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Research Article

The Relationship between Drinking Water and Incidence of Renal Stones in Hail Region, Saudi Arabia

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Abstract: The prevalence of nephrolithiasis is increasing and there is a great concern about the role of public water in urinary calculus formation. This study aims to determine the quality of tap water and detect any relationship with nephrolithiasis in 5 regions of Hail, Saudi Arabia. Tap waters samples were brought from 5 regions of Hail. All samples were subjected to physical examination including electrical conductivity (EC), pH, turbidity and total dissolved solids (TDS), chemical analysis including calcium, magnesium, total hardness and alkalinity. Microbiological examination was done. Physical and chemical results of all samples were within the standard values with no microbiological contamination. However, different water samples showed differences in levels. Increased electrical conductivity and total dissolved solids were found in Alkhuta and Qnaa. A high pH value was found in Hail, Ugda and Twaran, while high water turbidity was detected in Twaran. High calcium level and total water hardens was found in Alkhuta and Qnaa. Magnesium level was high Alkhuta, Qnaa and Ugda while low level was detected in Hail. Total water alkalinity was high in Qnaa. 65 % of involved patients had urinary symptoms. 27% of patients had calcium oxalate crystals, 45% had uric acid crystals and 36% had urate crystals. 41% of patients had bacteriurea, and 5% had yeast. Utrasonography (US) examination revealed renal gravels (39%), renal stones (9%), nephrosis (2%), and hydronephrosis (1%). Alkhuta and Qnaa revealed high EC, TDS, calcium and total hardness with high prevalence of renal gravels and renal stones. Ugda samples revealed high pH and patients had high urine calcium oxalate, uric acid and bacterurea. Twaran samples revealed high pH and turbidity with high calcium oxalate crystals and prevalent of renal gravels with one case of hydronephrosis. Hail samples revealed high pH, low calcium and magnesium levels with renal gravels without renal stones.
Keywords: Drinking Water, Quality Guidelines, Renal Stones, Saudi Arabia

INTRODUCTION

Water constitutes about 50 to 60% of human body weight and plays an active role in all the vital processes of human body. Safe and good quality drinking water is essential for human health [1]. Groundwater is the main source of drinking water in Saudi Arabia [2]. Drinking water standards have been developed to define the quality of water that is safe for consumers. Therefore, most of the standards set limits for chemicals that are potentially hazardous to human [5]. In Saudi Arabia, the quality of drinking water is receiving attention from environmentalist and water scientists [7]. Saudi Arabian Standards Organization, 1984 (SASO) developed drinking water standards for both bottled and unbolted water to define a quality of water that sustains a healthy population which set limits for the permitting and maximum contaminant level of chemical elements that endanger the health of consumers [6].

Epidemiological studies have reported the occurrence of many health problems, including cardiovascular disease, renal diseases, and congenital malformations of the central nervous system, cancer and even death due to exposure to high trace elements and mineral contents of the water [10].

The prevalence of nephrolithiasis is increasing [7, 8]. Patients with kidney stones often have a benign course, but life-threatening complications like acute kidney injury and infection can arise [9]. Nephrolithiasis is a very complex disease. People's concern is that public water supply may contribute to urinary calculus formation. Calcium oxalate and calcium phosphate calculi account for more than 80% of kidney stones. Less common stone types include uric acid, magnesium ammonium phosphate (struvite) and cysteine stones. Mineral content may widely vary in tap water depending on the geological characteristics of the aquifer site. Water hardness is defined as the molar sum of calcium and magnesium found in water, and is expressed as weight per volume (mg/L) [10]. Assuming a daily water intake of 2 L, people in areas with very hard water receive as much as 360 mg of calcium (30%

of the reference daily intake), and 170 mg of magnesium (40% of the reference daily intake) via drinking water. Previous investigations that tried to find a correlation between the water hardness and urolithiasis have led to contradictory results. Similarly, there is no consensus on the effects of mineral content of fresh water such as calcium and bicarbonate on the urinary calculus incidence [11, 12]. Certain pathophysiological studies have demonstrated an inhibitory effect of magnesium on calcium oxalate calculus formation [13]. Accordingly, magnesium supplements have been suggested for calcium oxalate calculus metaphylaxis [14]. However, in epidemiological studies, magnesium-calcium ratio in tap water was shown to be inversely related with the incidence of the calcium-containing urinary calculus [15].

