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IDENTIFICATION OF POTABLE WATER USING WATER QUALITY INDEX TECHNIQUE IN THE CITY OF AZ-ZANTAN, LIBYA

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ABSTRACT

To identify potable water in the city of Az-Zintan, Libya is achieved by the chemical analysis of different resources of drinking water supplied to Az-Zintan City. These resources are, rain water, groundwater and municipal water. This was carried out by subjecting twenty one groundwater samples, collected from twenty one selected sites, to comprehensive chemical analysis. Ten parameters have been considered for calculating the Water Quality Index (WQI) such as: pH, total hardness, calcium, magnesium, potassium, sodium, bicarbonate, chloride, sulphate, and total dissolved solids. Based on the computed water quality index values showed that the water that originates from rain is the most suitable for drinking and the water that originates from municipal water is unsuitable for drinking under normal conditions and therefore further action for salinity control is required.

تحديد مصدر المياه الملائمة لاغراض الشرب باستخدام طريقة تقييم مؤشر نوعية المياه في مدينة الزنتان، ليبيا

نافع حمادي العلواني و رشدي عايد ياسين

المستخلص

تم في هذا البحث تحديد مصدر المياه الصالحة للشرب في مدينة الزنتان في ليبيا باستخدام مؤشر نوعية المياه. ولتحقيق هذا الهدف تم إجراء تحاليل كيمياوية لمصادر مختلفة من المياه التي تتزود بها مدينة الزنتان وهي مياه الأمطار والمياه الجوفية ومياه البلدية، حيث تم اجراء التحليل الكيميائي لواحد وعشرون عينة مياه جمعت من احدى وعشرون موقعا لكافة المحددات الكيميائية. وتم اختيار عشرة محددات كيميائية لغرض حساب مؤشر نوعية المياه مثل (درجة الحموضة، وعسرة المياه، وكمية الاملاح الذائبة، والكالسيوم، والمغنيسيوم، والصوديوم، والبوتاسيوم والكلور، والكبريتات) واعتمادا على هذه التحليلات تم حساب مؤشر مياه منطقة الزنتان. لقد اظهرت النتائج من خلال القيم المحسوبة لمؤشر نوعية المياه ان المياه التي يكون مصدرها الأمطار هي الأكثر ملائمة للشرب والمياه التي يكون مصدرها مياه الحنفية غير صالحة لأغراض الشرب تحت الظروف الاعتيادية وتحتاج الى عمل كثير للسيطرة على الملوحة العالية.

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INTRODUCTION

The main objective of any water quality monitoring study is to assign water quality status for special use. Water quality index technique has been used in the present study to identify the source of suitable water for drinking purposes in Az-Zintan City. This technique is an effective tool to assess spatial and temporal changes in the quality of groundwater. Horton (1965) has used the WQI concept then it is developed by Brown *et al*. (1970) and Scottish (1975). Several studies have described the development of WQI method for groundwater such as Backman *et al*. (1998); Soltan (1999); Stigter *et al*. (2006a and b); Saeedi *et al*. (2009); Ramakrishnalah *et al*. (2009); Khalid (2011); Rizwan and Gurdeep (2010) and Charmaine and Anitha (2010). The city of Az-Zintan which is located 150 Km southwest of Tripoli relies mainly on rain water that is collected in winter as well as groundwater. In recent years, the city suffers from scarcity of water resources in addition to the risks resulting from low water levels and quality deterioration due to the continued attrition of these waters. Different resources of drinking water are supplied to Az-Zintan city such as rain water, groundwater and municipal water.

Az-Zantain City is one of the biggest cities in northwestern Libya, situated roughly 136 kilometres southwest of Tripoli. It is located between latitudes (31° 40' 22" and 32° 12' 26") N and Longitude (12° 00' 00" to 12° 52' 42") E, covering an area of approximately 116 Km^2 (Figure 1). The city and its surrounding area have a population of approximately 50,000 according to the census of 2006. The climate is very cold in the winter and hot in the summer. It lays on Aljabil algharbi 136 Km south-west of the Tripoli city which is extends at a distance of 500 Km from the Tunisian border and passes the Jebel Nafusa and Altarhuni. Geologicaly it is located in jabil Nafusa extend from NW of the Libyan country to the Alkumis city. It consists of limestone rocks series were formed at the end of Mesozoic to Cenozoic Era. It represents a series of valleys that moving towards the south and north. This series prevent progress sand to the north and embrace to the Aljafarh coastal plain.

