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Water Classification for Different Purposes Depending on the Concentration of some Heavy Metals in the Erbil Governorate, Iraqi Kurdistan Region

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Abstract

The investigation was conducted in Erbil governorate, Kurdistan Region, Iraq in 2020 to determine the concentration of some heavy metals (Fe, Pb, Mn, Zn, and Cd) in 354 water samples taken from rivers, springs, and wells during the dry and wet season of 2021. The results indicated non-significant differences between the concentration of the studied heavy metals in both seasons. The results indicated that the water of the studied rivers is suitable for irrigation, livestock watering, and drinking purpose. The water from the studied springs was suitable for irrigation and livestock, while for fish culture the concentration of iron for 6 springs and manganese for most of the springs was above allowable concentration. The water for 85 wells was suitable for irrigation, livestock, and fish culture and the water for 52 wells was suitable for drinking purposes.

Keywords: water classification, water resources, heavy metals, water quality.

1. Introduction

Water is an important renewable natural resource that is used widely for agricultural, drinking, and industrial purpose. The concentration of heavy metals in water are affected by numerous factors such as the geological and mineralogical composition of aquifers and recharge area [9]. The wells water classification for irrigation purposes depending on the concentration of some heavy metals (Pb, Mn, Fe Ni, and Zn) in the Iraqi Kurdistan region and Iraq was done by: Alany (2015), Ameen et al. (2019), Apha (2011), and Anzecc (2000) [2, 3, 4 5]. On the other hand Stevanovic and Lurkiewicz (2009) classified the water for six rivers, twenty-four springs, and twenty-five wells in Rania district, Sulaimani Governorate, Iraq depending on some heavy metals (Mn, Zn, Cd, and Pb) for ca different purpose [14]. According to ANZECC (2000), and Ayers and Westcot (1994), the most of the studied water samples were suitable for different uses in all the studied seasons (spring, summer, autumn, and winter [5, 7]. Awadh (2018) classified 24 water samples taken from Euphrates river, water samples from 8 springs and 24 wells from Al-Anbar governorate used for irrigation and drinking purpose depending on mean values of EC ($dS.m^{-1}$), pH, and concentrations of Fe, Pb, Cd, Ni and Ni ($mg{\cdot}L^{-1}$).

He found the following values: 1.19 $dS{\cdot}m^{-1}$, 7.84 mg $Fe{\cdot}L^{-1}$, 0.18, 0.023, 0.020,0.020 and 0.04 $mg.L^{-1}$) in samples from Euphrates river; EC=1.23 dSm^{-1}, pH = 6.95,0.011,0.008,0.002,0.005 and 0.006 mg L^{-1} in samples from 8 springs from Al-Anbar governorate, and EC=2.26 $dS{\cdot}m^{-1}$, p =7.60, 0.33,0.008,0.006,0.036 and 0.70 $mg.L^{-1}$ in samplesfrom 24 wells from Al-Anbar governorate [6]. The suitability of water from Dohuk dam, Iraqi Kurdistan region for drinking purposes was studied by Awadh (2018) from the point of view of Mn, Fe, Zn, Pb, Ni, and Cd concentrations.

He found the following values: 0.006, 0.014, 0.01, 0.006, 0.004 and 0.0036 mg.L^{-1} [3]. This study aims to classify different water resources in the Erbil governorate for different uses depending on EC, pH, and concentration of some heavy metals.

Table 1. The maximum permissible values of the studied parameters for different purposes

Parameters	Units	Maximum allowable values for agriculture and drinking			
		Agricultural uses			Drinking
		Irrigation	Livestock [7]	Fish culture [5]	[15]
EC	dS m^{-1}	3.00	8.00	4.60	0.50
pH	mg L^{-1}	8.40	9.00	9.00	8.40
Fe		5.00	ND*	< 0.01	0.30
Pb		5.00	0.10	< 0.007	0.015
Mn		0.20	0.50	< 0.01	0.05
Zn		2.00	24.00	< 0.005	5.00
Cd		0.10	0.05	< 0.0018	0.005

ND-not detectable

2. Material and Method

The methodology of this investigation included the following steps:

Sampling: The samples were taken from rivers, springs, and wells in Erbil governorate, Iraqi Kurdistan Region in wet and dry seasons or May and October 2020. The number of water samples is as follows: the number of samples for the wet season taken from rivers, springs, and wells was 41,36 and 100 samples respectively which equal to 177 samples in the wet season and 177 samples in the dry season. The total number of water samples for both seasons was 354 samples which were taken from 177 locations (Fig.1).

