Contamination Characteristics of Ground and Lake Waters of Thoothukudi City

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Abstract: Thoothukudi city has many heavy industries and a very busy port. It has a resident population of 410,760. The supply of water to meet the needs of this population is a huge challenge. People are dependent on groundwater and surface water resources present in the city. In view of the industrial activities within the city, the contamination characteristics of these water resources and their suitability for human consumption needs to be evaluated. 13 groundwater samples from various localities of the city and 5 lake water samples were analysed to understand the physical, chemical and microbiological properties. Heavy metals such as As, Cd, Cr, Cu, Hg, Mn, Ni, Pb, Zn, and Mo were analysed in the samples. None of the samples were found to be suitable for human consumption. The major contaminants were Cd, Hg, As, and coliform bacteria. The heavy metals were found to be from 1.2 to 211 times that of the acceptable limits.

Keywords: Contamination of groundwater, Lake water contamination, Heavy metals, Thoothukudi city.

I. INTRODUCTION

Thoothukudi city has an area of 91 sq.km and has a population of 4,10,760 according to the Government of India Census 2011. It is a port city with a busy harbour and many largescale industries. Most of the heavy industries deal with processing of hazardous materials, such as copper smelting, fertilizer manufacturing, heavy water production, thermal power production and sea food processing (Arasu et al., 2016). Based on the 2011 population of the city and as per the WHO (2019) recommended quantity of 20 litres per day for food and drinking water requirement per person a total quantity of 8.21 million litres per day is required for the city. This quantity is likely to have increased by 10% by now. Considering that Thoothukudi city is situated along the coast, this requirement will have to be met entirely from ground and surface water resources. Drinking water supply in Thoothukudi city is scarce as most of the surface water bodies such as lakes and streams are dry during eight months in a year apart from the monsoon and post-monsoon seasons. The channels connecting to Thamiraparani river either remain dry or are filled with the city’s sewage. There is only one large surface water body, the Korampallam lake, which holds water during the post-monsoon season. However, even Korampallam receives sewage and other effluents from the surrounding areas.

The drinking-water supply from the corporation of Thoothukudi sometimes is restricted to once in eight days (The Hindu, 2016). Therefore, it is important to assess the quality of groundwater available at different parts of Thoothukudi city and that of the Korampallam lake to ensure the health of the local populace. Arasu et al. (2016) have analysed the physico-chemical properties of groundwater around the SIPCOT industrial area of Thoothukudi city and found that many parameters were beyond permissible limits. Mondal et al. (2011) have mapped the sea-water intrusion levels in Thoothukudi city and analysed the heavy metal contamination present in the groundwater. Krishna Kumar et al. (2012) investigated that the trace elemental concentrations of groundwater aquifers along the Thoothukudi city coast and found that Pb, Cd, Hg, and Cr were higher than the WHO (2004) prescribed maximum limits. Mouliitharan et al. (2017) have enumerated the various types of anthropogenic inputs present in the surroundings of the Korampallam lakes and the other parts of the Thoothukudi. Rajaram and Ganeshkumar et al. (2019) have provided a review of heavy metal contaminations along the southeast coast of India, mainly, Tamil Nadu. Pandian et al. (2016) have appraised the quality of coastal aquifers within the Thoothukudi city for irrigation. Backman et al. (1998) have suggested the use of the contamination index for the quantification of groundwater pollution. Based on the analysis of the sediments in the Thoothukudi city, Magesh et al. (2013) have attributed heavy metal contamination to effluents from the thermal power plant, chemical industries, copper smelting, petrochemical industries, and shipping. Water quality pollution indices were computed by Selvam et al. (2015), for the Thoothukudi city. Singaraja et al. (2014), arrived at sea water intrusion indices based on the hydrochemistry of groundwater with reference to different standards. In this paper, a comprehensive analysis of ground waters from various localities of Thoothukudi city and the surface water of Korampallam lake is reported from the point of view of human consumption. This work was carried out between 27thSeptember 2018 to 3rd October 2018 in Thoothukudi city.

