

# Assessment of Groundwater Quality for Drinking Water from Deep Confined Aquifer in Wanathawilluwa



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**Abstract** Potable water draws attention of human being due to scarcity of clean water. Contamination of surface, subsurface and groundwater has thus become a serious problem in nationwide. Hence, the assessment of water quality is utmost important to preserve and restore the surface, subsurface and deep-water sources. The main intent of this paper is to present of the groundwater quality status for future planning and management of Wanathawilluwa aquifer in Puttalam district. The assessment of the water quality was carried out in the different locations at Wanathawilluwa. Physiochemical analysis was carried out for surface, subsurface and deep aquifer water samples to provide a single number for Water Quality Index (WQI) that expresses the overall water quality of corresponding water at certain location. WQI was calculated using the weighted arithmetic index based on several water quality parameters such as pH, Total Dissolved Solids, Phosphate, Nitrate, Turbidity, Electrical Conductivity, Dissolved Oxygen and Chemical Oxygen Demand. By representing the whole Wanathawilluwa aquifer, 21 deep and subsurface water samples from different locations were tested and results were compared with stipulated Sri Lanka Standards for potable water. The estimated WQI of Wanathawilluwa aquifer reveals that the overall water quality class is 'good' and water is acceptable for domestic use.

**Keywords** WQI · Groundwater · Wanathawilluwa aquifer · Physiochemical parameters

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## 1 Introduction

Water is an important requirement of human life and activities related with industry, agriculture, and etc. Water considers as one of the most precious parts of the environment. Among the main types of water, groundwater is a vital source of drinking water and it is a valuable resource. Groundwater is the water that exists underground in saturated zones beneath the land surface and it is contained in aquifers which are geological formations of permeable material capable to store water which consists of different materials such as unconsolidated sands and gravels, permeable sedimentary rocks such as sandstones or limestone, fractured volcanic and crystalline rocks. The speed at which groundwater flows, depends on the size of the spaces in the soil or rock [1]. Groundwater can be found almost everywhere and it is used for domestic and industrial water supply and irrigation all over the world. Groundwater resources are affected by excessive use of fertilizers and pesticides in agricultural areas, untreated/partially treated wastewater to the environment and excessive pumping and improper management of aquifers [2]. If groundwater becomes polluted, it will no longer be safe to drink. Safe drinking water is a basic requirement for good health, and it is also a basic right of human. According to WHO organization, about 80% of all the diseases in human beings are caused by water. Once the groundwater is contaminated, its quality cannot be restored by stopping the pollutants from the source. Therefore it becomes imperative to regularly monitor the quality of groundwater and to device ways and means to protect it. The quality of water is defined in terms of its physical, chemical and biological parameters [3]. Development and management of water quality plays a vital role in agriculture production, poverty reduction, environmental sustenance and sustainable economic development. In Sri Lanka, about 70% of rural and 25% of urban households satisfy their daily water requirements with groundwater by means of dug wells or tube wells. In Puttalam district, most of the population dependent on groundwater as the only source of drinking water supply. Wanathawilluwa area, which is considered in this study, is located in the dry zone of Puttalam district where groundwater is used for everyday activities of the residents and for agricultural activities. Among the identified six types of aquifers in Sri Lanka, at the Wanathawilluwa area there is a deep confined aquifer which is found within the sedimentary limestone and sandstone formations of the north-western and northern coastal plains [3, 4]. Recent drill boreholes in this area indicate that this aquifer is over 60 m thick, and in the deeper parts the sedimentary succession is over 500 m thick [5]. Since groundwater in Wanathawilluwa deep confined aquifer is used for daily need as consumption and irrigation it is vital to analyze the quality of the groundwater in order to ensure whether it is safe for consumption. Water quality index is one of the most effective tools to communicate information on the quality of water to the concerned citizens. It, thus, becomes an important parameter for the assessment and management of groundwater [3]. WQI is defined as a rating reflecting the composite influence of different water quality parameters and it is calculated from the point of view of the suitability of groundwater for human consumption [6]. Therefore the objective of this study is to discuss

the suitability of groundwater for human consumption based on computed water quality index values.