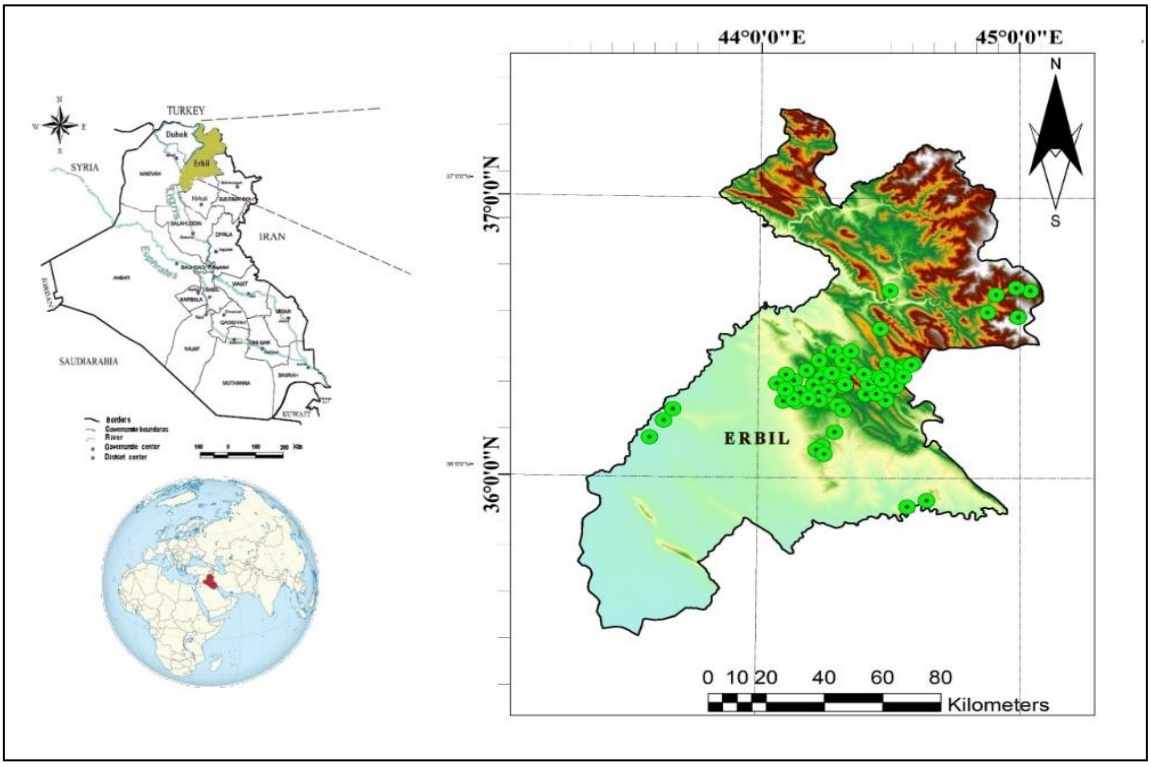

Figure 1. The map for the studied locations

Water chemical analysis**.** The water chemical properties (EC, pH, and concentration of Fe, Pb, Mn, Zn, and Cd were determined according to American public Health Association (2001) [4].

3. Results and Discusions

According to EC and pH values for the studied water resources (rivers, springs, and wells), most of the studied waters were suitable for irrigation, livestock, fish culture, and drinking purpose, except the water for 13 wells which were not suitable for the mentioned purpose due to their high EC values which ranged between 3.53 - 14.25 $dS \cdot m^{-1}$. Table 2 shows the concentration of the heavy metals (Fe, Pb, Mn, Zn, and Cd) in water samples for the studied rivers which ranged as follows: 0.00-0.140 mg $Fe \cdot L^{-1}$, 0.00-0.012 mg $Pb \cdot L^{-1}$, 0.03 -0.334 mg $Mn \cdot L^{-1}$, 0.005- 0.555 mg $Zn \cdot L^{-1}$, while Cd was not detectable. It means that the studied water of rivers is suitable for irrigation according to Ayers and Westcot (1994), since the concentration of the mentioned heavy metals was less than the maximum permissible values of 5 mg $Fe \cdot L^{-1}$, 5 mg $Pb \cdot L^{-1}$,0.20 mg $Mn \cdot L^{-1}$, 2 mg $Zne \cdot L^{-1}$ and 0.01 mg $Cd \cdot L^{-1}$, respectively [7].