II. METHODOLOGY

A sampling plan for groundwater collection was prepared such that sampling locations covered major residential areas of Thoothukudi city. Accordingly, 13 groundwater samples from different localities of the city were collected according IS 3025: 1987 standard.
Contamination Characteristics of Ground and Lake Waters of Thoothukudi city

Similarly, 5 samples of lake water were collected from the Korampallam lake. The coordinates of the sample locations were marked using a handheld GPS (Garmin eTrex). Table 1 provides the details about the sample locations and the sample types. The study area and the sample locations are shown in Figure 1. In situ analysis of the parameters such as pH, colour, temperature, salinity, conductivity, total dissolved solids (TDS), turbidity, and dissolved oxygen were measured using a portable water analysis kit (Systronics TYPE 371). The remaining sample was split in three parts and stored appropriately in sterile high-density polypropylene containers for further analysis. On one part of the sample microbiological examination was carried out according to IS 1622: 1981, another part was analysed for the elements Na, Ca, and K using flame photometer and the last part was analysed for heavy metals such as arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), manganese (Mn), nickel (Ni), lead (Pb), zinc (Zn), and molybdenum (Mo) using Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES). The details of the sampling locations and the types of samples is discussed in Table 1.

III. RESULTS AND DISCUSSION

The results of the groundwater analyses are presented in Table 2.

1. Physical characteristics of groundwater

From Table 2, it can be inferred that the physical characteristics of the groundwater from various localities of Thoothukudi city such as temperature, pH, conductivity, turbidity, dissolved oxygen, total dissolved solids and salinity are within acceptable limits as prescribed by IS 10500: 2012 and the WHO guidelines for drinking water.

2. Microbiological characteristics of groundwater

Except for the sample from Muttayyapuram all the other samples do not have any microbiological contamination. At Muttayyapuram the coliform count is 300 MPN which is above the prescribed limit of <2 MPN.

3. Chemical characteristics of groundwater

As far as the major element concentrations in the groundwater samples of the Thoothukudi city is concerned, it is observed that Ca is above the IS 10500: 2012 prescribed desirable limit of 75 ppm in 8 of the 13 localities. However, the Ca concentrations are below the permissible limit of 200 ppm. Among the heavy metals measured, As at 0.012 ppm and 0.017 ppm, respectively for G 9 of Kothalarivilai and G 12 of Muniasamy Nagar are above the desirable limit of 0.01 ppm but below the permissible limit of 0.05 ppm prescribed in the standard. Cd exceeds the desirable and permissible limit of 0.003 ppm in all the samples. The exceedance factor ranges from 1.33 to 3.67 times with an average of 2.57.

Hg content in groundwater collected from 9 out of 13 localities is extremely high with reference to the desirable and permissible limit of 0.001 ppm. Exceedance factors range from 4 to 211 times that of the acceptable limit. The worst affected areas in the order of decreasing intensity of contamination are Rathapanuram > Polpettai > Kothalarivilai > Muniasamy Nagar > Matha Koil > Melur > Rajiv Nagar > Muttayyapuram > Mattakadai. This is a serious cause for concern as mercury is a hazardous contaminant.

The heavy metals Cr, Cu, Mn, Ni, Pb, Zn, and Mo in the groundwater are all within acceptable limits in all the sampling locations. Overall, Hg in groundwater poses the highest threat to human health in Thoothukudi city followed by Cd and As. Based on these results, it can be concluded that the groundwater from all these localities in Thoothukudi are unfit for human consumption.

The results of the Korampallam lake water analyses are presented in Table 3.

4. Physical characteristics of Korampallam lake water

The Korampallam lake covers an area of about 4.48 sq. km which serves as a source of drinking water and for other domestic purposes for the surrounding areas. From Table 3, it can be inferred that the physical characteristics of the Korampallam lake waters such as temperature, pH, conductivity, turbidity, dissolved oxygen, total dissolved solids, and salinity are within acceptable limits as prescribed by IS 10500 : 2012 and WHO guidelines for drinking water.

5. Microbiological characteristics of Korampallam lake water

All the Korampallam lake water samples were found to be above the prescribed limit of <2 MPN at 350 MPN. This is 175 times above the acceptable limit.

