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Assessment of Seasonal Variation on Physicochemical and Microbiological Quality of Drinking Water at Mannuthy, Kerala

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ABSTRACT

A study was conducted to assess seasonal variation in physicochemical and microbiological quality of drinking water at Mannuthy in Thrissur district of Kerala state. A total of 100 well water samples, 25 each during four different seasons, viz. summer, pre-monsoon, monsoon and post monsoon were collected during the year 2009 and analyzed for temperature, pH, total hardness, Chemical Oxygen Demand, concentration of nitrate, fluoride, iron, heavy metals like lead, mercury, zinc, cadmium, Aerobic Plate Count, Coliform count, *Escherichia coli* and Enterococcal counts. Significant difference between seasons could be observed in all parameters studied except Chemical Oxygen Demand, concentration of mercury and *Escherichia coli* and enterococcal counts. The results were compared with WHO guidelines, 2006 and Bureau of Indian Standards (IS: 10500, 1991) desirable limits for drinking water.

Key words: seasonal variation, physico- chemical, microbiological, quality, drinking water.

INTRODUCTION

Water is most essential commodity for existence of life and is one of the most important renewable resources. Various physico- chemical parameters have a significant role in determining potability of water. Water intended for human consumption must be free from harmful microorgaisms, toxic substances, excessive amount of minerals and organic matter. As per World Health Organization (WHO), safe and wholesome drinking water is a basic need for human development, health and well being, and it is an internationally accepted human right [28].

Due to continuous population growth, demand for fresh water has increased rapidly. Groundwater is believed to be cleaner and free from pollution than surface water. Groundwater quality is a function of natural processes as well as anthropogenic activities. Application of uncontrolled fertilizers and manure is one of the main sources of groundwater pollution, especially in developing countries. The modern civilization, urbanization, prolonged discharge of industrial effluents, domestic sewage and solid waste dump also add to groundwater pollution, causing adverse health effects in human beings and animals. Quantitative parameters such as capacity of the source of water and qualitative parameters are affected also by climatic conditions, particularly temperature and precipitation which vary throughout the year. Considering all these facts the study was conducted to assess seasonal variation in physico- chemical and microbiological quality of drinking water at Mannuthy, Kerala.

MATERIALS AND METHODS

A total of 100 well water samples, 25 each during four different seasons of the year viz. summer (February), pre-monsoon (March-May), monsoon (June-September) and post monsoon (October-November) during the year 2009, were collected from Mannuthy in Thrissur district. The area is located between north latitudes 10° 10´ and 10° 46´ and east longitudes 75° 57´ and 76° 54´. Soil type of this area is laterite soil. Samples were analyzed for physical parameters like temperature and pH, chemical parameters like total hardness, Chemical Oxygen Demand (COD), nitrate, fluoride, iron and heavy metals like lead, mercury, zinc and cadmium and microbiological parameters like Aerobic Plate Count (APC), Coliform count (CC), *Escherichia coli* (ECC) and Enterococcal counts (EC).

Wells were randomly selected from the area which is falling within 2.5 km radius of institution where the study was carried out. Samples for analysis were taken directly from wells in sterile glass bottles of 250 millilitre capacity, after rinsing the bottles three times with water. In order to collect the samples directly from well, bottle with a string attached to neck was used. Another long clean string was tied to the end of sterile string and the bottle was lowered into the water and allowed to fill up. Then the bottle was raised and stoppered. The collected samples were transported to laboratory in ice within an insulated container and analyzed within 24 hours of collection.
Temperature and pH of each sample was measured using mercury filled glass thermometer and digital pH meter respectively [4].

Total hardness of the samples was estimated using Total hardness test kit (Hi-media, India). Measurement of COD was made photometrically in Spectroquant NOVA 60 (Merck, Germany) after digesting the samples in preheated Thermoreactor TR 320 (Merck, Germany). Concentration of nitrate, fluoride, iron, lead and mercury in water samples was measured photometrically in Spectroquant NOVA 60 (Merck, Germany) and expressed in mg/l. Estimation of zinc and cadmium was carried out using Atomic Absorption Spectrophotometer [14].

APC of each sample was estimated by pour plate technique [21]. CC, ECC and EC per millilitre of sample were estimated by spread plate technique [12], [9] and all the counts were expressed as $\log_{10}$ cfu/ millilitre.

Statistical Analysis

Analysis of variance (ANOVA) was done for comparing the data [25] using SPSS package (version 10).

RESULTS AND DISCUSSION

Mean temperature ranged from 26.32±0.01 to 28.68±0.26, and showed significant difference between seasons. Lowest temperature was recorded during monsoon and highest temperature was recorded during summer which was in accordance with ambient temperature pattern [2, 11].

