Research article

Suitability of Groundwater Use for Drinking and Irrigation Purpose, Case Study of Kien Svay District, Kandal Province, Cambodia

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Received 6 February 2018 Accepted 25 October 2018 (*Corresponding Author)

Abstract In Cambodia, some studies found that groundwater in some areas was contaminated by heavy metals and chemicals. Those contaminants can harm to human health if it is not properly treated. The research aims to analyze groundwater quality to find out the suitability of parameters for drinking and irrigation purpose, and to understand the condition of groundwater quantity used by local farmers. The study was conducted in Sre Ampil II Village, Chheu Teal Commune, Kien Svay District, Kandal Province in June 2017. Water samples from 6 tube wells with the depth $\geq$ 20 m and $\geq$ 50 m were collected to analyze its water quality. The sampling sites were done at the front-part, middle-part and rare-part of the village. Some parameters of drinking water: pH, TDS, EC, turbidity, hardness, As, Fe, Mn, Cl^-, F, NO_3^-, NO_2^-, SO_4^{2-}, *Escherichia coli* and total coliform were collected to analyze its concentration while the parameters such as pH, TDS, EC, hardness, salinity, As, Mn, Fe, SO_4^{2-}, Cl^-, NO_3^-, PO_4^{3-}, NH_4^-, Ca^{2+}, Mg^{2+}, and Na^+ were collected to analyze water quality for irrigation purpose. The results showed that only three of fifteen parameters exceeded desirable limit of FAO and the national standard of Cambodia as Mn concentration averagely was surpassed the standard limits (0.4 mg/L), especially in well 6 (2.64 mg Mn/L). For the concentration of harness, it was happened only in well 1 and 2 with its concentration of 306 mg/L and 360 mg/L, respectively, which was above the national standard (300 mg/L), yet it is below the standard recommended by FAO. *E. coli* and total coliform were also presented in all wells while its concentration were highly exceeded the guideline. The results of parameters in irrigation water from three tube wells showed that Mn (2.64 mg/L) and K^+ (5.19 mg/L) surpassed the guideline of FAO as it was only 0.2 mg/L and 2 mg/L, respectively, while other parameters were below the guideline. Considering this value as standard, the waters in the well 2 and 3 could problematic for long-term irrigation. Based on the groundwater testing, it could be concluded that water quality in the study is good for drinking and irrigating purpose as most of the parameters are below the guideline of Cambodia national standard and FAO.

Keywords groundwater quality, drinking water, irrigation purpose, Cambodia

INTRODUCTION

A fresh and reliable water supply is necessary for human, animal and plants to ensure a high quality of life and to push a strong economical and agricultural development. Intensive cultivating and urban development has caused a great demand on groundwater resources. There have been various studies on assessment of suitable groundwater quality for drinking and irrigation purposes (Aksever et al., 2016; Ziani et al., 2016; Nag and Das, 2014; Kumar et al., 2014; Kaka et al., 2011). Groundwater locates in the deep layer and penetrates into small pore space between the rocks. Due to this natural flowing process, some mineral particulate components and hardness, Fe, Mn, As, NO3- and other particulate components are transferred by the water movement to various places depending on the groundwater flow direction.

The groundwater chemistry is an essential parameter for evaluating potential exploitable water of an aquifer (Gallardo and Tase, 2007). The main factors influencing hydrochemical groundwater quality are precipitation and dissolved minerals, ion-exchange and sorption and desorption in the groundwater flow (Apodaca et al., 2002). This situation is compounded by the complexity of the mineralogy saliferous, over exploitation of the aquifer and its low recharge, which limits the usable capacity of the aquifer this because of the considerable variation in the concentration of ions and the Total Dissolved Solids (TDS) (Belkhiri et al., 2012). At the same time, the environmental impacts of human activity like unused fertilizers, pesticides, sewage water and discharge of industrial effluents are considered as potential anthropogenic sources responsible for contamination of the groundwater (Venugopal et al., 2009). The presence of different chemical and physical constituents in excess of their permissible limits for various uses can create health hazards and environmental problems (Al-Zarah, 2007) and hence the water quality analysis is critical in ensuring that water consumed by the population meets the required quality standards (Amfo-Otu et al., 2014). In Cambodia, some studies found that groundwater in some areas was contaminated by heavy metals and chemicals. Those contaminants can harm to human health if it is not properly treated.

