Analysis of surface water quality for irrigation in Padmanabhapuram fort (Kanyakumari District, Tamil Nadu) India

B K Ramesh¹, M Velayutham Pillai², S Vanitha³ and J Diagu⁴

¹,²,³Department of Civil Engineering, Kalasalingam Academy of Research and Education, Krishnankovil, Viruthunagar 626126, Tamilnadu.
²Department of Chemistry, Kalasalingam Academy of Research and Education, Krishnankovil, Viruthunagar 626126, Tamilnadu.
⁴Environmental Engineering, Department of Civil Engineering, Kalasalingam Academy of Research and Education, Krishnankovil, Viruthunagar 626126, Tamilnadu.

E-mail : bkramesh1000@gmail.com

Abstract: This study aimed to analyze the suitability of surface water quality (ponds) in Padmanabhapuram Fort campus (8°14’49”–8°15’11”N, 77°19’26”–77°19’55”E) in the Kanyakumari district for irrigation purposes. There are six small ponds on that campus. At present, these ponds are completely polluted. To have an idea and find solution for the problem related to water usable for irrigation, we carried out analysis of important physico-chemical parameters like total hardness, the potential of hydrogen (pH), electrical conductivity, salinity, total dissolved solids, calcium, carbonate, bicarbonate, total alkalinity, and sodium by instrumental and analytical methods. Other parameters, which are deemed to be significant for water used for irrigation such as sodium absorption ratio (SAR), magnesium hazard (MH), sodium content (% Na), Permeability index (PI), residual sodium carbonate (RSC), Kelly ratio (KR) and soluble sodium percentage (SSP) are also derived by respective empirical formulas of these parameters.

1. INTRODUCTION

Water has important role in the stability of nature including living beings. The surface of the Earth is covered by about 70% of water. However, the fresh water availability is less than 1%. Increasing human population, rapid industrialization and mining leads to the pollution of natural resources to a greater extent. For irrigation and drinking purposes, groundwater is the main source for millions of people. Humans use pond, river, and open well and other water sources for drinking and irrigation purposes. Due to various reasons like, lack of concern over environmental problems, indiscriminate disposal of wastes of various kinds, improperly treated sewage, unplanned application of agrochemicals that deteriorate the surface, subsurface water etc. [1] [2] the surface water get polluted. The chemical concentration in both surface and groundwater influence the anthropogenic activities and geographical formation [3]. Analysing the quality of water is important for knowing its suitability for various purposes, as well as to identify the problems for solving the related issues[4][5].

The knowledge of hydro-chemistry is also essential to find the water quality which is being used for irrigation and drinking [6].

Decrease in the quality of groundwater has an impact over its usage for domestic, industrial and
drinking purposes [7]. Drinking impure water and making use of very low quality water for edible purposes being the cause for about 80% of diseases in the world and 1/3rd of the deaths in all developing countries is due to the very low quality of drinking water (according to WHO) [8]. In India, a significant number of deaths is mainly due to the consumption of polluted water and making use of untreated water coming out from various factories which entered into the nearby pond or lake and also the rivers which are getting polluted by industrial wastewater [9].

In India, various researchers studied the water quality parameters in many places viz. Varanasi (Uttar Pradesh) [10], Chennai (Tamil Nadu) [11][12], Guntur (Andhra Pradesh) [13], Southern Tamil Nadu [14], Southern Kerala [15], Nagapattinam (Tamil Nadu) [16], Dausa (Rajasthan) [17], Garhwal Himalaya [18], Kashmir [19] and so on. These studies indicate the significance of water in daily lives as well as throws light on the fact that how environmental degradation affects the hydrosphere. Inspired by these literature reports, we thought of carrying out studies to know the quality of surface water for agricultural usage in Padmanabhapuram fort of Padmanabhapuram town situated in Kalkulam taluk of Kanyakumari District, Tamil Nadu, where ponds are being polluted over years. These ponds are having continuous inflow of water into them from various sources, but the water usage from these ponds is diminishing day by day due to increasing contamination. So, this article includes studies on water quality parameters of such water bodies mainly and also trying to find the reason behind the high rate of pollution experienced in some of the ponds.

