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Seasonal Variation of Groundwater Quality and Its Suitablility for Domestic and Agricultural Use in Chrey Bak Catchment, Tonle Sap Lake Basin

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Abstract: *Understanding the aquifer hydraulic properties and hydrochemical characteristics of water are crucial for the management plan and study skims in Cambodia, where groundwater has been used for domestic and agricultural purposes in the rural area. In this study, there are two times observed well during late wet season October 2017 and early wet season May 2018. Water Quality Index (WQI) was use to assess of groundwater for drinking and SAR, KR, SSP, MH, Na%, RSC, PI and Gibbs diagram use to evaluated and defined origin of groundwater quality for Agriculture. The overall assessment of groundwater quality for drinking purpose in both late and early wet season shown in excellent and good quality. The water quality can be accepted without the adverse effect of magnesium hazard to irrigation. However, with respect to RSC nearly a half number of samples fell into poor quality for irrigation, and another half number of sampling point were within the medium quality in the late wet season but showed a good grade in early wet season. In term of KR in both seasons, only a few samples are unsuitable for agriculture, and the rest of the sample are a good quality. The potential for a sodium hazard in late wet season increased as the result of the magnesium precipitated from a solution when water is applied to the soil. The causes were confirmed by the results of Gibbs diagram. However, the permeability of soil is not affected by Na^{+}, Ca^{2+}, Mg^{2+} and HCO_3^- which influence groundwater quality in both seasons. Respect to Na% and EC revealed that all samples of the groundwater samples fell into the good to permissible and excellent to good quality during both seasons. Therefore, Groundwater was found not to be affected by Na^{+} and EC, and it was suitable for irrigation. Based on the US salinity Laboratory's diagram, the groundwater for irrigation was found from low to medium in both wet and late wet season in term of conductivity and salinity. In conclusion, the groundwater quality in Chrey Bak catchment is very good for domestic and agriculture however treated groundwater before using still recommend due to some parameters such as arsenic and heavy metal are not included in this study.*

Keywords: Agriculture; Chrey Bak catchment; Domestic; Groundwater; Water Quality

1. INTRODUCTION

Groundwater is a major source of water to use for domestic, agriculture, industrial and any purpose. However, in Cambodia, groundwater is a vital source of water to use, especially, in the dry season, while surface water not available to use. About 53% of households access groundwater for domestic use in the dry season from shallow tube-wells or hand-dug wells (Johnston et al., 2013). Even the amount of groundwater is excessive, but the quality of groundwater for consumption has limited and concerned. A specific risk of groundwater quality has been identified in the rural area of Cambodia. However, it is widely acknowledged that the majority of well in the rural household have been bore/dug and utilized without any testing of water quality. There is a growing concern that untested borewell water in many provinces threatens to health and unsuitable for use (Guppy and Shantz, 2011). There are many pollutant parameters which discover in groundwater. Poor groundwater quality is primarily the result of domestic, agricultural and industrial pollution, and saline intrusion or naturally derived contaminants including heavy metals, fluoride, nitrate, and arsenic (Buschmann et al., 2008). Therefore, the water quality issue should be given greater attention in developing countries. The adequate amount of water is absolutely essential for the proper growth of plants, but the quality of water used for irrigation purposes should also be within the permissible limit; otherwise, it could adversely affect the plant growth. Questions have been raised to the social and environmental sustainability of this intensive model of crop production. The hydrochemical characteristics of groundwater play a vital role in classifying and evaluating water quality.

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Geochemical studies of groundwater provide a better understanding of possible changes in quality.

Identification of water quality for drinking and irrigation usually based mainly on a number of chemical contaminants. The contaminants are of both inorganic and organic origin than can be from point source and non-point source. Many naturally occurring major, minor and trace elements in drinking water can have an effect on human health and animal (Frengstad et al., 2001) while the major influences on crop and plant are salinity and soil permeability. In order to use groundwater safety and without harmful to human health, the classification of groundwater quality is very necessary for evaluation and its suitability for domestic and agriculture. When the level of groundwater quality has been clarified, then the impact factor and parameter on groundwater also defined and set a strategy to control and mitigate groundwater. The method that is able to provide information about groundwater quality is physical and hydrochemical analysis from wells in the study area to determine the main factor and mechanisms controlling the chemistry of groundwater.

The study aims 1) to evaluate groundwater quality for domestic use and agriculture use, and 2) to define the classification and origin of groundwater at Chrey Bak.

2. METHODOLOGY

2.1 Description of the study area

The Chrey Bak catchment of Tonle Sap Lake Basin was selected to discuss the impact of spatial variation of the rainy season of groundwater quality on irrigation and human health, where the agriculture is the main livelihood of rural people and the groundwater is the supplementary source for irrigation and the main source for drinking. Chrey Bak catchment is one of the sub-basins of Tonle Sab lake basin with around 700 km^2 in area, which is located in Kampong Chhnang province. Groundwater samples were collected from 12 shallow and deep wells of the area during the late wet season, October 2017 and early wet season, May 2018. However, in the early wet season missed on well data recorded (CB18). The location of the sampling points is shown in Figure 1. Observed well are pumped for 10 min to remove stored water in the wells, and each sample was filtered using 0.45µm filters of acetate cellulose and store sample in plastic bottles and keep in temperature 4℃ before transfer to Laboratory. The parameter analysis was based on the reference method of Official Methods of Analysis of AOAC (Association of Official Analytical Chemists) (AOAC, 1990). Each parameter has a different method reference such as Total hardness (AOAC 973.52), NO_3^- (AOAC 973.50), SO_4^{2-} (AOAC 973.57), Na^+ (AOAC 973.54), Ca^{2+} (AOAC 920.199), Mg^{2+} (AOAC 920.200), K^+ (AOAC 973.53), HCO_3^- (AOAC 973.42) and Cl^- (APHA 4500-Cl-B) based on Standard Method for the Examination of Water and Wastewater (APHA, 1992). Other parameters, like pH and EC were measure immediately during sampling.

