Physico-chemical Analysis of ground water samples from different taluks in Kanyakumari District, Tamil Nadu, India

M.P. Jeyasekhar
Associate Professor, Scott Christian College, Nagercoil

Abstract

The present study deals with the physico-chemical analysis of ground water samples collected from Thovalai, Agastheeswarm Vilavancode and Kalkulam taluks of Kanyakumari District, Tamilnadu. Available literature on physico-chemical parameters were meager. Therefore, to fill the gap the present study was carried out to evaluate the ground water quality for human consumption. Physical characteristics like turbidity, total dissolved solids, electrical conductivity, chemical factors like pH, alkalinity, total hardness, alkali and heavy metals like calcium, magnesium, sodium, potassium, iron, manganese, and free ions such as nitrate, fluoride, sulfate and phosphate were analysed following standard methods of APHA and results were compared with WHO standards. Among the parameters turbidity values were higher in all the four taluks *viz.* Thovalai 8 NTU, Agastheeswarm 9 NTU, Kalkulam 17 NTU, and Vilavancode 18 NTU these results were higher than the WHO standards of 5 NTU. Higher turbidity often promotes growth of harmful bacteria and protect the bacteria from disinfection. Excluding turbidity the quality of ground water is highly acceptable in almost all taluks of Kanyakumari District. Protecting natural resources of water and checking for standards is generally good for human beings, domesticated and non-domesticated animals.

Index Terms - water quality, physico-chemical parameters, WHO, Turbidity, Kanyakumari District

I. INTRODUCTION

The chemical formula or molecular formula is symbolised as H_2O for water. Water is also called Dihydrogen monoxide**.** It is an inorganic compound, made up of two atoms of hydrogen (H_2) and one atom of oxygen (O) connected by covalent bonds. Water can be seen in three phases water is liquid state of the compound, its solid phase ice and gas phase is called steam. The water is an amphometric substance can behave like acid and base.

Water constitutes about 60% of the body weight of almost all living organisms. Water plays an important role in the wealth of nation. Human civilizations hitherto known were close proximity to water and adjoining arable land (Fairservis, 1961). Therefore, water is essential for sustaining all forms of life, general well being, food production and economic development (Kumar et al, 2005). The surface water and ground water resources of the country play a major role in agriculture, livestock production, fisheries, hydropower generation, transport, industrial activities, recreational activities etc. (Kumar et al, 2005). On contrary, every state in India especially southern states are having conflict with its neighboring states for surface water. Maharashtra, Andhra Pradesh, Karnataka for sharing water over the Krishna river water; Karnataka, Tamil Nadu, Pondicherry and Kerala for Tamil Nadu were conflict over the river Cauvery. Kerala and Tamil Nadu dispute over the Mullaiperiyar dam for safety the survival (Gujja et al. 2010, Iyer 2011, Thatheyus et al 2013).

Water is essential nutrient, because only small amount can be manufactured by body through oxidation. The solid food contributes approximately 1 L water per day and water from oxidation 0.25 L per day. In addition on an average 2.9 L for males 2.7 L for females must consume water. Water consumption negatively effect on urinary stone disease, cancers in breast, colon, and urinary tract, childhood and adolescent obesity, mitral valve prolapsed, salivary gland function, overall health in elderly stage (Kleiner, 1999). However, water consumption increases in warm climates, with physical activity and during pregnancy and lactation (Moe and Rheingans, 2006).
Diarrhoeal diseases attributed to poor water supply, sanitation and hygiene account for 1.73 million deaths each year. Other diseases such as trachoma, schistosomiasis, ascariasis, trichuriasis, hookworm disease, malaria and Japanese encephalitis and contribute to an additional burden of disease (WHO, 2003).

Ground water is the major source for drinking and domestic purposes in both rural and urban areas. Besides, it is an important source for agriculture and industrial sectors. In rural areas where they get polluted drastically because of increased human activities. Ground water quality is mostly affected by either natural geochemical such as mineral weathering dissolution precipitation reactions, ion exchange etc the quality of ground water may vary from place to place. Once the ground water is contaminated, its quality cannot be restored back easily and to device ways and means to protect it (Khan and Ravikumar, 2013). Throughout the world, water use has been dramatically increased for the past five decades due to population growth and demands of irrigated agriculture (Moe and Rheingans, 2006).
Drinking water is derived from two basic sources: surface water, such as rivers and reservoirs, and ground water. All water contains natural contaminants, particularly inorganic contaminants that arise from the geological strata through which the water flows and to a varying extent, anthropogenic pollution by both microorganisms and chemical. In general ground water is less vulnerable to pollution than surface waters there are a number of possible sources of manmade contaminants, some of which are more important than others. The most common soluble constituents include calcium, sodium, bicarbonate and sulfate ions. Another common constituent is Chloride ion derived from intruded sea water, connate water and evapotranspiration concentrating salt, and sewage wastes for example nitrate can be a natural constituent but high concentration often suggest source of pollution.

Ground water is the primary source of drinking water for more than 98% of population in Kanyakumari, Tamil Nadu. Water is a basic and an essential ingredient for life. Therefore everybody should have a convenient access to an adequate and reliable source of wholesome drinking water. People are often unsatisfactory because of an inadequate quality, poor quality of water and often difficult accessibility.