Having lived close to the Tonle Basac River, the main occupation of the people in Kien Svay District, Kandal Province, Cambodia is agriculture and related labor. Mostly they are growing vegetables with the application of heavy amount of chemical pesticide and fertilizers for increasing crop yields. This practice leads to increased potential contamination of agro- chemicals in environment and the water sources, especially surface water and groundwater, due to the leakage of agro-chemicals through precipitation and runoff.

OBJECTIVES

The research aims 1) To analyze groundwater quality to find out the suitability of parameters for drinking and irrigation purpose and 2) To understand the condition of groundwater quantity used by local farmers.

METHODOLOGY

The study was conducted in Phum II village located in Kean Svay District, Kandal Province where the water quality in the tube wells is not yet identified for both irrigation and drinking purposes. There are 214 families with the population of 862 people living in the village. The area of household is 20 ha while the paddy rice farming areas are 110 ha including dry and wet season cultivation. Villagers in this village can do the farming third time per year.

Sampling and analysis: Six tube wells were selected to analyze groundwater parameters with different depths of 20, 25, 30, 50, 55 and 60 m (for drinking purpose) and 50, 55 and 60 m (for irrigation purpose). The samples of water quality were chosen from the family whose tube wells were used in both irrigation and drinking purpose and the samples were collected by classifying the village into three sites: the front-part, middle-part and rare-part of the village. Some parameters such as pH, EC, TDS, hardness, turbidity and salinity were analyzed at the sites to avoid the error as their values are quickly changed with the times, while the other parameters such as As, Cl^-, F, Fe, Mn, NO_3^-, NO_2^-, PO_4^{3-}, Mg^{2-}, K^+, Ca^{2+}, *Escherichia coli* and total coliform etc. were brought to analyze in the laboratory at Resource Development International-Cambodia (RDI) by using different method of water analysis based on each parameter. These samples were taken from drinking and irrigation water wells after 5 minutes of pumping, given sufficient time for the water temperature to stabilize and become representative of the temperature of the aquifer. Those analyzed parameters were compared with the drinking water standard guideline recommended by the FAO (2003) and World Health Organization (WHO, 2011) as well as the Cambodia Drinking Water Quality Standardby the Ministry of Industry and Handicraft (MIH, 2004).

Statistical analysis: Statistical analysis was conducted in this study. Microsoft Excel program was used to analyze describtive statistic and, standard deviation, while the statistical package was used to determine Two Sample T-test in order to compare the significant differences of water quality parameters with different depth of tube wells.

RESULTS AND DISCUSSION

Water Quality for Drinking Purpose:

The quality of groundwater depends both on the substances dissolved in the water and on certain properties and characteristics that these substances impart to the water (Heath 1982). The results of the analyzed water quality of the 6 tube wells with different depths of 20, 25, 30, 50, 55 and 60 m for drinking purpose mostly do not exceed two standard maximum allowable limit values. The results of statistical analysis of the chemical compositions of the groundwater samples are shown in Table 1. The table showed that most of the average values of those parameters are substantially below the limited standards, yet Mn concentration is exceeded the standard limit.

The values of pH indicated low alkalinity in the groundwater. The pH of groundwater in the study area is within the limits (6.5 to 8.8) of WHO guideline for drinking water quality. The electrical conductivity of the water samples was rated in the category permissible to suitable (EC = 484-801 μS/cm). The concentration of TDS ranged from 324 to 537 mg/L. The water with a TDS level less than about 600 mg/L is generally considered to be good (WHO, 2011). Also, the maximum permissible limit of TDS for drinking water is 800 mg/L as per the MIH (2004) drinking water standards. Thus, according to the WHO (2011), FAO (2003) and MIH (2004), the TDS values of all wells are suitable for drinking. The concentration of harness ranged from 198 to 360 mg/L and was exceeded above the national standard limits (300 mg/L) only in well 1 and 2 with their concentration of 306 mg/L and 360 mg/L, respectively. Ninety percent of analyzed samples were not exceeded the desirable national limit (200 mg/L) of chloride (Cl^-) according to WHO guideline for drinking water. Only ten percent of samples exceed the desirable limit (250 mg/L) of sulphate (SO_4^{2-}) of WHO guideline for drinking water. The NO_3^-, NO_2^- and F could not be detected by the machine. In Table 1, it is indicated that the concentration of Mn was very high above the standard limits. Arsenic presented in all wells and above the recommended standard of the WHO (2011) which the maximum permissible limit for As concentration in drinking water is 0.01 mg/L. The mean concentration values of Fe in the wells is 0.14 mg/L. According to the WHO (2011), maximum accessible values for Fe concentration in drinking water are 0.3 mg/L. Considering this as the standard value, the Fe contained in the water is still suitable for the drinking purpose, even though the well 5 reached to the peak of the limited standard (0.3 mg/L), following by well 6 (0.28 mg/L). *E. coli* and total coliform were also presented in all wells while its concentration were highly exceeded the guideline as the numbers of coliform were too numerous to count in the machine. However, the presence of these parameters do not cause serious illness to the human health as they could be eliminated by boiling water before drinking (RDI, 2016), or by using Biosand Filter-Zeolite, *E. coli* were completely removed during the first three trials after filtering total volumes of 1120 L, 1140 L and 1220 L (Mwabi et al., 2012). Moreover, the stables or pens which are located next to the wells should be removed to build at other place to avoid contamination.