2.2 Water quality index for drinking

Water quality index (WQI) was used in the literature since early 1965. WQI is a method of combining the results of several parameters into one overall value describing the quality of water which is attempted to provide a better understanding of the results of water quality monitoring and assist in the water quality management of the Mekong River.

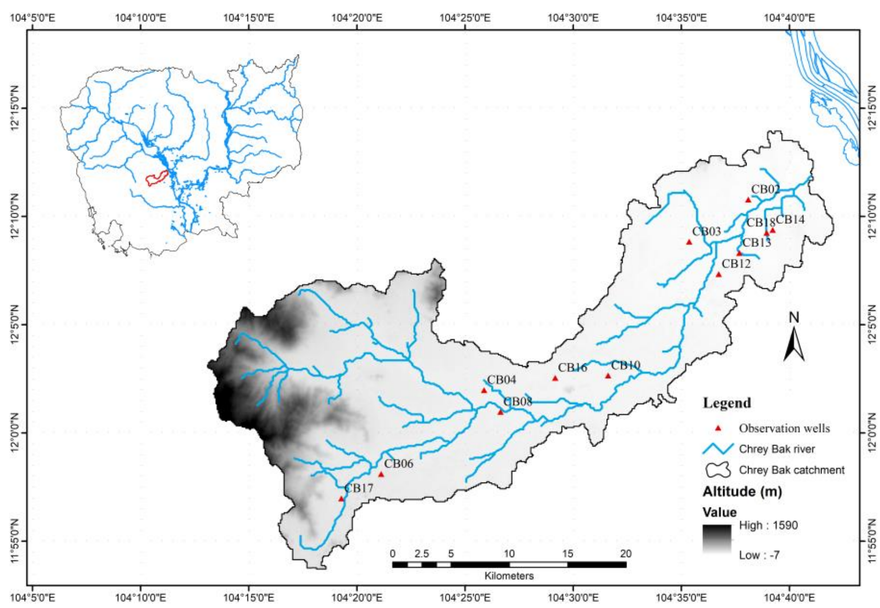

Fig 1. The location of sampling points of groundwater parameter in Chrey Bak catchment

The analyzed parameters of the groundwater samples include pH, total dissolved solid (TDS), total hardness (TH), chloride (Cl^-), magnesium (Mg^{2+}), calcium (Ca^{2+}), nitrate (NO_3^-), sodium (Na^+), phosphate (PO_4^{3-}), Sulfate (SO_4^{2-}), potassium (K^+), bicarbonate (HCO^{3-}) and electrical conductivity (EC). However, there are some important parameter of groundwater quality such as arsenic, and heavy metal did not include to this study due to limitation of time data collection in this study. Anyway, with these 13 parameters, there is enough to complete the objective of this study. Base on (Ramakrishnaiah et al., 2009), three steps are applied to computing WQI of groundwater:

For the first step, each of the parameters has been assigned a weight (W_i) according to its effective magnitude in the water quality of drinking utility. Not all measured parameter needs to select. The value of parameter weight based on the literature on previous studies (Batabyal and Chakraborty, 2015; Krishnakumar et al., 2014; Meher et al., 2015). The weight of parameters ranges from 2 to 5 as shown in Table 1.

The maximum weight of 5 has been assigned to the nitrate parameter due to its major importance in water quality assessment. Magnesium which is given the minimum weight of 2 as magnesium by itself may not be harmful.

For second step, the relative weight (W_i) is computed from the following equation:

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \quad \text{(Eq. 1)}$$

Where:

W_i = the relative weight

w_i = the weight of each parameter

n = the number of parameters

Calculation of the relative (W_i) value all the chemical parameters use is also provided.

For third step, a quality rating scale (q_i) for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the Bureau of Indian Standards (BIS) and the result multiplied by 100:

$$q_i = \frac{C_i}{S} \times 100 \quad \text{(Eq. 2)}$$

For computing the WQI, the SI is first determined for each chemical parameter, which is then used to determine the WQI as per the following equation

$$SI_i = W_i \cdot q_i \quad \text{(Eq. 3)}$$

$$WQI = \sum SI_i \quad \text{(Eq. 4)}$$

Where:

SI_i = the sub index of ith parameter

q_i = the rating based on the concentration of ith parameter.

The computed WQI values are classified into five types, “excellent water” to “water unsuitable for drinking” as shown in Table 2.