Mean pH ranged from 4.58±0.04 to 5.95±0.08, and was higher during monsoon and post monsoon and lower during summer and pre-monsoon seasons. Higher pH values during rainy season could be due to high photosynthesis of micro and macro vegetation resulting in production of high CO_2, shifting the equilibrium towards alkaline side. This could be attributed to the presence of luxuriant vegetation inside most of the wells during rainy season. Acidic pH of water may be due to dissolved carbon dioxide and organic acids such as fulvic and humic acids, which are derived from the decay and subsequent leaching of plant materials [15]. During dry seasons, there may be death and decay of plants due to lack of sufficient water which increases the organic acid content of water, in turn causing acidity. In addition great reduction in water volume in the wells also decreases the pH during dry season [19]. Acceptable range of pH for drinking water is 6.5-8.5 (IS: 10500, 1991). In the present investigation well water samples were not within acceptable range throughout the study. Low pH of groundwater can cause gastrointestinal disorders especially hyperacidity, ulcers and burning sensation. Water with pH below 6.5, causes corrosion of metal, pipes, resulting in release of toxic metals such as zinc, lead, cadmium, copper etc. Higher values of pH hasten the scale formation in water heating apparatus and also decrease the germicidal potential of chlorine. High pH induces the formation of trihalomethanes, which are toxic and carcinogenic [17]. They are formed in drinking water primarily as a result of chlorination of organic matter present in water [34].

Mean total hardness was in the range of 11.00±0.50-15.60±0.78 mg/l, and highest value was observed during monsoon. It could be due to the leaching of sulphates and carbonates during monsoon season to well water. Desirable limit for total hardness in drinking water as per Bureau of Indian Standards IS: 10500, 1991, is 300 mg/l. Mean total hardness of water was within this limit throughout the study. Hardness is the property of water which prevents the lather formation with soap and increases the boiling point of water. Water having hardness below 300 mg/l is considered potable but beyond this limit produces gastrointestinal irritation. Extremely hard water may lead to increased incidences of urolithiasis. Studies have shown that there is statistically significant negative correlation between water hardness and cardiovascular diseases [32]. Hard water also deposits incrustation in kitchen utensils as well as increases soap consumption. Such water can thus be both nuisance and economic burden to the consumer.

Higher values of COD indicate presence of oxidizable organic matter [8]. The entry of sewage water and the agricultural runoff might be responsible for increased level oxidizable organic matter [29]. Highest and lowest COD were observed during post monsoon and pre monsoon, respectively. The entry of sewage water and the agricultural runoff might be responsible for increased level of COD during post monsoon.

Seasonal variation of nitrate is mostly caused by plant growth and decay [6]. Mean nitrate concentration was lowest during summer and highest during post monsoon (table 2). The highest concentration during post monsoon might be due to application of nitrogenous fertilizers to agricultural land during rainy season and subsequent seepage through soil. The observed values were within WHO guidelines 2006 for nitrate in drinking water (50 mg/l) and the Bureau of Indian Standards (IS: 10500, 1991) desirable limit (45 mg/l) throughout the study. However, nitrate detected in well water samples might have originated from decaying organic matter [31], discharge of sewage and runoff from agricultural fields containing nitrate fertilizers [13]. Nitrate in drinking water as such are not toxic to health and about 85 per cent of ingested nitrate are rapidly adsorbed from gastrointestinal tract in healthy individuals and excreted by kidney. When nitrates are converted to nitrites toxic effects are encountered leading to potential health hazards. Higher level of nitrate may cause methaemoglobinemia or blue- baby syndrome in infants, in which blood loses its ability to carry sufficient oxygen. It may also be carcinogenic in adults. Nitrate may also react with creatinine present in vertebrate muscles to form nitrosarcosine which is carcinogenic [28].

Negligible concentration of fluoride observed in well water might have derived from what was present in the earth's crust. Minimum fluoride concentration observed during monsoon and post monsoon might be due the availability of large volume of water leading to dilution of chemicals present. Higher concentration during summer and pre-monsoon could be due to depletion of water leading to the concentration effect [4].The observed values were within WHO guidelines (2006) for fluoride in drinking water (1.5 mg/l) and Bureau of Indian Standards (IS: 10500, 1991) desirable limit (1 mg/l) during four seasons. Fluoride is present universally in almost every water, earth crust, minerals, rock etc. It is also present in toothpaste, drugs, cosmetics, mouth wash etc. A small amount of fluoride is beneficial for human health to prevent dental caries. However when consumed in higher doses (>1.5 mg/l) it leads to dental fluorosis or mottled enamel and excessively high concentration (>3 mg/l) of fluoride may lead to skeletal fluorosis. Crippling skeletal fluorosis can occur in water supply containing more than 10 mg/l of fluoride. In India an estimated 62 million people, including 6 million children suffer from fluorosis because of consuming fluoride contaminated water [25].