### 1.1 Study Area

The study was carried out in the deep confined aquifer in Wanathawilluwa which was located in the west coastal region of Sri Lanka and belongs to the Puttalam district in North Western Province of Sri Lanka. According to the Koppen’s climate classification [3] Wanathawilluwa belongs to tropical savanna climate where both wet and dry seasons were visible during the year. The short dry season is from June to September and another dry season is from January to March. Wet season is mainly falls on October to December time period. Also this area gets rain during inter monsoon period with the prominent rainfall type being convectional rain and there is no significant fluctuation in average temperature during the year. Compared to the wet zone temperature of this area is a high. In Wanathawilluwa area twenty-one numbers of sample locations were selected as shown in the Fig. 1. The Description of each location is given in Table 1.

Pre-existing tube wells—8 sampling locations (T1, T2, T3, T4, T5, T6, T7 and T16)

Dug wells—4 sampling locations (D1, D5, D9 and D15)

Surface water bodies—9 sampling locations (S3, S5, S8, S9, S10, S11, S12, S13 and S15).

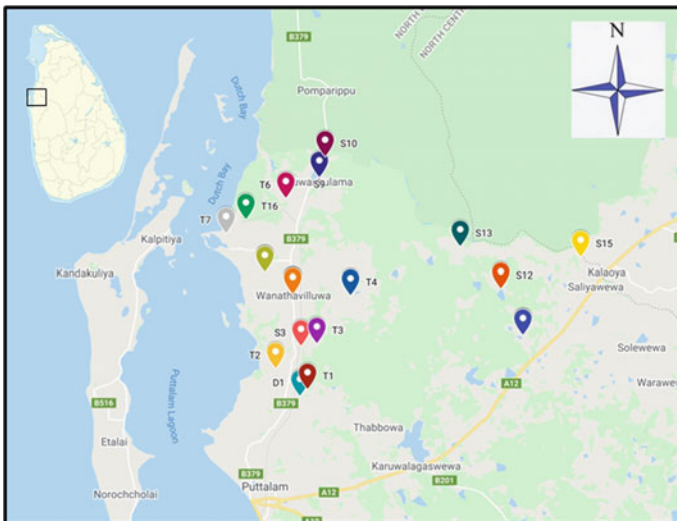


Fig. 1 Sampling locations in Wanathawilluwa

**Table 1** Details of sampling locations

Sample ID No.	Sampling location	GPS location (N)	GPS location (E)
<i>Deep water</i>			
T1	Mylankualam (EAP land)—total depth 70 m	08° 06.871'	079° 52.321'
T2	Samagipura—total depth 50 m	08° 07.823'	079° 50.843'
T3	9th Mile post Malwila—total depth 65 m	08° 08.968'	079° 52.753'
T4	Morapathawa Temple—total depth 70 m	08° 11.167'	079° 54.292'
T5	12th Mile Post Wanathawilluwa town—total depth 62 m	08° 12.181'	079° 51.543'
T6	Aruwakkaru—total depth 100 m	08° 15.609'	079° 51.322'
T7	Hafis Land Serakkuli—total depth 100 m	08° 13.991'	079° 48.558'
T16	Insee Lime Quarry Site—total depth 172 m	08° 14.623'	079° 49.473'
<i>Shallow water</i>			
D1	Mylankualam	08° 06.559'	079° 51.973'
D5	12th Mile Post Wanathawilluwa town	08° 11.196'	079° 51.636'
D8	Eriikanawilluwa, Karatiwu Road	08° 12.219'	079° 50.351'
D14	Balagollagama, Ihalapuliyankulama	08° 09.354'	080° 02.267'
<i>Surface water</i>			
S3	9th Mile post Malwila	08° 08.886'	079° 52.023'
S5	12th Mile Post Wanathawilluwa town	08° 11.196'	079° 51.636'
S8	Eriikanawilluwa, Karatiwu Road	08° 12.219'	079° 50.351'
S9	Achchimale tank	08° 16.420'	079° 52.947'
S10	Eluwankulama	08° 11.211'	079° 51.673'
S11	Maha wewa	08° 09.364'	080° 02.279'
S12	Pahalapuliyankulama wewa	08° 11.476'	080° 01.253'
S13	Kuda ottupallama wewa	08° 13.396'	079° 59.374'
S15	Neelabemma	08° 12.924'	080° 04.943'