2. STUDY AREA

The present study area, Padmanabhapuram was the former capital city of the erstwhile Travancore province. The Padmanabhapuram Palace complex, situated inside the fort, was the administrative headquarters for the Venad kingdom. The Kalkulam forts were established during the period of the King Iravi Varma Kulasekhara (1592-1609 C.E.). The area chosen for study is a part of the Kanyakumari district (Tamil Nadu State, India) with the geographical coordinates 8°14'49"– 8°15'11" N, 77°19'26"– 77°19'55" E.

The Kanyakumari district is a part of the composite east flowing river basin, “Between Pazhayar and Tamirabarani” as per the Irrigation Atlas of India. The district receives rain fall under the influence of both southwest and northwest monsoons. The average annual rainfall over the district varies from about 826 to 1,456 mm. The maximum humidity has been recorded during the months May-June with 95 %, and the minimum of 45 % is measured during January-February. Wind speed has been measured as 17.74 km/hr at highest level in August, the minimum wind speed has been registered during December (5.533 km/hr). The wind velocity is found to be low from October to December.

The soil of this area is categorized into three types: a) Red Soil, b) Red lateritic soil and c) Brown soil. The pH is found between 4.5 to 8 for different types of soil. The minerals found in the soil are highly rich in plant nutrient concentrations i.e. NPK.

2.1 Collection of samples with location

Pond 1 is Kalkulam Shri Mahadevar Temple pond, having 4,780 m² area. Pond 2 is Neerali pond with 798 m² area. This Neerali pond was used as a private swimming pool for the royal family of kings. Pond 3 is Mudakulam pond, with 602 m² area. Krishnankovil pond is the Pond 4, and its area is 100 m². Pond 5, Perumal pond is the biggest pond in Padmanabhapuram fort campus with 28,924 m² area and Pond 6 is Ramaswamikovil pond, with an area equal to 620 m².

3. MATERIALS AND METHODS

A total of six samples from ponds have been collected in 1 litre high density poly ethylene bottles (HDPEB). The bottles were washed well to avoid any impurities that may interfere with the analysis.
By using Digital Water and Soil analysis kit (Model-172), pH, Total Dissolved Solids (TDS) and Electrical Conductivity (EC) were measured. The concentration of calcium and total hardness of the water sample were estimated in the laboratory and the presence of magnesium was calculated by the difference between calcium and hardness while the total alkalinity, bicarbonate, and carbonate were found out by following standard laboratory procedures. Flame photometer was used to find sodium concentration. Sodium Absorption Ratio (SAR), Magnesium Hazard (MH), Sodium Content (% Na), Permeability Index (PI), Residual Sodium Carbonate (RSC), Kelly Ratio (KR) and Soluble Sodium Percentage (SSP) were derived from the analytical data obtained by respective empirical formulas.

4. RESULT AND DISCUSSION

Natural and human activities are the sources for change in water quality. As in any agricultural practice, the land is used for irrigation in Padmanabhapuram fort. The parameters which determined are provided in Table 1. The pH, salinity, Total Dissolved Solids (TDS), Sodium Absorption Ratio (SAR), Magnesium Hazard(MH), Sodium Content (% Na), Permeability Index (PI), Residual Sodium Carbonate (RSC), Kelly Ratio (KR) and Soluble Sodium Percentage (SSP).

| Water Source | pH  | EC   | TDS  | SAR  | MH   | % Na | RSC | KR | SSP | PI |
|--------------|-----|------|------|------|------|------|-----|----|-----|----|
| Pond 1       | 7.05| 1673 | 1104 | 5.43 | 23.9 | 69.90| 6.39| 1.80| 64.32| 90.1|
| Pond 2       | 7.15| 1210 | 798  | 3.36 | 40.8 | 55.47| 3.36| 1.07| 51.78| 79.8|
| Pond 3       | 7.43| 1049 | 692  | 3.51 | 37.6 | 57.81| 2.41| 1.15| 53.49| 79.9|
| Pond 4       | 6.99| 729  | 481  | 3.17 | 10.6 | 65.99| 0.91| 1.46| 59.38| 90.4|
| Pond 5       | 6.89| 708  | 468  | 2.25 | 24.6 | 52.12| 0.41| 0.91| 47.71| 79.4|
| Pond 6       | 6.08| 719  | 474  | 2.25 | 30.8 | 51.36| 0.88| 0.88| 46.89| 79.8|