Table 1 Summary of physical, chemical, and pollution parameters of drinking water

Parameters	Unit	Mean						Ave	Max	Min	SD	n	WHO (2011)	MIH (2004)
		Well 1 (20m)	Well 2 (25m)	Well 3 (30m)	Well 4 (50m)	Well 5 (55m)	Well 6 (60m)							
pH	-	7.30	7.10	6.90	7.10	6.90	6.80	7.01	7.30	6.80	0.07	3	6.5-8.8	6.5-8.5
EC	µs/cm	624.00	801.00	728.00	491.00	500.00	558.00	616.88	801.00	484.00	3.82	3	1500	-
TDS	mg/L	418.00	537.00	487.00	329.00	335.00	374.00	413.00	537.00	324.00	2.56	3	600-1000	800
Turbidity	NTU	0.86	0.93	1.05	1.17	2.03	1.94	1.32	2.06	0.85	0.02	3	5	5
Hardness	mg/L	306.00	360.00	288.00	234.00	216.00	198.00	267.00	360.00	198.00	14.70	3	500	300
Cl^-	mg/L	28.93	27.07	38.64	17.48	18.74	45.01	28.47	45.00	17.50	10.12	1	200	250
SO_4^{2-}	mg/L	51.78	113.84	65.94	18.40	28.14	56.00	55.68	113.84	18.40	30.69	1	200	250
NO_3^-	mg/L	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	1	50	50
NO_2^-	mg/L	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	1	3	3
Mn	mg/L	1.60	1.90	2.10	0.25	0.47	2.64	1.50	2.75	0.24	0.06	3	0.4	0.1
As	mg/L	0.013	0.021	0.016	0.021	0.036	0.027	0.021	0.030	0.010	0.005	3	0.01	0.05
Fe	mg/L	0.01	0.07	0.01	0.16	0.30	0.28	0.14	0.31	0.01	0.13	3	0.3	0.3
F	mg/L	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	1	1.5	1.5
E-coli	CFU/100mL	7.00	14.00	60.00	70.00	85.00	70.00	51.00	85.00	7.00		1	-	0
T-Coliform	CFU/100mL	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	870.00	2465.00	300.00		1	-	0

Note: n= Frequency of the testing parameters of the drinking water
DL = Detection Limit, TNTC = Too Numerous To Count

Water Quality for Irrigation Purpose:

