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ORIGINAL ARTICLE

The Impact of Potable Water Salinity on Human Health

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Abstract

OBJECTIVE: This study aimed to determine the relationship between salinity of drinking water and the formation of urinary stones. Compared with neighboring areas, the prevalence of urinary stones in the Aga area selected from the southern Dakahlia Governorate is significantly higher.
MATERIALS AND METHODS: A total of 87 volunteers were recruited between April 2019 and April 2020. Drinking water samples were collected from water sources used by clinically identified patients with urinary calculi and healthy people. The concentrations of the major and minor ions in the water samples were determined using other hydrochemical parameters.
RESULTS: Water quality parameters in the patients' regions increased as the total dissolved salts (TDS) increased. The anions in the area were in the order of $HCO3^-$ >Cl^-> $SO4^{2-}$, whereas the cations were in the order of Ca^{2+} > Na^+ >Mg^{2+} >K^+. The results of this study show that the quality of deep groundwater is better than that of shallow water.
CONCLUSION: The results suggest a significant risk of urinary stones among residents of the Aga District. To minimize the threat to human well-being, public authorities should take immediate action to provide residents with clean drinking water.

Keywords: Hydrochemistry, Patients, Potable water

1. Introduction

Groundwater is used by a sizable proportion of the world's population, particularly in underdeveloped countries [1]. Kawo and Karuppannan [2] and Jasrotia et al. [3] highlighted that several studies on groundwater and chemical quality have been conducted in several parts of the world. The flow of water in a distribution system must be stable with respect to its structure and physical properties [4]. The chemical reaction between an aquifer matrix and groundwater is a major determinant of the chemical composition of groundwater, according to the water chemistry index. The hydraulic conductivity and transmissivity of aquifer sediments are likely to increase as minerals dissolve in the aquifer matrix [5]. High mineralization processes originating from aquifer materials, as well as contamination through irrigation return flow due to the excessive application of agricultural pesticides and seepage from irrigation drainage canals, have all contributed to the worsening of groundwater quality. Physicochemical measurements can be used to assess the quality of groundwater [6]. Groundwater monitoring and chemical analysis are being conducted on a regular basis in areas defined by medium susceptibility because groundwater resources in these areas are also predicted to be poisonous [7]. In some countries, a link between drinking water geochemistry and population health is essential. The research by Qasemia et al. [8] may help provide existing baseline information about water quality, which can alert health professionals, residents, and water organizations to the importance of purity and quality of water. Salinity prevalence has a significant direct and indirect effect on human health [9], and it is associated with an increase in water-related disorders [10]. The incidence of urolithiasis has increased over the last few decades in both developed and developing countries [11]. Because of the

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high degree of implementation in patients with excretory organ stones and the long-term nature of the procedure, it is quite expensive [12]. Numerous studies have been conducted on the correlation between water quality and the production of urinary stones. Nephrolithiasis accounts for 2−3% of end-stage renal illness in cases related to nephrocalcinosis [13], whereas calcium oxalate accounts for 70−75% of urinary stones [14]. Notably, the presence of urinary tract stones may be associated with the occurrence of other diseases. A link between cancer and urolithiasis has recently been discovered [15]. There are established connections between a population's socioeconomic status, the type of urinary stone, and factors other than its chemical structure [16]. According to Hire et al. [17], settled people (67%) had a higher prevalence of urolithiasis than manual workers (29%). Mandour [18] demonstrated that a high level of total dissolved salts (TDS) in groundwater in Aga district, Egypt, was observed whenever groundwater served as the primary supply for the region's domestic water system. The study area provides the best opportunity to study the impact of water chemistry on human health, as demonstrated by patients with urinary stones, to determine the connection between the water sources available for civilian residents within the Aga district and the formation of urinary stones, and to identify the factors affecting urinary stone formation to reduce urolithiasis and stone recurrence.

2. Materials and methods

2.1. Study area

Aga District is located in the southern part of Dakahlia Governorate. The climate of Aga is desert. Throughout the year, virtually no rainfall occurred. The precipitation is approximately 36 mm (1.4 in) per year. Groundwater is the primary source of water for residential purposes in the study region; it slopes northward and flows southward [19]. The lithology of several wells fluctuates between 40 and 80 m underground, whereas the screen is located between 40 and 70 m underground. Residents or authorities dug wells and boreholes for domestic purposes.

2.2. Study participants

Participants' locations were selected based on the clinical data available at hospitals and urology clinics. The identity was verified by a supply of potable water obtained from research participants in accordance with the residential address. Men were more likely to develop urinary stones, with an increased prevalence among groups aged 36−59 years, when 84.61% (55) of all patients had apparent grounds for the symptom when compared to 46.15% (30) of all cases. The consumption of water has not been identified as a risk factor [20]. Consent was obtained from all participants before enrolling in the study.

Two groups were constituted:

(1) Group of patients expected to have urinary calculi (urolithiasis; 65 persons) among them, 76.93% (50) were males and 23.07% (15) were females, and their age ranged from 36 to 59. The patients had no history of urinary disease. They used water from the wells up to a depth of 60 m.
(2) A healthy group (control; 22) with no known history of stone formation or component formation was chosen to correspond to the age and sex of the group. The participants in the case group were chosen according to their age and sex (Table 1). They drank from the wells at a depth of 80 m.