Table 1. Water quality parameters of the samples

| Sl. No. | Parameter | Range       | Usability for Irrigation | Samples (6) |
|---------|-----------|-------------|--------------------------|-------------|
| 1       | pH        | <6.5        | Not suitable             | 1           | 17          |
|         |           | >8.4        | Not suitable             | -           | -           |
|         |           | < 250       | Excellent                | -           | -           |
|         |           | 250-750     | Good                     | 3           | 50          |
|         |           | 750–2,250   | Permissible              | 3           | 50          |
|         |           | > 2,250     | Doubtful                 | -           | -           |
|         |           | < 500       | Good                     | 3           | 50          |
|         |           | 500–2,000   | Permissible              | 3           | 50          |
|         |           | >2,000      | Not suitable             | -           | -           |
|         |           | <6          | No problem               | 6           | 100         |
|         |           | >9          | Severe Problem           | -           | -           |
| 2       | EC        | <500        | Good                     | 3           | 50          |
|         |           | 500–2,250   | Permissible              | 3           | 50          |
|         |           | >2,000      | Not suitable             | -           | -           |
|         |           | <6          | No problem               | 6           | 100         |
|         |           | >9          | Severe Problem           | -           | -           |
|         |           | <500        | Good                     | 3           | 50          |
|         |           | 500–2,000   | Permissible              | 3           | 50          |
|         |           | >2,000      | Not suitable             | -           | -           |
|         |           | <6          | No problem               | 6           | 100         |
|         |           | >9          | Severe Problem           | -           | -           |

Table 2. Permissible limits of water used for irrigation and actual values of samples
4.1. pH
To find whether a given solution is acidic or alkaline, pH is the scale used widely. For pure water at 25 °C (77 °F) pH will be equal to 7. The pH value ranging from 6.5 to 8.4 is the suitable range for irrigation water. Alkaline water contains higher concentrations of bicarbonate and carbonates. It increases the possibility of the elements calcium and magnesium to precipitate from the soil and can affect the plant growth. As shown in the table 2, if pH is greater than 7.5, it reduces the effectiveness of chlorine disinfection. Acidity of water also affects harmfully on plant growth, especially causes nutritional problems. The strong acidity of water also contributes to soil acidification and pH < 6 indicates the corrosive behavior of the water which leads to damage of tanks, metal pipes, and fittings.

The analysis report shows that the sample water from pond 6 is slightly acidic, having pH = 6.08, which falls below the lower limit. For the samples collected from remaining five ponds, pH is found to be within the prescribed limits.

4.2. Salinity
Salinity is nothing but the concentration of salt content present the sample, and it is measured in terms of electrical conductivity (EC). The unit used for the measurement of salinity is micro Siemens per centimeter (μS/cm). Higher values of salinity limits the ability of plants to take up water and the plants will begin to die if the limits are exceeded. Plants are affected by the toxicity of some elements in saline water, mainly sodium and chlorine.

As shown in the table 2, for agriculture use, no pond has found under excellent range, with EC of less than 250, and the range is actually found above 250-750. From this observation, we can conclude that three ponds are found good and recommended for use. There are three other ponds under the category of permissible limits i.e. 750-2,250. There is no one sample is found with EC more than 2,250 which make water unsuitable for irrigation.

4.3. Total Dissolved Solids (TDS)
TDS is termed as the dissolved solids in water sample measured in mg/l. Salinity, electrical conductivity and TDS are directly proportional each other. When salt contents increase, the plants need to use more energy to absorb nutrients from the soil and water. Some plants are sensitive to salinity and some can grow in high salinity water.

Sample water from Pond 4, pond 5 and pond 6 have TDS less than 500 and these water can be used for irrigation, whereas the remaining three ponds are having salinity values within the permissible limits recommended for agricultural use (table 2). There are no ponds with TDS more than 2,000.

4.4. Sodium Absorption Ratio
Sodium Adsorption Ratio is a measure of the amount of sodium present with respect to calcium and magnesium and calculated by the following formula:

\[
SodiumAbsorptionRatio(SAR) = \frac{Na}{(Ca)+(Mg)}\quad (1)
\]
In equation (1), the concentrations are expressed in milliequivalents / litre.