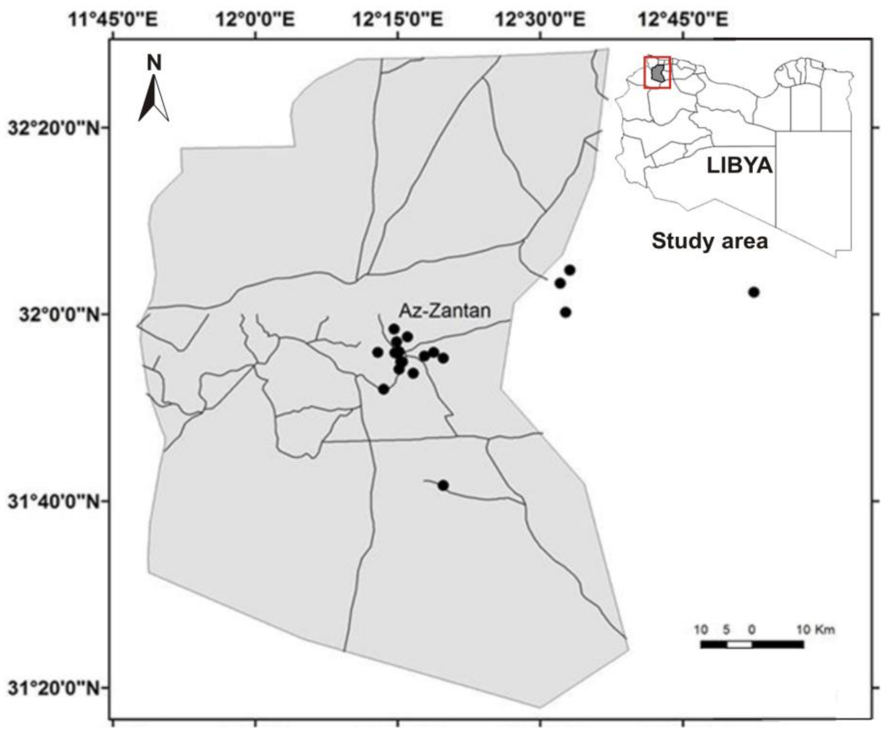

Fig.1: Location map of the study area

METHODOLOGY

21 water samples were collected from different sources of water supplied to Az-Zintan city during July 2002. These sources are, rain water, groundwater and municipal water. Each water sample was analyzed for 10 parameters which are Total Dissolve Sold (TDS), pH, total hardness (TH), calcium (Ca^{+2}), magnesium (Mg^{+2}), sodium (Na^{+}), potassium (K^{+}), chloride (Cl^{-}), sulphate (SO_4^{-2}) and bicarbonate (HCO_3^{-}) using standard procedures recommended by APHA, 1995 which are listed in Table 1.

Table 1: A summary of the methods used for the analysis of water samples

Serial No.	Parameters	Methods
1	PH, TDS and conductivity	Electrolytic
2	Na^{+2} and K^{+}	Flame photometer
3	Ca^{2+}, Mg^{2+}	EDTA titration
4	HCO^{3-}	H_2SO_4 titration
5	Cl^{-}	$AgNO_3$ titration
4	SO_4^{2-}	Spectrophotometers

The measured parameter values are summarized in Table (2) and the locations of these sites are shown in Figure (1).