Heavy metal pollution caused by various natural causes as well as anthropogenic activities. Natural causes such as soil erosion, weathering and anthropogenic activities include mining, agricultural fertilizer and pesticide application, sewage discharge, industrial effluents and land filling (Jaishankar et al. 2014, Vaverková, et al 2019, Zuang and Wang, 2020). There are 35 metals of which antimony, arsenic, bismuth, cadmium, cerium, chromium, cobalt, copper, gallium, gold, iron, lead, manganese, mercury, nickel, platinum, silver, tellurium, thallium, tin, uranium, vanadium, and zinc are heavy metals. These heavy metals certainly essential for plants and animals, at very low concentration they are required for biological functions. However in threshold concentration they become noxious (Jaishankar et al. 2014). Moreover, main threats to human health from heavy metals are exposure to lead, cadmium, mercury and arsenic (Järup, 2003). Heavy metal toxicity lead to lower energy level, damage the function of brain, lungs, kidney, liver, blood composition and other important organs. Long-term exposure leads to gradually progressing physical, muscular and neurological degenerative processes that imitate multiple sclerosis, Parkinson's disease, Alzheimer's disease and even cause cancer (Jaishankar et al. 2014).

In the agricultural field agricultural producers, fertilize the soil using chemical fertilizers, combat pests with chemical pesticides and various chemical application for diseases, irrigation and process of agricultural activities to make more efficient to soil for maximum production. Among the various activities, fertilizing the soil draws more attention (Savci, 2012). However, studies prove excessive use of fertilizers cause adverse environmental problems and ill effects on flora and fauna. In addition, excess use of chemical fertilizers aiming to success production causes increase soil salinity, water eutrophication, nitrate and heavy metal accumulation. Thus the heavy metals affect the plant and soil systems. The plants absorb the fertilizers through soil, thus they enter into the primary producers and consumers. Thus the fertilization process causes air, soil and water pollution (Savci, 2012).

The quality of water is of vital importance for mankind and it is associated with human welfare. Generally, the ground water quality is characterized by different physico-chemical characteristics (Thamilarasu and Sharmila, 2015). A good knowledge of the physico-chemical qualities of raw water is necessary so as to guide its suitability for use. Thus, the present research work was conducted to evaluate the different sources of drinking water samples for its physical, chemical, alkali metals and free ions nature. In this study, potable water sample from different taluks of Kanyakumari *viz.* Thovalai, Agastheeswaram, Vilanvancode and Kalkulam were analysed to find out whether the entire district has good quality water to drink.

II. MATERIALS AND METHODS

Study area

Kanyakumari is the southernmost district in Tamilnadu state and mainland India. Which is only place in the world Bay confluence of Bengal, Indian and Arabian sea happens. In addition, the mountainous chain of Western Ghats ends up. This district is surrounded by land, water and mountains. The political boundary of Kanyakumari District, Tamil Nadu adjoins with Trivanandapuram District Kerala. The administrative boundary of Kanyakumari District borders with Tirunelveli District in the North and North-East, Trivanandapuram District in the West, Gulf of Mannar in the East, Arabian Sea in the West. Historically the region was separated as Nanjinad and Edainad. Vilancode and Kalkulam taluks which comprised of Western Ghats and Edainad and Thovalai and Agastheeswarm forms Nanjinadu. Aralvaimozhy pass in the Western Ghats separates the Nanjinad and Edainad with the boundary being Vaezhimali or Vaezhi hills. The total geographical area of Thovalai is 369.07 sq.km, Agastheeswarm 490.8 sq.km, Vilavancode 441.8 and Kalkulam 430.8 sq.km.

Collection of water samples

Water samples were collected from the wells using pulley and lines and filled in 250ml sample bottles. About four samples were collected from each well starting from the surface reaching down to the depth of 75 to 100 feet. The sample were mixed well and made into a single sample for analysing different physico-chemical properties.

Physico-Chemical Analysis

The physico-chemical tests for the determination of appearance, colour, turbidity, total dissolved solids, conductivity, pH, total alkalinity, total hardness, calcium, magnesium, potassium, iron, manganese, nitrate, chloride, fluoride, sulfate and phosphate were conducted and calculations were followed as per standard method prescribed by American Public Health Association (2017).

Estimation of Turbidity

It is one of the water quality control method. This method is based on a comparison of the intensity of light scattered by the sample water. Turbidity of the water samples collected were measured by Nephelo turbidity meter. The units of turbidity from the calibrated nephelo meter are called Nephelometric Turbidity Units. The turbid effluent samples was taken in the large nephelometer tube and placed inside photo cell chamber. Based on the amount of light passing through the solution, turbidity was recorded in the digital meter in nepheloturbidity units. Separate tube was used for each in order to avoid mixing of the different samples.

Estimation of Total Dissolved Solids (TDS)

pre-prepared glass filter was inserted into the disk with the wrinkled side up in to filtration apparatus. Vaccum was applied and the disk was washed three times successive with 20 ml aliquots of reagent grade water. Total dissolved solids were estimated by heating the clean dish to 180±2°C for 1 hour in an oven followed by storing in a dissicators and weight was taken after working. sample was stirred with magnetic stirrer and 500 ml of sample was measured on to a glass-fiber filter under applied vaccum. The sample was washed three successive times with 10ml reagent grade water, allowing complete drainage between washings and continuing suction for about 3 minutes after filtration is complete. The total filtrate (with washings) was transferred weighed evaporating dish and evaporate to dryness on a steam bath or in a drying oven. Sample was poured on to the same disk successively after evaporation. The sample was dried and evaporated for at least 1 hr in an oven at 180°C± 2°C and cooled in an desiccators to balance temperature and subsequently weighed. The cycle of drying, cooling, desiccating and the weighing was continued until a constant weight was obtained. This is measure of inorganic ions and the most important criterion for evaluation water quality.