## 2 Methodology

A total number of 21 different locations were selected from the study area to determine the water quality parameters during the dry season. The coordinates of the sampling locations in terms of latitudes and longitudes were taken with the GPS. The water samples were collected from various sources such as private hand pumps,

government hand pumps, dug wells and surface water during July 2019. The depth of less than 30 m was considered as shallow aquifer while the depth greater than 30 m was considered as deep aquifer. Each of the groundwater samples was analyzed for parameters such as pH, electrical conductivity, Total Dissolved Solids, Total Phosphate, Nitrate, Dissolved Oxygen, Turbidity and Chemical Oxygen Demand using standard procedures recommended by APHA [7]. The pH, Conductivity, Salinity, Total Dissolved Solids (TDS), Dissolved Oxygen (DO) and temperature were measured by HQ40D Portable Multi Parameter. The Nitrate, Phosphate and Chemical Oxygen Demand (COD) were measured by colorimetric method.

### 2.1 Water Quality Index

One of the most effective tool for monitoring the surface as well as ground water pollution is WQI. Eight parameters have been selected for developing the Water Quality Index [8]. In the present study the WQI has been calculated in three steps.

In the first step, each of the 08 parameters (pH, TDS,  $PO_4^{3-}$ ,  $NO_3^-$ , DO, Temperature, Turbidity and COD) has been assigned a weight ( $w_i$ ) according to its relative importance in the overall quality of water for drinking purposes as shown in Table 2.

In the second step, the relative weight ( $W_i$ ) is computed from Eq. 1.

$$W_i = \frac{w_i}{\sum_{i=1}^n w_i} \tag{1}$$

$W_i$  and  $w_i$  is the relative weight and weight of each parameter, respectively, and  $n$  is the number of parameters.

In the third step,  $Q_i$  which is defined as a quality rating scale for each parameter is assigned by dividing its concentration  $C_i$ , in each water sample by its respective standard  $S_i$  according to the guidelines laid down in the

Sri Lankan Standards (Eq. 2)

**Table 2** Details of chemical parameters with their relative weight and assigned weight with drinking water standard [6]

Parameter	Unit	Drinking water standard
pH	–	6.5–8.5
Conductivity	mS/m	50
Nitrates	mg/l	50
Total phosphate	mg/l	2
COD	mg/l	10
Turbidity	NTU	2
TDS	mg/l	500
DO	mg/l	5

**Table 3** Range of WQI specified for drinking water [9]

S. No.	WQI range	Water quality
1	<50	Excellent
2	50–100	Good
3	100–200	Fair
4	200–300	Poor
5	>300	Very poor

$$Q_i = \frac{C_i \times 100}{S_i} \quad (2)$$

WQI can be determined by using the SI which considered as the first determination for each chemical parameter (Eqs. 3 and 4)

$$SI_i = W_i \times Q_i \quad (3)$$

$$WQI = \sum_{i=1}^n SI_i \quad (4)$$

The computed WQI values were categorized into five types as in Table 3.

