° 3'52.26"N	80°16'51.49"E	Chepakkam	1433
28	13° 5'33.01"N	80°16'27.53"E	Elephant gate bridge	3039
29	13° 6'13.31"N	80°16'22.47"E	Basin Bridge	784
30	13° 0'24.97"N	80°14'52.51"E	Annai Kasthuriba nagar	2651
31	13°13'29.26"N	80°19'9.07"E	Ennore	1242

(Source: PWD, Chennai)

Thiruverkadu, inflow from Buckingham canal, Otteri nalla and Arumbakkam odai that contains stagnant contaminated water along this stretch (Bhuvana & Ramesh 2012). The major inlet in the course of the river is the Island grounds in Chennai less than a kilometre before the mouth of the river. The river splits into two near Chindaripet and encircles a piece of land isolating it from the surrounding land before draining into the eastern sea. However, the mouth of the river is not too wide and does not have any inlet. The sewage inlets in the Cooum river, Otteri nalla canal, Arumpakkam odai and Buckingham canal are given in Table 1 and the schematic diagram is shown in Fig. 2.

There are a total 31 number of observation points (Table 1) in order starting from Tiruverkadu to Ennore of Cooum river with Chennai limits. Among the inlets, discharge was highest in Elephant Gate bridge comprising quite a number of industries in TANSI followed by Basin bridge and small scale industries in and around this region lead to lot of sewage discharge invariably in all the seasons. Annai Kasthuriba nagar shows the second highest discharge that is attributed to strategic location of the river having the lowest elevation of 3 - 4 m and higher river width of approx. 500 m, elevation increases as river flows towards east to Bay of Bengal, and west towards Adayar boat house and therefore quite a lot chances are there for overaccumulation of sewage load. The river is almost stagnant at this point and does not carry any water except during monsoon (Bunch 1997). Lowest discharge was observed at Cooum river mouth and Chetpet Mundro Bridge due to its proximity (< 1.5 km) to Bay of Bengal.

Surface water quality of Cooum river: Surface water is the untapped water in a region that is either not consumable due to pollution or surplus of water availability in that region. Nature of water depends on the anthropogenic activity within the vicinity. Due to urbanization, rivers in metropolitan cities are contaminated in physical, chemical and biological standards. Similarly, Coum river, once a virgin river considered to be a waterway, is by now highly polluted. Pollution is due to the discharge and dumping of sewage, sludge, domestic and industrial waste, all along the

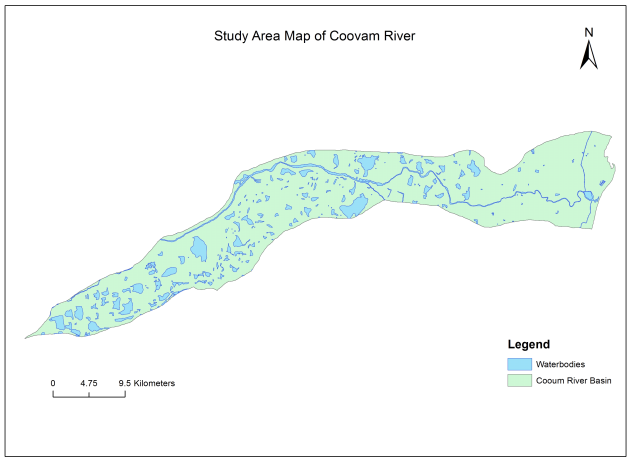

Fig. 1a: Study area map of Cooum river.

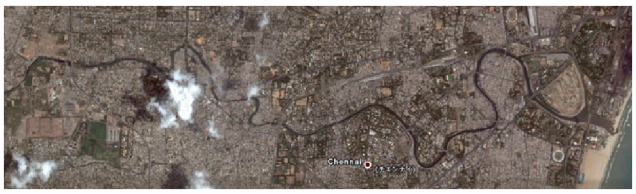

Fig. 1b: Image of Cooum river extracted from Google Earth (source: Google Earth).

Fig. 2. Inlet locations of Cooum River.

banks of the river. Quality of the surface water gives the indication of the pollution load in that river. Surface water sampling was done at four collection points a) at the mid point of Cooum river, b) centre point of north canal of Cooum river, c) another at the centre point of south canal, and d) finally at the mid point of Otteri Nullah. The data on surface water quality of Cooum are given in Table 2.

Premonsoon water quality results exhibited alkaline pH in Cooum river. North canal had the highest pH of 8.12 above normal in comparison to other regions, and is well in line with the findings of Rengaraj et al. (1996), due to discharge of domestic waste being recharged in the groundwater. Higher pH in water quality is due to the discharge of domestic wastewater containing detergents and industrial slag. These discharges are let out in Cooum where chemical and biochemical oxygen demand escalates especially in south canal i.e., 1204:375 respectively. Higher BOD and COD affects the growth of aquatic organisms, so they may be unable to thrive in this environment. Concentration of chloride is in higher order, especially in the north (890 mg/L) and south canal (990 mg/L) that exceeds WHO standards. All other parameters except, zinc content of south canal which was of 2.41 mg/L, exceeding the WHO limits exhibit that the Cooum surface water quality at the fourth level (Smical et al. 2015) is unfit for consumption purposes.

Groundwater quality: The data on groundwater quality of Cooum are given in Table 3. In general, pH of groundwater samples was alkaline in nature well within the limits of WHO standards. The EC values vary from 1760 to 2540 µS/cm. Water with high ion content tends to have higher conductivity, which is an indicator of high solid concentration dissolved in the water (Al-Mashagbah 2015). Groundwater is affected by total dissolved solids that are higher at all the sampling sites. Higher TDS in the range of (859-1611 mg/L) would be the result of storm water runoff and resuspension of sediments in the water column. Sodium concentration was much higher than the permissible limit (110-357 mg/L) invariably for all the places due dissolution of rock salts and weathering of sodium bearing minerals. Calcium, magnesium, potassium, bicarbonates, chlorides and nitrates are well within the WHO permissible limits (WHO 1984). Sulphate concentration was of 672 mg/L in Avadi region which could be due to discharge of untreated sewage and domestic waste accumulation in aquifer systems.