As per table 2, all the six ponds are satisfying the range for good irrigation use under SAR, i.e. < 6, and consequently good enough for irrigation.

**4.5. Magnesium Hazard (MH)**
MH is another indicator to know the water quality for irrigation. Szabolcs and Darab (1956) have proposed a relation to find the magnesium hazard. This hazard is known as Magnesium hazard (MH)

\[
\text{Magnesium Hazard (MH)} = \frac{(Mg)}{(Ca+Mg)} \times 100
\]

In equation (2), the concentrations are in milliequivalents / litre. As shown in the table 2 and figure 1, all the samples in this study are found to possess MH < 50, which is permissible for agriculture use.

**4.6 Sodium Content (% Na)**
The sodium in irrigation water is expressed as the percentage sodium or soluble sodium percentage (% Na) and can be determined using the following equation.

\[
\% \text{ Na} = \frac{Na+K}{Ca+Mg+Na+K} \times 100
\]

In equation (3), the concentrations are in milliequivalents / litre.

Water with sodium content <20 shows the suitability of it for irrigation. There are no ponds with % Na value 20-40 which is graded as good. The permissible limits of % Na is lying in the range 40-60, and is satisfied by four ponds. As shown in the figure 1 and table 2, remaining two ponds with 60-80 % of Na comes under doubtful category to be used for irrigation.

**4.7. Residual Sodium Carbonate (RSC)**
The residual sodium carbonate is used to determine the alkali hazard in water or soil. RSC is calculated by subtracting the calcium and magnesium contents from the sum of carbonate and bicarbonates.

\[
\text{RSC} = (CO3 + HCO3) - (Ca + Mg)
\]

In equation (4), the concentrations are in milliequivalents per litre.

As shown in the above table, there are three ponds with good category (less than 1.5) for irrigation, whereas one pond is under doubtful category with limit 1.25–2.5 to use, and the remaining two are coming under unsuitable category (above 2.50) which is not good for irrigation.

**4.8. Kelly Ratio (KR)**
Kelly’s ratio is measured as the ratio between Na and the sum of Mg and Ca. A Kelly’s ratio > 1 indicates an excess level of sodium in water. Therefore, water with the Kelly’s ratio < 1 is suitable for irrigation, while those with a ratio >2 are unsuitable for irrigation.

\[
\text{Kelly Ratio} = \frac{Na}{Mg+Ca}
\]

In equation (5), the concentrations are in milliequivalents per litre. In the present study, two ponds are having KR < 1.0 and are suitable for irrigation purpose and the remaining four ponds are having KR >1 which are not suitable for irrigation.
4.9. **Soluble Sodium Ratio (SSR)**

SSR can be used for finding sodium hazards. High sodium ion concentration in water can make problems on internal drainage system with respect to soil, and release of Ca and Mg are facilitated due to absorption of sodium by clay particles.

\[
SSR = \frac{Na}{Ca + Mg + Na} \times 100
\] (6)

In equation (6), the concentrations are in milliequivalents per litre.

Water samples taken from Pond 4 and pond 5 are possessing SSR < 50 which is categorized as good for irrigation, as shown in figure 1, four ponds are found with SSP > 50 which is not recommended for irrigation purpose (table 2).

4.10. **Permeability index**

Permeability Index has been developed empirically by Doneen (1964) after conducting a series of experiments. The presence of Na, K, HCO₃, Ca and Mg will contribute to the permeability index of the water sample and the same is calculated by the following empirical formula.

\[
PI = \frac{Na + K + \sqrt{HCO_3}}{Ca + Mg + K + Na}
\] (7)

In equation (7), the concentrations are in milliequivalents per litre.

As shown in the above figure 1, for good irrigation, permeability index value should be < 80. As shown in the above table 2, four ponds are having PI < 80 and are observed as satisfied. The remaining two ponds are having the PI range 80 - 100 which means that they are moderate in quality and can be recommended for irrigation but not for other domestic purposes.