Table 1. Relative weight of chemical parameters (Wi) of groundwater of Chrey Bak catchment

Parameters	Indian Standards	WHO (2011)	CNDWQS	Weight (wi)	Relative weight (Wi)
pH	7	6.5-8.5	6.5-8.5	4	0.13
TDS (mg/L)	500	1200	800	4	0.13
TH (mg/L)	300	-	300	2	0.07
Cl^- (mg/L)	250	250	250	3	0.10
Mg^{2+} (mg/L)	30	50	-	2	0.07
Ca^{2+} (mg/L)	75	75	-	2	0.07
NO_3^- (mg/L)	45	50	50	5	0.17
Na^+ (mg/L)	200	-	200	3	0.10
K^+ (mg/L)	12	-	-	2	0.07
HCO_3^- (mg/L)	300	-		3	0.10
SO_4^{2-} (mg/L)	200	10	250	4	0.12

Noted: CNDWQS (Cambodian National Drinking Water Quality Standard) (Vanny et al., 2015)

Table 2. Classification of water quality based on WQI

WQI value	Water quality
<50	Excellent
50-100	Good water
100-200	Poor water
200-300	Very poor water
>300	Water unsuitable for drinking

2.3 Suitability for Agricultrual Purpose

Sodium Absorption Ratio (SAR): The sodium adsorption ration (SAR) indicates the effect of relative cation concentration on sodium accumulation in the soil; thus, SAR is a more reliable method for determining this effect than sodium percentage. The SAR is an indicator of the amount of sodium in the water relative to calcium and magnesium (Grattan, 2002). SAR is calculated using the following formula:

$$SAR = \frac{\mathrm{Na}^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \quad \text{(Eq. 5)}$$

Ions are expressed as milliequivalents per liter (meq/L). The potential for a sodium hazard increases in waters with higher SAR values. The US salinity diagram used combination of EC and SAR to classified groundwater for agricultural.

Kelley's Ratio (KR): Sodium measured against Ca^{2+} and Mg^{2+} is used to calculate Kelley's ratio. The formula used in the estimation of KR ratio is expressed as:

$$KR = \frac{Na^{+}}{Ca^{2+} + Mg^{2+}} \quad \text{(Eq. 6)}$$

KR of more than one indicates an excess level of sodium in waters. Hence, waters with a Kelley's Ratio less than one are suitable for irrigation, while those with a ratio more than one are unsuitable for irrigation.

The Soluble Sodium Percent (SSP): The Soluble Sodium Percent (SSP) for groundwater was calculated by the formula:

$$SSP = \frac{Na^{+} \times 100}{Ca^{2+} + Mg^{2+} + Na^{+}} \quad \text{(Eq. 7)}$$

Where the concentrations of Ca^{2+}, Mg^{2+} and Na^{+} are expressed in meq/L. The Soluble Sodium Percent (SSP) values less than 50 or equal to 50 indicate good quality water, and if it is more than 50 indicating the unsuitable water quality for irrigation.

Residual Sodium Carbonate (RSC): Waters containing a carbonate plus bicarbonate concentration greater than the calcium plus magnesium concentration have what is termed "residual sodium carbonate."

$$RSC = (\mathrm{CO_3} + \mathrm{HCO_3}) - (\mathrm{Ca} + \mathrm{Mg}) \quad \text{(Eq. 8)}$$

The potential for a sodium hazard is increased as Residual sodium carbonate (RSC) increases, and much of the calcium and sometimes the magnesium is precipitated out of solution when water is applied to the soil. Salts become concentrated when the soil dries out, as less soluble ions such as calcium and magnesium tend to precipitate out and are removed from the solution.

Permeability Index (PI): The soil permeability is affected by the long-term use of irrigation water as it is influenced by Na^{+}, Mg^{2+}, and HCO_3^{-} contents in the soil. According to Doneen (1964), classification of PI greater than 75% is excellent, 25% to 75% is good, and less than 25% is unsuitable for agriculture purpose. The calculation of PI is following the formula below, where all concentrations of ion are in meq/l.

$$PI = \frac{100(Na^{+} + \sqrt{HCO_3^{-}})}{Ca^{2+} + Mg^{2+} + Na^{+}} \quad \text{(Eq. 9)}$$

Magnesium Hazard (MH): MH value for irrigation water is calculated following formula below, where all the concentrations are expressed in meq/L. To assessment groundwater quality for irrigation, magnesium hazard has been calculated by Szabolcs and Darab (1964).

$$MH = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} \times 100 \quad \text{(Eq. 10)}$$

Electrical Conductivity and Percent Sodium: EC and Na are the most common parameters that use in classify irrigation water. High salt content in irrigation causes osmotic pressure in soil solution. (Ramesh and Elango, 2012). High amount of sodium in water produces very harmful effects of changing soil properties and soil permeability (Nishanthiny et al., 2010). Wilcox diagram was used to classify groundwater quality for agriculture base relationship of EC and Na%.

$$Na\% = \frac{100(Na^{+} + K^{+})}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}} \quad \text{(Eq. 11)}$$

2.4 Classification and Estimation of Origins for Groundwater

The characteristics of cations and anions in groundwater represent the unique physico-chemical characteristics caused by the groundwater interaction with rock and soil while flowing in the aquifer. The aquifer represents the characteristics of water bodies with different chemical compositions. Therefore, such characteristics are called the hydrochemical facies of groundwater. In this study, the distribution of anions (Cl^{-}, HCO_3^{-}) and cations (Na^{+}, Ca^{2+}) as well as the TDS values were applied to plot the Gibbs diagram (Gibbs, 1970) to guess the dominance types such as evaporation dominance, rock dominance, and precipitation dominance.