Estimation of Electrical Conductivity (EC)

The ability of water to conduct an electric current is called electrical conductivity of water. In this study conductivity meter was used to measure the electrical conductivity. The units of measurements denoted as (µS/cm) Microsiemens Per Centimeter. Before using the conductivity meter, it was standardized with Potassium chloride (KCL) solution.

Chemical parameters

Estimation of pH

pH was estimated by the electrometric method. pH is technically defined as the negative base 10 algorithm of the effective concentration of H^+ ion in gram equivalents per liter. **p**H is determination of the activity of the hydrogen ions by potentiometric measurement using a standard hydrogen electrode and a reference electrode (APHA, 2017). A substance is said to be neutral when it is 7. When it exceeds more than 7 it is more basic and below 7 more acidic. The sample were tested with narrow pH indicator paper at the site of collection and in the laboratory the pH values were confirmed by testing the samples in a ELICO LI 120 combined electrode high sensitivity digital pH meter.

Estimation of Total Alkalinity

It is acid neutralising capacity of the water. The alkalinity on natural water is mainly represented by it content of carbonates, bicarbonate and hydroxides. 100 ml of effluent sample was taken in a 250 ml conical flask and 3 drops of phenolphthalein indicator were added. If the sample turned pink, it was titrated with 0.02N H_2SO_4 (sulfuric acid) until pink colour disappears. The volume (ml) of acid used was noted. In the same (used) effluent sample 3 drops of methyl orange indicator were added. If the effluent turned yellow, it was titrated with the same acid until a faint orange end point is obtained and the volume of acid used for titration, was noted.

Estimation of Total Hardness

The water hardness was understood to be a measure of the capacity of water to precipitate soap. Since soap is precipitated chiefly in calcium and magnesium ions. The total hardness is defined as the sum of the calcium and magnesium dissolved in water. The preferred method for determining hardness is to compute it from the results of separate determinations of calcium and magnesium (APHA, 2017). Total hardness was estimated using the EDTA method. In the present study Total hardness was estimated using Ethylenediaminetetraacetic acid and its sodium salts (EDTA). Exactly 25ml of sample was taken in the porcelain dish and 1 ml of buffer was added. After adding 2 drops of indicator solution the sample was titrated against EDTA, slowly until the red point changes from red to blue.

Estimation of Calcium, Potassium and Sodium

Effluent sample 20 ml was taken in clean 50 ml beaker. The flame photometer was switched on, the flame was ignited and a proper ratio of fuel gas and compressed air was maintained. The instrument was standardized by passing ion free distilled water through the atomiser and the galvanometer reading was set to zero. The atomiser was then fed with 10ppm K solution and the galvanometer reading was adjusted to 100. Once calibrated, each unit reading of galvanometer will be equivalent to 0.1ppm of K. The filtered effluent sample was atomised and burned inflame to estimate the quantity of potassium in the sample.

The same procedure was followed for estimating calcium and sodium by replacing the standard with CA and Na solutions respectively.

Estimation of Heavy metals Iron, Magnesium

Sample were estimated for chromium and iron using atomic absorption spectrophotometer. A shimadzu type Atomic Absorption Spectrophotometer (AAS) 6300 model with Air-C_2H_2 flame type of an average fuel glow rate of between 0.8-4.0$Lmin^{-1}$ and support gas flow rate between 13.5-17.50$Lmin^{-1}$ was used for sample analysis and operated as per the equipment manual. The single element hollow cathode laps for respective metals were of Hamamatsu photonic co.Ltd-L24 33 series. The atomic absorption analysis standards for the given elements were purchased from inorganic ventures Inc. and Sisco Research Laboratories Ltd. Calibration curves for various elements obtained from these standards were of first order reaction. The sample for Iron (Fe) analyses were aspirated with the help of an Automatic sampler for Atomic Absorption Spectrophotometer measurements. Series of reference standards-1, 2 and 3 ppm for the two metals were prepared from the purchased stock solution. The standards were prepared by pipetting 0.1, 0.2 and 0.3 ml respectively of the automatic sampler for standard calibration curve measurement. Percentage recovery rates of metals ranged from 94.8 to 102.3%. The samples were finally injected into the flame AAS and the reading were directly measured in computer.

Estimation of Manganese

The effluent sample was mixed with 5 ml concentrated Nitric acid (HNO_3) and 5 ml of Phosphoric acid (H_3PO_4) were added and till the mixture reduced to 90 ml. After cooling 0.3 gm of Potassium periodate (KIO_4) were added and subsequently boiled for one hour, cooled and diluted to 100ml, with ion free distilled water, free from reducing agents. A calibration curve was prepared using standard solutions containing 0.5 to 50 up to 150 mg.

Estimation of Free ions

Estimation of Nitrate

Filtered effluent sample of 250ml were taken in a kjeldahl flask fitted with the distillation set and condenser. Exactly 20ml of 4 percent boric acid (H_3BO_3) were taken in a 250ml conical flask, and placed below the outlet of the condenser so that the tip of the outlet dips in to the H_3BO_3 solution. 10ml of 40 per cent Sodium hydroxide (NaoH) were added in to the kieldahl flask and the condenser was fitted immediately. Distillation was carried out till about

40ml of distillate is accumulated in the receiving flask containing H_3BO_3. Heating was stopped and the conical flask was taken out. The distillate was titrated with 00.02 NH_2So_4 till the pinkish colour appeared.

