WATER QUALITY ASSESSMENT OF AGRO WELLS IN VAVUNIYA DISTRICT FOR THE USE OF AGRICULTURAL AND DOMESTIC PURPOSES

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ABSTACT

This study was conducted to assess agro-well water quality for the use of agriculture and domestic purposes in Vavuniys District. Water quality assessments were done on randomly selected 10 wells in the Thandikulum and Kurumakadu area from July, 2004 to October, 2005. pH, turbidity, conductivity, and feacal coliform were analyzed using the water quality kit while Nitrate-N, Nitrite-N, Ammonia-N, Phosphate, Chloride, Fluoride, Calcium, Magnesium, Sulphate, were analyzed using the UV/Visible Spectrophotometer. Nitrate-N was analyzed using the Ultraviolet Spectrophotometric screening method and others were analyzed with colorimetric methods. Even though, the agro wells are constructed for agricultural purposes, due to the water scarce conditions more than 70% of the wells are used for drinking, washing and bathing purposes too.

In all wells, Turbidity, Nitrite-N, Sulphate, Chloride, Electrical conductivity were within the recommended level for drinking water. The feacal coliform (thermotolerant E.coli) was much higher in wells near residential areas. Nitrate-N was above the recommended level of 10 mg/l for drinking water in some wells. For agricultural purposes, the recommended range 5-30 mg/l of Nitrate-N was not exceeded by any of the wells. The ammonia concentration was increased after rainfall and it exceeds the recommended level of 0.2 mg/l. The maximum limit of Fluoride$^-$ for insignificant risk (1.5 mg/l) was exceeded by some of the wells and were in the range of 0.28 mg/l to 1.74 mg/l.

Based on the recharge estimates, depths of well, nearness to agricultural, livestock and pit latrine, the areas associated with the agro wells were categorized into three aquifer vulnerability zones; AVA1, AVA2 and AVA3. Deeper wells away from the pollution sources are better for domestic purposes compared to the others. This research indicates that the water

quality of agro wells is recommended for agricultural purposes in this area but not for drinking purposes unless these wells are located in AVA3 zone and the water is treated.

INTRODUCTION

Water is probably the most important natural resource in the world and the life cannot exist without it. Groundwater resources have been extensively used since ancient times for domestic purposes using shallow open wells in almost all parts of Sri Lanka. Therefore, groundwater is a very significant and a vulnerable resource. Bacteriological, chemical and physical safety is a prime importance in the use of groundwater for domestic use.

Vavuniya is an agricultural area where people use minor irrigation tanks and dug wells to meet their domestic and agricultural water requirements. Groundwater is the major source of water supply for domestic consumption in the district. However, the water resources are polluted by many activities such as fertilizer and pesticide application and feacal contamination. The feacal contamination is higher due to poor sanitation facilities. The increase in salinity of well water due to over exploitation and Nitrate pollution through continuous use of organic manure and inorganic fertilizers is also a major problem in this area. Some areas are affected by wastewater discharge. As a result, a significant proportion of the population does not have access to safe source of drinking water.

Unlike rivers, aquifers do not have any self cleansing capacity. Hence once polluted they remain polluted. Therefore, the priority must be given to the systematic ground water monitoring and appropriate measures to minimize the pollution. However, no systematic monitoring of well waters has been undertaken on Vavuniya District for many years.

OBJECTIVES

The objectives of this study were;