### 3 Results and Discussion

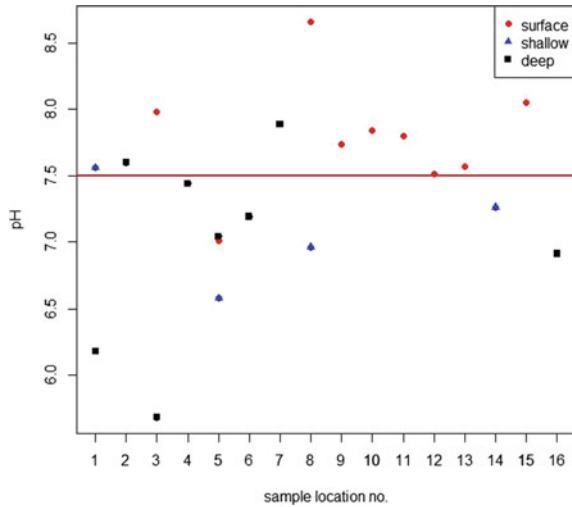
#### 3.1 pH

pH takes an important place in clarification process and disinfection of drinking water. Sri Lanka Standards (2013) has prescribed permissible limit of pH to be 6.5–8.5. When the pH of water is less than 7, such water is more likely to be corrosive and it adversely affect on taste and appearance of water. The pH value of groundwater samples in the present study has been analyzed and it lies in the range 5.68–8.66 (Fig. 2).

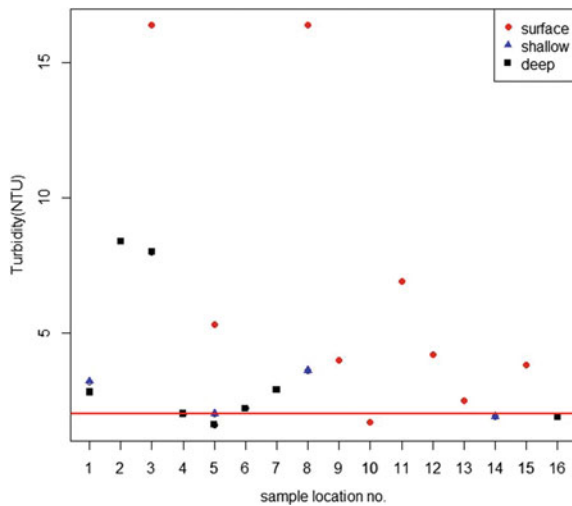
#### 3.2 Turbidity

The turbidity of the collected samples has been observed in the range 1.6–16.4 NTU (Fig. 3). Standard value for the turbidity in drinking water is 2 NTU. In the present study, none of the samples were well within the acceptable limit (Table 2).

**Fig. 2** Variation of pH in sample locations



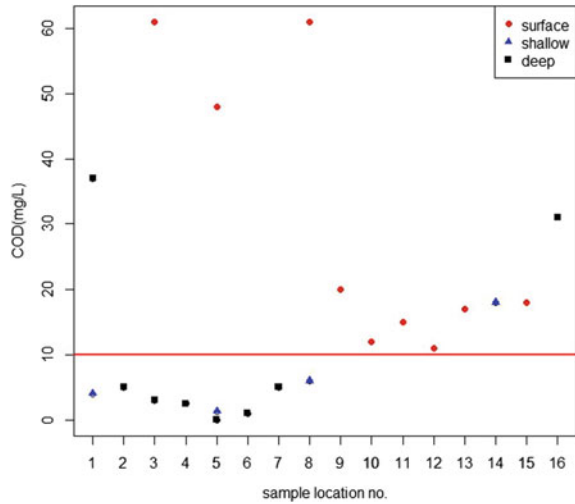
**Fig. 3** Variation of turbidity in sample locations



### 3.3 Chemical Oxygen Demand (COD)

The quantity of COD determines the quantities of organic matter found in water. Chemical Oxygen Demand (COD) content of water samples in studied area was between the ranged from 0–500 mg/L (Fig. 4). The lowest COD value was recorded in tube well water sample at 12th Mile Post Wanathawilluwa town water sampling area and the highest COD values recorded in surface water samples at 9th Mile post Malwila and Erikanawilluwa sampling areas. According to WHO (2012), almost all

**Fig. 4** Variation of COD in sample locations



the surface water samples were not within the recommended permissible limit for drinking purpose. The maximum allowable COD value for drinking water is 10 mg/L.