Table 2: Chemical analysis of water samples in the Az-Zintan City (Uints in ppm)

	Source water sample	TDS	pH	TH	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Cl^{-}	SO_4^{-2}	HCO_3^{-}
1	**Tap water 1**	1100.8	7.4	700	110	102	50	1.95	320	115	305
2	**Tap water 2**	1203.2	8.0	836	138	118	55	2.05	335	128	346
3	**Groundwater 1**	883.2	7.2	680	92	108	37	1.17	315	129	121
4	**Groundwater 2**	1081.6	7.6	750	156	102	35	1.17	245	112	360
5	**Groundwater 3**	857.6	7.4	655	82	108	27	0.78	260	132	345
6	**Groundwater 4**	825.6	7.1	620	86	98	28	0.78	255	125	380
7	**Groundwater 5**	1171.2	7.6	816	135	115	46	1.56	245	155	350
8	**Groundwater 6**	979.2	7.3	730	152	84	46	1.56	315	64	308
9	**Tap groundwater 1**	1075.2	7.9	870	128	132	48	1.95	270	96	360
10	**Tap groundwater 2**	1139.2	8.0	858	150	116	19	1.56	240	135	350
11	**Rain water (Tap) 1**	883.2	7.2	581	68	88	38	1.2	305	114	135
12	**Rain water (Tap) 2**	832	7.9	615	116	78	37	1.73	280	72	220
13	**Rain water (Stored) 1**	800	7.3	612	75	102	31	0.92	248	142	335
14	**Rain water (Stored) 2**	768	7.2	590	98	83	39	1.34	210	44	322
15	**Rain water (Collected) 1**	262.4	6.9	224	48	25	24	0.7	60	53	76
16	**Rain water (Collected) 2**	160	7.6	125	22	17	21	0.56	58	34	65
17	**Rain water (Collected) 3**	236.8	8.3	180	42	18	18	0.74	62	75	72
18	**Rain water (Collected) 4**	76.8	7.6	65	12	8.5	11	0.45	20	28	35
19	**Rain water (Collected) 5**	83.2	7.4	70	14	8.5	7	0.53	22	35	42
20	**Rain water (Collected) 6**	179.2	7.4	137	25	18	7	0.78	38	27	55
21	**Rain water (Collected) 7**	332.8	6.7	128	25	16	115	0.73	35	28	52

- **Calculation of Water Quality Index**

The Water Quality Index is usually calculated from the standpoint of suitability of groundwater for human use. The weight ***(wi)*** for each chemical parameters has been assigned in the first step depending on their relative importance in the quality of the water use for drinking as shown in Table (3). Five is the maximum weight assigned for specific chemical parameters which are believed to be of great importance in the evaluation of water quality and give a minimum weight of (2) for the chemical parameter that is believed to be not detrimental to the overall quality of water (Table 3). The relative weight (***Wi)*** is calculated in the second step from equation number 1 below:

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 1$$

Where, **Wi** = relative weight
wi = weight of each chemical parameter
n = number of chemical parameters

The relative weight ***(Wi)*** is calculated and the value of each parameter is given in Table (3). A quality rating scale ***(qi)*** has been also calculated for each parameter in the third step by the following equation:

$$qi = (Ci / Sl) \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 2$$

Table 3: Relative weights of chemical parameters (Ramakrishnalah *et al*., 2009)

Chemical parameters (In ppm)	Laybian standard	Weight (wi)	Relative weight (Wi)
TDS	500	4	0.138
pH	6.5	2	0.069
TH	200	2	0.069
Ca^{+2}	75	2	0.069
Mg^{+2}	30	2	0.069
Na^{+}	20	2	0.069
K^{+}	10	3	0.103
Cl^{-}	200	3	0.103
SO_4^{-2}	200	4	0.138
HCO_3^{-}	200	5	0.172
Total		∑ wi = 29	∑ Wi = 1

Where, ***qi*** = quality rating
Ci = each parameter concentration in mg/L unite for each water sample
Sl = Laybian drinking water standard in mg/L unite for each parameter

To calculate the water quality index, firstly the sub index of the chemical parameter ***(Sli)*** is determined and then the WQI is calculated using the following equations

$$SIi = Wi.\ qi \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 3$$

$$WQI = \sum SIi \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 4$$

According to Ramakrishnalah *et al*. (2009) the calculated values of WQI are classified into five categories: "excellent to unsuitable water" as shown in Table (4).