Table 2. EC and pH Concentration of some heavy metals in water of studied rivers in Erbil

No.	Locations	$dS.m^{-1}$	pH	Concentration ($mg.L^{-1}$)				
				Fe	Pb	Mn	Zn	Cd
1	Shiwa Rash	0.46	7.58	0.052	0.005	0.048	0.137	N.D.
2	Shiwa rash 2	0.52	7.43	0.007	0.002	0.025	0.047	N.D.
3	Kodo1 (Hajiomaran)	0.44	7.65	0.007	0.002	0.334	0.090	N.D.
4	Kodo2 (Hajiomaran)	0.25	7.91	0.017	0.000	0.022	0.179	N.D.
5	Grdmaydan	0.53	7.51	0.018	0.002	0.032	0.396	N.D.
6	Zinwey Shekh1(Sartatan)	0.37	7.75	0.026	0.003	0.013	0.264	N.D.
7	Zinwey Shekh 2(Azady1)	0.31	7.77	0.024	0.000	0.010	0.099	N.D.
8	Azady 2	0.39	7.51	0.035	0.000	0.072	0.187	N.D.
9	Rayat	0.33	7.61	0.027	0.000	0.005	0.106	N.D.
10	Alana 1	0.41	7.72	0.030	0.002	0.053	0.251	N.D.
11	Alana 2	0.32	7.81	0.014	0.000	0.050	0.183	N.D.
12	Rubaridarband (1Gunda zhoor)	0.32	7.69	0.001	0.000	0.050	0.381	N.D.
13	Rubaridarband(2Gundazoor)	0.28	7.85	0.029	0.001	0.030	0.361	N.D.
14	Rubari darband 3	0.24	7.93	0.033	0.000	0.039	0.266	N.D.
15	Rubari Gojar 1	0.36	7.55	0.074	0.000	0.003	0.005	N.D.
16	Rubari Gojar 2	0.37	7.58	0.038	0.009	0.005	0.043	N.D.
17	Rubari make (Sule)	0.87	7.05	0.047	0.003	0.052	0.094	N.D.
18	Rubari make(warte)	0.82	6.99	0.047	0.001	0.057	0.019	N.D.
19	Chame marana (Shexan)	0.36	7.47	0.018	0.002	0.077	0.228	N.D.
20	Galli sakran	0.25	7.84	0.038	0.003	0.072	0.250	N.D.
21	Rubari nawand(darmanaw)	0.35	7.75	0.045	0.002	0.050	0.085	N.D.
22	Rubari basan(nawprdan)	0.28	7.77	0.061	0.004	0.056	0.051	N.D.
23	Rubari quba (Gallala)	0.34	7.75	0.065	0.004	0.065	0.043	N.D.
24	Rubari kani razan	0.28	7.58	0.062	0.002	0.025	0.086	N.D.
25	Rubari nawkelakan	0.28	7.74	0.070	0.003	0.048	0.069	N.D.
26	Rubari barsirin	0.39	7.43	0.079	0.005	0.039	0.289	N.D.
27	Rubari akoyan(goranje)	0.50	7.23	0.035	0.005	0.033	0.474	N.D.
28	Rubari khalifan	0.51	7.28	0.065	0.004	0.070	0.132	N.D.
29	Rubari khalifan2	0.52	7.15	0.061	0.004	0.025	0.191	N.D.
30	Rubari razga sarkand	1.14	7.25	0.099	0.001	0.085	0.555	N.D.
31	Rubari razga 2	1.29	7.3	0.049	0.009	0.041	0.407	N.D.
32	Rubari razga 3	0.88	7.29	0.075	0.006	0.121	0.180	N.D.
33	Zey gawra efrazi kamal	0.52	7.36	0.056	0.003	0.061	0.053	N.D.
34	Zey gawra kawra sor	0.44	7.55	0.074	0.004	0.018	0.493	N.D.
35	Zey gawra gopal	0.39	7.58	0.078	0.000	0.061	0.426	N.D.
36	Rubari degalla 1	0.89	7.3	0.123	0.004	0.052	0.271	N.D.
37	Rubari degalla 2(Alleawa)	1.39	7.57	0.144	0.005	0.116	0.344	N.D.
38	Rubari degalla 3	0.83	7.32	0.111	0.012	0.037	0.399	N.D.