In Hail, a region located in north central of Saudi Arabia, there are many wells scattered throughout some villages used as a main source of drinking water by rural residents. As the prevalence of stones increases and medical expenditures mount, the need to focus on prevention intensifies. The present study was aimed to determine the clinically important levels of minerals and to determine the microbiological content of tap water and address whether there is a correlation between the nephrolithiasis incidence and water supply ingredients in five different areas of Hail region, Saudi Arabia.

MATERIAL AND METHODS

Our study proposes to investigate the quality of drinking waters used for human consumption on an extended area in Hail region. Samples were collected from five different areas of Hail, namely Hail project, Alkhuta, Ougda, Qenaa and Tawaren. We collect two types of samples from each region from water tanks of water treatment plants; one for chemical and physical analysis and the other for microbiological examination. For chemical and physical analysis, water samples were collected in high density polyethylene containers. Previously washed in a solution of 10% nitric acid in an ultrasonic bath for 15 minutes, followed by repeated rinsing with bidistilate water and finally rinsing with ultrapure water (resistivity 18 MΩcm-1), Until collection containers were kept in sealed polyethylene bags, water samples were stabilized with ultrapure nitric acid (0.5% HNO3). Physical analysis for collected water samples include the determination of pH using a calibrated pH meter, EC using a calibrated conductivity meter, turbidity and TDS using the gravimetric method.

A quantitative method was used for accurate determination of concentrations of common ions and heavy metals (calcium, magnesium and iron), in waters with inductively coupled plasma quadruple mass spectrometry (ICP-Q-MS). ICP-MS is a relatively new method for determining multi-element analysis and ideal for water, since the vast majority of target compounds can be detected below 0.1 mg/l [16, 17]. Therefore a Perkin Elmer ELAN DRC (e) instrument was used with a Mein hart nebulizer and silica cyclonic spray chamber and continuous nebulization. The operating conditions are listed below: Nebulizer Gas flow rates: 0.95 l/min; Auxiliary Gas Flow: 1.2 l/min; Plasma Gas Flow: 15 l/min; Lens Voltage: 7.25 V; ICP RF Power: 1100 W; CeO/Ce = 0.031; Ba++/Ba+ = 0.016. Therefore a multi-standard calibration method was applied: Perkin Elmer 10 mg/ml of twenty-nine metals (ICP-MS Standard, Matrix: 5% HNO3, Perkin Elmer Life and Analytical Sciences), a standard of 10 mg/ml Hg (Mercury standard 5% HNO3 matrix, Perkin Elmer), and multi-standard PerkinElmer 10 mg/ml rare-metal standard (Atomic Spectroscopy Standard, Matrix 5% HNO3).

For microbiological examination, the samples were collected in sterile plastic containers and kept in a cooling bag at 4^o C and sent within 6 hours to Hail regional laboratory where each bottle was adequately shaken then, two samples of one milliliter each sample was taken for microbiological study, properly labeled and recorded.

1. One ml. sample was inoculated in Blood Agar Plate (BAP) and another one ml. The sample was inoculated on Sabouraud's Dextrose Agar Plate (SDAP).
2. All samples were incubated for 24 to 48 hours at 25 to 30 degrees and observed for growth.
3. Fungal identification was done microscopically. Samples were cultured quantitatively and levels of bacteria were determined as Colony-forming Units (CFUs) per milliliter. Bacterial identification was conducted using the Vitek II system of bacterial identification.

One hundred patients attending primary healthcare center in the five regions were asked to participate in the study after taken their written consent.

Exclusion criteria: patient with

- Diabetes mellitus.
- Chronic renal diseases
- Hypertension
- Senile enlarged prostate
- Receiving nephrotoxic drugs (e.g., NSAIDs, aspirin, sulfonamides, quinolone or diuretics), are excluded from the study.

