International Journal of the Physical Sciences Vol. 7(29), pp. 5118-5126, 26 July, 2012
Available online at http://www.academicjournals.org/IJPS
DOI: 10.5897/IJPS12.360
ISSN 1992-1950 ©2012 Academic Journals

Full Length Research Paper

Quality of irrigation and drinking water in Nangarparkar Region of Thar Desert of Pakistan

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Accepted 07 June, 2012

The pioneer study evaluates water quality status in Nangarparkar area of Thar Desert of Pakistan. Water samples obtained from wells, ponds and storage tanks greatly varied in their chemical composition and nutrient contents. Percentage of hazardous well water samples for irrigation purpose were: pH: 30%; electrical conductivity (EC): 27%; total soluble salts (TSS): 100%; CO_3^-: 70%; HCO_3^-: 27%; Cl^-: 53%; Na^+: 23%; K^+: 40%; Ca^{+2}: 13%; Mg^{+2}: 17%; PO_4^-: 7%; NO_3^-: 100% and for drinking: pH: 30%; EC: 50%; TSS: 100%; CO_3^-: 67%; HCO_3^-: 97%; Cl^-: 100%; Na^+: 100%; K^+: 83%; Ca^{+2}: 100%; Mg^{+2}: 83%; NO_3^-: 0%. Percentages of hazardous pond water samples for drinking purpose are as follows: pH: 20%; EC: 0%; TSS: 100%; CO_3^-: 73%; HCO_3^-: 93%; Cl^-: 100%; Na^+: 100%; K^+: 0%; Ca^{+2}: 60%; Mg^{+2}: 67%; NO_3^-: 40%. Percentages of hazardous storage tank water samples for drinking are expressed as follows: pH: 0%; EC: 0%; TSS: 100%; CO_3^-: 100%; HCO_3^-: 80%; Cl^-: 100%; Na^+: 100%; K^+: 0%; Ca^{+2}: 100%; Mg^{+2}: 80% and NO_3^-: 60%. Storage tanks were more benign than wells and ponds. Nitrates were the dominant contaminant in irrigation water.

Key words: Water quality, irrigation, drinking, Thar Desert, Nangarparkar, Pakistan.

INTRODUCTION

In Pakistan, water quality monitoring and information management is still in its infancy, despite its being highly vital to all water quality improvement programs. In Sindh province of Pakistan, only 28% of the area has fresh groundwater suitable for irrigation. Moreover, Thar, Nara and Kohistan regions seriously face the problem of non-potable highly brackish water (Kahlown et al., 1998).

Taluka Nangarparkar is the most remote area of Thar Desert of Pakistan. This region faces severe scarcity of good quality irrigation and drinking water. The inhabitants mostly rely on the rainfall for their agriculture and livelihood. Consequently, the precious land is being degraded rapidly (Soomro et al., 2000). Since the region has no artificial irrigation system, frequent droughts badly affect agricultural activities (Shaikh, 2003). The major water sources involve harvested rainwater, collected in special structures locally known as '*Tarai'* (ponds) and '*Tankas'* (storage tanks), coupled with the groundwater acquired through different types of dug wells locally called as '*Khoh*'. Further description of these water bodies is presented in the material and methods section for the readers who are not familiar with the environment of Thar Desert. The quality of groundwater is generally very poor to explore it for irrigation and drinking purposes (Bhutto, 2008). Rainwater collection systems provide comparatively safe quality water due to the non-contaminated isolated collection surfaces, that is. roofs (Lye, 2002). Runoff water harvesting techniques are considered very fruitful in dealing with the water shortage in a befitting manner in the arid and semiarid regions (Mathur et al., 2000; Carlsson et al., 2001; Shangguan et al., 2002; Krishna, 2003). Since water quality is dynamic and not a static property, its analysis plays a pivotal role in the timely evaluation of the hazards of water pollution

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Figure 1. Map of Taluka Nangarparkar showing sampling sites.

reason, the monitoring and evaluation of the quality of (PCRWR, 2005; Pandy and Tiwari, 2009). For this rain and groundwater, its suitability for drinking and irrigation purposes remained the subject of many researches (Gupta and Gupta, 1999; Pandian et al., 2005; Rajan and Paneerselvam, 2005; Thakare et al., 2005; Shikha et al., 2007). This study evaluated the quality and nutrient status of rain and groundwater in Taluka Nangarparkar of Thar Desert of Pakistan for their suitability in relation to irrigation and drinking purposes.