### 3.4 Dissolved Oxygen (DO)

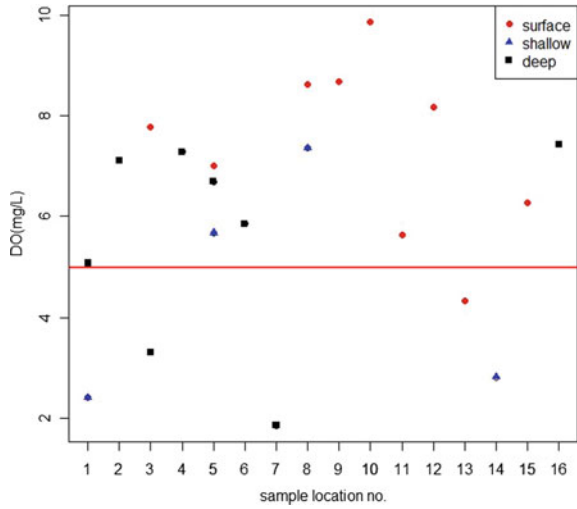
Dissolved oxygen (DO) refers to the level of free, non-compound oxygen present in water. It is an important parameter in assessing water quality because of its influence on the organisms living within a body of water. A dissolved oxygen level that is too high or too low can affect water quality. DO of collected samples vary in the range of 1.86–9.86 mg/L (Fig. 5). According to the results DO in collected samples, most of sample locations are above the standard value 5 mg/L.

### 3.5 Conductivity

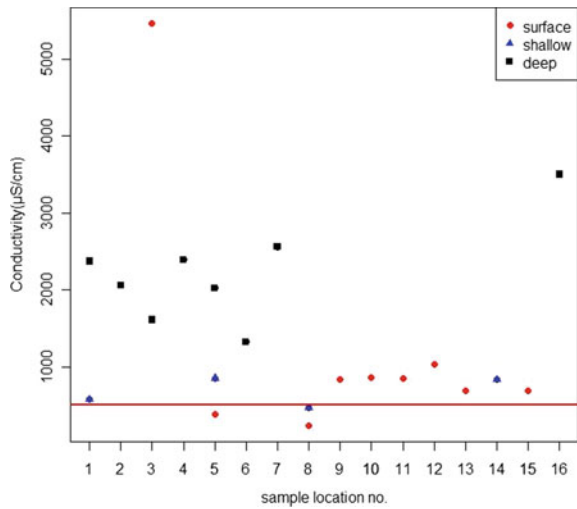
Conductivity is a parameter which measures the capability of water to pass an electrical flow due to the presence of dissolved ions. Organic compounds do not conduct electric current very well and hence their contribution to conductivity is very low. So the conductivity could be an indicator to identify the dissolved solids in water. Conductivity of collected samples varies in the range of 241–5460  $\mu\text{S}/\text{cm}$  (Fig. 6).



**Fig. 5** Variation of DO in sample locations



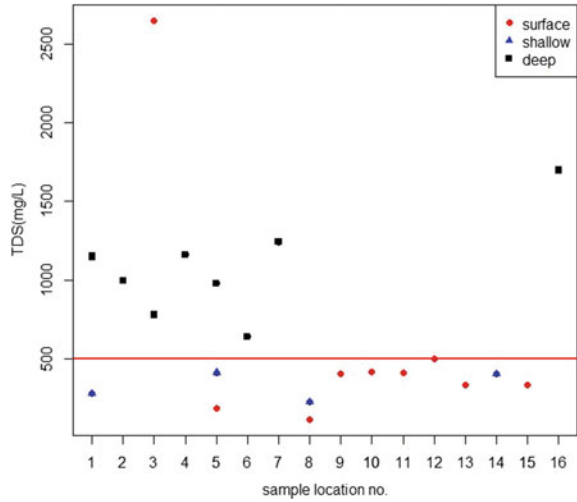
**Fig. 6** Variation of conductivity in sample locations