All subjects were subjected to:

1. Full history taking with particular emphasis on age, gender, residence, occupation most frequent type of drinking water used, high-salt intake diet, history of any systemic diseases, any drug intake and family history of Renal diseases

2. Urinary symptoms e.g., dysurea frequency, nocturea, change urine color and abnormal urine odor.
3. Thorough clinical examination.
4. Complete urine analysis.
5. Kidney urinary ultrasonography (US) after an overnight fasting.

RESULTS

Table 1 revealed the physical characteristics of drinking water samples of the five examined areas Hail, ALkhuta, Ugda, Qnaa and Twaran. As regards EC (µS/cm) it was 347, 1046, 521, 717 and 384 respectively with higher values detected in ALkhuta and Qnaa. The pH was 8.4, 7.91, 8.49, 7.8 and 8.4 respectively, where most samples are near higher limit. Water turbidity was 0.44, 0.26, 0.38, 0.31 and 1.38 with the higher value detected in Twaran. Lastly, TDS was 229, 724, 350, 487 and 254 respectively with highest level detected in ALkhuta.

Table 1: The physical characteristics of drinking water samples

Sample site	EC (µS/cm)	pH	Turbidity (NTU)	TDS (mg/L)
Hail	347	8.4	0.44	229
ALkhuta	1046	7.91	0.26	724
Ugda	521	8.49	0.38	350
Qnaa	717	7.8	0.31	487
Twaran	384	8.4	1.38	254
SAS (1984)	800-2300	6.5-8.5	25.0	1500
GCS (1993)	160-1600	6.5-8.5	5.0	1000
WHO limits (2011)	1500	< 8	5.0	1000

- EC: electrical conductivity
- NTU: Nephelometric turbidity unit
- TDS: total dissolved solids
- ND: not detected
- SAS: Saudi Arabia Standard
- GCS: Gulf Countries Standard
- WHO: World Health Organization

Table 2: Chemical analysis of studied drinking water samples (mg/L)

	Calcium mg/1	Magnesium mg/1	Calcium. Hardness	Magnesium Hardness	Total hardness mg/1	Total alkalinity
Hail	23.84	2.69	59.6	11.2	70.8	43.43
ALkhuta	108.16	11.33	270.4	47.2	317.6	75.64
Ugda	54.56	11.52	136.4	48	184.4	128.83
Qnaa	90.72	16.13	226.8	67.2	294	215.7
Twaran	51.04	9.02	127.6	37.6	165.2	143
SAS (1984)	200	30-150	500	NS	500	NS
GCS (1993)	200	150	500	NS	500	NS
WHO limits (2011)	NS	NS	NS	NS	500	200

- NS: No known standard level.

Table 3: General guidelines for classification of water hardness (INERIS, 2004)

Hardness as mg/L CaCO3	Degree of hardness
0 – 30 Very soft	0 – 30 Very soft
31 – 60 soft	31 – 60 soft
61 – 120	120 Moderately soft/ moderately hard
121 – 180	Hard
>180	Very hard

Table 4: total results of clinical examination, urine analysis and kidney-urinary tract Utrasonography of all persons enrolled in the study

Item	Patient data	
Age	45.95±22.37	
Urinary symptoms		
	N	**%**
• Frequency	33	33
• Dysurea	27	27
• Change color	5	5
Urine analysis		
	N	**%**
Crystals:		
• Ca oxalate	25	25
• Uric acid	45	45
• Urate	36	36
Organelle		
• Bacteria	41	41
• Yeast	5	5
Mucus	27	27
Kidney-Urinary Tract US		
	N	**%**
• Gravels	39	39
• Stone	9	9
• Nephrosis	2	2
• Hydronephrosis	1	1

Table 5: results of clinical examination, urine analysis and kidney-urinary tract Utrasonography of persons enrolled in the study from the different five regions