RESULTS AND DISCUSSION

The chemical analyses of the different sources of water are compared with the Libyan standard chemical parameters for drinking (Table 3). Ten parameters have been considered for calculating the WQI such as: Total dissolved solids (TDS), pH, total hardness, calcium, magnesium, potassium sodium, bicarbonate, chloride and sulphate which have discussing below.

Table 4: Water quality classification based on WQI value

WQI value	Class	Water quality	Percentage of studied water sample
< 50	I	Excellent	28.5
50 – 100	II	good water	4.8
100 – 200	III	poor water	66.7%
200 – 300	IV	very poor water	Nil
> 300	V	Unsuitable water	Nil

- ***Total dissolved solids (TDS)***

Is the expression used to assess the mass concentration of soluble components in water. It is regularly determined in (mg/l) or (ppm) units. The concentration of TDS for drinking water is less than 500 ppm (Horton, 1965). In the study area the levels of TDS ranges from 77 to 1204 mg/L as shown in Figure (2). Seven samples show TDS values beyond the desirable limit of 500 mg/L. The highest concentration of total dissolved solids is found in tap water and groundwater due to the dense residential area and due to intensive irrigation. Gupta *et al*. (2004) pointed out that the high values of dissolved solids may affect people who are suffering from kidney and heart disease and Kumaraswamy (1999) pointed out it may cause a laxative or constipation effects.

- ***Total hardness (TH)***

Values varies from 65 to 870 mg/L as shown in Figure (2). The hardness for the different sources of water in Az-zaintan is found to be high for all locations and fall above the desirable limit of Libyan specification which may be due to presence of calcium (Ca^{2+}) and magnesium (Mg^{2+}). According to Sawyer and McCarty's (1967) classification for hardness consists of 21% of samples fall under the soft class and 71% is classified as extremely hard water.

- **pH**

Values in the study area varies from 6.67 – 8.26 as shown in Figure (3). The results showed that the values of pH in all samples of the various sources tended to be slightly basic except two samples of rainwater whose values tended to be slightly acidic, and in any case, all the values of the pH fall within the permissible limits.