Table-1: Physical quality of well water samples

	Seasons			
Parameter	Summer	Pre-monsoon	Monsoon	Post monsoon
Temperature	28.68 ± 0.26^{c}	27.50 ± 0.13^{b}	26.32 ± 0.01^{a}	28.52 ± 0.13^{c}
pH	4.98 ± 0.07^{b}	4.58 ± 0.04^{a}	5.19 ± 0.06^{c}	5.95 ± 0.08^{d}

Mean values in a row bearing different superscripts differ significantly ($p<0.05$), N= 25 in each group

Table-2: Chemical quality of well water samples

	Mean concentration during four seasons, mg/l			
Parameter	Summer	Pre-monsoon	Monsoon	Post monsoon
Total hardness	11.00 ± 0.50^{a}	13.33 ± 0.49^{b}	15.60 ± 0.78^{c}	13.40 ± 0.63^{b}
COD	95 ± 7.30	79.67 ± 2.71	90.60 ± 6.29	106.48 ± 3.80
Nitrate	3.35 ± 0.21^{a}	4.22 ± 0.27^{b}	3.95 ± 0.20^{ab}	5.13 ± 0.84^{c}
Fluoride	0.06 ± 0.01^{b}	0.09 ± 0.02^{b}	0.02 ± 0.01^{a}	0.00 ± 0.00^{a}
Iron	0.09 ± 0.02^{ab}	0.07 ± 0.01^{a}	0.12 ± 0.01^{bc}	0.17 ± 0.001^{c}
Lead	0.09 ± 0.03^{ab}	0.08 ± 0.01^{a}	0.13 ± 0.01^{b}	0.07 ± 0.01^{a}
Mercury	0	0	0	0
Zinc	0.05 ± 0.01^{a}	0.07 ± 0.01^{ab}	0.10 ± 0.01^{b}	0.14 ± 0.01^{c}
Cadmium	0.00 ± 0.00^{a}	0.01 ± 0.002^{a}	0.04 ± 0.002^{c}	0.01 ± 0.001^{b}

Mean values in a row bearing different superscripts differ significantly ($p<0.05$), N= 25 in each group

Table -3: Microbiological quality of well water samples

	Mean microbial count (log_{10} cfu/ml)			
Parameter	Summer	Pre-monsoon	Monsoon	post monsoon
APC	3.36 ± 0.10^{c}	2.88 ± 0.13^{b}	2.89 ± 0.08^{b}	2.37 ± 0.70^{a}
CC	0.61 ± 0.10^{a}	1.05 ± 0.15^{b}	1.19 ± 0.63^{b}	1.17 ± 0.10^{b}
EEC	0.06 ± 0.06	0.35 ± 0.11	0.34 ± 0.12	0.29 ± 0.05
EC	0.81 ± 0.16	0.51 ± 0.14	0.89 ± 0.17	0.97 ± 0.17

Mean values in a row bearing different superscripts differ significantly ($p<0.05$), N= 25 in each group

The iron concentration observed might be due to the distribution of laterite soil, containing excess iron [20]. Furthermore, leaching of iron can take place easily under existing anoxic condition [14]. Mean iron concentration during different seasons showed significant difference. Lower concentration was observed during summer and pre-monsoon, whereas, monsoon and post monsoon concentrations were higher with highest during post monsoon. The higher concentration of iron observed during rainy season there could be due to leaching of iron naturally present in laterite soil. The unlined nature of wells facilitated the entry of iron from soil into well, increasing iron content after rain. Throughout the year, mean iron concentration was within the Bureau of Indian Standards (IS: 10500, 1991) desirable limit (0.3mg/l) for drinking water. Toxic effect due to exposure to iron leads to abdominal discomfort, lethargy and fatigue. Liver is the major site of iron storage. Excess iron deposition leads to shrinkage of liver, followed by fibrosis and cirrhosis. Ingestion accounts for most of the toxic effect of iron because iron is absorbed rapidly in gastrointestinal tract.

Mean lead concentration ranged between 0.07±0. 01 and 0.13±0.01 mg/l, which was above the WHO guidelines, 2006 (0.01 mg/l) and IS: 10500, 1991 (0.05 mg/l) for lead in drinking water. Lead in drinking water might have originated from lead present in soil. This could also be attributed to lower pH of well water [27] and soil [22], as acidification of soil and water may increasingly mobilise potentially toxic elements such as cadmium, lead and mercury [1, 10, 22]. This makes them more available in the food chain. It was found that mean lead concentration was highest (0.13±0.01 mg/l) during monsoon, which could be attributed to the leaching of lead during rainy season contaminating the ground waters. Acute effects of lead poisoning are hallucination, delusion, poor memory and irritability. Exposure to lead is cumulating over time. High concentration of lead in body can cause death or permanent damage to central nervous system and kidneys. Lead poisoning stunts a child’s growth, damages the nerves system and cause learning disabilities. It is also linked to crime and antisocial behaviour in children.