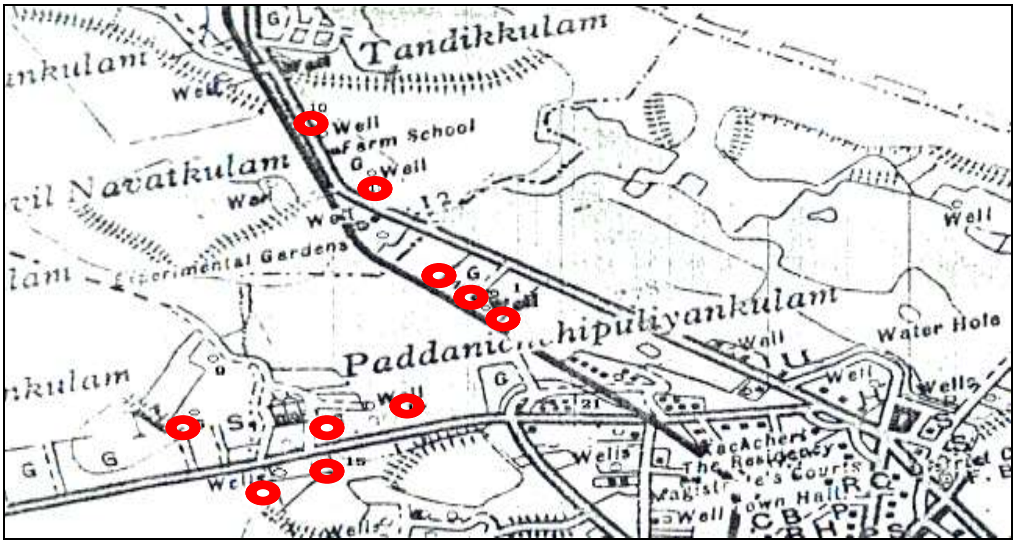
To assess the groundwater quality with respect to domestic and agricultural purposes in Vavuniya District by assessing some selected water quality parameters (pH, Turbidity, Conductivity, Fecal-coliform, Chlorides, Fluorides, Nitrites, Nitrates, Ammonia, Sulphates, Calcium and Magnesium),
To identify the causes for contamination of agro-well water pollution and to demarcate water quality zones based on the assessment and
To recommend preliminary solutions and precautions to overcome the problems.

The study area

The identified study area includes Thandikulum and Kurumankadu in Vauniya District. It lies between longitudes $80^0 28'$ – $80^0 32'$ and latitudes $8^0 43'$-$8^0 48'$ and covers an area of about 74km^2.

The study area is situated in the Northern dry zone of Sri Lanka. Therefore, climatic conditions are very important in ground water occurrence in hard rock terrains where the precipitation is very low. The average rainfall of the district is 1406 mm (Meteorology Dept., Vavuniya, 2004). Nearly 70% of annual rainfall occurs during a short period of Northeast monsoon from October to January. Mean annual temperature is 27.5 ^{0}C (Meteorology Department, Vavuniya, 2004). Evaporation and evapotranspiration is very high and it prevails over a long period of the year. Daily variation in temperature is high as 9 ^{o}C, therefore the evaporation and evopotranspiration is also high. This area falls within the Agro-Ecological Region of DL1b (Natural Resources Management Centre, Dept. of Agriculture, 2003).

The population in Thandikulum was about 2362 in 2002 according to Divisional Secretariat, Vavuniya after resettlement and relocation during the past few years. Most of the population is engaged in agriculture and agriculture based industries. The Study area with the sampled well locations is given in Figure 01.



Sampled wells for water quality

Figure 01: The study area and the sampled wells

METHODOLOGY

Agro-well water quality was monitored in the Thandikkulum and Kurumankadu areas of Vavuniya Divisional Secretariat Division from June 2004 to October 2005. Out of 21 wells identified for the study, a total of 10 wells used for domestic and agricultural purposes were randomly selected for water quality analysis. A total of 10 representative samples were collected from agro wells and analyzed for major ions, trace minerals and microbial counts.

Table 01 presents the details of the 10 wells in the study area. Well number 7, 15, 17 and 21 are domestic wells, while well number 1 and 13, are agricultural wells. Other wells are used both for agricultural as well as for domestic purposes. In 1, 5, 7, 9, 10, 13, 15, 17, and 21 wells, water level fluctuates in between 0-6 m depth, whereas in well number 6 water level fluctuates up to 10 m depth. Groundwater from shallow large diameter wells are used for domestic purposes such as drinking, cooking, washing, watering vegetable plots and for livestock.

Table 01: Details of the sampled wells

Well No	Depth (m)	Diameter(m)	Location
01 $_{a}$	9.45	6.25	Thandikulum
05 $_{a,d}$	7.67	4.24	Thandikulum
06 $_{a,d}$	19.83	4.03	Thandikulum
07 $_{d}$	15.47	4.64	Thandikulum
09 $_{a,d}$	11.17	3.00	Thandikulum
10 $_{a}$	13.7	2.60	Thandikulum
13 $_{a}$	21.11	4.72	Thandikulum
15 $_{d}$	16.85	2.73	Kurumankad
17 $_{d}$	11.62	2.86	Kurumankad
21 $_{d}$	10.53	2.65	Kurumankad

$_{a}$ agricultural wells
$_{a, d}$ agricultural and domestic wells
$_{d}$ domestic wells

Samples were collected using a depth sampler. Turbidity and feacal coliform were measured on site using a water quality kit. pH was analyzed using the pH meter and the electrical conductivity was measured using the conductivity meter in the field. Each sample was poured into a 1.5l polythene bottle after rinsing it twice or thrice with the same water and covered with a lid and then transported to the laboratory at the Open University, Nawala, for chemical analysis. (Samples were kept under 4 ^{o}C using ice during the transportation).