2.3. Water samples

Water samples were obtained from the participants and analyzed between April 2019 and April 2020. Prior to sample collection, an appropriate time (1−2 min) was allowed for the tap water to flow through the release pipe. Sixty-five water samples were collected from the patients, locations, and 22 samples were collected from non-patient locations to support the clinical data.

2.4. Methods

The participants were asked to supply 87 tap water samples (500 ml each). Physicochemical parameters (temperature (T), pH, and electrical conductivity (EC)) were calculated in the field during sampling and compared with the laboratory values. Other hydrochemical parameters were studied to determine the major ions (cations; potassium (K^+), sodium (Na^+), calcium (Ca^{2+}), and magnesium

Table 1. Age and sex of the participants.

	Urolithiasis group ($n = 65$)	Control group ($n = 22$)
	Age (Mean ± SD)	
	50.2 ± 9.3	50.5 ± 9.5
Sex (%)		
M	76.93% (50)	77.27% (17)
F	23.07% (15)	22.73% (5)

(Mg^{2+})) and (-anions; bicarbonate ($HCO3^-$), chloride (Cl^-), and sulfate ($SO4^{2-}$)) in the same laboratory after the samples were cooled in a refrigerator until the examinations were conducted.

TDS (mg/l) was calculated from the estimated EC using the following formula [21,22]:

$$\text{TDS}\ (\text{mg}/\text{L}) = 0.67 \times \text{EC}\ (\mu\text{S}/\text{cm})$$

These samples were analyzed using the digestion technique in the laboratories of the Genetic Engineering and Biotechnology Unit of Mansoura University. The collection, preservation, and analysis methods of the American Public Health Association (APHA) [23] standards were used here. The concentrations (μg/g) of the heavy metals studied (lead (Pb), iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu)) were estimated using a graphite-furnace atomic-absorption spectrometer (Buck Scientific Company, USA). The calibration standards and quality control (QC) samples were prepared daily. The privacy and confidentiality of the sample's records and data were determined through the coding system.

2.5. Statistical analysis

The IBM-SPSS program for Windows [24] was used to incorporate and analyze the data. The total cations and anions were used to calculate the analytical error, which was found to be ±5 % [25], indicating the chemical data-dependability. Quantitative data were initially tested for normality using the Shapiro-Walk test ($P > 0.050$) indicated that the data were ordinarily distributed. Quantitative data are expressed as mean ± when the samples were distributed normally in both groups; the quantitative data were compared using independent sample t-test. Connection between two continuous variables when data was determined using the Pearson's correlation test. Statistical significance was set at $P \leq 0.050$. Findings are presented graphically whenever possible. The graphed program (version 14.2.371, Golden Software, LLC, USA), a Piper's trilinear diagram was created to ensure the relative abundance of the common ions in the water samples.

3. Results

Table 2 summarizes the chemical parameters applicable to patients and management settings. TDS, Na^+, Ca^{2+}, Mg^{2+}, Cl^-, $HCO3^-$, and Mn levels were significantly higher and Cu levels significantly lower in the urolithiasis group, whereas there were no significant differences in K^+, $SO4^{2-}$, Pb, Fe, and Zn. The EC can be used to determine the salinity of water in the body. However, some samples exceeded the WHO limits [26] (Table 2). TDS had a statistically significant direct correlation with Na^+,

Table 2. Physicochemical parameters (in ppm) of the water samples.

Parameter	Urolithiasis group ($n = 65$)				Control group ($n = 22$)				P
	Min	Max	Mean	SD	Min	Max	Mean	SD	
T	20.9	27.8	23.45	3.2	24.3	25.7	25	1.08	
pH	7.03	7.45	7.24	0.12	7.01	7.2	7.1	0.25	
EC	773.8	1631.9	1052.6980	250.6640	435.6716	588.8059	515.2646	33.9568	
TDS	503	1060.8	705.3077	167.94492	291.9	394.5	345.2273	22.75110	0.000
$HCO3^-$	88	313.5	206.7231	46.85033	44	150	91.0455	31.81416	0.000
Cl^-	15	237	106.1077	64.27386	11.2	88	52.3636	26.95242	0.000
$SO4^{2-}$	10	79	30.0923	16.05724	8	41	21.0455	10.93477	0.016
Na^+	67.69	239	144.2000	56.37630	48	100	84.7273	11.69526	0.000
K^+	2	13	7.6154	7.32225	3.05	9.93	5.9545	2.05814	0.298
Ca^{2+}	81.36	284	173.3385	72.92746	64	74	69.1818	2.90544	0.000
Mg^{2+}	12	116.0	39.5538	28.96821	12	40	20.3182	7.85212	0.000
Fe	0.005	0.551	0.121615	0.1577478	0.001	0.25	0.128364	0.0820282	0.849
Mn	0.004	0.554	0.217677	0.1714381	0.001	0.099	0.034364	0.0298417	0.000
Pb	0.001	0.051	0.008585	0.0118663	0.003	0.009	0.004227	0.0028441	0.093
Cu	0.001	0.565	0.258585	0.1621969	0.002	0.567	0.340273	0.1674555	0.046
Zn	0.111	1.999	0.597508	0.4316411	0.132	1.979	0.589318	0.4221524	0.939
WHO (26) maximum permissible limits									
Parameter		TDS	K	Na	Ca	Mg	Fe	Mn	Pb
Limit		1000	10	200	200	100	0.3	0.4	0.01
No of samples		3	8	16	21	3	11	10	7

All parameters given in mg/L except EC (μS/cm) and T (°C).
ppm, part per million.
Data presented as mean (SD).
P value by t-test.