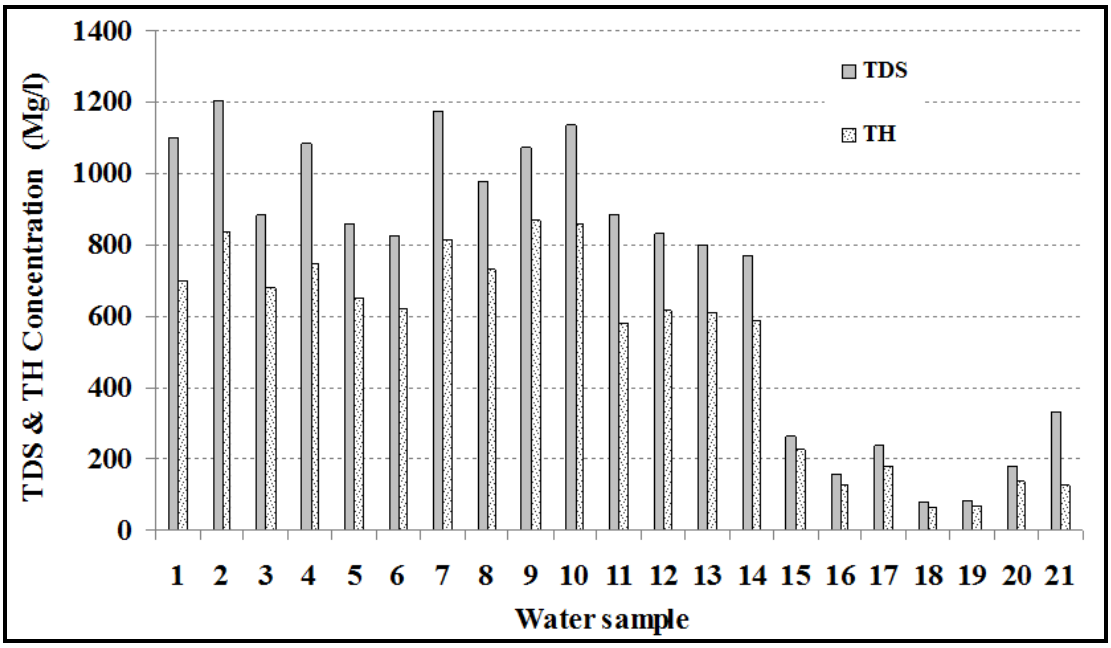

Fig.2: Values of TH and TDS for all studied samples

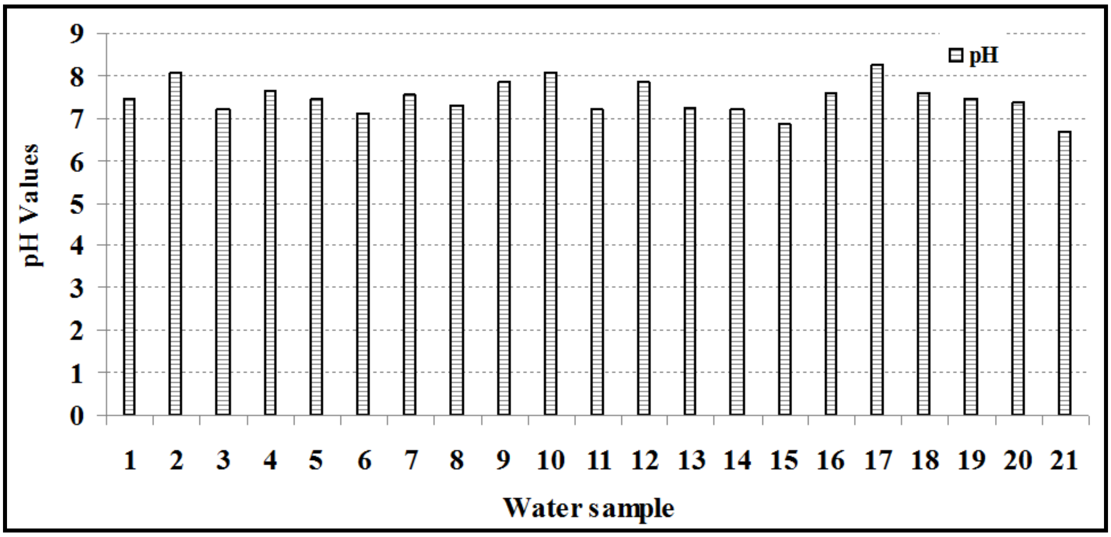

Fig.3: Values of pH for all studied samples

- **Cations concentration**

A significant increase has been observed in the concentrations of calcium in the municipal water, groundwater, and mixed water while all other samples collected from rainwater lie within the permissible limits as shown in Figure 4. The concentration of magnesium increases in the water samples of the municipal water, groundwater, and mixed water while for samples from rainwater lied within the permissible limits (Figure 4). The results showed that pure concentrations of both sodium and potassium are very low in all samples collected from all sources as shown in Figure 4.

- **Anions concentration**

A Clear rise has been observed in the concentration of chloride ion in the values of municipal water and groundwater samples, and some of the mixed water samples, especially those mixed with municipal water that exceeded the maximum allowable limit (Figure 5). The reasons of the high concentrations of chloride may be due to disinfection of bacteria and other biological contaminants by chlorine derivatives (Chanda, 1999). Sulfate concentrations were within the preassemble limit in the water samples originated from all sources. A remarkable increase of bicarbonate concentration is found in groundwater samples number 6, 9 and 4 (380, 360, 360 mg\l) respectively (Figure 5). But the concentrations of bicarbonate in rainwater samples are low and remained within the secure range for drinking.