The, NO_3^-—N, NH_4^+—N, NO_2^-—N, Fluoride, Chloride, Sulphate, Magnesium, Calcium, were determined by colourimetrically using UV/Visible Spectrophotometer (APHA, 1989).

Chemical analysis

No sooner the samples reached the laboratory, water was filtered and the filtrate was used for analysis (In case of water samples needed to be stored for long periods, a few drops of chloroform were added to prevent any algal growth and then stored in the refrigerator.) Nitrate-N, Nitrite-N, Ammonia-N, Phosphate, Chloride, Fluoride, Calcium, Magnesium, Sulphate, were analyzed using the UV/Visible Spectrophotometer. Nitrate-N was analyzed using the Ultraviolet Spectrophotometric screening method and others were analyzed using colorimetric methods. Membrane filtrate method was used for detecting microbial quality.

RESULTS AND DISCUSSION

Water quality characteristics

According to the results, most of the wells have clear water with turbidity less than 5TU. In two wells (wells 1& 13) growth of blue green algae was seen. However, it has not affected to the colour of water in the wells.

pH

Figure 02 shows the temporal variation of pH in agro well water of the study area. The pH of water varies between 6.4 and 7.4 over a period of 15 months. Except for the well number 01 during the rainy period, all the other wells show pH within WHO permissible limit of 6.5-8.5 irrespective of the season. The well number 01 was not used or drinking purposes and had a growth of blue green algae. This could be the reason for high pH of water.

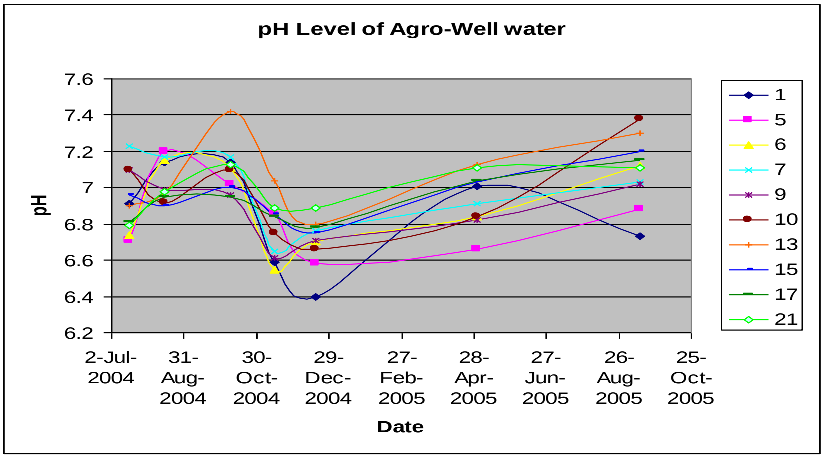


Figure 02: Temporal variation of pH in of agro-well water

The lowering of pH values associated with the rains may be due to the influx of acidic ions after the rains.

Electrical conductivity of ground water of agro wells in the study area ranged from 0.05-0.22 dS/m. Based on the standard reports by Nagarajah et al. (1988) the water of the majority of wells can be categorized as low salinity water where EC is in the range of 0-0.25 ds/m. The behavior of electrical conductivity shows that there is an increase immediately after rainfall in October except for well number 6 (Figure 03). The increase of conductivity just after the rainfall may be due to the wash off of salts by nearest fields. The conductivity pattern of well number 06 is different from other agro-wells. In this well the conductivity decreased remarkably from the beginning to the mid of the rainy period and did not show an increase immediately after the rains. Well number 06 is situated in a paddy field. In all other wells in the middle of the rainy period, the conductivity decreased again increased towards the end of rainy period. However, this fluctuation was not seen in well number 07. This may be due to the dilution of well water probably with surface runoff.

Wells 10 and 13 which are located in School of Agriculture, Vauniya showed lower conductivity compared to other wells. According to the results, the higher conductivity may have contributed to low pH (acidic condition).