MATERIALS AND METHODS

In other to obtain the most leading and reliable results and covering the maximum geographical area, the water sampling philosophy in the present study involved the selection of 29 most densely populated villages of all seven Union Councils of Taluka Nangarparkar (Figure 1). The detailed site information of sampled water bodies of the study area (Table 1) clearly depicts that the water sampling encompassed villages of varying population magnitude ranging from 237 persons only (Village Neebaro Union Council Pillu) to the most densely populated villages of 3750 persons (Village and Union Council Virawah), representing a total population of 34,067 persons (Table 1). Three different types of water bodies were prevailent in the study area, viz. wells (locally called as *Khoh*), ponds (locally called as *Tarai*) and storage tanks (locally called as *Tanka*). Details about the structures, dimensions and designs of these water bodies are given in Figures 2, 3, 4 and 5. The structure of the wells revealed that walls and top of the wells are made of bricks. The cemented roofs of the wells are used to stand while fetching water from the well (Figure 2). The survey data

Table 1. Site information of sampled water bodies of Taluka Nangarparkar.

Union Council (UC) & Village	Population	Name of Owner	Water body		
			Well ●	Pond ■	Tank ▲
			Number in Map		
UC Nangarparkar					
Nangarparkar City	2000	Old water supply well	1	…	…
		New water supply well	2	…	…
Mondro	1238	Ali Muhammad Chandio	3	3	1
Deh Kharak	1413	Mubarak Kharak	4	2	…
Nariasar	1048	Govt. property	5	1	…
Ghertayari	655	Mohan Kolhi	6	…	…
Mau	756	Mansingh Thakur	7	…	…
UC Pithapur					
Pithapur	997	Muhammad Alam Kumbhar	8	4	…
Kasbo	1315	Versi Mal Menghwar	9	5	2
Wadharaiy	1176	Ratno Kolhi	10	…	…
UC Harho					
Rathi	1379	Moula Bux Samoon	11	6	…
Goondi	1441	Yaseen Samoon	12	7	3
Jhuglio	845	Papu Dal	13	…	…
Ameen Ji Dhani	353	Imam.ul.ddin Gajju	14	…	…
UC Virawah					
Virawah	3750	Saindad Khaskheli	15	8	…
Dotar	1720	Arab Dal	16	9	...
Mokhai	1531	Rasheed Thebo	17	…	…
Dano Dandhal	1294	Allah waryo Khaskheli	18	…	…
UC Satidera					
Balhari	1109	Usman Dal	19	10	…
Deve-jo-Tar	896	Ratno Kolhi	20	11	…
Tar Abdul Rahim	476	Jamal ul ddin Samoon	21	…	…
Wagho Bajeer	863	Abdul Ghani	22	…	…
UC Tigusar					
Hirar Detha	622	Murlidhar Mukhi	23	12	4
Ranpario	817	Ghulam hyder Rahimoon	24	13	…
Othi	562	Gul Hassan Unnar	25	…	…
Beh Shareef	334	Muhammad Usman	26	…	…
UC Pillu					
Pillu	1990	Sardaro Bheel	27	14	…
Gori	1921	Bhanu Mal Bheel	28	15	5
Neebaro	234	Idrees Thebo	29	…	…
Sunder	1332	Jameel Ahmed Rajar	30	…	…

(not presented) revealed that the wells were the most dependable source of irrigation water in the study area, as compared to ponds and storage tanks. About two-third of the sampled wells were 15 to 30 meter deep, while the remaining were 32 to 60 m deep. Ponds

Figure 2. Structure of well found in the Nangarparkar. The roof of the well is made up of bricks and is almost covered [Photo credit to the first author].

Figure 4. External structure of a cistern or storage tank found in the Nangarparkar region of Thar Desert of Pakistan [Photo credit to the first author].

Figure 3. Structure of a pond found in the Nangarparkar [Photo credit to the first author].