6. Chemical characteristics of Korampallam lake water

With respect to the major element concentrations in the Korampallam lake water samples, Ca is above the IS 10500: 2012 desirable limit of 75 ppm in samples collected from two locations L1 and L3. However, the Ca concentrations are below the permissible limit of 200 ppm. Among the heavy metals measured, Cd at all the lake water sampling locations are above the desirable limit of 0.003 ppm. Cd exceedance factors range from 2.33 to 4 times that of the acceptable limit with an average exceedance of 3.2 times. All the other heavy metals measured such as As, Cr, Cu, Hg, Mn, Ni, Pb, Zn, and Mo are within the acceptable limits. Overall, Korampallam lake water is unfit for human consumption as it has high coliform and Cd content.
IV. CONCLUSIONS

The presence of high number of coliform bacteria indicate there is contamination of groundwater at Muttyayapuram and all the lake water samples by the influx of sewage. This poses a risk of pathogenic diseases such as typhoid fever, viral fever, bacterial gastroenteritis and hepatitis A to the local population that are exposed to these waters. In the groundwater, Arsenic contamination in Kothalrivilai and Muniaswamy Nagar can expose the local population to dermatological and neurological illnesses, cancer and vascular disease. The very high levels of mercury present in 69 % of the groundwater samples risk the local populations to neuromuscular disorders, renal failure, and cognitive and motor disorders. The prevalence of cadmium in all the groundwater and the lake water samples is a major cause of concern as ingestion of this heavy metal through contaminated water can cause reproductive and developmental deficiencies, carcinogenesis, and renal failure among other ailments. Since all the groundwater and lake samples have been contaminated and are not suitable for human consumption it is recommended that the local government issue advisories against the consumption of these waters to the local people. Suitable alternative water supply must be provided immediately. Appropriate studies for the identification of the sources of contamination and measures to eliminate those are required on an urgent basis.

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REFERENCES

1. GoI. (2011). Government of India, Census 2011. http://censusindia.gov.in/2011census/dcbh/3326_PART_B_DCHB_THOOTHUJKUDI.pdf Accessed on 24 April 2019.
2. Arasu, Thillai & Murugan, Arumugam & Badusha, M.S.M. (2016). A study of physico-chemical analysis of ground water in and around SIPCOT, Tuticorin, Tamil Nadu, India. International Journal of Earth Sciences and Engineering, 9, 2499-25022.
3. WHO (2019): World health Organization Guidelines for water requirement
4. The Hindu. (2016): Drinking water crisis looms large over Thoothukudi. https://www.thehindu.com/news/national/tamil-nadu/Drinking-water-crisis-looms-large-over-Thoothukudi/article14591051.ece Accessed on 24 April 2019.
5. Mondal, N. C., Singh, V. P., Singh, S., & Singh, V. S. (2011). Hydrochemical characteristic of coastal aquifer from Tuticorin, Tamil Nadu, India Environmental monitoring and assessment, 175(1-4), 531-550.
6. Kumar, S.K., Magesh, N.S., & Chandrasekar, N. (2012). Trace element concentration in groundwater, Tuticorin city, Tamil Nadu, India. Bulletin of environmental contamination and toxicology, 88 6, 876-9.
7. WHO (2004): World Health Organization: Guidelines for drinking-water quality (Vol. 1). World Health Organization. https://www.who.int/water_sanitation_health/dwq/GDWQ2004web.pdf Accessed on 24 April 2019.
8. Moultharan, N., Sudhan, C., Bharathi, S., & Vinoth, S. Pollution impact assessment in mangrove associated thermal bridge estuary, Thoothukudi, Tamil Nadu (2017).
9. Rajaram, R., & Ganeshkumar, A. (2019). Anthropogenic Influence of Heavy Metal Pollution on the Southeast Coast of India. In Coastal Zone Management (pp. 381-399), Elsevier.
Table 1. Details of the sample locations, their coordinates and the types of sample