Mg^{2+}, Ca^{2+}, Cl^{-}, $SO4^{2-}$, and HCO3⁻ each in the total cohort and urolithiasis group, but not with HCO3⁻ in the control group. In addition, in TDS, there was a statistically significant high correlation with Na^{+}, Ca^{2+}, and HCO3⁻ in the total cohort, whereas in the urolithiasis group, there was a statistically significant moderate correlation with HCO3⁻ and significant correlations as in the total cohort. TDS demonstrated a statistically significant moderate correlation with Mg^{2+} and Cl^{-} in the total cohort; and a statistically significant weak correlation with $SO4^{2-}$ and Mg^{2+} in the total cohort group, as well as with Cl^{-} and $SO4^{2-}$ in the urolithiasis group. There was a significant correlation between TDS and HCO3⁻ in the control group (Table 3).

3.1. Piper trilinear diagram

The Piper trilinear diagram is a graphical representation of the chemical ion distribution properties in water [27,28]. The diagram was generated using the concentrations of major cations and anions to determine the hydrogeochemical facies and evaluate the geochemistry of groundwater (Fig. 1). Urolithiasis water variation (Group 1) and presence of Na−K−Cl and Na−Ca-(HCO3)2 in the samples indicated that the water was extremely saline. The groundwater of the non-dominant type was predominant in the control samples (group 2).

3.2. The grid system diagram

The grid system diagram (Fig. 2) for the analyzed samples can be subdivided into the following 4 major grids: Cl−Na, Cl−Ca, HCO3−Na, and HCO3−Ca.

Table 3. Pearson's correlation coefficient (r_s) between TDS and individual elements.

Parameters	Total cohort (n = 87)		Urolithiasis group (n = 65)		Control group (n = 22)	
	r_s	P	r_s	P	r_s	P
Major elements						
Na^{+}	0.747	0.000	0.675	0.000	0.386	0.076
K^{+}	0.075	0.491	−0.011	0.929	−0.070	0.757
Ca^{2+}	0.904	0.000	0.864	0.000	−0.254	0.254
Mg^{2+}	0.624	0.000	0.614	0.000	0.342	0.120
Cl^{-}	0.517	0.000	0.389	0.001	0.036	0.875
$SO4^{2-}$	0.340	0.001	0.251	0.044	−0.097	0.667
$HCO3^{-}$	0.753	0.000	0.459	0.000	0.532	0.011
Minor elements						
Fe	0.056	0.608	0.116	0.356	−0.283	0.201
Mn	0.269	0.012	−0.131	0.299	−0.408	0.060
Pb	0.109	0.313	−0.037	0.768	0.112	0.620
Cu	−0.179	0.098	−0.031	0.803	−0.123	0.586
Zn	0.135	0.211	0.208	0.097	0.264	0.23

To determine the mutual connection between the hydrochemical parameters, the correlation.

The coefficient (r) was determined as follows:

(1) The sodium-calcium scatter plot revealed a significant direct correlation between sodium and calcium levels in the total cohort (r = 0.664, P = 0.000) (Fig. 3a). In the group with urolithiasis, a significant association was observed (r = 0.547, P = 0.000) (Fig. 4a).
(2) The scatter plot of sodium against magnesium revealed a significant direct correlation between
(3) Sodium and magnesium levels in the total cohort (rs = 0.422, P = 0.000) (Fig. 3b) In the group with For urolithiasis, a significant correlation was established (rs = 0.339, P = 0.006) (Fig. 4b).
(4) The equivalent plot of Mg versus Ca reveals a good linear connection in the total cohort (rs = 0.663, P = 0.000) (Fig. 3c), and a significant correlation was observed in the urolithiasis group (rs = 0.630, P < 0.000) (Fig. 4c), but not in the control group (rs = −0.007, P = 0.976).
(5) The scatter plot of calcium by bicarbonate shows a significant direct correlation between calcium and Bicarbonate levels in the total cohort (rs = 0.658, P = 0.000) (Fig. 3d), and the significant correlation was conjointly observed in the urolithiasis group (rs = 0.435, P = 0.000) (Fig. 4d) but not in the control group (rs = 0.096, P = 0.672).
(6) The scatter plot of magnesium with bicarbonate shows a significant direct correlation between magnesium and bicarbonate levels in the total cohort (rs = 0.426, P = 0.000) (Fig. 3e), and a significant was observed in the urolithiasis group (rs = 0.291, P = 0.019) (Fig. 4e).

4. Discussion

Our study highlights the problem of urolithiasis in a cohort of inhabitants. Previous studies have demonstrated that continuous use of saltwater can result in the production of urinary stones [29]. Participants over the age of 30 (36−59 years), of whom 76.93% (50) were males and 23.07% (15) were females, drew water from wells at 80 m depth. The majority of urolithiasis cases are vulnerable at the age of 30−60 [30]. Many men tend to develop kidney stones for various reasons, including ureter ducts that are narrower than those in women and hormones that prevent the formation of renal calculus in women [31]. Men over 50 years of age are more susceptible to lithiasis [32]. Shallow wells are more polluted by irrigation water [33], and shallow