Table 2. EC and pH Concentration of some heavy metals in water of studied rivers in Erbil - continued

No.	Locations	dS.m^{-1}	pH	Concentration (mg.L^{-1})				
				Fe	Pb	Mn	Zn	Cd
39	Zey bchwk (mala zyad)	0.43	7.52	0.011	0.001	0.072	0.037	N.D.
40	Zey bchwk taqtaq	0.49	7.51	0.041	0.006	0.045	0.491	N.D.
41	Zey bchwk 3(se grdkan)	0.41	7.54	0.054	0.004	0.040	0.472	N.D.
Max. value for irrigation.		3.0	8.5	5.00	5.00	0.20	2.00	0.10
Max. value for livestock.		16	9.0	---	0.10	0.05	24.00	0.05
Maximum value for fish culture		<5.0	9.0	<0.01	<0.007	0.01	0.05	<0.0018
Maximum value for drinking		0.75	8.5	0.3	0.015	0.4	5	0.005

Concerning the livestock drinking the water, we found that for 31.70% of the studied rivers was not.The river's water was not suitable for fish culture, because the concentration of the studied heavy metals except Cd was higher than the maximum permissible concentration for fish culture as mentioned by Australian and New Zeland Environment and Conservation Council (2000) [5].

The maximum allowable concentration of heavy metals for fish culture is very low in comparing with their allowable concentrations for other agricultural uses and drinking due to the accumulation of heavy metals by fishes and then translocation to humans through the food chain. On the other hand, 12 water samples for the studied rivers were not suitable for drinking purposes due to high Mn concentration which was above the maximum permissible concentration according to [7]. Depending on data recorded in Table 3 according to Ayers and Westcot (1994), and United States Environmental Protection Agency (2018), the water of all studied springs was suitable for irrigation, livestock, and drinking.For fish culture the water for most of the studied springs was not suitable, since their Fe concentration was above maximum permissible value for 6 springs and manganese concentration for most springs also above allowable concentration for fish culture. We consider that the reason of this situation may due to consider the reasons mentioned before [7, 15].

Table 4 shows that the water for most of the studied wells was suitable for irrigation, livestock, fish culture, and drinking purposes except for the water for 15 wells, whose Pb concentration was slightly higher than the allowable concertation for fish culture or not suitable.

Table 3. EC, pH, and some heavy metals concentration in water of springs in Erbil

No.	Locations	EC dSm^{-1}	pH	Concentration (mg L^{-1})				
				Fe	Pb	Mn	Zn	Cd
1	Haji omaran sarw	0.32	7.59	0.05	0.00	0.02	0.12	N.D.
2	Sheki balakan	0.35	7.78	0.05	0.00	0.04	0.24	N.D.
3	Kani graw 1 haji omaran	3.68	5.94	0.03	0.00	0.04	0.29	N.D.
4	Kani graw 2 haji omaran	3.48	5.72	0.08	0.00	0.02	0.03	N.D.
5	Kani graw 3 haji omaran	3.64	5.98	0.06	0.00	0.04	0.12	N.D.
6	Kani asn rayat	0.56	6.99	0.03	0.00	0.00	0.20	N.D.
7	Qasre	0.61	6.87	0.02	0.00	0.03	0.08	N.D.
8	Bndayzan	0.38	7.05	0.04	0.00	0.07	0.25	N.D.
9	Kani shakh (Khoshkan)	0.34	7.69	0.05	0.00	0.05	0.23	N.D.
10	Kani basan(khoshkan)	0.35	7.68	0.06	0.00	0.07	0.24	N.D.
11	Prdi jale(gallala)	0.47	7.20	0.04	0.00	0.07	0.20	N.D.
12	Kani mrad (gallala)	0.42	7.25	0.05	0.00	0.04	0.05	N.D.
13	Kani zil	0.65	7.15	0.01	0.00	0.05	0.02	N.D.
14	Kani Razan	0.47	6.99	0.01	0.00	0.03	0.09	N.D.
15	Kani badlian(kani zheriy)	0.91	6.64	0.07	0.00	0.04	0.11	N.D.
16	Kani swara(sidakan)	0.53	6.65	0.06	0.00	0.00	0.17	N.D.
17	Kome alman	0.59	6.93	0.05	0.00	0.05	0.31	N.D.
18	Sarwchawai doli akoyan	0.57	6.75	0.06	0.00	0.05	0.31	N.D.
19	Kani matkan	0.62	6.95	0.05	0.00	0.05	0.39	N.D.

Table 3. EC, pH, and some heavy metals concentration in water of springs in Erbil – continued