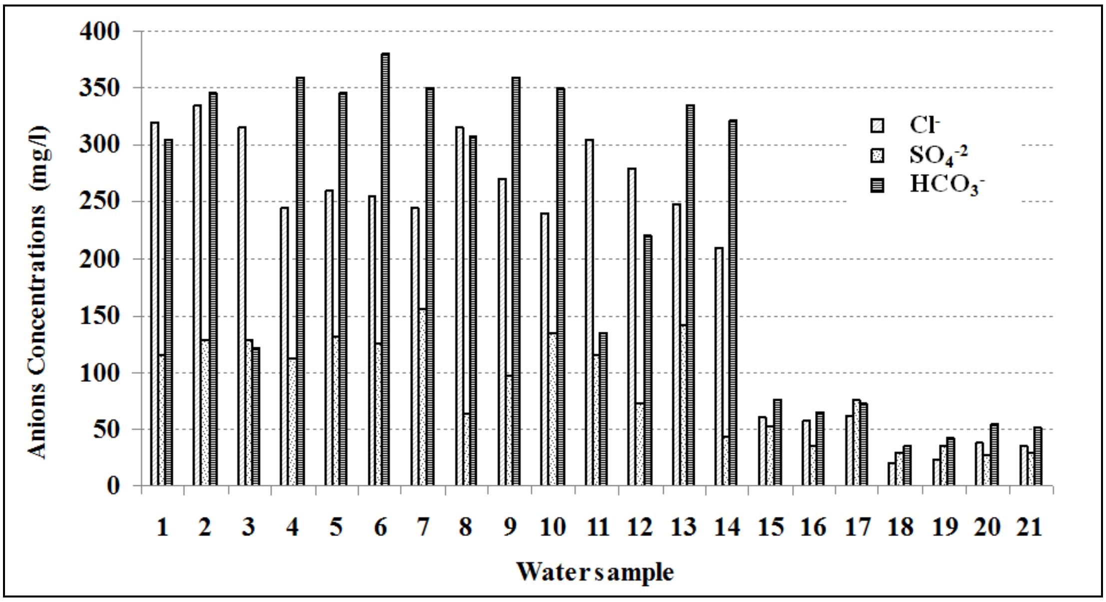

Fig.4: Cations values for all studied samples

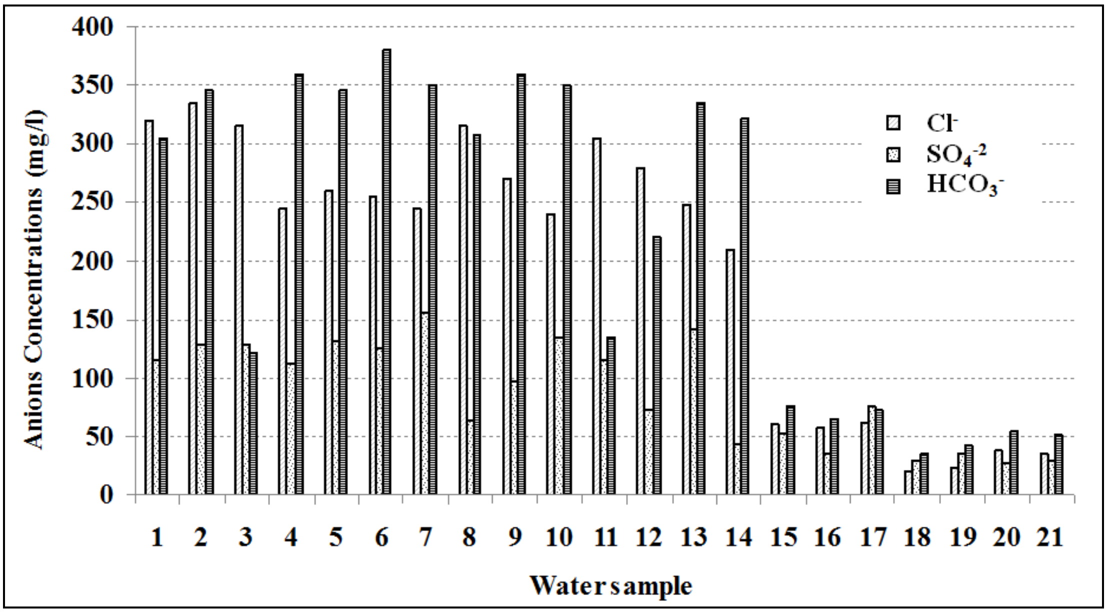

Fig.5: Anions values for all studied samples

- **Water Quality Index (WQI)**

The water samples in Az-Zintan city fall under different quality as shown in Figure (6) and Table (5). Water quality Index (WQI) values range from 25 to 170 in the study area;