Three wells with different depth of 50, 55 and 60 m were analyzed for its water parameter for the irrigation purpose. It is important to understand the pH in water supplies for the irrigation. As indicated in Table 2, the pH values of the wells in the investigation area ranged from 6.80 to 7.10 with an average value of 6.95. According to FAO (2003), the pH value of irrigation water should be between 6.0 and 8.5. Well 1 could be described as alkaline (pH > 7), while wells 2 and 3 are acidic (pH < 7), 6.90 and 6.80, respectively. All of the pH values of water in those wells are suitable for irrigation water standard of FAO (2003). Also, according to the Food and Agriculture Organization (FAO) (Misstear et al., 2006), permissible limit pH ranged from 6.5 to 8.4 for irrigation water is suitable. The EC values of the wells ranged from 484 to 560 µS/cm with an average value of 516.44 µS/cm (Table 2). TDS values of wells were measured, and these values varied from 324 to 375 mg/L with an average value of 345.88 mg/L (Table 2). The palatability of water with a TDS level of less than about 600 mg/L was generally considered to be good (WHO 2011). Salinity represented by the TDS, varies between 0.20 and 0.30 mg/L. Higher concentrations of salinity indicated that the ionic concentrations were more in the groundwater. The content of Ca^{2+} in water samples collected from different depth of wells varied from 60 to 69 mg/L. Irrigation waters containing less than 400 mg Ca^{2+}/L is suitable for irrigating crops (Groeneveld and Meeden, 1984). Considering this value as standard, Ca^{2+} content in 95% water samples could safely be used for irrigation and would not affect soils. The concentration of Na^+ in water samples from wells varied from 58 to 66 mg/L. Irrigation water generally containing less than 920 mg/L Na^+ is suitable for crops and soils. The observed Na^+ content in all water samples had far below this specified limit. The concentration of K^+ present in the water samples ranged from 0 to 5 mg/L. According to Groeneveld and Meeden, (1984), the recommended limit of K^+ in irrigation water is 2.0 mg/L. Considering this value as standard, the waters in the well 2 and 3 could problematic for long-term irrigation. It is noted that the concentration of K^+ value seemed increasingly parallel with the depth of the wells as the more deeper the wells are, the more K^+ concentration accumulates (Table 2). The concentration of Mg^{2+} in water samples is within the range of 32-45 mg/L. Irrigation waters containing less than 60 mg Mg/L are suitable for irrigating crops while the analyzed water samples are below this limit and may not have a negative impact on soils or irrigating water.

Water samples collected from three wells contained a chloride concentration ranging from 17 to 45 mg/L. Maximum permissible limit of Cl^- in irrigation water is 1064 mg/L and all analyzed water samples were far below the standard limit. The SO_4^{-2} concentration in water samples ranged from 18 to 56 mg/L, while the standard limit of SO_4^{-2} in irrigation water is 960 mg/L and all water samples collected from the wells are below this acceptable limit of irrigation water quality. PO_4^{3-}, NO^{3-} and NH_4^- could not be detected by the machine as their concentration are very high exceeded the desirable limit of the FAO guideline. Thus, the irrigation water may have negative impact from these elements and might be harmful for crop production.

Table 2 Summary of physical, chemical, and pollution parameters of irrigation water

Parameters	Units	Well 1 (50 m)	Well 2 (55 m)	Well 3 (60 m)						FAO (2003)
			Mean		Max	Min	Aver	SD	n	
pH	-	7.10	6.90	6.80	7.10	6.80	6.95	0.106	3	6-8.5
EC	µs/cm	491.00	500.00	558.00	560.00	484.00	516.44	30.078	3	0-3000
TDS	mg/L	329.00	335.00	374.00	375.00	324.00	345.88	20.190	3	0-2000
Turbidity	NTU	1.17	2.03	1.94	2.06	1.15	1.71	0.385	3	-
Salinity	ppt	0.20	0.20	0.30	0.30	0.20	0.23	0.047	3	-
Ca^{2+}	mg/L	61.86	69.19	60.59	69.19	60.59	63.88	3.790	1	0-400
Na^+	mg/L	60.43	66.14	58.59	66.14	58.59	61.72	3.214	1	0-920
K^+	mg/L	0.00	2.63	5.19	5.19	0.00	2.60	2.118	1	0-2
Mg^{2+}	mg/L	32.59	33.22	45.63	45.63	32.59	37.14	6.004	1	0-60
Cl^-	mg/L	17.48	18.74	45.01	45.01	17.48	27.07	12.691	1	0-1000
SO_4^{2-}	mg/L	18.40	28.14	56.00	56.00	18.40	34.18	15.933	1	0-960
PO_4^{3-}	mg/L	<DL	<DL	<DL	<DL	<DL	<DL	-	1	0-2
NO_3^-	mg/L	<DL	<DL	<DL	<DL	<DL	<DL	-	1	0-10
NH_4^-	mg/L	<DL	<DL	<DL	<DL	<DL	<DL	-	1	0-5
Mn	mg/L	0.25	0.46	2.64	2.75	0.24	1.12	1.081	3	0-0.2
As	mg/L	0.02	0.03	0.03	0.03	0.02	0.024	0.003	3	0-0.1
Fe	mg/L	0.16	0.30	0.28	0.31	0.15	0.24	0.064	3	0-5

Note: n= Frequency of the testing parameters of the irrigation water, DL = Detection Limit