Estimation of Chloride (Cl)

10ml of standard Sodium Chloride (NaCl) solution in a porcelain basin and ion-free distilled water was added to make the volume around 100ml. Then 0.5ml of Potassium chromate (K_2CrO_4) was added and the solution was titrated against 0.1N Silver nitrate ($AgNO_3$), till red precipitate of silver chromate ($Ag_2CrO_{4)}$ appears. From the amount of 0.1N $AgNO_3$ chloride content was calculated.

Estimation of Fluoride

about 5ml of acid-ziconium reagent were pipette out into each of the 100ml. Nessler tube containing 0.0, 1.0, 2.0 to 8.0 to 14.0ml of standard Sodium Fluoride (NaF) solution. The effluent samples were treated with zirconium reagent and the fluoride concentration with standards.

Add the mixed acidified solution (from A) to the 1.0 liter flask containing clear Zirconium-Alizarin solution (from B) and make up to 1 liter mark with distilled water. Within an hour, the solution turns to yellow from red and is ready for use. the solution was kept away from the sunlight.

Estimation of Sulfate

Various volumes of 0.5ml, 1.0l, 2.5ml, 0.5ml and 10.0ml of 50 ppm standard SO_4 solution were separately taken in 25ml volumetric flasks and ion free double dilled water was added, whenever required to make the total volume around 10ml. Then add 1ml volume of gum acacia and 1 g of Barium chloride ($BaCl_2$) powder were added to each volumetric flask with distilled water. The contents were mixed thoroughly. The absorbance of the contents of each flask was read in a double beam spectrophotometer at 440nm and a standard curve for sulfate was prepared. The sulfate content of the effluent was estimated by following the same procedure and the sulfate content was estimated by referring to the standard graph.

Estimation of Phosphate

About 10ml of the effluent were taken in a 25ml volumetric flask and adequate amount of ion-free double distilled water to each flask followed by 5ml of ascorbic acid molybdate mixture. The volume was made up to 25ml and the extinction developed blue colour was read in a spectrophotometer at a wavelength of 660nm.

III. RESULTS AND DISCUSSION

The result up the study recorded physico-chemical characteristics of potable well water from the four taluks of Kanyakumari District. The physical parameters include Turbidity, Total Dissolved Solids (TDS), Electrical Conductivity. The chemical parameters pH, total alkalinity, total hardness, alkali and heavy metals include calcium, magnesium, sodium, potassium, iron, manganese. Free ions nitrate, chloride, Fluoride, Sulfate and Phosphate.

Physical parameters

Turbidity

The term 'turbidity' commonly used to describe the optical clarity of fluid. In addition, it is the optical clarity of water. The amount of suspended particulates dissolved inorganic chemical species, organic matter content and temperature together impact the body of water (Kitchener et al. 2017). The use turbidity measurement is a surrogate relative indicator of suspended sediment concentration (SSC) or total suspended solids (TSS). This reduces the visual range in water as a result affecting the ability of predator to hunt its prey and photosynthesis (Liu et al 2018, Kitchener et al. 2017). Turbidity can also reflect the chlorophyll, organic matter, microorganisms etc, (Maksimovich et al, 2015, Liu et al 2018). According to WHO (1984) assessed 5 NTU as guideline value and preferably <1 NTU for disinfection efficiency. Increased turbidity reduces the acceptability of water. Most of the consumer correlate turbidity with safety and consider them as unsafe (WHO, 2022). Although most particles that contribute to turbidity have no health significance. In the present study the nephelometric turbidity units were lowest at Thovalai (8 UT Units) and highest in Vilanvancode (18 UT Units). None of the samples were within permissible limits of 5 NTU by WHO (Table 1).

Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) is the term refers to describe the inorganic salts and small amounts of organic matter present in solution in water (WHO, 1996). The principal constituents are usually calcium, magnesium, sodium, and potassium cations and carbonate, hydrogen carbonate, chloride, sulfate, and nitrate anions (WHO 1984, WHO 1996). According to WHO (1984) based on the taste consideration 1000mg/l as guideline has been proposed for TDS. However, less than 600mg/l considered being good when the limit exceeds 1000mg/l unpalatable (WHO 2022). There is negative or positive effect of TDS has not been considered so for. The test is considered to be general quality test. All the taluks of kanyakumari were palatable and TDS recorded were Thovalai 131 mg/l, Agastheeswaram (394 mg/l), Vilanvancode (104 mg/l) and Kalkulam 322 mg/l (Table 1).

Electrical Conductivity

The ability of water to conduct an electric current is called electrical conductivity of water. There are positively changed ions such as sodium, potassium, calcium, and magnesium as well as negatively changed ions chloride, carbonate, sulfate, and bicarbonate. Ions such as nitrates and phosphates are biologically important they are being minor contributors to conductivity. Pure water is not a good conductor of electricity since electrical current is transported through with the rise of concentration ions conductivity increases. Hence conductivity increases as water dissolves more ionic species. Solutions of most inorganic compounds are relatively behaved as good conductors reciprocally organic compounds conduct a current very poorly (APHA, 2017).

Kumar and Sinha (2010) pointed out that electrical conductivity had significant correlation with ten parameters such as temperature, pH value, alkalinity, total hardness, calcium, total solids, total dissolved solids, chemical oxygen demand, chloride and iron concentration of water

Hitherto, no guideline value was recommended by WHO, ISI (Kumar and Puri, 2012).