Gibbs diagram: Gibbs diagram is used to interpret the effect of hydrogeochemical processes such as precipitation, rock-water interaction mechanism, and evaporation on groundwater geochemistry. The reaction between groundwater and aquifer minerals has a significant role in controlling groundwater quality, which is useful to assume the genesis of water. Gibbs ratio is calculate using the following equation.

$$Gibbs\,ratio\,I\,(\,for\,anion) = \frac{Cl^{-}}{Cl^{-} + HCO_3^{-}} \qquad \text{(Eq. 12)}$$

$$Gibbs\,ratio\,II\,(\,for\,cation) = \frac{Na^{+} + K^{+}}{Na^{+} + K^{+} + Ca^{2+}} \qquad \text{(Eq. 13)}$$

The majority of groundwater occur in the middle part of Gibbs diagram (boomerang shape) indicated water-rock interaction. the position of groundwater either right or left side of diagram based on soil and aquifer properties. Evaporation from groundwater is not negligible so the right upper of Gibbs diagram explain that evaporation is the main process driving groundwater chemistry. Moreover, groundwater also receive water from surface especially precipitation. Hence the lower right corner of Gibbs diagram show precipitation dominance of groundwater (Marandi & Shand, 2018).

3. RESULTS AND DISCUSSION

3.1 Seasonal groundwater quality in Chrey Bak catchment

As mentioned about the objectives of this paper, groundwater samples were classified based on their use as agricultural, residential, and drinking water. Table 3 represents the descriptive statistics of the Groundwater quality in Chrey Bak catchment. The pH of groundwater ranges from 6.32 to 7.55 with mean value 6.95 in late wet season 2017 and 5.89 to 7.07 with mean 6.58 in early wet season 2018. The concentration of TDS varies from 58 mg/l to 618 mg/l with average 228.75 mg/l in the late wet season and varies from 77 mg/l to 398 mg/l with average 227.91 mg/l in the late wet season. The concentration of TDS in the late wet season is a little higher due to effect from rainfall. TH value in the late wet season is from 51.1 mg/l to 512.02 mg/l wile mean 146.79 mg/l and in the early wet season is from 29.68 mg/l to 263.07 mg/l while mean 109.34 mg/l indicating the increased concentration towards late wet season. According to the grading standards of TH (as CaCO3), groundwater can be divided into soft water (TH<150 mg/l), moderately hard water (150<TH<300 mg/l), hard water (300<TH<450 mg/l), extremely hard water (TH<450 mg/l) (Sadat-Noori et al., 2014).The EC is between 99.35 µS/cm to 920.34 µS/cm with mean 382.56 µS/cm in late wet season and between 130.40 µS/cm to 667 µS/cm with mean 380.87 µS/cm. Among the cation Mg^{2+}, Ca^{2+}, K^{+}, and Na^{+} range from 1.3 to 60.6, 14.03 to 103.81, 0.5 to 125, and 0.79 to 79 with a mean of 11.34, 39.8, 19.05, and 26.1 in late wet season, respectively while in early wet season range from 0.6 to 34.65, 10.46 to 66.8, 0.66 to 86.62, and 0.63 to 63.30 with mean of 6.82, 32.37, 20.19, and 26.76, receptively. For anions such as NO_3^{-}, HCO_3^{-} and Cl^{--} lie between 0.8 to 46.2, 140.3 to 1195.6, 10.7 to 99.32 with average 12.26, 300.34 and 30.94 in late wet season, respectively and 0.03 to 21.67, 36.6 to 311.1, and 0.04 to 0.2 with average 9.99, 125.88 and 0.11 in early wet season respectively. However, the concentration of SO_4^{2-} was missing in late wet season and have only in early wet season with range from 1 mg/l to 63 mg/l with mean 16.27 mg/l. and PO_4^{-} was missing in early wet season and have only in late wet season vary from 42 mg/l to 175 mg/l with average 43.35 mg/l. Among these anions, Cl^{-} is very high in late wet season compare early wet season which may casue salty tase and has a laxative effect (P. S. J. M. E. S. Kumar and Environment, 2016). Based on average value of parameter compare to IS, WHO and CNDWQS standard for drinking water indicated that all paramerter are under standard and suitable for drinking except for potassium with average 20 mg/l while IS standard permit only 12 mg/l.

3.2 Water qualityindex for drinking

Table 4 and Figure 2 show a value of WQI of groundwater in Chrey Bak catchment during late wet season 2017 and early wet season 2018. Based on this table indicate that most groundwater samples provided an excellent and good water quality for drinking and domestic in both early and late wet season. The value of WQI ranges from 26.85 to 135.06 in the late wet season and 22.14 to 84.72 in early wet season. During late wet reason, 25% of groundwater sample were "poor", 17% were "good" and 58% were "excellent". In early wet season 27% of groundwater sample were "good", and 73% were "excellent". However, some groundwater sample such as CB02, CB08, and CB014 deteriorated in the late wet season due to contaminant leached from the land surface and lateritic soil and rocks because of rainfall during the wet season. The WQI value in the late wet season seems to be higher than in early wet season. The higher WQI value in the study area was observed due to higher concentration of parameters in groundwater sample in late wet season than in early wet season. However, the lower value of WQI in early wet season indicate a dilution effect.