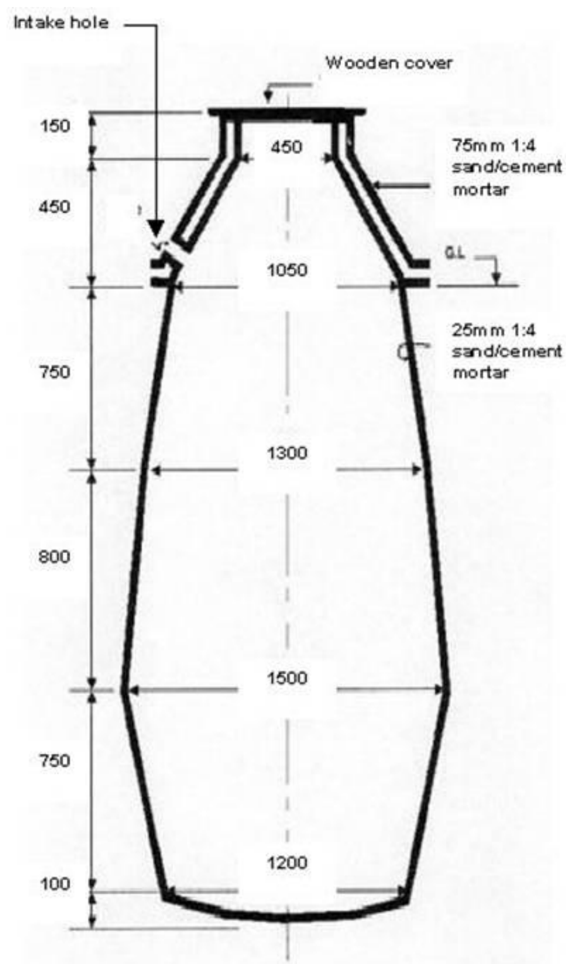

Figure 5. Internal design structure of a storage tank found in Nangarparkar.

are basically the natural low-lying areas where rainwater is stored during rainy season (Figure 3). Ponds of the study area vary in their dimensions and water storage capacity. The area of majority of ponds ranged from <0.5 to 1.0 ha with an estimated water retention ranging from 400 to 4000 m^2. The storage tanks are the other popular water storage structures found in the area. The external and internal structures of the storage tanks, along with their dimensions, are presented in Figure 4 and 5, respectively. The storage tank is made of cement mortar; a hole is made for channeling rain water into the cistern (Figures 4 and 5). The water storage capacity of storage tanks is not more than 5000 liters. There is no any silt trap or other necessary systems installed in the tank to control unwanted foreign bodies entering into cistern and maintain hygienic condition. The water is collected from open top, covered by wooden or cemented plate (Figure 5). A total of 50

Table 2. Chemical composition and nutrient content of well water of taluka Nangarparkar (n = 30).

Parameter	pH	EC (μS cm^{-1})	TSS (mg L^{-1})	CO_3^{-2} (mg L^{-1})	HCO_3^- (mg L^{-1})	Cl^- (mg L^{-1})	Na^+ (mg L^{-1})	K^+ (mg L^{-1})	Ca^{+2} (mg L^{-1})	Mg^{+2} (mg L^{-1})	PO_4^{-3} (mg L^{-1})	NO_3^- (mg L^{-1})
Minimum	7.6	3.9	2496	189	912	4023	1958	41	990	120	0.2	15
Max.	9.2	45	28800	915	8000	17890	11050	1150	5890	830	2.5	50
Mean	8.3	21.9	14022	623	3441	10787	5875	593	2866	366	1	33

Table 3. Chemical composition and nutrient content of pond water of taluka Nangarparkar (n =15).

Parameter	pH	EC	TSS	CO_3^{-2}	HCO_3^-	Cl^-	Na^+	K^+	Ca^{+2}	Mg^{+2}	PO_4^{-3}	NO_3^-
		(μS cm^{-1})	(mg L^{-1})									
Minimum	7.3	6	3840	0	980	1067	2134	18	89	45	0.2	19
Maximum	8.2	17	10880	934	4223	13450	5648	189	489	369	2.2	50
Mean	7.7	12.3	7910	615	2358	8744	4026	77	237	182	1	38