EC measurement is an excellent indicator of TDS, which is a measure of salinity that affects the taste of potable water (Werkneh et al. 2015). It has linear relationship with total dissolved solids (Pal et al. 2015) and dependent on temperature (Nayer et al. 2020). The conductivity of water in the study sites were Vilavancode 158 mho/cm, Thovalai 198 mho/cm, Kalkulam 322 mho/cm and Agastheeswaram (598 Micro mho/cm). This result clearly indicates that in Agastheeswarm taluk water in study areas was considerably ionized and has the higher level of ionic concentration activity due to excessive dissolve solids (Table 1).

Chemical Parameters

pH

pH of water refers to hydrogen ion concentration. The pH value range between 0 and 14 and the mean value 7 considered neutral less than and more than 7 acidic and basic in property respectively. Based on the value the solution is termed acidic or alkaline. Lower value of pH approximately 7 or less is acidic and more likely to be corrosive in nature. The guideline value set by WHO (1984) is between 6.5 and 8.5. However no health based guideline was promised by WHO. Generally pH is considered operational water quality parameter and hitherto no direct impact on consumers recorded WHO (2022). The pH of water sample shows Kalkulam 6.01, Thovalai 6.33, Vilavancode 6.98 and Agastheeswaram 7.14. All the samples were within the limits of WHO (Table 1).

Alkalinity

Alkalinity is standard method for water quality measurements. In the present study total alkalinity test was carried out. There are two different concepts Carbonate Alkalinity and Total Alkalinity concepts are found in literature (Dickson 1981, Zhu and Anderson 2002, Michałowski and Asuero 2012). The total alkalinity to refer to the general case in which all ions which affect the titration are included where as carbonate alkalinity

refer to carbonate and bicarbonate ions are neutralized (Zhu and Anderson 2002). In simple way alkalinity is the capacity to neutralize acid (Mohsin et al 2013). The WHO (1984) standards tell the alkalinity only in terms of total dissolved solids (TDS) of 500 mg/l is good. However, excessive quantities above the level may cause unpalatable to human and cause scaling of water pipes. In study sites, results show that alkalinity ranges from 60 to 264 (mg/l). Thus, these values were under the permissible limit of WHO standards (Table 1). The alkalinity of water sample from the different taluks ranged from 20 mg/l (Vilavancode) to 232 mg/l (Agastheeswaram).

Total Hardness

The hardness of water is defined as the amount of calcium and magnesium concentrations and is a measure of the capacity of water to precipitate soap (Patil et al., 2012). It is often measured as calcium carbonate (CaCO3) because it consists mainly calcium and carbonates the most dissolved ions in hard water. Hard water is characterized with high mineral contents that are usually not harmful for humans (Mohsin et al. 2013). According to WHO (2022) reports consumers tolerate the hardness of water level up to 500 mg/l. But, harness below 100 mg/l cause low buffering capacity and may cause corrosion in water pipes whereas above 200mg/l may cause scale deposition in treatment works, distribution system, pipe works and tanks within buildings. However, health-based guideline value of 500 mg/l is set so for by WHO (1984). In the present study all the water samples were minimum hardness was recorded viz. none of them Vilavancode 40 mg/l, Thovalai 44 mg/l, Kalkulam 116 mg/l and Agastheeswarm 164 mg/l (Table 1).

Alkali and Heavy metals

Calcium (Ca)

Calcium is necessary in plant and animal nutrition and is an fundamental component of bones, shells, and plant structures. Calcium is fifth most abundant element 4.9 % on the earth crust (APHA, 2017). About 95% calcium in human body stored in bones and teeth. The high deficiency of calcium in humans may caused rickets, poor blood clotting, bones fracture etc. and the exceeding limit of calcium produced cardiovascular diseases (Mohsin et al. 2013). They are commonly found in the form of calcium (calcium carbonate) and dolomite (calcium magnesium carbonate). Calcium carbonate solubility is controlled by pH and dissolved CO2 (APHA, 2017). The hardness of drinking water is largely contributed by calcium and magnesium (Rosenlund et al, 2005). Therefore, no guideline value set for calcium and magnesium (WHO, 1984). WHO (2022) elucidate that the drinking-water can be a contributor to calcium and magnesium intake and could be important for those who are marginal for calcium and magnesium. However, there is no minimum concentration in drinking water was set WHO (2009). The results of present study shows that calcium was highest in Agastheeswarm 42mg/l followed by Kalkulam 26 mg/l, Thovalai 13mg/l and Vilavancode 11mg/l (Table 1).

Magnesium (Mg)

The element occurs in most of the water along with calcium at lower ratio. They found in average abundance of 2.1 % in earth crust in soil 0.03 to 0.84% and in streams and waterbodies 4mg/l and 5 mg/l respectively (APHA, 2017). It is an essential for proper functioning of living organisms and non-toxic at the concentrations generally met with in natural waters (Mohsin et al 2013, Nayer 2020). WHO (2009) recommends dietary intake of 350 mg/day magnesium for adult human beings. However, for drinking water even minimum concentration of magnesium was not set. Since it is one of the contributors of hardness of water guideline value was set for magnesium (WHO, 1984). Rosenlund et al (2005) stated that the decreased risk for cardiovascular disease has been related particularly high levels of magnesium in drinking water. The Magnesium of water sample was the lowest at Thovalai and Vilavancode (3 mg/l) and highest in Agastheeswaram (14mg/l) (Table 1).