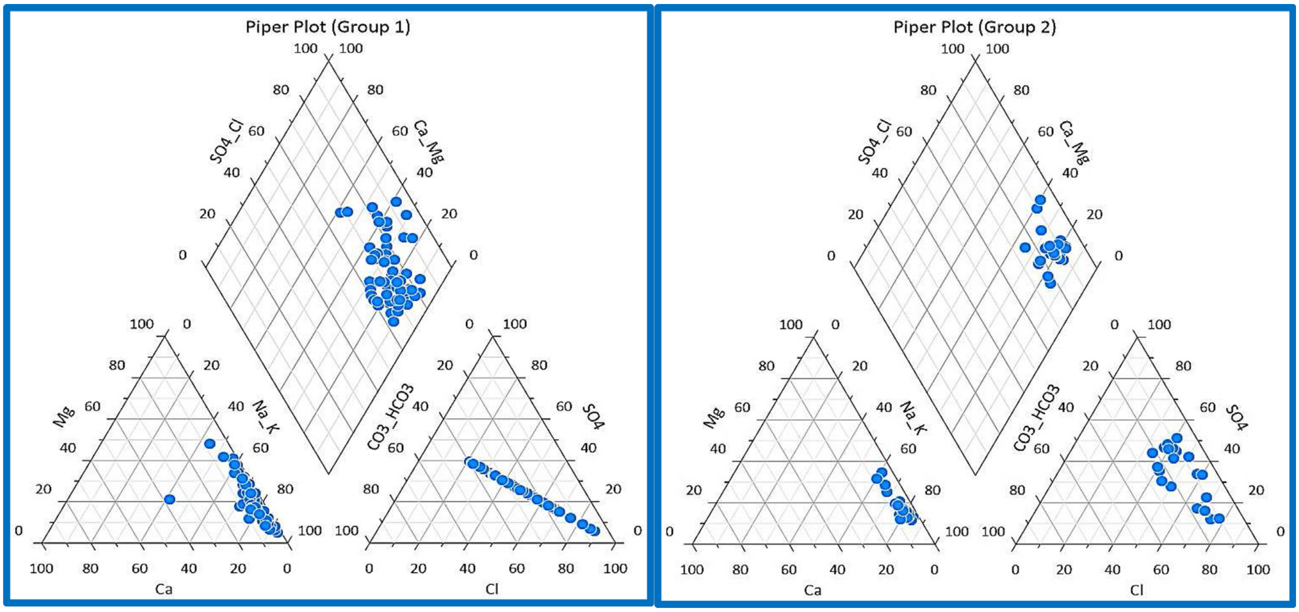

Fig. 1. Piper plot of chemical analysis of domestic water samples (groups 1 and 2).

groundwater is typically the most impacted by small-scale irrigation farming [34], particularly in developing countries. Groundwater pollution from fertilizer leaching is widespread in agricultural areas, and the extent of contamination varies according to soil conditions, climate conditions, the types of fertilizer used, and agricultural techniques. Deep groundwater is more suitable for drinking than shallow groundwater, which is almost certainly a fragile aquifer system [35]. The groundwater geochemistry of the case and control locations was studied in terms of physical parameters and major ionic constituents, as the quality of drinking water has a significant effect on the prevalence of various disorders. The average EC of the water samples in the patient's regions was relatively high, indicating

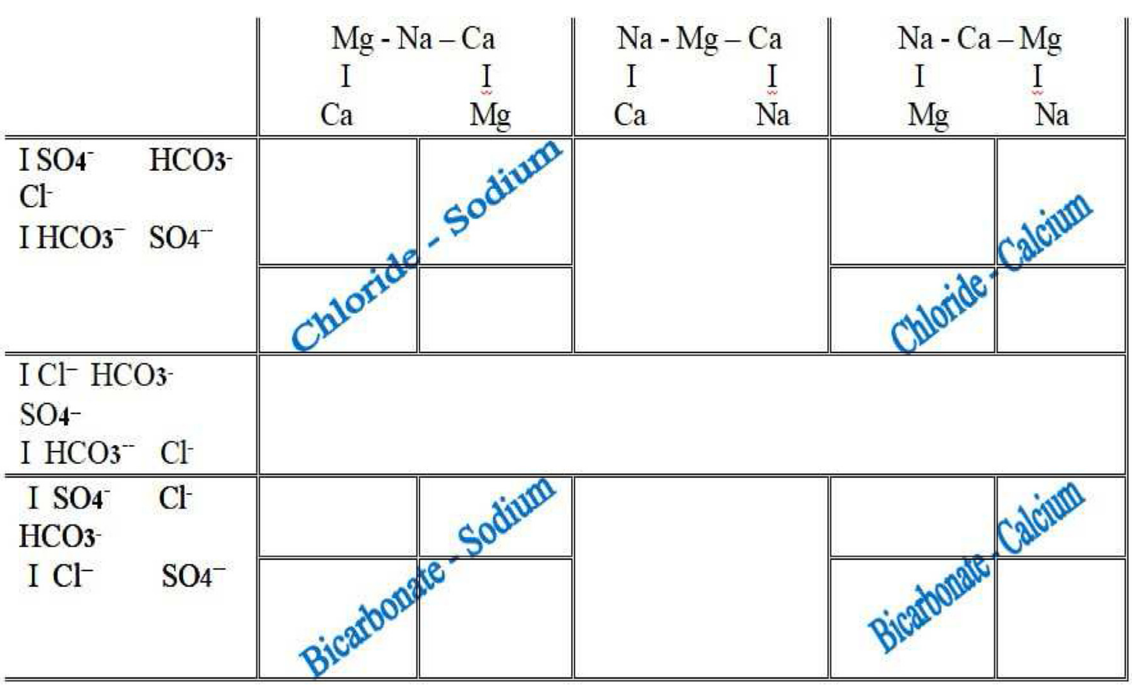

Fig. 2. The Grid system diagram.