Table 3. Descriptive statistics of the Groundwater quality of Chrey Bak catchment in both late and early wet season

Parameters	Late wet season 2017				Early wet season 2018			
	Min	Max	Mean	SD	Min	Max	Mean	SD
pH	6.32	7.55	6.95	0.40	5.89	7.07	6.58	0.38
TDS (mg/L)	58.00	618.00	228.75	179.44	77.00	398.00	227.91	117.87
TH (mg/L)	51.10	512.02	146.79	131.41	29.68	263.07	109.34	73.85
EC (µS/cm)	99.35	920.34	382.56	290.72	130.40	667.00	380.87	197.87
Mg^{2+} (mg/L)	1.30	60.60	11.34	16.00	0.60	34.65	6.82	9.68
Ca^{2+} (mg/L)	14.03	103.81	39.80	28.09	10.46	66.80	32.37	17.95
K^{+} (mg/L)	0.50	125.00	19.05	40.34	0.66	86.62	20.19	27.36
Na^{+} (mg/L)	0.79	79.00	26.10	21.94	0.63	63.30	26.76	19.10
NO_3^{-} (mg/L)	0.80	46.20	10.30	12.26	0.03	21.67	9.99	7.95
HCO_3^{-} (mg/L)	140.30	1195.60	359.49	300.34	36.60	311.10	125.88	98.14
Cl^{-} (mg/L)	10.70	99.32	40.91	30.94	0.04	0.20	0.11	0.05
SO_4^{2-} (mg/L)	-	-	-	-	1.00	63.00	16.27	20.42
PO_4^{3-} (mg/L)	42.00	175.00	82.08	43.35	-	-	-	-

Table 4. WQI value and classification of groundwater at Chrey Bak catchment during both late and early wet season

Well code	Late wet season 2017		Early wet season 2018	
	WQI Value	Water Quality	WQI Value	Water Quality
CB02	103.71	Poor water	65.61	Good water
CB03	35.68	Excellent	24.90	Excellent
CB04	35.80	Excellent	30.26	Excellent
CB06	28.11	Excellent	22.14	Excellent
CB08	114.51	Poor water	48.57	Excellent
CB10	26.85	Excellent	56.60	Good water
CB12	29.29	Excellent	23.04	Excellent
CB13	35.66	Excellent	32.41	Excellent
CB14	135.06	Poor water	84.72	Good water
CB16	31.90	Excellent	23.11	Excellent
CB17	50.63	Good water	44.53	Excellent
CB18	68.43	Good water	-	-

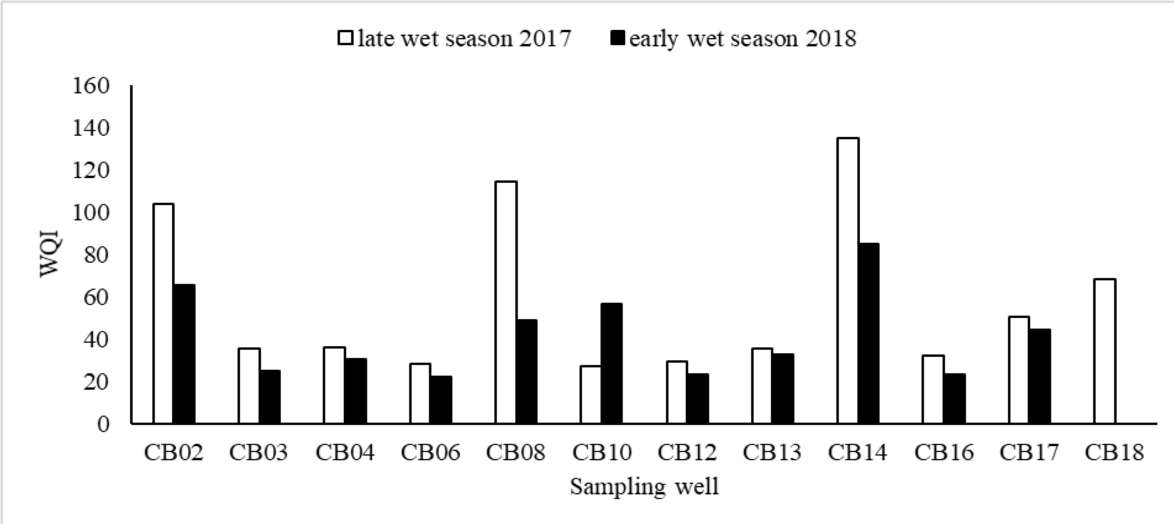

Fig 2. Graph of comparison WQI of groundwater quality of Chrey Bak catchment during late and early wet season