Sodium (Na)

Sodium element is about occupies 2.5% earth crust and found in soil 0.02 to 0.62. In ground and stream water it is 5mg and 6.3mg per liter (APHA 2017). Sodium compounds are used in many applications, including caustic soda, salt, fertilizers, and water treatment chemicals. Mohsin et al (2013) stated that proper quantity of sodium in human body prevents many diseases like kidney damages, hypertension, headache etc. Soil permeability can be decreased due to high sodium ratio. Sodium salts in the form of sodium chloride are found in daily intake of foods and in drinking water. Guideline value set by the WHO (1984) 200 mg/l when it exceeds more than 200mg/l may change the palatability of food and water (WHO, 2022). In the study none of the colleges exceeds more than 200mg/l. Yet very low value of 29mg/l was recorded in Vilavancode (17mg/l) and high in Kalkulam (49 mg/l) (Table 1).

Potassium (K)

Potassium or Kallium (in latin) is essential for living organisms and plants. Earth crust composed of about 1.84% and in soil sample ranged from 0.1 to 2.6 %l. Likewise, in streams it is 2.3mg/l and ground water ranged from 0.5 to 10 mg/l (APHA, 2017). About 110 to 140 gram of potassium found in the human body (Mohsin et al., 2013) and functions like heart protection, regulation of blood pressure, protein dissolution, muscle contraction, nerve stimulus are regulated. The recommended daily requirement is greater than 3000 mg (WHO, 2022). According to WHO (2022) potassium level found in drinking water at the concentrations well below those of health concern. In the present study, The Potassium of water sample was the lowest at Vilavancode (3 mg/l) and highest in Agastheeswaram (11mg/l) (Table 1).

Iron (Fe)

Anaerobic groundwater may contain ferrous iron at concentrations up to several milligrams per litre without discoloration or turbidity in the water when directly pumped from a well. When it is exposed to atmosphere, however, the ferrous iron oxidizes to ferric iron, giving an objectionable reddish-brown colour to the water (WHO, 2022). Iron also promotes the growth of iron bacteria, which oxidizes ferrous iron to ferric iron and in the process deposit a slimy coating on the piping. These iron bacteria in open undisturbed water bodies and in condition devoid of dissolved oxygen produce iridescent film or scum (Thompson, 1946). The permissible limit set for Iron 0.3mg/l by WHO (1984). At levels above 0.3 mg/l, iron stains laundry and plumbing fixtures. There is usually no noticeable taste at iron concentrations below 0.3 mg/l, although turbidity and colour may develop. The Iron content of water samples from various taluks of Kanyakumari district were lowest at Thovalai (0.94 mg/l) and highest in Vilavancode (1.88mg/l). These values were within the permissible limits of WHO standards (Table 1).

Manganese (Mn)

According to WHO (1984) manganese guideline value 0.1 mg/l for drinking water based on the staining property. However in the present study, manganese found 0.14 mg in Vilavancode and Kalkulam taluks where as Thovalai and Agastheeswaram it was below detectable level (Table 1).

Free ions

Nitrate (NO^-_3)

Nitrate (NO^-_3) is found naturally in the environment and is an important plant nutrient. It is present at varying concentrations in all plants and is a part of the nitrogen cycle. Nitrate can reach both surface water and groundwater as a result of agricultural activity (by means of fertilizers and manures) and anthropogenic activities (Savci et al 2012, WHO 2022). In surface water nitrate can change surface runoff fertilizer, exploitation by phytoplankton and denitrification bacteria whereas ground water concentration show comparatively slow and low. Although, nitrate is available form of dissolved nitrogen in groundwater. However, it can also be in the form of nitrite (NO2-), nitrogen (N2), nitrogen oxide (N2O) and organic nitrogen. It is possible to examine the toxicological effects of nitrate in three stages. The toxicological effects of nitrogen have been addressed by Savci et al (2012). When it exceeds 50 mg/l cause inflammation in digestive and urinary system. WHO (1984) 1.5 mg/l concentration recommended for guideline value. The Nitrate content of water of sampled from different taluks ranged from 2mg/l (Vilavancode) to 6 mg/l (Agastheeswaram). Consumption of vegetables and meat are the sources of exposure to nitrate and nitrite (Table 1).

Chloride (Cl^-)

High concentration tastes salty. WHO (1984) 250mg/l was set as guideline value for chloride content in water. Concentration above the limit can be detected by taste, frequent consumption consumer get accustomed to even low levels of chloride induced taste. The Chloride of water sample from the different taluks ranged from 28 mg/l (Vilavancode) to 92 mg/l (Kalkulam) (Table 1).

Fluoride (F^-)

Fluoride is common element available in earth crust. They found in all water with its highest concentration in ground waters. Due to continuous erosion in the mountains fluoride is removed and transferred to lower plateau through streams and river to the sea. Owing to the reason, high mountain areas are low fluoride and sea being the high fluoride content. In addition, foot of high mountains hills and in areas with geological deposits of marine origin usually high fluoride content were observed in many parts of the world India is not an exception (WHO, 1986). Fluoride is absorbed by vegetation from soil and water. For protection against dental caries some countries add fluoride with water or table salt. WHO (2022) recommend 1.5mg/l as guideline value in drinking water. Among the sampled areas only Thovalai had 0.2mg/l rest of them viz. Agastheeswaram, Vilavancode, Kalkulam had 0.4mg/l. Well water may contain 10 mg/l. Including India high concentration of fluoride found most of the parts in the world (Table 1).