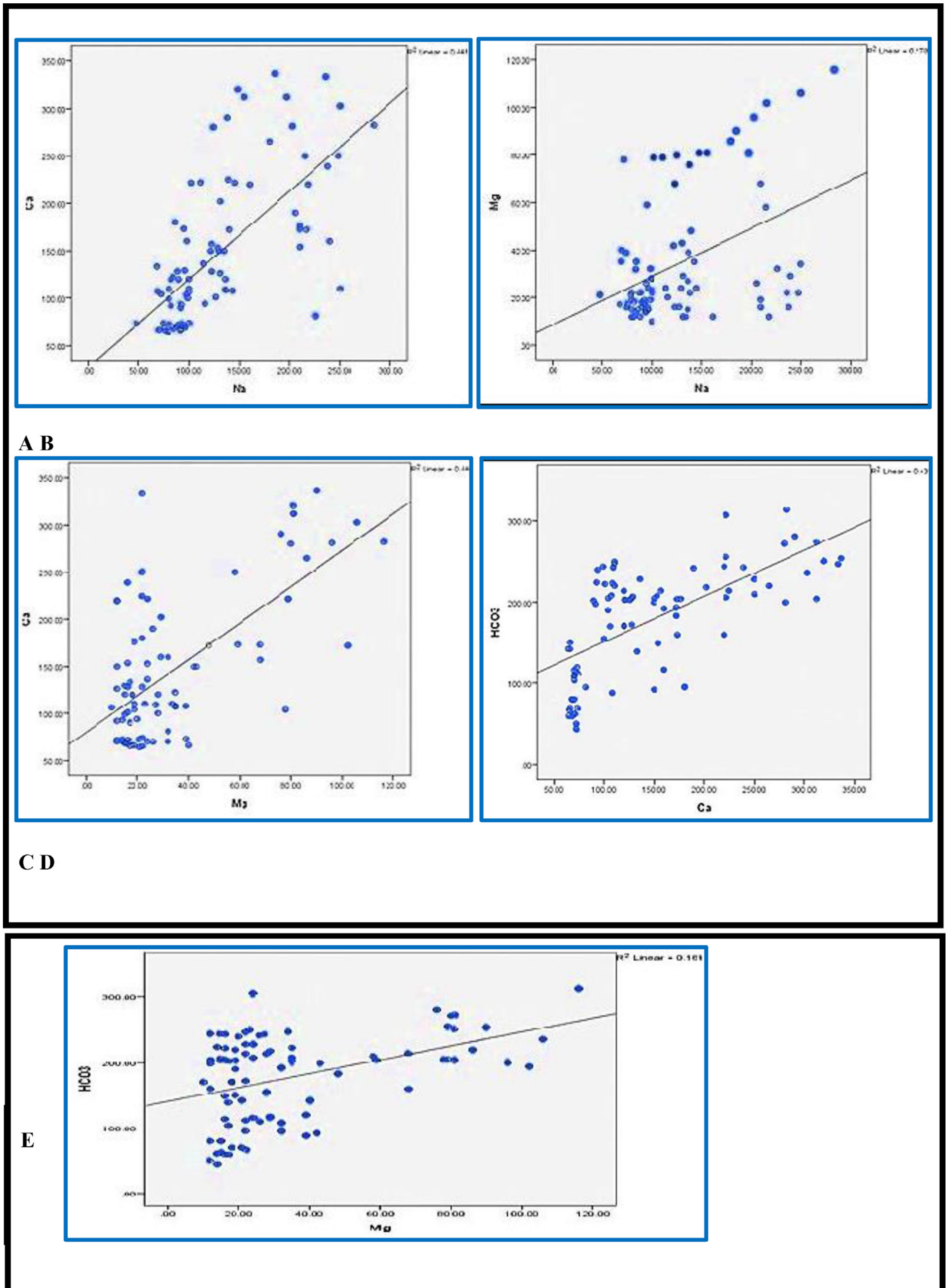

Fig. 3. Major Ion relationships for the total cohort.