3.3 Groundwater quality for irrigation

For irrigation purposes, the suitability of groundwater depends on mineral constituents in water and on both soil and plant (Hwang et al., 2016). The most harmful for irrigation is salinity, where ions contributed to soil salinity include Cl^-, SO_4^{2-}, HCO_3^-, Na^+, Mg^{2+}, and rarely, NO_3^- or K^+ (Bernstein, 1975). Total concentration, as measure by EC is the main harmful for plants. The indirect impact of salt on plant can destroy soil structure, permeability, and aeration (Trivedy and Goel, 1984). Drainage of soil also impacts on crop growth if the soil is open and well-drained combined with good water quality, the crop and plant may grow well but if a poorly drained area combined with good water quality, the crop still not grown well. Evaluationg of groundwater quality for agriculture based on hydrochemical parameter is crucial to determine suitable water for plants.. Table 5 Show the classification of groundwater quality for agriculture during late wet season 2017 and early wet season 2018. Table 6 represent the result of analysis of classification for evaluating of groundwater in Chrey Bak catchment during late wet season 2017 and early wet season 2018. The result of SAR varied from 0.04 to 2.02 and 0.02 to 3.26 in late wet season and early wet season, respectively. As show in Table 5 all groundwater sample is in an excellent class based on SAR in both late and early wet season. For KR value range from 0.03 to 1.41 in the late wet season and 0.01 to 3.00 in the early wet season. In term of KR value, almost groundwater sample is in good class. Only one groundwater sample (CB16) is unsuitable for agriculture in the late wet season and in early wet season 8 groundwater samples (73%) is good class and 3 groundwater samples (27%), CB4, CB13 and CB16 are unsuitable for agriculture because of the effect of sodium on groundwater. The value of SSP in late wet season 4 groundwater sample are in excellent class, six are in good class, and 2 (CB04 and CB06) are in fair class. In early wet season lie between 2.82% to 58.59% with only one groundwater sample are in excellent class, four are in good class, and 6 (CB02, CB04, CB10, CB13, CB14, CB16) are in fair class. For MH value range from 9.19% to 49.30% which all groundwater sample is in acceptable class in the late wet season. In early wet season MH value varied from 5.12%to 54.87% which only one sampling (CB17) well is in not the acceptable class. The Na% value in late wet season range from 4.71% to 59.93% and in early wet season range from 3.59% to 54.87%. Based on Na% 4 groundwater sample (CB06, CB10, CB12, CB17) are in excellent class, 4 (CB03, CB08, CB13, CB18) are in good class and 4 (CB02, CB04, CB14, CB16) are in permissible class in late wet season. In early wet season only one groundwater sample (CB08) is in excellent 4 (CB03, CB06, CB12, CB17) are in good class, 4 (CB02, CB04, CB10, CB13) are in permissible class, and 2 (CB14, CB16) are in doubtful class. The RSC value ranges from 0.96 to 9.38 and -0.56 to 0.23 in the late wet season and early wet season, respectively. There are only one (CB13) is in good class, and the rest of the groundwater sample are in medium and poor quality class in late wet season. However, in early wet season, all groundwater sample is in good class. The negative RSC value reveals that the concentration of Ca^+ and Mg^{2+} is in excess, and a positive RSC prove that Na^+ existences in the soil are possible (Rawat et al., 2018). The value of PI in late wet season varied from 57.50% to 140.35% and 43.22% to 107.62% in late wet season and early wet season, respectively. Many samplings well in both late and early wet season are in excellent to good class, and none groundwater sample is unsuitable for agriculture.

Table 5. Classification groundwater quality of Chey Bak catchment for agriculture purpose during late and early wet season

	Value	Class	Late wet season 2017	Early wet season 2018
			No. of well (%)	No. of well (%)
SAR	<10	Excellent	12 (100)	11 (100)
	10-18	Good	-	0
	18-26	Doubtful	-	0
	>26	Unsuitable	-	0
KR	<1	Good	11 (92)	8 (73)
	>1	Unsuitable	1 (8)	3 (27)
SSP	<20	Excellent	4 (33)	1 (9)
	20-40	Good	6 (50)	4 (36)
	40-80	Fair	2 (17)	6 (55)
	>80	Poor	-	0
MH	>50	Not-Acceptable	-	1 (9)
	<50	Acceptable	12 (100)	10 (91)
Na %	<20	Excellent	4 (33)	1 (9)
	20-40	Good	4 (33)	4 (36)
	40-60	Permissible	4 (34)	4 (36)
	60-80	Doubtful	-	2 (19)
	>80	Unsuitable	-	0
RSC	<1.25	Good	1 (8)	11 (100)
	1.25-2.5	Medium	6 (50)	0
	>2.5	Poor quality	5 (42)	0
PI	>75%	Excellent	10 (83)	7 (64)
	25%-75%	Good	2 (17)	4 (36)
	<25%	Unsuitable	-	0

3.3.1 Electrical Conductivity (EC) and Na%

EC and Na concentration are essential in classifying groundwater for agricultural purpose because high salt content high EC and make soil contaminant or saline soil. Classifying groundwater base on Na% and EC following Wilcox (Wilcox, 1955) show in Figure 3. The result indicates that 17% of groundwater sample (CB08 and CB14) of the groundwater samples fall in the permissible to doubtful, while 83% fall in excellent to a good class during late wet season while all groundwater sample in early wet season falls into excellent class. As a result, show that groundwater does not affect by Na and EC, and it suitable for irrigation.

3.3.2 Salinity Hazard and Akali Hazard

The plot of the analytical data on the US salinity diagram, in which the EC is taken as a salinity hazard and SAR as an alkalinity hazard show in Figure 4. EC is classified from C_1, C_2, C_3, and C_4 (low, medium, high, and very high, respectively) and SAR is classified from S_1, S_2, S_3 a and S_4 (low, medium, high,, and very high, respectively) (Richards, 1969). Figure 4 show that 6 samples (CB16, CB10, CB12, CB03, CB13 and CB06 fall in C_1S_1, it's mean, low Conductivity and low SAR, 4 samples (CB18, CB02, CB17 and CB04) fall in C_2S_1, (medium/low) and the 2 samples (CB08 and CB14) are fall in C_3S_1, (medium/medium) in late wet season. There are 4 (CB03, CB06, CB12 and CB16) groundwater samples fall in C_1S_1 (low EC/low SAR) and 7 (CB02, CB04, CB08, CB10, CB13, CB14, and CB17) groundwater samples fall in C_2S_1 (medium EC/low SAR).