Sulfate (SO_4^{2}-)

Sulfate is widely distributed in natural waters in concentrations ranging from a few to several thousand milligrams per liter. Sulfates have little effect on taste. WHO (1984) reported 400mg/l based on the taste consideration. However no major negative impact on human beings have been reported (Mousin et al 2013). In the present study the estimated value of sulfate concentration ranged from 9 (Thovalai) to 19 (Kalkulam) (Table 1).

Phosphate (PO_4^{3-})

Phosphorus is essential for the growth of plants and animals. Phosphorus occurs in natural waters and in wastewaters almost solely as phosphates. These are classified as orthophosphates, condensed phosphates and organically bound phosphates. Non-organic fertilizers contain phosphates. Small amounts of orthophosphate or certain condensed phosphates are added to some water supplies during treatment and used in larger quantities for laundering or other cleaning. Orthophosphates applied to cultivated land as fertilizers are carried into surface waters. Organic phosphates are formed primarily by biological processes. The amount of phosphate may increase in drinking water and other water bodies such as ponds, rivers as a result of transport of phosphorus fertilizer from agriculture and animal husbandry (Vasudevan et al 2008, Savci et al 2012). The Phosphate of water sample from the different taluks ranged from 0.03 mg/l (Thovalai) to 0.20 mg/l (Kalkulam) (Table 1).

Table 1. Physico-chemical parameters Thovalai, Agastheeswarm, Vilavancode and Kalkulam taluks of Kanyakumari District, Tamil Nadu, India

Parameters	Thovalai	Agastheeswarm	Vilavancode	Kalkulam
Physical				
Turbidity (NTU)	8	9	18	17
TDS mg/l	131	394	104	322
Electrical Conductivity mho/cm	198	598	158	322
Chemical				
pH	6.33	7.14	6.98	6.01
Total Alklalinity mg/l	40	232	20	80
Total Hardness mg/l	44	164	40	116
Alkali and Heavy Metals				
Calcium mg/l	13	42	11	26
Magnesium mg/l	3	14	3	12
Sodium mg/l	19	46	17	49
Potassium mg/l	4	11	3	7
Iron	0.94	1.06	1.88	1.76
Manganese	0	0	0.14	0.14
Free Ions				
Nitrate mg/l	4	6	2	3
Chloride mg/l	32	40	28	92

Fluoride mg/l	0.2	0.4	0.4	0.4
Sulfate mg/l	9	13	11	19
Phosphate mg/l	0.03	0.1	0.15	0.2

IV. CONCLUSION

The physico-chemical characteristics of potable drinking water samples from tube wells of the four different taluks of Kanyakumari District were analysed to check the quality of drinking water. Physical characteristics like turbidity, total dissolved solids, electrical conductivity, chemical factors like pH, alkalinity as $CaCO_3$ (mg/l), total hardness as $CaCO_3$ (mg/l), alkali and heavy metals like calcium, magnesium, sodium, potassium, iron, manganese, and free ions such as nitrate, fluoride, sulfate, phosphate were analysed following standard methods of APHA.

All the physico-chemical characteristics were well within the permissible and allowed limits. Values of parameters studied ranged were Tubidity 8-18 NTU, followed by Total Dissolved Solids 104-394 mg/l, Electrical Conductivity 158-198 µS/cm, pH 6.01 - 7.14,Total Alkalinity 20-232 mg/l, Total Hardness 40-164 mg/l, Calcium 11-42 mg/l, Magnesium 3-14 mg/l, Sodium 17-49, Potassium, iron 0.94-1.88 mg/l, Manganese 0.0-0.14 mg/l, Nitrate 2-6 mg/l, Chloride 28-92 mg/l, Fluoride 0.2-0.4 mg/l, Sulfate 9-19 mg/l, 3-11mg/l, Phosphate 0.03-0.20 mg/l. However, turbidity values measured in the four taluks Thovalai 8 NTU, Agastheeswarm 9 NTU, Kalkulam 17 NTU, and Vilavancode 18 NTU these results were higher than the WHO standards of 5 NTU. Excluding turbidity the quality of ground water is highly acceptable in almost all taluks of Kanyakumari District.

Monitoring the drinking water quality is essential for determination of current status of hydrological condition of water. This will help us to avoid pollution contamination and undesirable diseases. Protecting natural resources of water and checking for standards is generally good for human beings and domestic and wildlife.

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REFERENCES

1. American Public Health Association, & American Water Works Association. (2017). Standard methods for the examination of water and wastewater. In *Standard methods for the examination of water and wastewater*.
2. Dickson, A. G. (1981). An exact definition of total alkalinity and a procedure for the estimation of alkalinity and total inorganic carbon from titration data. *Deep Sea Research Part A. Oceanographic Research Papers*, *28*(6), 609-623.
3. Fairservis, W. A. (1961). The Harappan civilization: new evidence and more theory. American Museum novitates; no. 2055.
4. Gujja, B., Joy, K. J., & Paranjape, S. (2010). Babhli water conflict: Less water, more politics. Economic and Political Weekly, 12-15.