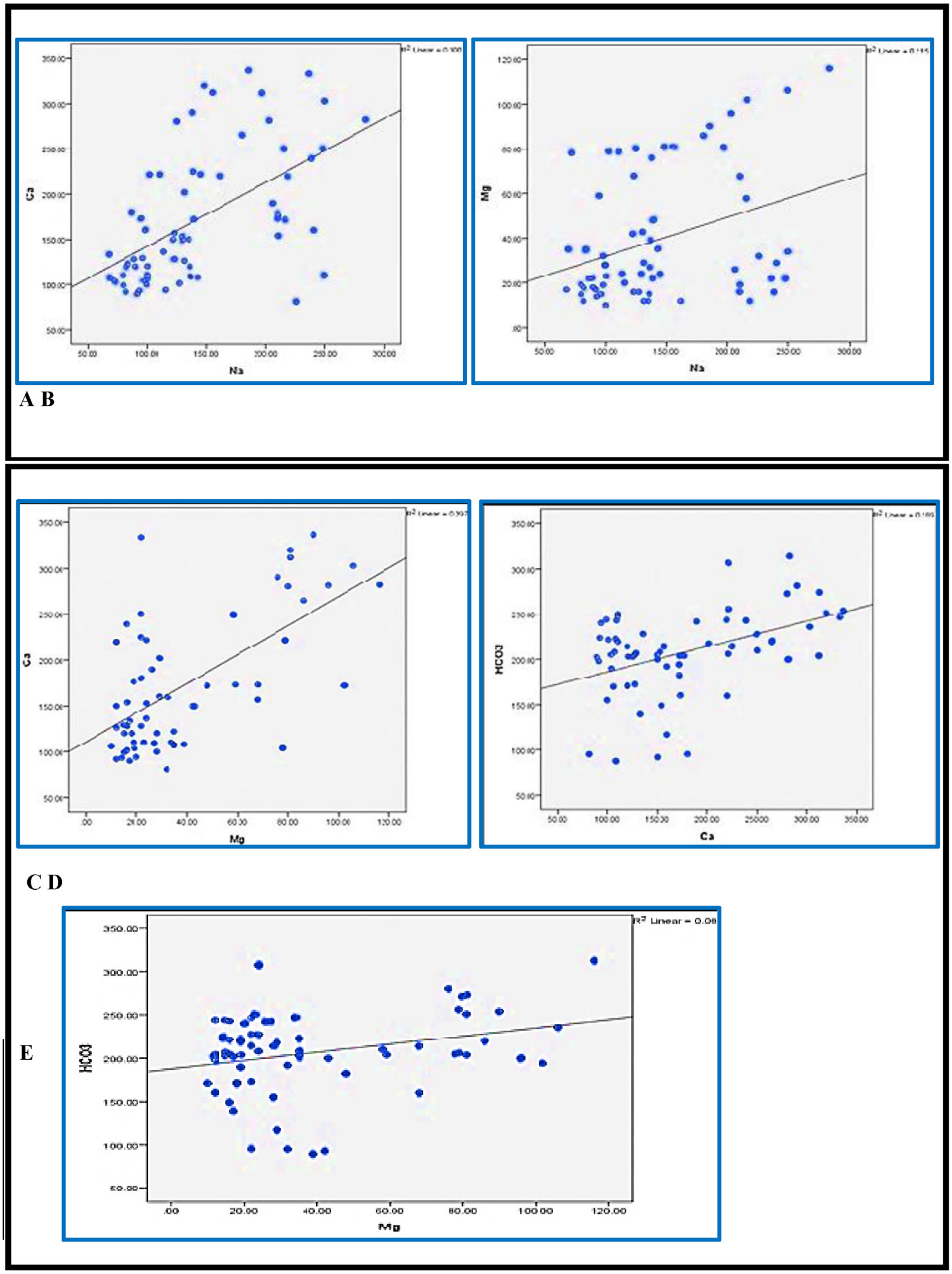

Fig. 4. Major Ion relationships for the urolithiasis group.

that the water contained a significant concentration of TDS.

High TDS (urolithiasis group) levels above a certain value affect all other water parameters, including hardness, taste, and corrosion resistance. This finding is in line with Asma and Kotani's [36] findings that saline sites have a higher risk of developing water-borne diseases than non-saline locations. In this study, a low TDS (control group) indicates that the water is generally treated using conventional methods, although it reduces the basic domestic use of water. The predominant anions and cations in the water samples are $HCO3^-$ and $Ca2^{++}$, respectively. Calcium ions are less mobile than magnesium ions owing to their increased affinity for oxygen-containing molecules. This results in the presence of crystalline calcium compounds, such as phosphate and oxalates, in the circulatory blood system. The anions changed in the order $HCO3^- > Cl^- > SO4^{2-}$, whereas the cations varied in the order $Ca^{2+} > Na^+ > Mg^{2+} > K^+$. HCO3 has a positive correlation with Ca^{2+}, indicating that it contains more calcium than dissolved calcium bicarbonate. According to Abboud [37], the geology and quality of drinking water affect the distribution of the components of urinary stone samples collected from various regions. Thus, the hypothetical salt combinations in the water samples are NaCl, Ca(HCO3)2, and NaHCO3. According to Sethy et al. [38], cati*on* exchange reactions are induced by a high concentration or depletion of Na relative to Cl. Statistical analysis can be used to identify areas prone to geographic and geological diseases. Although we could analyze the variations in exposure to households or long exposure in the areas of residence, unique geology provides ideas for natural experiments on the possible effects of municipal domestic water supplies from groundwater (well water) on the population. Owing to changes in the natural environment and human activities, the quality of groundwater has gradually deteriorated, leading to a water shortage crisis and a series of environmental challenges [39]. The disintegration of carbonate rocks is the main factor regulating the concentration of ions in groundwater, as shown by the combination of ion ratio plots and multivariate statistical methods. The data gathered in this study are also used to interpret the geochemical processes responsible for groundwater chemistry in the study area. The chemical composition of groundwater in the study area is strongly influenced by water–rock interactions, which is consistent with the findings of Haddock et al. [40], who stated that residents served by highly shallow wells of calcium carbonate may be at an increased risk of urolithiasis when compared with those served by deep well waters.