Item	Hail		ALkhuta		Ugda		Qnaa		Twaran	
Age	35±14.67		46.33±29.3		57.5±22.37		42.1±20.95		62±17.89	
Urinary symptoms										
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
• Frequency	3	12	11	44	6	24	3	12	10	40
• Dysurea	0	0	11	44	0	0	6	24	10	40
• Change color	0	0	5	20	0	0	0	0	0	0
Urine analysis										
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Crystals:										
• Ca oxalate	0	0	3	12	12	48	7	28	3	12
• Uric acid	6	24	9	36	12	48	8	32	10	40
• Urate	9	36	6	24	12	48	4	16	5	20
Organelle										
• Bacteria	6	24	5	20	12	48	3	12	5	20
• Yeast	0	0	5	20	0	0	0	0	0	0
Kidney-Urinary Tract US										
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
• Gravles	6	24	9	36	6	24	8	32	10	40
• Stone	0	0	3	12	0	0	6	24	0	0
• Nephrosis	0	0	2	8	0	0	0	0	0	0
• Hydronephrosis	0	0	0	0	0	0	0	0	1	4

Table 2 revealed chemical analysis of studied drinking water samples (mg/L). Calcium levels was 23.84, 108.16, 54.56, 90.72 and 51.04 mg/1 respectively, with the highest value present in the ALkhuta although lie within the standard range. Magnesium was 2.69, 11.33, 11.52, 16.13 and 9.02 mg/1 respectively. Calcium hardness was 59.6, 270.4, 136.4, 226.8 and 127.6 respectively, while magnesium hardness was 11.2, 47.2, 48, 67.2 and 37.6 mg/1 respectively. Total hardness was 70.8, 317.6, 184.4, 294 and 165.2 which all within the slandered values. Lastly total alkalinity was 43.43, 75.64, 128.83, 215.7 and 143 respectively.

Table 3: revealed classification of water hardness as mg/L CaCO3 (calcium carbonate) [18] Where level 0 - 30 is very soft, 31 - 60 is soft, 61 - 120 is moderately soft/ moderately hard, 121 - 180 is hard and >180 is very hard. Microbiological examination and culture for all samples revealed no growth. Table 4 revealed results of clinical examination, urine analysis and kidney-urinary tract US of all patients enrolled in the study where the mean age of all patients was 45.95±22.37. As regard urinary symptoms 33 % had frequency, 27% had dysurea and 5% had change urine color. Urine analysis results revealed that 25% had calcium oxalate crystals, 45% had uric acid crystals and 36% had urate crystals. 41% had bacteria and 5% had yeast. 27% revealed mucus in the urine. Kidney-urinary tract US revealed 39% of patient had renal gravels, 9% had stones, 2% with nephrosis, and 1% had hydronephrosis.

Table 5 revealed the detailed results of clinical examination, urine analysis and kidney-urinary tract US of persons enrolled in the study of the different five regions. Each group includes 25 patients attained local primary health center for medical consultation. The mean age for Hail was 35±14.67, ALkhuta was 46.33±29.3, Ugda was 57.5±22.37, Qnaa was 42.1±20.95 and Twaran was 62±17.89 with no statistical significant reference between all groups. In Hail area 3 (12%) cases had frequency. ALkhuta 11 (44%) cases had frequency, 11 (44%) cases had dysurea and 5 (20%) cases had changed urine color. Ugda 6 (24%) cases had frequency. Qnaa 3 (12%) cases had frequency, 6 (24%) cases had dysurea, and in Twaran 10 (40%) cases had frequency, and 10 (40%) cases with dysurea. Urine analysis revealed in Hail group 6 (24 %) cases had uric acid crystals and 9 (36%) cases had urate crystals. ALkhuta group 3 (12 %) had calcium oxalate crystals, 9 (36%) cases had uric acid crystals and 6 (24%) had urate crystals. Ugda group 12 (48%) cases had calcium oxalate crystals, 12 (48%) cases had uric acid crystals and 12 (48%) had urate crystals. Qnaa group, 7 (28%) cases had calcium oxalate crystals, 8 (32%) cases had uric acid crystals and 4 (16%) had urate crystals. Twaran group 3 (12%) cases had calcium oxalate crystals and 10 (40%) cases had uric acid crystals and 5 (20%) had urate crystal. Hail group 6 (24 %) cases had bacteria in the urine, ALkhuta group 5 (20 %) had bacteria, 5 (20%) cases had yeast, Ugda group 12 (48%) cases had bacteria, Qnaa group, 3 (12%) cases had bacteria and Twaran group 5 (20%) cases had bacteria. Kidney urinary tract US revealed that Hail group 6 (24 %) cases had renal gravels, ALkhuta group 9 (36 %) had renal gravels, 3 (12%) cases had renal stones, and 2 (8%) showed renal nephrosis, Ugda group 6 (24%) cases had renal gravels, Qnaa group, 8 (32%) cases had renal gravels with 6 (24%) had renal stones and Twaran group 10 (40%) cases had renal gravels and 1 (4%) case had hydronephrosis.