water samples were collected in thoroughly decontaminated 1.5-litre plastic bottles, including 30 samples from wells, 15 samples from ponds and five samples from storage tanks following the standard methodology (Jaiswal, 2003). The water analysis followed recommended protocols. The electrical conductivity (EC) and pH were determined following the methods prescribed by Jackson (1973). The carbonates, bicarbonates and chlorides were determined by titration method as prescribed by AOAC (1950). Sodium was determined by flame photometry as suggested by Toth et al. (1948). Potassium was analysed using the method of Stanford and English (1949). Calcium and magnesium were evaluated by titration with EDTA as outlined by Bray (1951). Phosphates were determined by molybdophosphoric blue color method as described by Murphy and Rilley (1962). Nitrates were determined using Kjeldahl distillation in the presence of Devarda alloy as prescribed in AOAC (1950). Sulphates were evaluated by using Turbidimetric method as suggested by Tabatabi (1974). The descriptive statistics was done through MS-Excel (Microsoft, 2005) while correlation analysis was performed by using Statistix ver. 8.1 (Analytical Software, 2005). The categorization of water samples for their suitability in relation to irrigation and drinking purposes was done by using standard limits.

RESULTS

Quality and nutrient dynamics of well water samples

The chemical composition and nutrient status of water samples collected from dug wells of Taluka Nangarparkar are presented in Table 2. The pH ranged from 7.6 to 9.2 with an average value of 8.3; electrical conductivity (EC), 3.9 to 45.0 with an average value of 21.9 µS cm^{-1}; total soluble salts (TSS), 2496 to 28800 with an average value of 14022 mg L^{-1}; carbonates (CO_3^-), 189 to 915 with an average value of 623 mg L^{-1}; bicarbonates (HCO_3^-), 912 to 8000 with an average value of 3441 mg L^{-1}, chlorides (Cl^-), 4023 to 17890 with an average value of 10787 mg L^{-1}; Na^+ conten, 1958 to 11050 with an average value of 5875 mg L^{-1}; K^+ content, 41 to 1152 with an average value of 593 mg L^{-1}; Ca^{+2} content, 990 to 5890 with an average value of 2866 mg L^{-1}; Mg^{+2} content, 120 to 830 with an average value of 366 mg L^{-1}; PO_4^{-3} content, 0.2 to 2.5 with an average value of 1.0 mg L^{-1}; NO_3^- content, 15 to 50 with an average value of 33.0 mg L^{-1}.

Quality and nutrient dynamics of pond water samples

The chemical properties and nutrient content of water samples collected from ponds of Taluka Nangarparkar are presented in Table 3. pH is from 7.3 to 8.2 with an average value of 7.7; EC, 6.0 to 17.0 with an average value of 12.3 µS cm^{-1}; TSS, 3840 to 10880 with an average value of 7910 mg L^{-1}; CO_3^{-2}, 0 to 934 with an average value of 615 mg L^{-1}; HCO_3^-, 980 to 4223 with an average value of 2358 mg L^{-1}; Cl^-,1067 to 13450 with an average value of 8744 mg L^{-1}; Na^+, 2134 to 5648 with an average value of 4026 mg L^{-1}; K^+ content, 18 to 189 with an average value of 77 mg L^{-1}; Ca^{+2} content, 89 to 489 with an average value of 237 mg L^{-1}; Mg^{+2} content, 45 to 369 with an average value of 182 mg L^{-1}; PO_4^{-2} content, 0.2 to 2.2 with an average value of 1.0 mg L^{-1} and NO_3^- content, 19 to 50 with an average value of 38 mg L^{-1}.

Quality and nutrient content of storage tank water samples

The chemical properties and nutrient content of water samples collected from storage tanks of Taluka Nangarparkar are presented in Table 4. pH ranged from 7.6 to 8.1 with an average value of 7.8; EC, 3.4 to 6.5 with an average value of 4.8 µS cm^{-1}; TSS, 2176 to 4160 with an average value of 3354 mg L^{-1}; CO_3^{-2}, 0 to 678 with an average value of 436 mg L^{-1}; HCO_3^-, 890 to 2023 with an average value of 1436 mg L^{-1}; Cl^-, 934 to 1556 with an average value of 1243 mg L^{-1}; Na^+ content, 1345 to 2236 with an average value of 1659 mg L^{-1}; K^+ content, 88 to 195 with an average value of 134 mg L^{-1};

Table 4. Chemical composition and nutrient content of tank water of taluka Nangarparkar (n = 5).