No.	Locations	EC dSm^{-1}	pH	Concentration (mg L^{-1})				
				Fe	Pb	Mn	Zn	Cd
20	Kani gorangi	0.56	7.02	0.06	0.00	0.00	0.23	N.D.
21	Kani mala nabi(bexal)	0.51	6.66	0.05	0.00	0.08	0.19	N.D.
22	Kani majidawa (balakian)	0.86	6.38	0.08	0.00	0.04	0.20	N.D.
23	Kani maran	0.44	6.99	0.06	0.00	0.07	0.15	N.D.
24	Kani bnawea	0.56	6.64	0.01	0.01	0.04	0.12	N.D.
25	Kani Smandar(xate)	0.55	7.19	0.05	0.01	0.03	0.34	N.D.
26	Kani mozarin(xate)	0.44	7.47	0.04	0.00	0.00	0.27	N.D.
27	Kani darchnar(balisan)	0.53	7.36	0.01	0.01	0.10	0.28	N.D.
28	Kani mzgawte gawray harir	0.52	7.17	0.08	0.01	0.04	0.25	N.D.
29	Kani gwndi bawean	0.50	7.57	0.08	0.01	0.03	0.32	N.D.
30	Kani sarta (shakrok)	0.57	7.17	0.04	0.00	0.04	0.16	N.D.
31	Nawkandani xwarw	2.45	7.69	0.12	0.00	0.10	0.46	N.D.
32	Zebarok	1.33	6.78	0.10	0.00	0.10	0.41	N.D.
33	Kani graw	0.71	6.65	0.04	0.01	0.02	0.53	N.D.
34	Khatibian kani shink	1.51	7.48	0.09	0.01	0.10	0.22	N.D.
35	Kani mzgawte gawray Hiran	0.57	7.18	0.04	0.00	0.10	0.20	N.D.
36	Kani gomatal	2.14	6.53	0.10	0.01	0.08	0.18	N.D.
Maximum allowable concentration for irrigation		3.0	8.5	5.00	0.20	2.00	0.10	5.00
Maximum allowable concentration for live stoke		16	9.0	0.10	0.05	24.0	0.05	---
Maximum allowable concentration for fish culture		<5	9.0	<0.01	<0.007	0.01	0.05	<0.0018
Maximum allowable concentration for drinking		0.7	8.5	0.3	0.015	0.40	5.00	0.005

Table 4. EC, pH, and Concentration of some heavy metals in water for the studied wells

No.	Locations	EC dSm^{-1}	pH	Concentration (mg L^{-1})				
				Fe	Pb	Mn	Zn	Cd
1	Makosan	0.61	7.67	0.004	0.000	0.024	0.060	N.D.
2	Gojar	1.15	8.65	0.036	0.002	0.007	0.020	N.D.
3	Doli khnaqa (Bana badll)	0.55	7.76	0.051	0.003	0.001	0.115	N.D.
4	Barsul	0.56	7.56	0.061	0.002	0.060	0.090	N.D.
5	Sarnaws	0.7	7.59	0.004	0.003	0.074	0.032	N.D.
6	Khwartali (warte)	0.48	7.31	0.065	0.004	0.045	0.042	N.D.
7	Qasre	0.65	7.59	0.057	0.002	0.048	0.067	N.D.
8	Dashti mawan	0.97	7.52	0.031	0.003	0.031	0.098	N.D.
9	Rashdwr	0.59	7.77	0.048	0.001	0.085	0.065	N.D.
10	Gwndi kanizel	0.68	7.67	0.004	0.003	0.056	0.052	N.D.
11	Barzewa	0.79	8.31	0.061	0.004	0.011	0.130	N.D.
12	Badlean	0.69	7.70	0.070	0.003	0.025	0.191	N.D.
13	Badllean 2	1.33	7.42	0.017	0.002	0.064	0.086	N.D.
14	Shekhan	0.57	7.76	0.022	0.001	0.052	0.069	N.D.
15	Delezean	0.79	7.35	0.064	0.004	0.040	0.447	N.D.
16	Beroean	0.57	7.79	0.040	0.002	0.008	0.419	N.D.
17	Akoean (loghan)	0.77	7.53	0.034	0.001	0.041	0.264	N.D.
18	Majedawa (balakean)	0.68	7.41	0.080	0.003	0.049	0.080	N.D.
19	Grdxewat	1.39	7.56	0.062	0.002	0.038	0.149	N.D.
20	Jolamergi xwarw	0.86	7.35	0.084	0.003	0.020	0.073	N.D.
21	Gwndi alana (garamera)	0.51	7.61	0.024	0.000	0.069	0.036	N.D.
22	Gwndi sharsina	0.53	7.71	0.010	0.003	0.028	0.182	N.D.
23	Ashkaphta	0.51	7.52	0.000	0.005	0.032	0.156	N.D.
24	Twtme	0.56	7.27	0.034	0.003	0.009	0.263	N.D.
25	Shekhmamwdean (zenaterexoshnawan)	0.54	7.18	0.037	0.004	0.082	0.226	N.D.
26	Dore (heran)	0.53	7.71	0.056	0.004	0.078	0.190	N.D.
27	Shewamasi	2.96	7.05	0.108	0.007	0.052	0.316	N.D.