Chemical elements in subsurface water come from geogenic and anthropogenic sources. The weathering of minerals is one of the major natural sources. Ion exchange is also an important process for elements. Anthropogenic sources include fertilizers, industrial effluent, and leakage from service pipes. The elements as Mn, As and Fe of well samples were determined for water quality in the study area. The maximum contents of Mn, As and Fe of well water samples were determined as 2.75, 0.03 and 0.31 mg/L, respectively, while the average values of these elements were 1.12, 0.024 and 0.24 mg/L. The Mn, As and Fe contents of the water samples are within the permissible limit of FAO (2003) and WHO (2011). Thus, the irrigation water is in a good condition for irrigating the crops. However, the suitability of groundwater for irrigation is conditional on the effects of the mineral constituents of water on both the plant and soil. The excessive amount of dissolved ions in irrigation water affects plants and agricultural soil physically and chemically, thus reducing the productivity (Ziani et al., 2016). Agriculture and related labor are the main occupation of the rural people in the Kien Svay District, Kandal Province, Cambodia. Therefore, the determination of irrigation water quality in the ground is gaining importance.

Table 3 Statistical analysis of water quality in different depth (20-30 m and 50-60 m)

Parameters	Units	Well depth (m)		Main-Whitney (P value)
		20-30	50-60	
pH	-	7.10	6.90	0.261
EC	µs/cm	717.00	516.00	0.050
TDS	mg/L	329.00	335.00	0.050
Turbidity	NTU	0.95	1.71	0.050
Harness	ppt	318.00	216.00	0.050
SO_4^{2-}	mg/L	77.19	34.18	0.127
Cl^-	mg/L	29.88	27.07	0.513
Mn	mg/L	1.86	1.12	0.513
As	mg/L	0.017	0.024	0.077
Fe	mg/L	0.03	0.25	0.040*
E. Coli	CFU/100mL	27.00	75.00	0.046*

*Note: * Significant difference at P<0.05*

Statistical analysis of some parameters such as pH, EC, TDS, turbidity, hardness, SO_4^{2-}, Cl^-, Mn, As, Fe and *E. coli* with the different depths of wells indicated that there is no significant difference (P<0.005) between the concentration of values pH, turbidity, EC, harness, TDS, Mn, SO_4^{2-}, As, Cl^-, Mn, As in the groundwater of the study area (Table 3). However, the concentration of Fe and *E. coli* in the tube wells with the depth of 20 to 30 m and 50 to 60 m illustrated that the two parameters were significantly different as the P value are P=0.040 and P=0.046, respectively. Based on this comparison, it can be concluded that the depths of the tube well are not highly related with the water parameters as they would sometimes be changed. The findings of this study are different from the RDI (2012), that collected over 1,000 water samples in five provinces since 2005 from tube wells (also known as boreholes) with the depth ranged from 15 to 80 m and open wells (also known as dug wells) with 3-15 meter depth to analyze some parameters such as pH, salinity, hardness, turbidity, As, F, NO_3^-, NO_2^-, Mn, Fe and Cl^-. The results showed that the more deeper the tube wells are, the more good quality of water would be obtained without contaminating from micro-organisms and bacteria, but it was effected from the chemical and hardness which occurs naturally while the shallow tube wells and surface water always contaminated by bacteria.

CONCLUSION

Suitability of groundwater samples according to exceeding the permissible limits prescribed by WHO and FAO for drinking purposes indicated that the groundwater in the study area are chemically suitable for drinking and irrigation purpose. Yet, Ca^{2+}, Mn, *E. coli* and total coliform were exceeded the standard limit. The Mn concentration in 6 tube wells was highly above the standard (0.1 mg/L). Moreover, the presence of *E. coli* and total coliform in these wells were high. Therefore, some measures should be applied to prevent diseases or other illness caused by the contaminated water. The results of the comparison between different well depths showed that the depth of the tube well does not clearly related with contaminant to the groundwater in the study area as some parameters of drinking and irrigation water sometimes changed and affected by the contaminant from other sources. In the study area, it can be noticed that some wells are located closely to the stables or pens; as a result, some of water parameters are changeable unexpectedly. In general, based on the observation in the village and results, the water quality in the study area is good for irrigation even though some parameters are above the limited standard of FAO. For the analyzed parameters of drinking water quality, some of them are above the standard limits of WHO (2011) and national standard of Cambodia, MIH (2004) which is not recommended to drink as it could harm the human health. However, *E. coli* and total coliform are easy to eliminate by boiling water before drinking (RDI, 2016).

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