5. Iyer, R. R. (2011). Mullaperiyar: A Plea for Sanity. Economic & Political Weekly, 46(51), 13.
6. Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B. B., & Beeregowda, K. N. (2014). Toxicity, mechanism and health effects of some heavy metals. Interdisciplinary toxicology, 7(2), 60.
7. Järup, L. (2003). Hazards of heavy metal contamination. *British medical bulletin*, *68*(1), 167-182.
8. Khan, S. M. N., & Kumar, A. R. (2013). Geogenic assessment of water quality index for the groundwater in Tiruchengode Taluk, Namakkal District, Tamilnadu, India. Chemical Science Transactions, 2(3), 1021-1027.
9. Kitchener, B. G., Wainwright, J., & Parsons, A. J. (2017). A review of the principles of turbidity measurement. Progress in Physical Geography, 41(5), 620-642.
10. Kleiner, S. M. (1999). Water: an essential but overlooked nutrient. Journal of the American Dietetic Association, 99(2), 200-206.
11. Kumar, M., & Puri, A. (2012). A review of permissible limits of drinking water. *Indian journal of occupational and environmental medicine*, *16*(1), 40.
12. Kumar, N., & Sinha, D. K. (2010). Drinking water quality management through correlation studies among various physico-chemical parameters: A case study. *International journal of environmental sciences*, *1*(2), 253.
13. Kumar, R., Singh, R. D., & Sharma, K. D. (2005). Water resources of India. Current science, 794-811.
14. Liu, Y., Chen, Y., & Fang, X. (2018). A review of turbidity detection based on computer vision. IEEE access, 6, 60586-60604.
15. Maksimovich, N. G., Khmurchik, V. T., & Demenev, A. D. (2016). The role of microorganisms in elevating the turbidity of dam seepage water. Power Technology and Engineering, 50(1), 6-8.
16. Michałowski, T., & Asuero, A. G. (2012). New approaches in modeling carbonate alkalinity and total alkalinity. Critical Reviews in Analytical Chemistry, 42(3), 220-244.
17. Moe, C. L., & Rheingans, R. D. (2006). Global challenges in water, sanitation and health. Journal of water and health, 4(S1), 41-57.
18. Mohsin, M., Safdar, S., Asghar, F., & Jamal, F. (2013). Assessment of drinking water quality and its impact on residents health in Bahawalpur city. International Journal of Humanities and Social Science, 3(15), 114-128.
19. Nayar, R. (2020). Assessment of water quality index and monitoring of pollutants by physico-chemical analysis in water bodies: a review. International Journal of Engineering Research and Technology, 9(01).
20. Pal, M., Samal, N. R., Roy, P. K., & Roy, M. B. (2015). Electrical conductivity of lake water as environmental monitoring–A case study of Rudrasagar Lake. Journal of Environmental Science, Toxicology and Food Technology, 9(3), 66-71.
21. Patil, P. N., Sawant, D. V., & Deshmukh, R. N. (2012). Physico-chemical parameters for testing of water-a review. International journal of environmental sciences, 3(3), 1194.
22. Rosenlund, M., Berglina, N., Hallqvist, J., Bellander, T., & Bluhm, G. (2005). Daily intake of magnesium and calcium from drinking water in relation to myocardial infarction. *Epidemiology*, 570-576.

23. Savci, S. (2012). Investigation of effect of chemical fertilizers on environment. Apcbee Procedia, 1, 287-292.
24. Thamilarasu, P., & Sharmila, R. (2015). Physico-Chemical Characteristics Of Groundwater Analysis In Namakkal District Of Tamilnadu State. Rasayan J. Chem..[Online], 8(1), 92-97.
25. Thatheyus, A. J., Dhanaseeli, D. P., & Vanitha, P. (2013). Inter-State Dispute over Water and Safety in India: The Mullaperiyar Dam, a Historical Perspective. American Journal of Water Resources, 1(2), 10-19.
26. Thomson, R. M. (1946). Studies on the breeding places and control of Anopheles gambiae and A. gambiae var. melas in coastal districts of Sierra Leone. Bulletin of entomological Research, 36(2), 185-252.
27. Vasudevan, S., Sozhan, G., Ravichandran, S., Jayaraj, J., Lakshmi, J., & Sheela, M. (2008). Studies on the removal of phosphate from drinking water by electrocoagulation process. Industrial & Engineering Chemistry Research, 47(6), 2018-2023.
28. Vaverková, M. D., Maxianová, A., Winkler, J., Adamcová, D., & Podlasek, A. (2019). Environmental consequences and the role of illegal waste dumps and their impact on land degradation. Land Use Policy, 89, 104234.
29. Werkneh, A. A., Medhanit, B. Z., Abay, A. K., & Damte, J. Y. (2015). Physico-chemical analysis of drinking water quality at Jigjiga City, Ethiopia. American Journal of Environmental Protection, 4(1), 29-32.
30. WHO. (1984). Guidelines for drinking-water quality: volume 1: recommendations. World Health Organization.
31. WHO. (1986). Appropriate use of fluorides for human health. World Health Organization.
32. WHO & International Programme on Chemical Safety. (1996). Guidelines for drinking-water quality. Vol. 2, Health criteria and other supporting information, 2nd ed. World Health Organization
33. WHO. (2003). Domestic water quantity, service level and health.
34. WHO (2009) Cotruvo J, Bartram J, eds. Calcium and Magnesium in Drinking-water : Public health significance, Geneva.
35. WHO (2022) World Health Organization. "Guidelines for drinking-water quality: incorporating first and second addenda.
36. Zhu, C., Anderson, G., & Burden, D. S. (2002). *Environmental applications of geochemical modeling*. Cambridge University Press.
37. Zhang, Q., & Wang, C. (2020). Natural and human factors affect the distribution of soil heavy metal pollution: a review. *Water, air, & soil pollution, 231*(7), 1-13.

AUTHOR

M.P. Jeyasekhar, Associate Professor, Scott Christian College, Nagercoil and jeyasekhar24@yahoo.com