Table 4. EC, pH, and Concentration of some heavy metals in water for the studied wells – continued

No.	Locations	EC dSm^{-1}	pH	Concentration ($mg\ L^{-1}$)				
				Fe	Pb	Mn	Zn	Cd
28	Khatebean	14.25	6.25	0.279	0.005	0.563	0.521	N.D.
29	Qalla mwrtk	0.73	7.42	0.052	0.002	0.053	0.505	N.D.
30	Barbean	1.05	7.29	0.044	0.003	0.070	0.177	N.D.
31	Chra	0.42	7.52	0.093	0.001	0.066	0.555	N.D.
32	Mandawa	0.87	7.76	0.071	0.004	0.073	0.417	N.D.
33	Wsumarean	0.50	7.95	0.044	0.001	0.072	0.498	N.D.
34	Shaxollan	0.56	7.78	0.049	0.000	0.086	0.133	N.D.
35	Jezhne kan afandi (najme)	0.54	7.52	0.060	0.003	0.079	0.275	N.D.
36	Darabane gawra (bar hwshtr)	0.49	7.61	0.038	0.003	0.082	0.218	N.D.
37	Gopal	0.39	7.73	0.088	0.000	0.006	0.006	N.D.
38	Efraze kamal aghah	0.48	7.56	0.049	0.002	0.091	1.726	N.D.
39	Rashwan	0.65	7.96	0.053	0.005	0.090	0.056	N.D.
40	Shewarash	0.64	7.79	0.019	0.005	0.070	0.059	N.D.
41	Agholan (doli gaynj)	0.62	7.55	0.066	0.007	0.101	0.509	N.D.
42	Grdarashi zab	0.68	7.59	0.070	0.008	0.024	0.099	N.D.
43	Bastam	0.86	7.85	0.060	0.004	0.035	0.014	N.D.
44	Mala omer	1.72	7.68	0.063	0.005	0.063	0.213	N.D.
45	sufaea	0.92	7.56	0.067	0.004	0.051	0.250	N.D.
46	Ghetel	0.78	7.69	0.038	0.002	0.085	0.280	N.D.
47	Gwer	0.39	7.72	0.011	0.003	0.077	0.684	N.D.
48	Gameh Tapa	4.85	7.47	0.048	0.005	0.091	0.260	N.D.
49	Shamshwla 1	1.88	7.59	0.045	0.005	0.060	0.226	N.D.
50	Shamshwla 2	1.69	7.25	0.030	0.007	0.099	0.236	N.D.
51	Pemarabr(Qawgh)	2.88	7.54	0.022	0.002	0.039	0.260	N.D.
52	Jmka	0.59	7.75	0.088	0.002	0.085	0.541	N.D.
53	Tarjan	1.32	7.18	0.105	0.005	0.106	0.799	N.D.
54	Tandwra	1.18	7.52	0.064	0.006	0.068	0.357	N.D.
55	Serawa	3.53	7.72	0.040	0.007	0.112	0.290	N.D.
56	Awena	6.42	7.31	0.013	0.007	0.131	0.445	N.D.
57	Shekhsherwan	1.05	7.17	0.033	0.004	0.034	0.381	N.D.
58	Helawa	1.88	7.42	0.014	0.003	0.136	0.431	N.D.
59	Grdazaban	1.51	7.15	0.028	0.002	0.077	0.202	N.D.
60	Ashaba lak	0.76	7.5	0.052	0.004	0.038	0.195	N.D.
61	Awdalok	1.53	7.08	0.059	0.005	0.002	0.146	N.D.
62	Jdida Lak	1.87	7.25	0.038	0.003	0.007	0.870	N.D.
63	Gozapanka	4.99	7.24	0.045	0.008	0.076	0.167	N.D.
64	Dwshiwan	5.76	7.15	0.054	0.008	0.085	0.244	N.D.
65	Mala kagha	2.93	7.39	0.052	0.009	0.073	1.278	N.D.
66	Kapang rash	1.28	7.42	0.030	0.007	0.068	0.357	N.D.
67	Kandall yarmja	3.97	7.59	0.034	0.009	0.094	0.010	N.D.
68	Gawara	2.11	7.55	0.077	0.008	0.036	0.013	N.D.
69	Demakar	8.39	7.03	0.057	0.006	0.103	0.049	N.D.
70	Chaghamera	6.03	7.21	0.082	0.006	0.066	0.032	N.D.
71	Darakhurma	3.41	7.28	0.012	0.006	0.082	0.094	N.D.
72	jana	1.61	7.42	0.054	0.008	0.080	0.098	N.D.
73	Chlhaweza	2.26	7.4	0.044	0.002	0.088	0.169	N.D.
74	Shorija	3.16	7.75	0.010	0.002	0.105	0.572	N.D.
75	Malla qara	10.06	7.15	0.098	0.000	0.140	0.127	N.D.
76	Shorazartka	2.40	7.42	0.043	0.001	0.116	0.559	N.D.
77	Tallkhaim	1.48	8.35	0.067	0.006	0.101	0.662	N.D.
78	Qurshaghlu	1.64	7.36	0.064	0.000	0.086	0.043	N.D.
79	merkhuzar	1.05	7.21	0.016	0.002	0.124	0.850	N.D.
80	Qazikhana	9.09	7.8	0.081	0.005	0.109	0.382	N.D.
81	Shekhan	0.68	7.38	0.059	0.001	0.053	0.307	N.D.
82	Sheraw (prdey)	0.93	7.18	0.043	0.002	0.092	0.336	N.D.
83	Sequchan	0.75	7.59	0.057	0.001	0.124	0.541	N.D.
84	Grdasor	0.61	7.24	0.080	0.003	0.064	0.205	N.D.