| S. No. | Sample code | Latitude       | Longitude       | Locality          | Type of water |
|-------|-------------|----------------|-----------------|-------------------|---------------|
| 1     | G 1         | N 08°50'27.01" | E 78°03'40.42" | VEERAPANDIAPURAM  | GW            |
| 2     | G 2         | N 08°46'31.64" | E 78°05'24.97" | KORAMPALLAM      | GW            |
| 3     | G 3         | N 08°48'08.67" | E 78°05'32.13" | MADATHUR         | GW            |
| 4     | G 4         | N 08°48'00.40" | E 78°08'46.29" | SHANMUGAPURAM    | GW            |
| 5     | G 5         | N 08°48'35.77" | E 78°09'18.20" | RATHANAPURAM     | GW            |
| 6     | G 6         | N 08°48'32.78" | E 78°08'41.84" | POLPETTAI        | GW            |
| 7     | G 7         | N 08°47'58.71" | E 78°7'16.25"  | RAJIV NAGAR      | GW            |
| 8     | G 8         | N 08°45.074"   | E 78°11.120"   | MUTTAYYAPURAM    | GW            |
| 9     | G 9         | N 08°39'31.49" | E 78°01'48.00" | KOTHALARIVILAI   | GW            |
| 10    | G 10        | N 08°47'42.46" | E 77°50'44.91" | MELUR            | GW            |
| 11    | G 11        | N 08°48'33.57" | E 78°9'22.56"  | MATTAKADAI       | GW            |
| 12    | G 12        | N 08°47'71.61" | E 78°7'27.92"  | MUNIASAMY NAGAR  | GW            |
| 13    | G 13        | N 08°48'17.73" | E 78°9'21.25"  | MATHA KOIL      | GW            |
| 14    | L 1         | N 08°46.154"   | E 78°05.287"   | KORAMPALLAM      | LW            |
| 15    | L 2         | N 08°46.028"   | E 78°05.207"   | KORAMPALLAM      | LW            |
| 16    | L 3         | N 8°46'16.39"  | E 78°5'12.72"  | KORAMPALLAM      | LW            |
| 17    | L 4         | N 08°46'14.35" | E 78°05'31.47" | KORAMPALLAM      | LW            |
| 18    | L 5         | N 08°46'13.90" | E 78°05'33.49" | KORAMPALLAM      | LW            |

GW – Groundwater; LW – Lake Water

Fig. 1. Google Earth snapshot of study area with sample locations
### Table 2: Results of the physical, chemical, and microbiological analyses of ground waters

| S. No | Sample code | G 1 | G 2 | G 3 | G 4 | G 5 | G 6 | G 7 | G 8 | G 9 | G 10 | G 11 | G 12 | G 13 |
|-------|-------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------|-------|------|------|
| 1     | Temperature (°C) | 28.9 | 28.7 | 28.2 | 29  | 28.8 | 28.4 | 28.4 | 28.7 | 28.3 | 28.3 | 28.5 | 29.3 | 28.3 |
| 2     | pH          | 7.0  | 7.3  | 6.74 | 7.31| 7.74 | 7.37 | 6.2  | 7.1  | 7.31 | 7.36 | 7.33 | 7.9  | 7.2  |
| 3     | Conductivity (µS) | 203 | 0   | 487 | 140 | 1170| 1530| 1060| 361 | 308 | 184  | 1210 | 1930 | 299 | 114 |
| 4     | Turbidity (NTU) | 0   | 0   | 17  | 0   | 0   | 0   | 0   | 0   | 1.2 | 0   | 1.3  | 3.8  | 1.1  |
| 5     | DO          | 2.5  | 3.6  | 2.8  | 2.5 | 2.6  | 2.8  | 2.4  | 2.7  | 2.9  | 2.6  | 1.6  | 2.4  |       |
| 6     | TDS (ppt)   | 1.0  | 5    | 2    | 0.2 | 5    | 7    | 3.5  | 0.88 | 0.7  | 1.8  | 2    | 1.6  | 1    |
| 7     | Salinity    | 1.0  | 2    | 7.1  | 8.6 | 0.7  | 0.54 | 1.8  | 2    | 1.5  | 6    | 0.09 | 0.61 | 0.97 |
| 8     | Na          | 28.6 | 35.2 | 1.42 | 680 | 75.7 | 28.2 | 69.6 | 2    | 174 | 0    | 164  | 0    | 6.9  |
| 9     | K           | 51.3 | 35.4 | 1.42 | 82.8 | 92.5 | 92.9 | 64.3 | 3    | 31   | 24   | 19   | 2    | 6.9  |
| 10    | Ca          | 98.0 | 10.5 | 67.8 | 150 | 100  | 99.5 | 100  | 29   | 18   | 11.1 | 100  | 150  | 99.5 |
| 11    | As          | BD   | BD   | BD   | BD  | BD   | 0.0  | 0.0  | BD   | BD   | BD   | BD   | BD   | BD   |
| 12    | Cd          | 0.0  | 0.0  | 0.0  | 0.01| 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  |
| 13    | Cr          | 0.0  | 0.0  | 0.0  | 0.00 | 0.0  | 0.00 | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  |
| 14    | Cu          | BD   | BD   | BD   | BD  | BD   | 0.0  | 0.0  | BD   | BD   | BD   | BD   | BD   | BD   |
| 15    | Hg          | BD   | BD   | BD   | BD  | BD   | 0.0  | 0.0  | BD   | BD   | BD   | BD   | BD   | BD   |
| 16    | Mn          | 0.0  | 0.0  | 0.02 | 0.02| 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 17    | Ni          | 0.0  | 0.0  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 18    | Pb          | BD   | BD   | BD   | BD  | BD   | 0.00 | 0.00 | BD   | BD   | BD   | BD   | BD   | BD   |
| 19    | Zn          | BD   | BD   | BD   | BD  | BD   | 0.00 | 0.00 | BD   | BD   | BD   | BD   | BD   | BD   |
| 20    | Mo          | 0.0  | 0.0  | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 21    | Coliform (MPN) | BDL | BD  | BD   | BD  | BD   | BD   | BD   | BD   | BD   | BD   | BD   | BD   | BD   |