Parameter	pH	EC ($\mu S\ cm^{-1}$)	TSS	CO_3^{-2}	HCO_3^-	Cl^-	Na^+	K^+	Ca^{+2}	Mg^{+2}	PO_4^{-3}	NO_3^-
			($mg\ L^{-1}$)									
Minimum	7.6	3.4	2176	0	890	934	1345	88	256	125	0.5	29
Maximum	8.1	6.5	4160	678	2023	1556	2236	195	349	314	1.5	60
Mean	7.8	4.8	3354	436	1436	1243	1659	134	306	230	0.9	47

Ca^{+2} content, 256 to 349 with an average value of 306 mg L^{-1}; Mg^{+2} content, 125 to 314 with an average value of 230 mg L^{-1}; PO_4^{-3} content, 0.5 to 1.5 with an average value of 0.9 mg L^{-1}; NO_3^- content, 29 to 60 with an average value of 47 mg L^{-1}.

Categorization of water samples for their suitability in relation to irrigation and drinking purposes

The data obtained in this study for various chemical properties and nutrient contents of water samples collected from wells, ponds and storage tanks were categorized for their suitability of irrigation (only dug wells) and drinking (all three sources). A deep analysis of the data (Table 5) revealed that for irrigation purpose the prevalence of hazardous samples on the basis of various chemical composition and nutrient contents were: pH: 30%, EC: 27%, TSS: 100%, CO_3^{-2}: 70%, HCO_3^-: 27%, Cl^-: 53%, Na^+: 23%, K^+: 40%, Ca^{+2}: 13%, Mg^{+2}: 17%, PO_4^{-3}:7%, NO_3^-: 100%. Similarly, the data (Table 6) illustrated that for drinking purpose the existence of hazardous samples on the basis of various chemical properties and nutrient contents were: pH: 30%, EC: 50%, TSS: 44%, CO_3^{-2}: 67%, HCO_3^-: 97%, Cl^-: 100%, Na^+: 100%, K^+: 83%, Ca^{+2}: 100%, Mg^{+2}: 83%, NO_3^-: 0%. The categorization of pond water samples for drinking purpose, on the basis of various chemical properties and nutrient contents, revealed that the existence of hazardous samples were: pH: 20%, EC: 0%, TSS: 100%, CO_3^{-2}: 73%, HCO_3^-: 93%, Cl^-: 100%, Na^+: 100%, K^+: 0%, Ca^{+2}: 60%, Mg^{+2}: 67%, NO_3^-: 40% (Table 6). The categorization of storage tank water samples for drinking purpose, on the basis of various chemical properties and nutrient contents (Table 6), revealed that the existence of hazardous samples were: pH: 0%, EC: 0%, TSS: 100%, CO_3^-: 100%, HCO_3^-: 80%, Cl^-: 100%, Na^+: 100%, K^+: 0%, Ca^{+2}: 100%, Mg^{+2}: 80%, NO_3^-: 60%.

DISCUSSION

Water quality monitoring and information management is scarce, even though it is important to all water quality improvement programs (Kahlown et al., 1998). For these reasons, it becomes highly indispensable to monitor the available water resources in a routine way for their better management and utilization. The present study confirmed these findings for an important region of Pakistan, the Thar Desert. The water samples taken from various sources of Taluka Nangarparkar, that is, dug wells, ponds and storage tanks were mostly found unfit for most of the chemical parameters and nutrient contents (Tables 5 and 6). Earlier, it has been reported that in Sindh only about 28% of the area has fresh groundwater suitable for irrigation. The area with non-potable highly brackish water include Thar, Nara and Kohistan (Kahlown et al., 1998). In Taluka Nangarparkar, people of the area mostly harvest rainwater by utilizing ponds and storage tanks. Runoff water harvesting techniques are proved very effective in managing the water shortage in the arid and semi arid regions (Mathur et al., 2000; Carlsson et al., 2001; Shangguan et al., 2002; Krishna, 2003). Samoon and Oad (2005) conducted study to evaluate the existing rainwater harvesting practices used in Thar Desert of Sindh (Pakistan), and to analyse the quality of harvested rainwater. The electrical conductivity (EC) of harvested rainwater of Mithi region ranged from 150 to 161 $\mu S\ cm^{-1}$. The EC of stored rainwater was higher than actual EC of rainwater. The pH of harvested rainwater ranged from 7.1 to 7.2. Carbonates were present in only two samples ranged from 0.18 to 0.29. Bicarbonate of rainwater ranged from 0.82 to 2.3, whereas, bicarbonate level was slightly increased in one sample due to absorbing gases from the atmosphere. Chloride, sulfate, calcium, magnesium and sodium values of harvested rainwater were mostly under range. Total Soluble Salts (TSS), and sodium adsorption of rainwater ranged from 3.7-4.5, 94.7-120.0 mg L^{-1} and 0.56 to 2.93, respectively. Chemical analysis of groundwater showed that EC level ranged from 1706 to 5040 $\mu S\ cm^{-1}$. The pH level ranged from 7.5 to 8.2 while TSS ranged from 1030 to 3040 mg L^{-1}. All other impurities were high in rainwater. The study concluded that rainwater harvesting concept should be extended and that the groundwater was unfit for drinking purpose.