Throughout the study, no mercury could be detected in water samples.

Mean zinc concentration was highest in post monsoon. This could be attributed to the leaching of zinc present in soil. Lower pH of groundwater accounts for higher zinc concentration [1, 10], which might have contributed to some amount of zinc in well water. Throughout the study, mean zinc concentration of well water samples were within the limit of 5 mg/l as prescribed by Bureau of Indian Standards (IS: 10500, 1991).

Mean cadmium concentration was found to be highest during monsoon and exceed the WHO guideline (0.003 mg/l) and IS: 10500, 1991 (0.01 mg/l) for cdamium in drinking water during pre-monsoon, monsoon and post monsoon seasons. The cadmium might have been derived from soil, which accumulates cadmium through the application of soil additives such as phosphatic fertilizers and sewage sludge [26]. Cadmium is found in earth crust at an average concentration of 0.1 mg/kg. Adsorption capacity of soils for cadmium increases with increase in pH of soil [26]. Due to the distribution of highly acidic laterite soil, adsorption capacity of soil for cadmium might be low leading to availability of free cadmium in soil which in turn enters the groundwater sources. These might be the reasons for cadmium in well waters. Cadmium concentration was found to be highest in monsoon season which might be due to leaching of cadmium present in soil. Cadmium is more mobile in aquatic environment than most other metals. It is also bio accumulative and persistent in the environment. Cadmium has no biochemical and nutritional function and is highly toxic to human being, plants and animals. In larger doses cadmium can accumulate in liver and kidneys and can replace calcium in bones, leading to painful bone disorders and renal failure. Kidney is considered to be the critical target organ in humans chronically exposed to cadmium by ingestion.

Mean APC showed significant difference between seasons with highest count during summer (3.36±0.10 log_{10} cfu/ml). It might be due to depletion of water in wells during dry seasons leading higher count due to concentration effect. Coliform organisms indicate faecal contamination of water. Mean coliform count was highest during monsoon (1.19±0.63 log_{10} cfu/ml). This could be due to to poor filtering action of soil and more percolation as well as seepage of domestic sewage through soil [7]. For water entering the distribution system, coliforms should be absent in 100 ml sample [3]. Only 16 per cent samples were within this limit during four seasons. It was understood that only 52% households had practice of disinfection of wells, of which, 36% disinfected wells at two months interval and 52% at six months interval. Bleaching powder was the disinfectant used and it was pointed out that the quantity of bleaching powder used was not sufficient for effective disinfection. These also might have contributed to higher counts of indicator organisms. Presence of coliforms in water indicates faecal contamination. So care must be taken to avoid such organisms.

Mean *E. coli* count showed no significant difference between seasons, but was highest during pre-monsoon. This might be attributed to depletion of water level during dry seasons. For water in the distribution system, *E. coli* should be absent in 100 ml sample [3]. Only nine per cent samples were within this limit in all seasons. *E. coli*, a type of faecal coliform bacteria, is found in intestinal tract of warm blooded animals. The presence of *E. coli* in water is an indication of recent sewage or animal waste contamination. Among *E. coli*, O 157: H7 is an emerging waterborne pathogen. This causes severe diarrhoea, renal failure and death.

Mean enterococcal count showed no significant difference between seasons, but was highest during post-monsoon 0.97±0.17 log_{10} cfu/ml. Presence of enterococci in water is a confirmatory evidence of recent faecal pollution of water [23]. Another study [16] reported enterococcal count of 0-1 cfu/ml in pucca wells and 0-9 cfu/ml in kutcha wells in and around Thrissur, Kerala. Whereas Prejit *et al*. reported mean enterococcal count of 14.56±6.07 cfu/ml in dug wells of Thrissur district [24]. It was found that 36 per cent wells did not conform the minimum distance from nearest polluting source such as septic tank, animals shed, manure pit, waste disposal site etc, which also added to higher counts. To avoid bacterial contamination, wells should be located not less than 15 metres from likely source of contamination [23]. Higher count observed in the present study during monsoon and post monsoon could be due to seepage from nearby septic tanks, facilitated by unlined nature of wells.

CONCLUSION

The groundwater quality of the study area showed seasonal variation except for COD, concentration of mercury, ECC and EC. Mean pH, lead, cadmium, CC and ECC exceeded the limits for drinking water prescribed by WHO and Bureau of Indian Standards. Construction of sanitary wells, keeping adequate distance from polluting sources, with adequate platform, drainage and parapet is recommended. Steining of wells and covering the wells with nets should also be adopted. Disinfection of wells with required amount of suitable disinfectant at regular interval also helps to minimize pollution mainly of microbial origin. Education of households on safe handling and use of drinking water is also recommended.

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