5. CONCLUSION

In this study pH, Salinity, Total dissolved solids and Electrical conductivity were measured for water samples collected from six ponds in Padmanabhapuram Fort Campus. Sodium Absorption Ratio (SAR), Magnesium Hazard (MH), Sodium Content (%Na), Permeability Index (PI), Residual Sodium Carbonate (RSC), Kelly Ratio (KR) and Soluble Sodium Percentage (SSP) were calculated from the standard formulas. From the analysis it can be concluded that, pond 1, which is nearer to a temple, where population density is high, has exceeded permissible limits for all parameters except MH and SAR. The Pond 5 has been found to be least polluted amongst the all, which is situated near hill where the population density is low and susceptibility for pollution is also less.
REFERENCES

[1]. Ewusi A, Obiri-yeboah S, Voigt HS (2013) Groundwater quality assessment for drinking and irrigation purposes in Obuasi Municipality of Ghana: a preliminary study. *J Environ Earth Sci* 5(1):6–17

[2]. Kalpana L, Elango L (2013) Assessment of groundwater quality for drinking and irrigation purposes in Pambar river sub-basin, Tamil Nadu. *Indian J Environ Protection* 33(1):1–8

[3]. Plummer LN, Bexfield LM, Anderholm SK (2003) *How ground-water chemistry helps us understand the aquifer*. In: Bartolino JR, Cole JC (eds) U.S. Geological Survey Circular, p 1222

[4]. Arshid J, Aasimah T, Yousuf AR, Akbar M, Aabid HN (2011) Geochemistry and irrigation quality of groundwater along River Jhelum in South Kashmir, India. *Recent Res Sci Technol* 3(6):57–63

[5]. Ifatimehin OO, Musa SD (2008). The prospects of sustainable management of domestic 48 water supply and sanitation in Kogi strata. *J. Environ Policy Issues* 4(1–2):33–44

[6]. Srinivas Y, Hudson Oliver D, Stanley Raj A, Chandrasekar N (2013) Evaluation of groundwater quality in and around Nagercoil town, Tamil Nadu, India: an integrated geochemical and GIS approach. *Appl Water Sci* 3:631–651

[7]. Raja NJ, Shukla UK, Ram P (2011) Hydrogeochemistry for the assessment of groundwater quality in Varanasi: a fast-urbanizing center in Uttar Pradesh, India. *Environ Monit Assess* 173:279–300

[8]. Sajil Kumar PJ, Elango L, James EJ (2013) Assessment of hydrochemistry and groundwater quality in the coastal area of South Chennai, India. *Arab J Geosci.* Doi:10.1007/s12517-013-0940-3

[9]. Nagaraju A, Sunil Kumar K, Thejaswi A (2014) Assessment of groundwater quality for irrigation: a case study from Bandalamottu lead mining area, Guntur District, Andhra Pradesh, South India. *J. ApplGeochem* 14(4):466–481

[10]. Padmalal D, et.al (2012) Hydro chemical characterization and water quality assessment of the coastal springs of southern Kerala, India. *J ApplGeochem* 14(4):466–481

[11]. Gnanachandrasamy G, et.al(2013) Accessing groundwater quality in lower part of Nagapattinam district, Southern India: using hydrogeochemistry and GIS interpolation techniques. *Appl Water Sci*. doi:10.1007/s13201-014-0172-z

[12]. Krishna Kumar S, et.al(2014) Hydro-geochemistry and application of water quality index (WQI) for groundwater quality assessment, Anna Nagar, part of Chennai City, Tamil Nadu, India. *Appl Water Sci.* doi: 10.1007/s13201-014-0196-4

[13]. Tiwari KK, et.al(2012) geochemical parameters for assessment of groundwater quality around urban and suburban areas of Dausa city in Rajasthan, India. *J ApplGeochem* 14(2):184–193

[14]. SinghA K, Hasnain SI (1998) Major ion chemistry and weathering control in a high altitude basin: Alaknanda River Garhwal Himalaya, India. *Hydrol Sci* 43(6):825–843

[15]. Arshid J, et.al(2011) Geochemistry and irrigation quality of groundwater along River Jhelum in South Kashmir, India. *Recent Res Sci Technol* 3(6):57–63

[16]. WHO (2004) *Guidelines for drinking water quality*, 3rd edn. World Health Organization, Geneva

[17]. Brindha K, Elango L (2012) Groundwater quality zonation in a shallow weathered rock aquifer using GIS. *J Geo Spat Inf Sci* 1–10

[18]. Olajire AA, Imekopari FE (2001) Water quality assessment of Osun River: studies on inorganic nutrients. *Environ Monit Assess* 69(1):17–28