DISCUSSION

Drinking water must be free from organisms that are capable of causing disease and from minerals and organic substances to ensure proper health and wellness. Drinking water should be palatable (free from apparent turbidity, color, odor and any objectionable taste) that it may be consumed in any desired amount without health adverse effects. Drinking enough water will decrease the burden on the kidneys by flushing out waste products. The maximum allowed concentration of different substances in public water supply is controlled throughout the world by legislation which varies to some extent from one country to another. Drinking water quality standards in Saudi Arabia (SAS) are emanated by the Saudi Arabian Standards Organization (SASO) [5]. Gulf Cooperation Council Countries Standards (GCS, 1993) [19] for un-bottled drinking water has been issued in 1982 by SASO and Standardization and Metrology Organization for Gulf Cooperation Council Countries (GSMO). Beside the primary aim of the World Health Organization (WHO) Guidelines for drinking water quality [20].

EC value in the studied area varied from 347 to 1046 µs/cm. All samples are within the recommended range however it is relatively high in Alkhuta (1046) and Qnaa (717). High EC indicates the presence of high quantity of dissolved inorganic substances [21]. TDS is the summation of all solids dissolved in the water, such as non-organic materials, bicarbonate, carbonate, nitrate, potassium, sodium, magnesium and chloride. TDS influences alternate attributes of drinking water, for example, taste and hardness [22]. TDS varied from 229 to 724mg/l with high levels found in Alkhuta (724) and Qnaa (487) still with the standard levels. Solid information on conceivable wellbeing impacts connected with the ingestion of TDS in drinking water is not accessible. Certain components of TDS, such as chlorides, sulfates, magnesium, calcium, and carbonates, affect corrosion in water-distribution systems [23]. Water with TDS concentrations less than 1000 mg/litre is usually acceptable to customers [24].

Turbidity is a measure of the relative clarity of water. Turbidity is used as an indicator of the effectiveness of drinking water treatment processes, particularly filtration. All our samples had very low levels of turbidity. Three samples had a high allowed level of pH Hail (8.40, Ugda (8.49) and Twaran (8.4). Some studies revealed that pH range from 7.5 - 8.3 are ideal. The lower the pH, the more corrosive the water will be. This can lead to health problems if metal particles are leached into the water supply from the corroded pipes Also, excessively alkaline water may be corrosive. Excess water iron may increase the hazard of pathogenic contamination as many organisms require iron to grow [25].

Our results revealed that Alkhuta and Twaran had relatively higher calcium levels (108.16 and 90.72 respectively) while Qnaa, Ugda and Alkhuta had a relatively higher magnesium level (16.13, 11.52, and 11.33 respectively). Magnesium is rapidly expelled from the bodies of healthy humans. People with kidney disease, who cannot excrete excess magnesium, may suffer from hypertension, muscle weakness, confusion, and coma. High calcium levels can lead to the formation of excess calcium carbonate deposits in plumbing and decreased cleansing action of soaps [26]. Caudarella and colleagues showed that drinking calcium-rich water increases urinary calcium level. It also causes concomitant hypooxaluria [27]. Coen and coworkers showed that preventing from urinary calculus recurrences through increasing water intake between meals should preferably be achieved using a relatively low-calcium water, and calcium-rich waters should be avoided [28].The relation between magnesium content of drinking water and nephrolithiasis incidence is not well clear in epidemiological studies. Kohri and coworkers occluded that, calcium and magnesium levels of the tap water were not correlated with urinary calculus incidence. Nevertheless, they observed that the magnesium calcium ratio of the tap water in different geological areas was negatively correlated with the incidence of calcium-containing urinary calculi [29].