Table 4. EC, pH, and Concentration of some heavy metals in water for the studied wells – continued

No.	Locations	EC dSm^{-1}	pH	Concentration (mg L^{-1})				
				Fe	Pb	Mn	Zn	Cd
85	Kani bzra	0.75	7.34	0.059	0.002	0.084	0.281	N.D.
86	Rulka or Lurka	0.54	7.42	0.021	0.003	0.026	0.907	N.D.
87	Sarmazra	1.04	7.62	0.038	0.003	0.006	1.207	N.D.
88	Kardz	0.63	7.59	0.045	0.002	0.057	0.324	N.D.
89	Gomatall(qortasoran)	1.05	7.39	0.156	0.008	0.052	0.031	N.D.
90	Gomashin	0.91	7.83	0.044	0.011	0.042	0.258	N.D.
91	Kani gozar (Talaban)	0.46	7.66	0.062	0.003	0.033	0.052	N.D.
92	Shilla	1.03	7.17	0.013	0.005	0.042	0.473	N.D.
93	Elnjaghi gawra(marzan)	1.25	7.45	0.055	0.007	0.068	0.399	N.D.
94	Elnjagi bchwk	1.66	7.45	0.057	0.004	0.080	0.170	N.D.
95	Aski koea (qaysare)	0.91	7.36	0.010	0.002	0.028	0.608	N.D.
96	Hamaok	0.48	7.31	0.008	0.003	0.078	0.016	N.D.
97	Darbasar	1.15	7.42	0.026	0.004	0.079	0.253	N.D.
98	Sewaka	0.70	7.19	0.050	0.000	0.032	0.570	N.D.
99	Gomaspan	1.09	7.61	0.028	0.005	0.074	0.167	N.D.
100	Bakhchay gawra	0.65	7.62	0.023	0.002	0.080	0.748	N.D.
Max. allowable value for irrigation		3.0	8.50	5.00	0.20	2.00	0.10	5.00
Maxvalue for livestoke.		16.0		0.10	0.05	24.00	0.05	---
Max. value for fish culture.		<5.0		<0.01	<0.007	0.01	0.05	<0.0018
Max. value for drinking		0.75		0.30	0.015	0.40	5.00	0.005

The radar shapes (Figs. 2, 3, and 4) explain the mean concentration of the studied heavy metals (Fe, Pb, Mn, and Zn) for the studied water resources (rivers, springs, and well) in Erbil governorate respectively. Shifting the lines or points toward the external circle means an increase in the concentration of heavy metals as shown by different colors while shifting the lines or points to words in the inner circle refers to a decrease in their concentration.

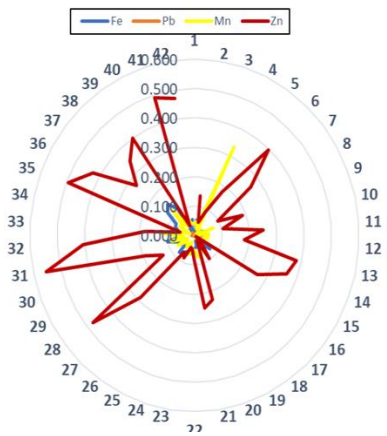

Figure 2. The mean concentration of heavy metals from water samples of the studied rivers in Erbil