5. Conclusion

Urolithiasis is a major problem. Therefore, monitoring the spread of this undesirable phenomenon is necessary. A hydrogeochemical study was conducted in an area with a high incidence of urinary stones to identify any relationship between disease prevalence and groundwater chemistry. The data obtained from this study were used to interpret the geochemical processes responsible for the groundwater chemistry in the study area. This study concluded that potable water with high mineral content, mainly calcium, sodium, chloride, and bicarbonate, increases the risk of urinary stone formation in consumers. The water quality parameters of the urolithiasis group indicated a high mineral concentration in conjunction with an increase in TDS. This finding demonstrates that human activity controls the majority of the groundwater chemistry in the study area. The results show that deep groundwater is of better quality than shallow water. They also show a high risk of urolithiasis among the people of the Aga district, and to reduce the threats to human well-being, public authorities should quickly act to reduce dangers and provide safe drinking water to the people. Our findings suggest the following conclusions:

(1) The wells should be at least 80 m deep and placed safely away from all potential pollution sources.
(2) Pollution has a bearing on the standard of shallow groundwater; the decay of pollutants affects water quality. Thus, deep groundwater is more suitable than shallow groundwater, particularly for aquifer systems that are sensitive.
(3) As for safety measures, water bodies should undergo constant monitoring and potable water should undergo advanced water treatment processes if required.
(4) There is a need for typified medical protection for people who get straightforwardly uncovered or unintentionally in seriously polluted water.
(5) Additional research is needed to determine the sources of anthropogenic inputs and strategies to prevent or reduce them in the groundwater.

Compliance with ethical standards

All data are within the manuscript.

Conflicts of interest

No conflict of interest.

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References

[1] Adimalla N, Li P, Venkatayogi S. Hydrogeochemical evaluation of groundwater quality for drinking and irrigation purposes and integrated interpretation with water quality index of studies. Environ Process 2018;5:363−83. https://doi.org/10.1007/s40710-018-0297-4.

[2] Kawo NS, Karuppannan S. Groundwater quality assessment using water quality index and GIS technique in Modjo River Basin, Central Ethiopia. J Afr Earth Sci 2018;147:300−11. https://doi.org/10.1016/j.jafrearsci.2018.06.034.

[3] Jasrotia AS, Taloor AK, Andotra U, Bhagat BD. Geo-informatics based groundwater quality assessment for domestic and irrigation uses of the western Doon valley, Uttarakhand, India, Ground. Sustain Dev J 2018;6:200−12. https://doi.org/10.1016/J.GSD.2018.01.003.

[4] Porsana ZP, Zareib A, Alimohammadi M. Evaluation of corrosion and scaling potential of drinking groundwater in Gonbad-e Kavus Zahra. Desalination Water Treat 2020;195: 19−25. https://doi.org/10.5004/dwt.2020.25895.

[5] El Osta M, Masoud M, Ezzeldin H. Assessment of the geochemical evolution of groundwater quality near the El Kharga Oasis, Egypt using NETPATH and water quality indices. Environ Earth Sci 2020;79:56. https://doi.org/10.1007/s12665-019-8793-z.

[6] Gad M, El Osta M. Geochemical controlling mechanisms and quality of the groundwater resources in El Fayoum Depression, Egypt. Arabian J Geosci 2020;13:861. https://doi.org/10.1007/s12517-020-05882-x.

[7] El Osta M, H Hussein H, Tomas K. Numerical simulation of groundwater flow and vulnerability in wadi el-natrun depression and vicinities, West Nile Delta, Egypt. J Geol Soc India 2018;92:235−47. https://doi.org/10.1007/s12594-018-0986-7.

[8] Qasemi M, Afsharnia M, Farhang M, Ghaderpoori M, Karimi A, Abbasi H, et al. Spatial distribution of fluoride and nitrate in groundwater and its associated human health risk assessment in residents living in Western Khorasan Razavi, Iran. Desalination Water Treat 2019;170:176−86. https://doi.org/10.5004/dwt.2019.24691.

[9] Shammi M, Rahman M, Bondad SE, Bodrud-Doza M. Impacts of salinity intrusion in community health: a review of experiences on drinking water sodium from coastal areas of Bangladesh. Healthcare, Multidisciplinary Digital Publishing Institute 2019;7:50. https://doi.org/10.3390/healthcare7010050.

[10] Nahian MA, Ahmed A, Lázár AN, Hutton CW, Salehin M, Streatfield PK. Drinking water salinity associated health crisis in coastal Bangladesh. Elem Sci Anthropocene 2018;6: 1−14. https://doi.org/10.1525/elementa.143.

[11] Alelign T, Petros B. Kidney stone disease: an update on current concepts. Adv Urol 2018;4:3068365. https://doi.org/10.1155/2018/3068365.

[12] Roberson D, Sperling C, Shah A, Ziemba J. Economic considerations in the management of Nephrolithiasis. Curr Urol Rep 2020;21:18. https://doi.org/10.1007/s11934-020-00971-6.

[13] Courbebaisse M, Prot-Bertoye C, Bertocchio J-P, Baron S, Maruani G, Briand S, et al. Nephrolithiasis of adult: from mechanisms to preventive medical treatment. Rev Med Int 2017; 38(1):44−52. https://doi.org/10.1016/j.revmed.2016.05.013.10.

[14] Schubert G. Stone analysis. Urol Res 2006;34:146−50. https://doi.org/10.1007/s00240-005-0028-y.

[15] Tae BS, Balpukov U, Cho SY, Jeong CW. Eleven-year cumulative incidence and estimated life time prevalence of urolithiasis in Korea: a National Health Insurance Service-national sample cohort based study Korean. Med Sci 2018;33: e13. https://doi.org/10.3346/jkms.

[16] Jayaraman U- Ch, Gurusamy A. Review on urolithiasis pathphysiology and Aesculapius discussion. IOSR J Pharm 2018; 8:30−42.