Conclusion

The water samples of the study area were found to be hazardous on the basis of various chemical properties to

Table 5. Categorization of well water of for irrigation purpose of taluka Nangarparkar (n = 30).

Categorization	Interpretation	Percent samples
pH		
7.0-8.5	Safe	70
>8.5	Hazardous	30
EC (μS cm^{-1})		
<15	Safe	20
15-30	Marginal	53
>30	Hazardous	27
TSS (mg L^{-1})		
<1000	Safe	0
1000-1800	Marginal	0
>1800	Hazardous	100
CO_3^{-2} (mg L^{-1})		
0-300	Safe	30
>300	Hazardous	70
HCO_3^{-} (mg L^{-1})		
0-6100	Safe	73
>6100	Hazardous	27
Cl^{-} (mg L^{-1})		
0-10500	Safe	47
>10500	Hazardous	53
Na^{+} (mg L^{-1})		
0-9200	Safe	77
>9200	Hazardous	23
K^{+} (mg L^{-1})		
0-780	Safe	60
>780	Hazardous	40
Ca^{+2} (mg L^{-1})		
0-4000	Safe	87
>4000	Hazardous	13
Mg^{+2} (mg L^{-1})		
0-600	Safe	83
>600	Hazardous	17
PO_4^{-3} (mg L^{-1})		
0-2	Safe	93
>2	Hazardous	7
NO_3^{-} (mg L^{-1})		
0-10	Safe	0
>10	Hazardous	100

Table 6. Categorization of water bodies for drinking purpose of taluka Nangarparkar.

Categorization	Interpretation	Percent samples		
		Wells (n = 30)	Ponds (n = 15)	Tanks (n = 5)
pH				
≤8.5	Safe	70	80	100
>8.5	Hazardous	30	20	0
EC (µS cm^{-1})				
≤20	Safe	50	100	100
>20	Hazardous	50	0	0
TSS (mg L^{-1})				
<500	Safe	0	0	0
500-1500	Marginal	0	0	0
>1500	Hazardous	100	100	100
CO_3^{-2} (mg L^{-1})				
≤350	Safe	33	27	0
>350	Hazardous	67	73	100
HCO_3^- (mg L^{-1})				
≤1000	Safe	3	7	20
>1000	Hazardous	97	93	80
Cl^- (mg L^{-1})				
<200	Safe	0	0	0
200-600	Marginal	0	0	0
>600	Hazardous	100	100	100
Na^+ (mg L^{-1})				
<20	Safe	0	0	0
20-200	Marginal	0	0	0
>200	Hazardous	100	100	100
K^+ (mg L^{-1})				
<20	Safe	0	7	0
20-100	Laxative effect	7	60	20
>100-340	Bad Taste	10	33	80
>340	Hazardous	83	0	0
Ca^{+2} (mg L^{-1})				
<75	Safe	0	0	0
75-200	Marginal	0	40	0
>200	Hazardous	100	60	100
Mg^{+2} (mg L^{-1})				
<30	Safe	0	0	0
30-150	Marginal	17	33	20
>150	Hazardous	83	67	80
NO_3^- (mg L^{-1})				
<100	Safe	100	60	40
100-500	Marginal	0	0	0
>500	Hazardous	0	40	60

varying level. Generally water samples collected from dug wells were more hazardous as compared to the samples taken from the pond and storage tanks. The water samples showed a wide range of behavior in terms of their chemical properties and nutrient contents by touching both the low and high extremes. It is suggested that the quality of water bodies should be monitored on regular basis for its proper use for irrigation and drinking purposes.

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