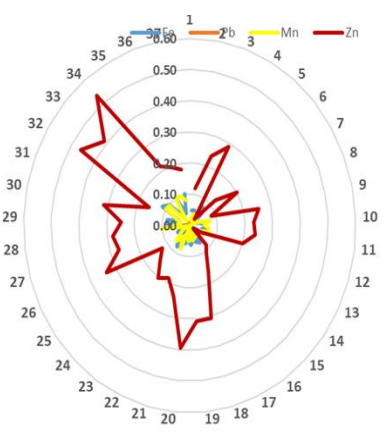

Figure 3. The mean concentration of heavy metals from the studied springs

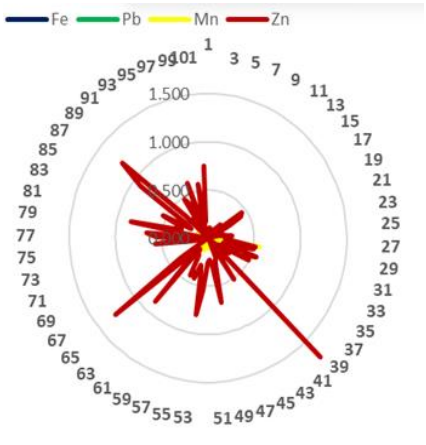

Figure 4. The mean concentration of heavy metals from the studied wells

4. Conclusions

The results indicated varying heavy metals concentrations among water resources, most of the studied water samples for rivers, springs, and wells were suitable for irrigation and livestock. The water for most rivers and some wells were not suitable for fish culture due to the high concentration of manganese.

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References

[1] Ahmad A.B., A.O. Esmail, 2015, Some heavy metal pollution investigation in Sulaimani province groundwater, J. of Zankoi Sulaimani Part (A) Pure and Applied Science, 17(4), 37-60.

[2] Alani A.S.K., 2015, The chemical composition of irrigation water and its effect on ion pairing, some chemical properties of soil and plant growth, Erbil Kurdistan region-Iraq, M.Sc. Thesis, College of Agriculture, Salahuddin University- Erbil.

[3] Ameen H.A., O.A. Rekani, V.I. Barwari, 2019, Application of pollution indices for heavy metal contamination assessment in surface water of Duhok dam, Kurdistan region, Iraq. Journal of Duhok University, 22(1), 252-264.

[4] American public Health Association (A.P.H.A.), 2001, Standard methods for the examination of water and wastewater, 18th. ed. A.P.H.A., Washington.

[5] Australian and New Zeland Environment and Conservation Council (ANZECC), 2000, Australian New Zeland guidelines for fresh and marine water quality. National Water Quality Management Strate-gy, 4(3), 3-4.

[6] Awadh S.M., 2018, A preliminary assessment of the geochemical factors affecting groundwater and surface water quality around the rural communities in Al-Anbar Western Desert of Iraq. Environmental Earth sciences, 1-18.

[7] Ayers R.S., and D.W. Westcot, 1994, Food, agriculture organization of the United Nations (FAO), water quality for agriculture, Irrigation and Drainage, Rome, Paper, 29.

[8] Baba A.B.A.,2020. Impacts of natural processes and anthropogenic activities on the water quality of Dukan catchment area IKR-Iraq. Ph.D. Thesis, College of Agriculture University of Sulaimani, KRI.

[9] Esmail A.O., 1986, Limitation of some ground water suitability in Erbil plain for different uses. M Sc. Thesis, Salahuddin University-Erbil, College of Agriculture.

[10] Rajab K.S., A.O. Esmail, 2021, Role of ion pairs and activity in estimation of ionic strength from electrical conductivity of irrigation water. Accepted for publication in Journal of Agricultural Science University of Baghdad (SCOPAS), 2023.

[11] Rajab K.S., A.O. Esmail, 2022, Influence of Ion Pairs and Activity on the Index of Irrigation Water Quality Relying on Some Modern Terms in Erbil Governorate, Accepted for publication in ZANKO Journal in 7(2), Slahaddin Univ. Erbil.

[12] Sajadi D.M.D., A.O. Esmail, 2020, Identify of groundwater quality in Erbil province for agricultural and drinking uses depending on salinity and some heavy metals concentration, Iraqi Journal for Soil Science, 20 (1), 253-265.

[13] Salam B.M., 2019, Identifying water suitability for different uses in Rania district, Sulaimani governorate, Kurdistan region, Iraq. MSc. thesis Salahaddin Univ., Erbil.

[14] Stevanovic Z., A. Lurkiewicz, 2009, Groundwater management in northern Iraq. Hydrogeology Journal, 17(2), 367-378.

[15] United State Environmental Protection Agency (USEPA), 2018, Edition of the Drinking Water Standards and Health Advisories. USEPA 822-F18-001.