Alkhuta and Qnaa areas had very hard water and Ugda and Twaran samples were hard. Water hardness is the total concentration of calcium and magnesium picked up by water passing through underground mineral deposits. The United States National Research Council has announced that hard water can act as a dietary supplement for calcium and magnesium [30]. More than 3/4th of renal stones are mainly composed of calcium salt and occur as calcium oxalate and less commonly as calcium phosphate. Increased urinary ion excretion and decreased urine volume will increase free ion activity and favor stone formation. The impact of water hardness on urinary stone formation remains unclear. A weak correlation between water hardness and urinary calcium, citrate, and magnesium levels has been observed. Some studies suggest that intake of soft water is preferable to hard water since it is associated with a lower risk of calcium nephrolithiasis [31]. Seirakowski and coworkers observed an inverse relationship between the water hardness and nephrolithiasis incidence [32]. Barkers and Donnan in their study showed a positive correlation with the total hardness of drinking water [33]. Others found no significant relationship [34].

Urine analysis results revealed calcium oxalate crystals were 12% in Alkhuta and 28% in Qnaa while it was 48% in Ugda and 20% in twaran. Uric acid crystals are more common in Ugda (48%), Twaran (40%), (36%) and Qnaa (32%). Also, urate crystals are more common in Ugda (48%) and Hail (36%). US revealed presence of gravels in 40% in Twaran, 36 % in Alkhuta and 32 % in Qnaa and the presence of renal stones in Qnaa (24%) and 12 % in Alkhuta. Nephrosis was detected in 8 % in Alkhuta. It was noticed that the incidence of renal gravels, stone and nephrosis occurred in samples with hard and very hard water. Alkalinity is a measure of water ability to neutralize acids, and is related to the pH. It results primarily from carbonate minerals, such as those found in limestone. Alkalinity and total hardness are usually equal in concentration when both are reported in mg/L calcium carbonate as they come from the same minerals. Much higher alkalinity than total hardness considered testing for sodium whiles much lower alkalinity than total hardness.

The lower the alkalinity, the more likely water is to be corrosive. Water with high alkalinity (greater than 150 mg/L) may contribute to scale buildup in plumbing. Values near 150 are considered ideal [35]. Only Qnaa sample had a higher degree of alkalinity (215.7 mg/L) with a high incidence of renal gravels and stone formation. Turki A 2009 [36] examined the quality of 40 wells water in selected villages in Hail Region used mainly for drinking purposes without receiving any treatment. Of the 40 well water tested, about 20 % of samples failed to meet drinking water guidelines of SAS, GC.S and WHO respectively. TDS varied widely from 166 to 2400 mg/l. 36% of the tested water samples had higher nitrate level above the limit set by local and international standards. Only 52.5% of tested samples comply with the range of fluoride concentrations and Coli form bacteria (mainly E. coli and E. aero genes) were detected in 20% of examined well water indicating faecal contamination. This revealed much improvement of water quality and availability of water treatment plants in this short period which will be reflected on the general health in this area.

CONCLUSION

All studied water samples results are within the standard level with different changes from one area to another with no detectable microbiological. Alkhuta and Qnaa revealed high EC, TDS, calcium and total hardness. Many patients had frequency and/or dysurea. Both areas showed high prevalence of renal gravels and renal stones. Ugda samples revealed high pH. The only presenting symptom is frequency with high urine calcium oxalate, uric acid and bacterurea. Twaran samples revealed high pH and turbidity. Frequency and dysurea are common symptoms. There was high calcium oxalate crystals and prevalent of renal gravels with one case of hydronephrosis. Hail samples revealed high pH, low calcium and magnesium levels. Alkhuta and Qnaa had very hard water while Ugda and Twaran had hard water which favors stone formation. Qnaa sample had a higher degree of alkalinity (215.7 mg/L) with a high incidence of renal gravels and stone formation.

Recommendation

- Regular monitoring of water quality to maintain a proper quality and eliminate any possible health problems.
- More water treatment plants should be installed by local government to provide safe drinking water especially in remote areas.
- Ultrasonography screening in areas with the relevant water quality is mandatory for early detection of renal gravels, stones and complication.
- Qnaa, Ugda and Alkhuta had a relatively higher magnesium levels so, people with renal diseases, should be take care about this excess magnesium.

Work limitation

Limited patient number involved in the study.

Conflict of interest

The authors declare that there is no conflict of interest.

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