Water quality index: Water quality index (WQI) is an informative tool represented by its classified values according to rating, to depict the overall water quality status of a study site. The results provide an overall view of water quality for the public to be aware of the status that influences the health condition of an individual. In this study, relative importance in the overall quality of water for consumption, weight (wi) and relative weight (Wi) are arrived in Table 4. A quality scale rating based on concentration of variable to standard value. A sub index was calculated through integrating relative weight to quality scale rating. Overall sub index values have resulted in WQI value of groundwater as 221 for Govindampadi to 321 for Avadi (Table 5). It is understood from the analysis that the water quality was very poor in all the regions and worse for Avadi region. It is

Table 2: Cooum river surface water quality compared with WHO standards.

Characteristics	Cooum (mg/L)	B Canal North (mg/L)	B Canal South (mg/L)	Otteri Nullah (mg/L)	WHO Standards
pH (No units)	7.76	8.12	7.44	7.22	6.5-8.5
TDS	1434	20553	2525	1119	-
BOD	71.00	16.33	375.33	161	-
COD	195	315	1204	549	-
Dissolved Oxygen	BDL	4.75	BDL	BDL	-
Chlorides	501.3	892	990	349	600
Sulphates	3.33	2.00	8.69	5.33	400
Total Chromium	BDL	0.57	0.90	0.44	0.05
Lead	0.09	BDL	BDL	BDL	0.01
Zinc (Zn)	0.34	0.35	2.41	0.43	0.01-0.05
Copper (Cu)	0.11	0.35	0.86	0.25	2

Table 3: Groundwater quality status of adjoining regions of Cooum river.

Parameters	Govindavadi (mg/L)	Thandalam (mg/L)	Avadi (mg/L)	WHO Standards
Ca	44	68	40	200
Mg	63	71	107	150
Na	246	110	357	100
K	9	3	5	10
HCO_3	354	165	256	500
SO_4	117	177	672	400
Cl	347	347	284	600
NO_3	4	0	4	45
TDS	1021	859	1611	500
Conductivity (µS/cm)	1760	1880	2540	<1400
pH (No units)	7.5	8.0	8.6	6.5-8.5

Table 4: Physico-chemical parameters, WHO guidelines and relative weights.

Chemical parameters	Standard permissible Value (WHO)	Unit	Weight (wi)	Relative Weight (Wi)
pH	6.5-8.5	unit	4	0.118
EC	500	(µS/cm)	4	0.118
TDS	500	(mg/L)	4	0.118
Na	200	(mg/L)	2	0.059
K	200	(mg/L)	2	0.059
Ca	75	(mg/L)	2	0.059
Mg	50	(mg/L)	1	0.029
Cl	250	(mg/L)	3	0.088
HCO_3	500	(mg/L)	3	0.088
SO_4	250	(mg/L)	4	0.118
NO_3	50-70	(mg/L)	5	0.147

Σ wi = 34 Σ Wi = 1.001

advisable for the locality to take appropriate care or remedial measures before consumption of water. It also provides an insight that number of samples have to be increased in order to know a better picture of the study site.

Solid waste dumping: Cooum river was made a narrow river due to dumping of solid wastes at both the sides of the river as well illegal mushrooming of hutments all along the sides of Cooum river within the Chennai limits. About 3,500 illegal hutments along its banks are the primary reasons for its narrowness. A prominent location identified for dumping municipal solid waste of around 7 tonnes every day was in Maduravoyal and the collected municipal solid wastes are being carried by lorries and dumped in Vanagaram river bed. Apart, records showed that nearly 30 per cent of the estimated 55 million litres of untreated sewage being let into the waterways of Chennai daily. About 60 per cent of the untreated sewage gets into the Buckingham canal and the Adyar river. Such wastes have almost no dissolved oxygen, and instead there are traces of heavy metals like copper, besides sewage and sludge.

Sedimentation and sand formation in Cooum: The sediments in waterways might be of alluvium from underlying alluvial basin, sediment transported by the waterways from upstream, marine sediment transported across or into river mouths by along shore drift, runoff from the city, direct discharges from industries and direct disposal of solid wastes. The littoral drift results in formation of sand bar at the mouth of Cooum are solely due to the arresting of littoral drift by the construction of Chennai Harbour. Due to this

Table 5: Classification of Water Quality Index.

WQI Value	Classification
<50	Excellent water
50-100	Good water
100-200	Poor water
200-300	Very poor water
>300	Water unsuitable for drinking

sand formation, there is no connection between the river and sea during dry weather season and hence the sewage stagnation is prominently observed within the city limits. The river has to be periodically cleaned to prevent sand deposits near the river mouth that is close to the Napier Bridge near Bay of Bengal. Two dredgers were employed for removing sand bars at frequent intervals to facilitate tidal action and avoid flooding.

CONCLUSION

Sewage flow, surface water quality and groundwater quality of Cooum sub basin was analysed to understand the implication of variations on the environment. Disposal of sewage, sludge and domestic waste has not only altered the river course, but also affects the physical, chemical and biological nature of surroundings. These chemical constituents ultimately affect the surface water, subsequently reaches groundwater through rechargeable zones and enters aquifer system. This results in very poor groundwater quality as analysed through WQI. This study suggests the public to take precautionary measure before utilizing groundwater for consumption. Quite a lot of data set are also necessitated for various seasons as well for years to get a holistic view for this research.

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