### 3.6 Total Dissolved Solids (TDS)

TDS comprise inorganic salts principally such as calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulphates and some small amounts of organic matter that are dissolved in water. The presence of dissolved solids in water may affect its taste. Acceptable limit for TDS is 500 mg/L (Table 2), the samples in the present study lies in the range of 117.0–2650.5 mg/L (Fig. 7).

**Fig. 7** Variation of TDS in sample locations



### 3.7 Nitrate

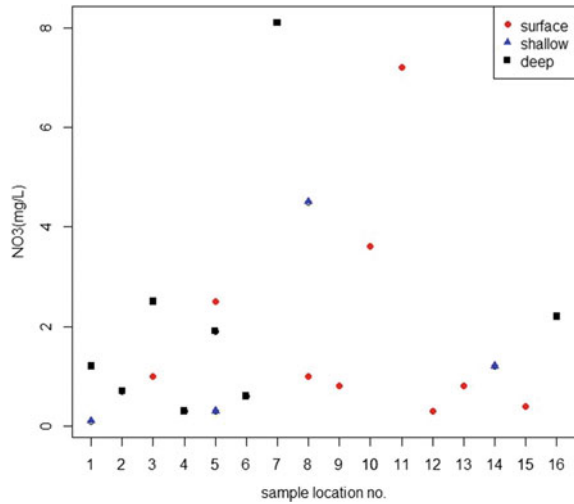
Groundwater may have a Nitrate ( $\text{NO}_3$ ) contamination as a consequence of leaching from natural vegetation. The presence of large quantities of nitrate in drinking water is a potential health hazard because if nitrates combined with amines, amides, or other nitrogenous compounds through the action of bacteria in the digestive tract it may result in the formation of nitrosamines, which are potentially carcinogenic. The maximum allowable nitrate concentration for drinking water is 50 mg/L as  $\text{NO}_3$ . The concentration of nitrate in water samples of the study area ranges between 0.1 and 8.1 mg/l (Fig. 8) and it is within the desirable limit (Table 2).

### 3.8 Phosphate

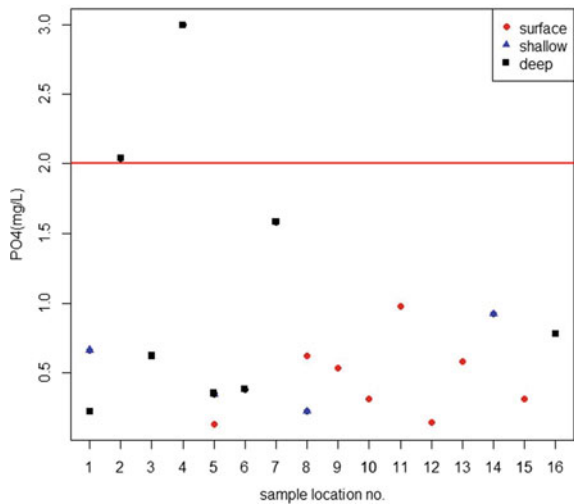
The contamination of water bodies with phosphate has resulted in widespread via fertilizers, wastewater, and washing detergents. The maximum allowable phosphate concentration for drinking water is 2 mg/L (Table 2). The concentration of phosphate in water samples of the study area ranges between 0.13 and 2.04 mg/l (Fig. 9).