Perera et al., (2002), have studied 94 agro wells in 34 cascades in Anuradhapura district for one year period and indicated that 30% of the wells showed EC values between 1-2 dS/cm and 10% of the wells showed EC more than 0.2 dS/cm. According to FAO, if not properly managed, water having an EC of 2000 µS/cm could retard the yield of sensitive crops like onion by 40%. Seasonal variation of EC has been observed and the values tend to be high during the period from July to September (Pathmarajah , 2002).

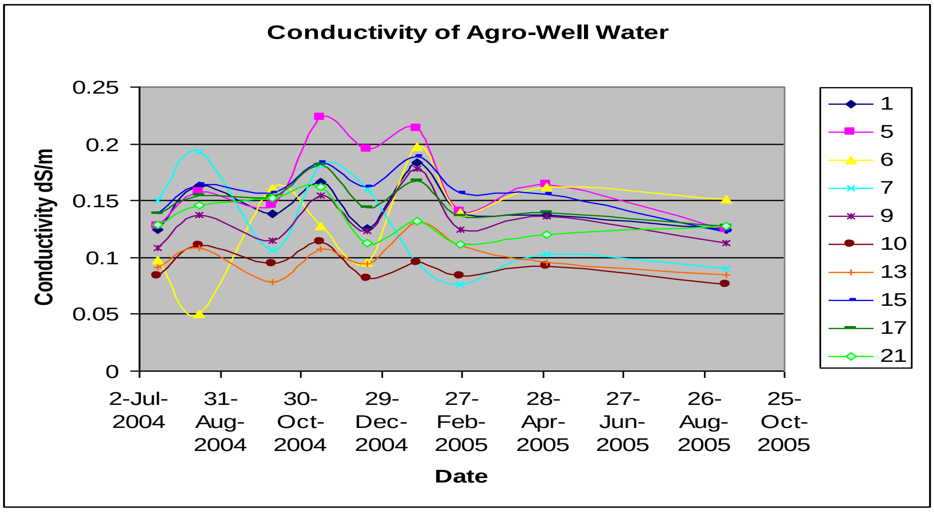


Figure 03: Temporal variation of electrical conductivity in agro-well water

Nitrate-Nitrogen

Results showed high NO_3^--N levels above the permissible limit of 10 mg/l (WHO standards) in over 50% of the wells (number 1, 6, 9, 15, 17 and 21) (Figure 04).

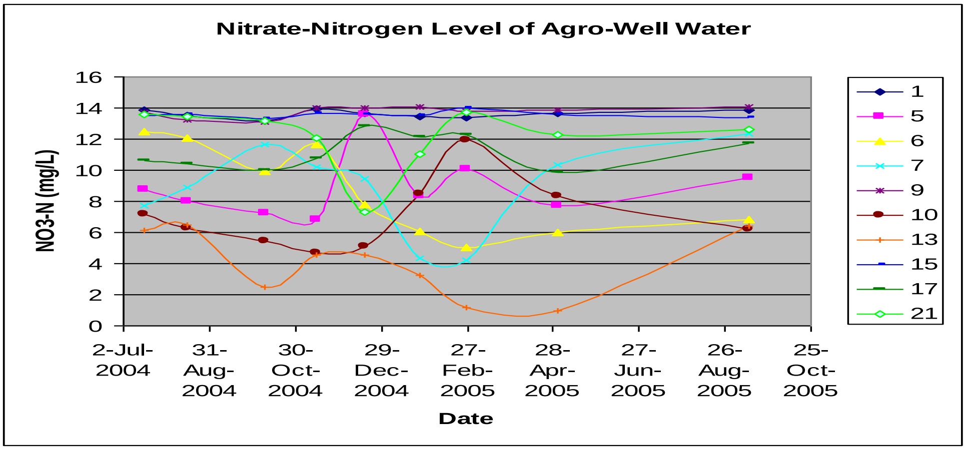


Figure 04: Temporal variation of Nitrate-Nitrogen in agro-well water

Wells 1, 10 and 13 are used only for agricultural purposes while 7, 15, 17 and 21 are used for domestic purposes. The other three wells are used both for domestic as well as for agricultural purposes. All the wells except well number 7, the level of Nitrate shows a decreasing pattern until the beginning of October.