[17] Hire P, Tomar SS, Kher K. Clinical profile and management of multiple urolithiasis. Int J Adv Res Ideas Innov Technol 2017;3:584−97.

[18] Mandour RA. Hydrogeochemical distributions of some trace elements in drinking water with Specialemphasis on the toxic effect of iron in Mansoura environs, PhD. Fac. SCI: Mans.Univ; 2004.

[19] Abu El-Izz MS. Landforms of Egypt. Cairo: the American University Press; 1971. p. 281.

[20] Roudakova K, Monga M. The evolving epidemiology of stone disease. Indian J Urol 2014;30:44−8. https://doi.org/10.4103/0970-1591.124206.

[21] Weiner ER. Applications of environmental aquatic chemistry: a practical guide. 3rd ed. Taylor & Francis: Boca Raton: CRC Press; 2013.

[22] Sharma DA, Rishi MS, Keesari T. Evaluation of groundwater quality and suitability for irrigation and drinking purposes in southwest Punjab, India using hydro chemical approach. Appl Water Sci 2017;7:3137−50. https://doi.org/10.1007/s13201-016-0456-6.

[23] APHA. Standard methods for the examination of water and waste waters. 23rd ed. Washington, DC: American Public Health Association; 2017.

[24] IBM Corp. Released IBM SPSS Statistics for windows, version 25.0. Armonk, NY: IBM Corp.; 2017.

[25] Laxman KD, Dhakate R, Sakram G, Srinivas B. Hydrochemical appraisal of groundwater quality for drinking and agricultural utility in a granitic terrain of Maheshwaram area of Ranga Reddy district, Telangana State. India Hydro Res 2021;4:11−23. https://doi.org/10.1016/j.hydres.2021.02.002.

[26] Who. Guidelines for drinking-water quality: 4thed. Incorporating the first addendum. World Health Organization; 2017. p. 1−631.

[27] He S, Li P. A MATLAB based graphical user interface (GUI) for quickly producing widely used hydro-geochemical diagrams. Geochemistry, https://doi.org/10.1016/j.Chemer.2019:125550.

[28] Piper AM. Agraphic procedure in the geochemical interpretation of water−analyses. Trans Am Geophys Union AGU 1944;25:914−28. https://doi.org/10.1029/TR025i006p00914.

[29] Garg VK, Suthar S, Singh S, Sheoran A, Garima M, Meenakshi J, et al. Drinking water quality in villages of southwestern Haryana, India: assessing human health risks associated with Hydrochemistry. Environ Geol 2009;58: 1329−40. https://doi.org/10.1007/s00254-008-1636-y.

[30] Sulistyawati S, Astuti FDWI, Trisasri R, Rustiawan A. Well water consumed and urolithiasis in Gedangsari subdistrict. Yogyakarta Kesmas Natl Public Health J 2016;11:26−31. https://doi.org/10.21109/kesmas.v11i1.1165.

[31] Anwar F. Pria-lebih-mudah-kena-batu-ginjal-ketimbangwanita, ini-alasannya. Detik Health 2014. Available from: http://health.detik.com/read/2014/12/11/191552/2775043/763/pria-lebih-mudah-kena-batu-ginjal-ketimbangwanita, ini-alasannya, l991101755.

[32] Abboud IA. Analyzing correlation coefficients of the concentrations of trace elements in urinary stones. J J f Earth Environ Sci 2008;1:73−80.

[33] Jayasumana C, Orantes C, Herrera R, Almaguer M, Lopez L, Silva LC, et al. Chronic interstitial nephritis in agricultural communities: a worldwide epidemic with social, occupational and environmental determinants. Nephrol Dial Transplant 2017;32(2):234−41. https://doi.org/10.1093/ndt/gfw346.

[34] Li S, Luo W, Jia Z, Tang S, Chen C. The pros and cons of encouraging shallow groundwater use through controlled drainage in a salt-impacted irrigation area. Water Resour Manag 2018;32:2475−87. https://doi.org/10.1007/s11269-018-1940-6.

[35] Zaghloul ZM, Khalil MM, Badria FA, Ghanem AA, Mandour RA. Pollution by Iron of the quaternary drinking water and its effect on human health in Dakahlia Governorate. J Environ Sci 2005;29:1−15.

[36] Asma KM, Kotani K. Salinity and water-related disease risk in coastal Bangladesh. EcoHealth; 2021. https://doi.org/10.1007/s10393-021-01517-z.

[37] Abboud IA. Concentration effect of trace metals in Jordanian patients of urinary calculi. Environ Geochem Health 2008;30: 11−20. https://doi.org/10.1007/s10653-007-9103-3.

[38] Sethy SN, Syed TH, Kumar A, Sinha D. Hydrogeochemical characterization and quality assessment of groundwater in parts of Southern Gangetic Plain. Environ Earth Sci 2016; 75(232):1−15. https://doi.org/10.1007/s12665-015-5049-4.
[39] Toolabi A, Bonyadi Z, Paydar M, Najafpoor AA, Ramavandi B. Spatial distribution, occurrence, and health risk assessment of nitrate, fluoride, and arsenic in Bam groundwater resource. Iran Groundw Sustain Dev 2021;12: 100543. https://doi.org/10.1016/j.gsd.2020.100543.
[40] Haddock RL, Olson DR, Backer L, Malilay J. Urolithiasis, urinary cancer, and home drinking water source in the United States territory of Guam, 2006−2010. Int J Environ Res Public Health 2016;13(523):2006−10. https://doi.org/10.3390/ijerph13060523.