Note: All values in ppm unless otherwise specified. BDL – Below Detection Limit

### Table 3: Results of the physical, chemical, and microbiological analyses of lake water samples

| S. No | Sample code | L 1 | L 2 | L 3 | L 4 | L 5 |
|-------|-------------|-----|-----|-----|-----|-----|
| 1     | Temperature (°C) | 28.6 | 28.6 | 28.9 | 28.5 | 29.4 |
| 2     | pH          | 7.2  | 7.26 | 7.43 | 7.4  | 7.19 |
| 3     | Conductivity (µS) | 235 | 243 | 248 | 234 | 620 |
| 4     | Turbidity (NTU) | 4.2  | 2.4  | 8    | 1.6  | 0.5 |
| 5     | DO          | 2    | 3.3  | 3.2  | 2.3  | 2.9 |
| 6     | TDS (ppt)   | 0.1  | 0.11 | 0.13 | 0.12 | 0.32 |
| 7     | Salinity    | 0.12 | 0.12 | 0.12 | 0.12 | 0.31 |
| 8     | Na          | 11.5 | 13.82 | 14.1 | 17.64 | 48.34 |
| 9     | K           | 60.19 | 39.49 | 19.43 | 28.34 | 51.43 |
| 10    | Ca          | 76.85 | 50.19 | 111.91 | 1.25 | BDS |
| 11    | As          | BDS  | BDS  | BDS  | BDS  | BDS |
| 12    | Cd          | 0.011 | 0.012 | 0.008 | 0.001 | 0.007 |
| 13    | Cr          | 0.001 | BDS  | BDS  | BDS  | BDS |
Contamination Characteristics of Ground and Lake Waters of Thoothukudi city

|   |       | 0.005 | 0.004 | 0.003 | 0.002 | 0.001 |
|---|-------|-------|-------|-------|-------|-------|
| 14| Cu    |       |       |       |       |       |
| 15| Hg    | BDL   | BDL   | BDL   | BDL   | BDL   |
| 16| Mn    | 0.002 | BDL   | 0.006 | 0.003 | 0.001 |
| 17| Ni    | 0.002 | BDL   | 0.005 | 0.002 | 0.001 |
| 18| Pb    | BDL   | BDL   | 0.004 | BDL   | 0.006 |
| 19| Zn    | BDL   | BDL   | BDL   | BDL   | BDL   |
| 20| Mo    | 0.002 | 0.001 | 0.001 | BDL   | 0.001 |
| 21| Coliform (MPN) | 350  | 350  | 350  | 350  | 350  |

Note: All values in ppm unless otherwise specified. BDL – Below Detection Limit