Table 6. Result of analysis of groundwater quality of Chrey Bak catchment for agriculture purpose

Late wet season 2017							
Well code	SAR	KR	SSP (%)	MH (%)	Na (%)	RSC	PI (%)
CB02	1.47	0.63	38.78	22.21	58.26	4.43*	99.17
CB03	0.59	0.28	22.18	24.29	22.54	2.06	96.57
CB04	1.32	0.67	40.05	24.15	40.47	1.66	98.73
CB06	0.04	0.03	2.82	18.67	4.71	1.62	140.35
CB08	1.52	0.34	25.12	49.30	25.38	9.38*	57.50
CB10	0.34	0.22	18.13	9.19	19.05	1.32	127.98
CB12	0.19	0.11	9.67	34.65	10.66	1.50	113.78
CB13	0.69	0.42	29.62	47.76	38.15	0.96	109.09
CB14	1.08	0.44	30.47	26.48	59.93	2.77*	85.80
CB16	2.02	1.41*	58.59	27.48	58.90	1.58	123.93
CB17	0.64	0.24	19.51	21.14	19.95	4.30*	83.60
CB18	1.17	0.35	26.14	25.45	27.56	3.97*	67.84
Early wet season 2018							
Well code	SAR	KR	SSP	MH	Na (%)	RSC	PI(%)
CB02	1.31	0.63	56.57	28.77	56.57	0.10	80.82
CB03	0.51	0.26	21.31	10.14	21.31	-0.28	74.05
CB04	1.68	1.05*	57.21	7.00	57.21	-0.10	92.37
CB06	0.28	0.20	23.61	5.12	23.61	-0.38	82.79
CB08	0.02	0.01	3.59	54.87*	3.59	-0.16	43.22
CB10	1.92	0.67	43.07	18.41	43.07	0.21	70.49
CB12	0.43	0.30	25.87	24.76	25.87	-0.32	86.45
CB13	1.83	1.21*	59.72	28.67	59.72	-0.56	85.03
CB14	1.73	0.82	64.65	15.99	64.65	-0.10	81.21
CB16	3.26	3.00*	75.48	11.92	75.48	0.01	107.62
CB17	1.01	0.39	35.45	18.81	35.45	0.23	68.50
CB18	-	-	-	-	-	-	-

* under poor water quality

3.4 Classification of Groundwater

The groundwater quality for drinking and irrigation purposes was assessed based on WHO, USEPA, and ISI standards. The groundwater quality is significantly changed by the influence of weathering and anthropogenic inputs (S. K. Kumar et al., 2009). The Gibbs diagram is a method for estimating the origin of ions in groundwater by focusing on the correlation between the concentration of cations (Na^+, Ca^{2+}), anions (Cl^-, HCO_3^-), and TDS (Hwang et al., 2016). Three distinct fields, such as evaporation dominance, rock dominance, and precipitation dominance areas, are shown in the Gibbs diagram (Figure 5). In this study, Gibbs plot, which TDS versus ($Na^++K^+/Na^++K^++Ca^{2+}$) for cations (a), and TDS versus ($Cl^-/Cl^-+HCO_3^-$) for anions (b), were plotted to illustrate the groundwater evolution process, and which fields influence to the groundwater quality. The diagram shows that most of the cations and anions in groundwater have precipitation dominance to rock-dominance origin fields in both late and early wet season. However, the diagram characterizes that most of the samples are located in the rock dominance field, which plays a major role in the water chemistry of the water under the subsurface. Geological location is one of the most important factors affecting groundwater quality (Reddy et al., 2010).

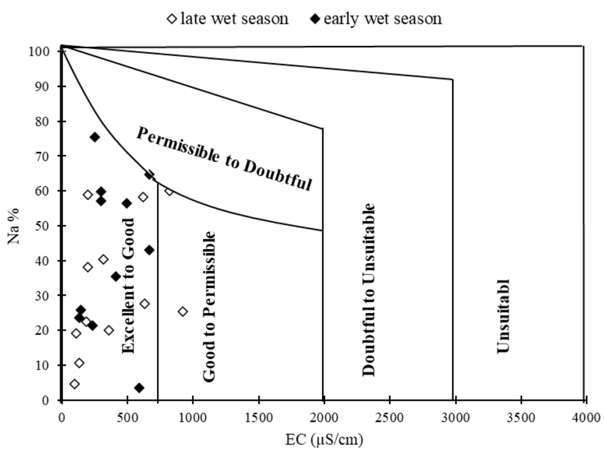

Fig 3. Rating of groundwater samples for irrigation on the basis of electrical conductivity (EC) and sodium percentage (Na%) Wilcox diagram