The summary of WQI variation of 21 samples is given in Table 4. It is observed that minimum and maximum value of WQI has been found to be 54 and 342 delineated 'Good' and 'Very poor' category, according to range of WQI specified for drinking water as shown in Table 3. The maximum WQI value is found in surface water and minimum WQI value is in shallow well water. In the present study, in Wanathawilluwa deep confined aquifer it is observed that majority of groundwater samples i.e., 58% qualify in the 'Good water quality' category which is suitable for all purposes. The variation of the WQI based on the sampling locations are given in Fig. 10.

**Fig. 8** Variation of  $\text{NO}_3$  in sample locations



**Fig. 9** Variation of  $\text{PO}_4$  in sample locations



## 4 Conclusion

The WQI for 21 samples ranges from 54 to 342. The high value of WQI at these stations has been found to be mainly from the higher values of iron, nitrate, total dissolved solids, hardness, fluorides, bicarbonate, chloride and manganese in the groundwater. In this part, the groundwater quality may decrease due to no inflow of good quality fresh water during dry season. 58% of the samples are within the WQI range of 50–100, which is considered as the good quality for drinking. Also 38% of samples are within the range 100–200, which is considered as fair

**Table 4** Details of WQI and water quality of samples

Sample No.	Sample location	WQI	Water quality
<i>Deep water</i>			
T1	Mylankualam (EAP land)—total depth 70 m	155	Fair
T2	Samagipura—total depth 50 m	133	Fair
T3	9th Mile post Malwila—total depth 65 m	100	Good
T4	Morapathawa Temple—total depth 70 m	118	Fair
T5	12th Mile Post Wanathawilluwa town—total depth 62 m	85	Good
T6	Aruwakkaru—total depth 100 m	69	Good
T7	Hafis Land Serakkuli—total depth 100 m	119	Fair
T16	Insee Lime Quarry Site—total depth 172 m	180	Fair
<i>Shallow water</i>			
D1	Mylankualam	56	Good
D5	12th Mile Post Wanathawilluwa town	54	Good
D9	Eriikanawilluwa, Karatiwu Road	60	Good
D14	Balagollagama, Ihalapuliyankulama	82	Good
<i>Surface water</i>			
S3	9th Mile post Malwila	342	Very poor
S5	12th Mile Post Wanathawilluwa town	130	Fair
S8	Eriikanawilluwa, Karatiwu Road	199	Fair
S9	Achchimale tank	98	Good
S10	Eluwankulama	77	Good
S11	Maha wewa	103	Fair
S12	Pahalapuliyankulama wewa	86	Good
S13	Kuda ottupallama wewa	79	Good
S15	Neelabemma	86	Good

quality of drinking water. Analysis of results reveals the fact that WQI pertaining to the groundwater of Wanathawilluwa area needs some degree of treatment before consumption.

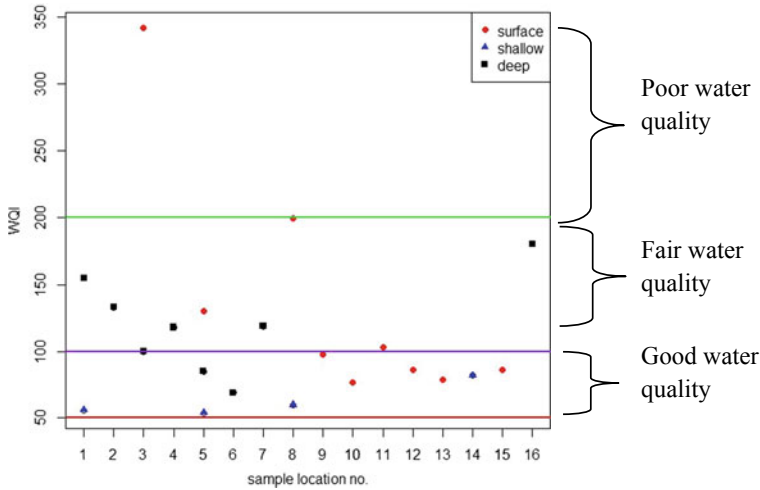


Fig. 10 Variation of WQI in sampling locations

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