therefore it can be categorized into five types of quality: excellent to unsuitable for drinking as shown in Figure 5. Accordingly, 28% of water samples fall in class (I) (Excellent water), 0.04% fall in class (II) (good water), 38% fall in class (III) (very poor water) and 28% fall in class (IV) (Unsuitable water). It has been observed that through these values the water that originates from rain is most suitable for drinking and the water obtained from tap is unsuitable water.

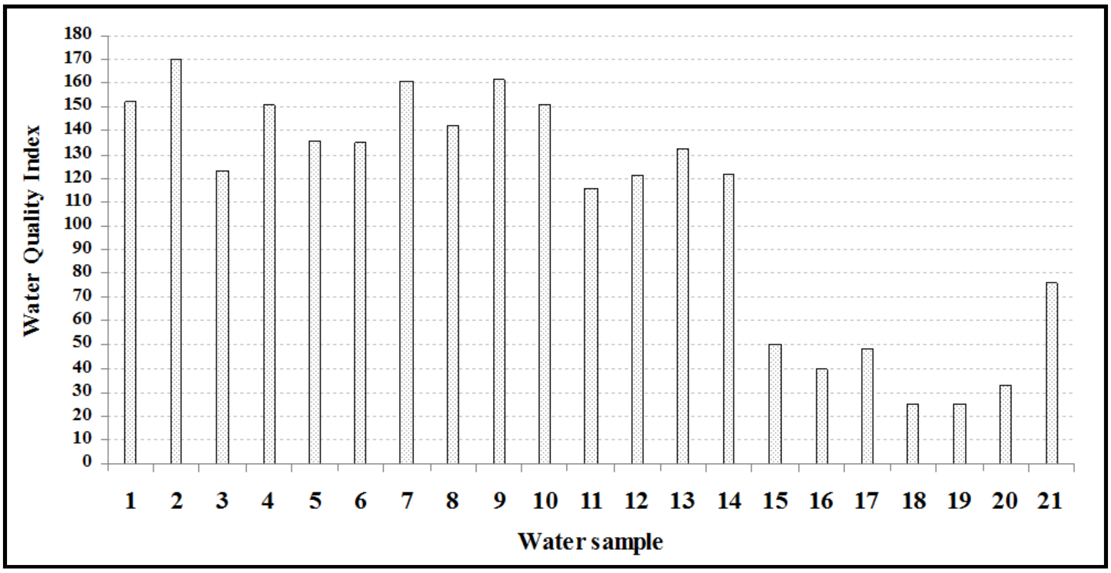

Fig.6: Values of WQI for all studied samples

Table 5: Water quality classification based on WQI value

Water sample		WQI Value	Water Quality
1	Tap water 1	152	Unsuitable water
2	Tap water 2	170	Unsuitable water
3	Groundwater 1	123	Poor water
4	Groundwater 2	151	Unsuitable water
5	Groundwater 3	136	Poor water
6	Groundwater 4	135	Poor water
7	Groundwater 5	161	Unsuitable water
8	Groundwater 6	143	Poor water
9	Tap groundwater 1	161	Unsuitable water
10	Tap groundwater 2	151	Unsuitable water
11	Rain water (Tap) 1	116	Poor water
12	Rain water (Tap) 2	121	Poor water
13	Rain water (Stored) 1	132	Poor water
14	Rain water (Stored) 2	122	Poor water
15	Rain water (Collected) 1	50	Excellent
16	Rain water (Collected) 2	40	Excellent
17	Rain water (Collected) 3	48	Excellent
18	Rain water (Collected) 4	25	Excellent
19	Rain water (Collected) 5	25	Excellent
20	Rain water (Collected) 6	33	Excellent
21	Rain water (Collected) 7	76	Good