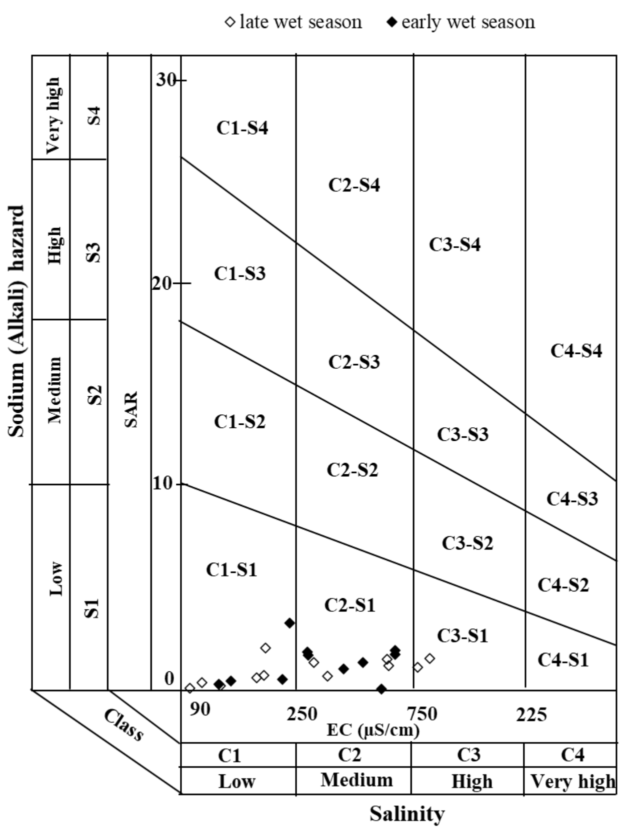

Fig 4. Classification of groundwater quality based on US Salinity Laboratory diagram.

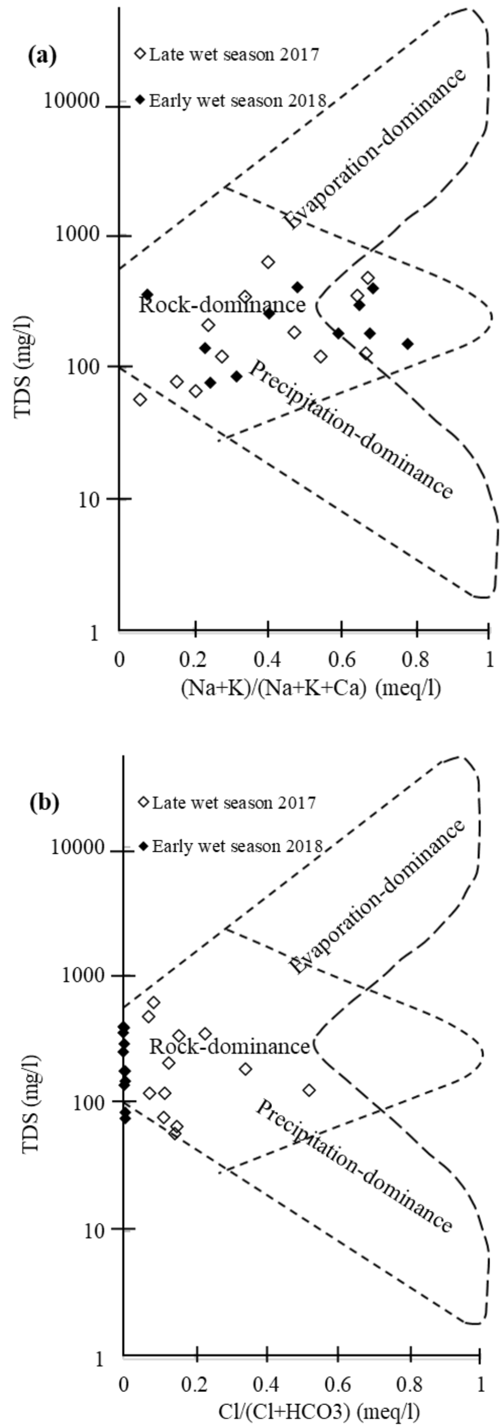

Fig 5. Chadha diagram of groundwater by using anions and cations (a) Gibbs ratio I (for anion); (b) Gibbs ratio II (for cation)

4. CONCLUSIONS

The assessment revealed the potential and suitability of groundwater for domestic and agricultural use. We found 58% of groundwater sample was excellent while 16% and 25% of the samples are in good and poor quality during late wet season and 64% and 36% of groundwater sample was excellent and good quality respectively, during early wet season in term of domestic use. All groundwater sample was not affected by sodium in term of SAR in both late and early wet season. All samples in this study can be acceptable for agricultural irrigation without the effect of magnesium hazard in late wet season and only one groundwater sample was impact from magnesium in early wet season. However, with respect to residual sodium carbonate, nearly half number of samples fell into poor quality for irrigation and the other half number of samples were within the fair quality during late wet season. In contrast during early wet season all groundwater sample was good quality for agriculture. The potential for a sodium hazard increased as the result of the magnesium precipitated from a solution when water is applied to the soil. The causes were confirmed by the results of Gibbs diagram. However, the permeability of the soil is not affected by Na^{+}, Ca^{2+}, Mg^{2+} and HCO_3^{-} which influence groundwater quality during both late and early wet season. The 33% groundwater samples were within an excellent quality. 33% was in a good quality. The remaining were in a permissible quality and none of the samples fell into doubtful and unsuitable quality in term of sodium percentage in late wet season. However, in early wet season based on sodium percentage two groundwater samples was in doubtful class. The classification of groundwater based on Na% and EC represent in Wilcox diagram revealed that all samples of the groundwater samples fell into the good to permissible and excellent to good quality during both seasons. Therefore, Groundwater was found not to be affected by Na^{+} and EC and it was suitable for irrigation. Based on the US salinity laboratory's diagram, the groundwater for irrigation was found from low and medium in both late and early wet season in term of conductivity and salinity. Hence, the overall groundwater quality in Chrey Bak catchment is suitable for domestic and agriculture. However, there still have a slight impact from alkalinity and salinity. In addition, other parameters like arsenic and heavy metal are not included in this study so, to make sure groundwater quality is safety for any usage, groundwater treatment still recommend before using groundwater. Filtration like bio-sand filter is the easy way to treat groundwater at home

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