The behavior of NO_3- N shows two distinct patterns

a) Very small or no fluctuation with rainfall and having high NO_3 concentrations.
b) Very distinct fluctuation with rainfall while having low to moderate concentrations. This clearly shows that some of the wells (located in discharged areas) are almost over saturated with nutrients while the others especially the ones located in recharge areas get NO_3 fluxes probably from leaching and infiltration immediately after the rainfall.

The increment of Nitrate concentration in wells 1, 6, 9, and 13 may be due to the consequent leaching of Nitrates after rainfall. The decrease of Nitrate concentration may be due to the dilution nature after heavy rainfall due to very high water level. The reasons for high Nitrate pollution may be the fertilizers applied to vegetable cultivation, over irrigation and consequent leaching of Nitrate ions. It may also have enhanced by the sandy soil region in the soil profile where the thickness vary from 5m to 12 m. For agricultural purposes, the recommended range of 5 to 30 mg/l of Nitrates was not exceeded by any of the selected wells.

Studies conducted in Jaffna by Nagarajah et al. (1988) and in Kalpitiya by Kuruppuarachchi et al. (1990) have reported high concentration of Nitrate in groundwater under different soil conditions. The low Nitrate content in the agro wells of the study area compared to Kalpitiya may be due to the soils which have more clay than the Kalpitiya soils. They further stated that unlike Kalpitiya, the risk of Nitrate and chloride pollution is minimal due to comparatively high rainfall of this region (Pathmarajah, 2002).

Nitrite-Nitrogen

The provisional guideline value for Nitrite-nitrogen in drinking water is 3mg/l (WHO, 1993). According to the results, the Nitrite-nitrogen level is less than the recommended value in all wells. Well number 1 showed the highest Nitrite level which is used only for the agricultural purposes and was full of blue-green algae. The Nitrite-nitrogen and Nitrate-nitrogen level showed an inverse relationship during the study period.

Ammonium-Nitrogen

Groundwater usually has NH_4^+ concentration below 0.2 mg/l (WHO, 1993). Ammonia in water is an indicator of possible bacterial, sewage and animal waste pollution. All the wells showed NH_4^+ below the permissible level prior to the rainfall. However, in almost all the wells, ammonium concentration increased remarkably with the beginning of wet season probably due to excess leaching.

After rainfall, until February, the amount of ammonium was decreased due to dilution. At the beginning of the rainy season, the ammonium concentration increased remarkably in well number 6. This well is situated very close to a paddy field and the increment may be due to leaching of fertilizer. Well number 15 and 21 are used for domestic purposes. Both these wells are situated closer to pit latrines and were reported to be contaminated due to runoff of animal waste closer to the wells.

Fluoride

Fluorides in the wells in the study area vary from 0.28 to 1.74 mg/l. The recommended level is 1.5 mg/l (WHO, 1993). Concentrations above this value carry an increasing risk of dental fluorosis, and much higher concentrations lead to skeleton fluorosis. Recent studied in Anuradhapura District well water showed that the higher concentration of Fluoride may cause even Kidney diseases.

Well number 9 showed the highest amount of Fluoride which was above the permissible level of 1.5 mg/l. In the beginning of the rainy season, the Fluoride concentration was slightly increased in 7, 9, 10, 15 and 17 wells. The Fluoride concentration was decreased again in the middle part of the rainy season due to dilution. The Fluoride levels in all wells have increased in the latter part of the rainy season. In wells 5, 6, and 9, the Fluoride concentration was above the permissible level. All three wells were used for drinking purposes as well as for agricultural purposes.

Sulphate

In the wells of the study area Sulphate concentration ranged from 10 to 70 mg/l. Sulphate is one of the least toxic anions. However, the selected wells did not exceed the permissible level of 200 to 600 mg/l recommended by the WHO (1993).

Magnesium

The magnesium content in well waters ranged from 22.69 to 94.45 mg/l. The high amount of magnesium causes hardness in water. Rearing poultry can be a reason for higher amount of magnesium since poultry manure has a high content of magnesium (Moore, 1998) which is a common fertilizer in some areas.

Calcium

Calcium content in well water was very high in the study area and ranged from 55.09 to 415.33 mg/l. The high amount of Calcium in drinking water may be due to its geological condition. The high amount of calcium showing in the well no 15 may be due to drainage water with poultry manure. Green house experiments conducted by Wijewardena (1994) showed that the drainage water from pots treated with poultry manure had high calcium content compared to that from untreated pots. Hence, raring poultry near agro wells and the drainage water with their manure could be a reason for high content of calcium in well waters.