STATISTICAL ANALYSIS

Statistical analysis such as minimum, maximum, mean and standard deviation of the water quality parameters used in the calculation of WQI are presented in Table (6). Statistical package for social sciences (SPSS Version13) has been used to carry out the analysis. The mean and standard deviations is calculated to know the chemical parameters which are deviating from Libyan standard for drinking water. It has been observed that mean, and standard deviation for Cl^-, SO_4^{2-}, pH and K^+ parameters are within the limits of Libyan standard for drinking water while Ca^{2+}, Mg^{2+}, Na^+, HCO_3^-, TDS and TH parameters are higher than the Libyan standard limits as shown in table (6). The highest value was observed at the municipal sites.

Table 6: Comparison of chemical parameters in study area

	TDS	TH	pH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	HCO_3^-
Minimum	76.8	65.0	6.7	12.0	8.5	7.0	0.5	20.0	27.0	35.0
Maximum	1203	870	8	156	132	115	2	335	155	380
Mean	711.01	516.29	7.48	84.48	73.57	35.19	1.15	197.05	87.76	220.67
Std. Deviation	400.18	291.75	0.40	48.92	43.73	23.03	0.51	116.67	44.19	136.70

The degree of a linear association between any two of the water quality parameters, and water quality parameters with WQI as measured by the simple correlation coefficient (r) is presented in Table (7). Correlation analysis measures the closeness of the relationship between the chosen variables. If the correlation coefficient is nearer to +1 or –1, it indicates the perfect linear relationship between the two variables. This approach is tried to set up the nature of the relationship between WQI and chemical parameters of the water quality. It is noted that the TDS variations are mainly controlled by calcium (r = 0.93), magnesium (r = 0.96), potassium (r = 0.84), chloride (r = 0.93), sulphate (r = 0.81) and bicarbonate (r = 0.88). Highly significant relationship is observed in some sites between Mg^{2+} and Cl^- which indicate the permanent hardness of the water in nature. Highly significant interrelation is also observed between computed WQI with the values of TDS (r = 0.99) TH (r = 0.98), Ca^{2+} (r = 0.91), Mg^{2+} (r = 0.96), K^+ (r = 0.8), Cl^- (r = 0.92), SO_4^{2-} (r = 0.80) and HCO_3^- (r = 0.91).

Table 7: Correlation coefficient matrix of water quality parameters and WQI

	TDS	*TH*	*pH*	*Ca^{2+}*	*Mg^{2+}*	*Na^+*	*K^+*	*Cl^-*	*SO_4^{2-}*	*HCO_3^-*	*WQI*
TDS	1										
TH	0.99	1									
pH	0.24	0.27	1								
Ca^{2+}	0.93	0.94	0.34	1							
Mg^{2+}	0.96	0.98	0.22	0.86	1						
Na^+	0.32	0.22	-0.35	0.22	0.21	1					
K^+	0.84	0.82	0.39	0.83	0.75	0.35	1				
Cl^-	0.93	0.93	0.16	0.84	0.93	0.24	0.78	1			
SO_4^{2-}	0.81	0.81	0.24	0.66	0.86	0.07	0.49	0.77	1		
HCO_3^-	0.88	0.90	0.23	0.85	0.89	0.16	0.65	0.78	0.72	1	
WQI	0.99	0.98	0.18	0.91	0.96	0.39	0.80	0.92	0.80	0.91	1

CONCLUSION

This study was conducted to determine the appropriate potability of water supplied to the city of Az-Zintan using water quality index method. The results show that the high value of WQI has been found in areas where the water is a municipal water or groundwater. Accordingly it is not used for drinking purposes or need to be treated for use. On the other hand the low value of WQI has been found in areas where the source of water is rainy water and it is the most suitable for drinking purposes.

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