Chloride
The concentration of chloride in well water ranged from 111 to 393 mg/l. It was within the recommended level of 200 to 600 mg/l. The increased chloride content was due to the leaching of chloride iron from the soil zone to the well water after the rains.

Fecal coliform
In agro wells 1, 5, 10, 15, the fecal coliform amount is very high during the rainy period (Table 02). Except in agro well number 1 and 10, other two are used for drinking purposes. Coliforms are low in well number 9, 13 and 21 during the year.

Table 02: Fecal coliforms in agro wells.

Well No.	Coliform count July 2004	Coliform count Oct. 2004	Coliform count May 2005	Coliform count Sep. 2005
1	1000 <	1000 <	64	200 <
5	1000 <	1000 <	26	120
6	216	200	1000 <	200 <
9	160	214	-	270
10	1000 <	1000 <	38	300
13	100	62	10	80
15	40	1000 <	10	52
21	104	150	16	62

Groundwater vulnerability and protection

Aquifer vulnerability is the probability of groundwater pollution in the event of a pollutant is released at the ground surface. Susceptibility is a qualitative measure of the relative ease with which a groundwater resource can potentially be contaminated by anthropogenic activities.

The aquifer in the Vavuniya study area is mainly an unconfined crystalline hard rock aquifer. Most of the agro-wells on the weathered overburden of this aquifer are very vulnerable to groundwater pollution. During the rainy season, all the pollutants get washed in to the wells and therefore the pollutant concentration in the wells is high during the rainy season

Delineation of aquifer vulnerability zones
The aquifer vulnerability was mapped considering the factors namely; shallow depth to ground water, near to pit latrines, near to agricultural lands and near to livestock raring areas.

Aquifer vulnerability area 1 (AVA1)

Areas around the Agro wells 1, 5, 6, 9, 15, 17 and 21 have been classified as AVA1. Such wells are high in Nitrate-nitrogen concentration throughout the year irrespective of dry and wet period and well number 9 has very high concentration of Fluoride throughout the year. Wells 6 and 21 are located near to pit latrines. Reason for the high concentration of pollutants may be due to their shallow depth (Table 01.) and close proximity to the livestock raring and agricultural areas which helps the pollutants to reach the groundwater table fairly quickly. All these wells are used for domestic purposes at present.

Aquifer vulnerability area 2 (AVA2)

Wells 7 and 10 may fall into the AVA2. Although well 10 is an agricultural well near to an agricultural land, the concentration of Ammonia and Nitrate is much low except in rainy season. In these two wells, the Nitrite concentration is also less compared with other agro wells. These two wells are deeper than wells in AVA1.

Aquifer vulnerability area 3 (AVA3)

Areas around Agro well number 13 can be classified to class AVA3 due to the lowest amount of Nitrate in well 13. However, this well is not used for domestic purposes. The fecal coliform amount is also low in this well. . This is a deep well.

Protection measures

Agro-wells of shallow depth, near to the agricultural, livestock rearing and pit latrines are highly vulnerable to groundwater pollution (AVA1 class) hence such well should not be used for drinking and domestic purposes. The wells in the AVA 2 and 3 could be used for domestic purposes after boiling the water at 105°C. Agro-wells of more than 8 m depth away from agricultural lands, pit latrines and livestock rearing areas could be considered safe for domestic purposes. Drinking of water is suitable after boiling and filtering.

CONCLUSIONS AND RECOMMENDATIONS

It is evident that the agro well water is not suitable for drinking unless the water is treated. Except agro well number 7, 10 and 13 all other wells are vulnerable to water contamination. Agro wells which have higher amount of Nitrate concentrations throughout the year (1, 9, 15 and 17) should not be used for drinking purposes. In the wells where Nitrate and Fluoride contents are high, there is a high possibility of getting kidney diseases and urinary problems.

Wet season rainfall usually flushes the soil zone regularly. People in this area use this water for drinking purposes even during wet season. Therefore, precautions have to be taken when using well water during the wet season. The water quality decreases in shallow agro wells than in deeper agro wells.

Continues monitoring and quality assessment in well water are necessary to avoid quality hazards to the people in the area.

The indiscriminate placement of wells close to contamination sources such as pit latrines, livestock raring areas etc. should be controlled. Proper well construction and maintenance is necessary. Wells close to agricultural fields should not be used for drinking purposes.

Proper separation distances should be maintained between wells and the potential sources of contamination.

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