Hydrochemical Attributes and Their Spatial Variation in the Rainwater of Kuwait

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Abstract

Rainwater is one of the major sources of freshwater for harvesting to enhance the freshwater resource, especially from the management perspective. The present study has attempted to investigate the temporal and spatial variations of ion chemistry in the rainwater of Kuwait by collecting samples from industrial and residential regions. Fifty samples were collected at 12 different locations during the wet period from November 2018 to December 2019, and the parameters EC, TDS, pH, and major and minor ions were analyzed. The average pH (7.10 and 7.16) of rainwater in each region was alkaline. In industrial areas, $SO_4^{2}-$ was the most dominant ion, followed by Ca^{2+} and other ions, whereas in residential, HCO_3- and SO_4^{2-} showed the highest concentrations. Ionic ratios were computed to understand the influence of anthropogenic activity and the neutralizing ions. The enrichment factors calculated for the samples identified that crustal, marine, and anthropogenic sources of the neutralizing ions have influenced the rainwater chemistry. The principal component analysis (PCA) revealed that the anthropogenic influence is more significant from oil refineries, apart from other industrial activities, and sea salt fractions.

Keywords

Rainwater · Major ions · Industrial and residential regions · Enrichment factor · Principal component analysis

1 Introduction

Kuwait is a semi-arid region with harsh climatic conditions and limited rainfall. But then, global climate change impacted the country and altered the conditions. Rain interacts with the suspended pollutants in the atmosphere. They may be either natural or anthropogenic (Boga et al., 2019). The chemical relationship between particulate matter and precipitation is the primary concern. Rainwater chemistry helps to understand the crustal, marine, and anthropogenic influences (Chenchouni et al., 2022). Therefore, the study aims to determine the wet deposition chemistry collected from rain events in industrial and residential regions and to investigate rainwater harvesting suitability.

2 Methodology

The annual rainfall in Kuwait ranges from 110 to 125 mm. Eighteen rainwater samples from industrial regions and thirty-two from the residential areas accounting for fifty were collected from twelve different locations in Kuwait (Fig. 1) during the rainy season between November 2018 and December 2019, according to standard procedures (IAEA/GNIP, 2014). The physical, chemical, and microbiological parameters, such as alkalinity, pH, electrical conductivity, total dissolved solids, major cations, and anions, were determined using the standard methods (SMEWW, 2017). To determine the crustal, marine, and anthropogenic influence in rainwater and to assess the interrelationship

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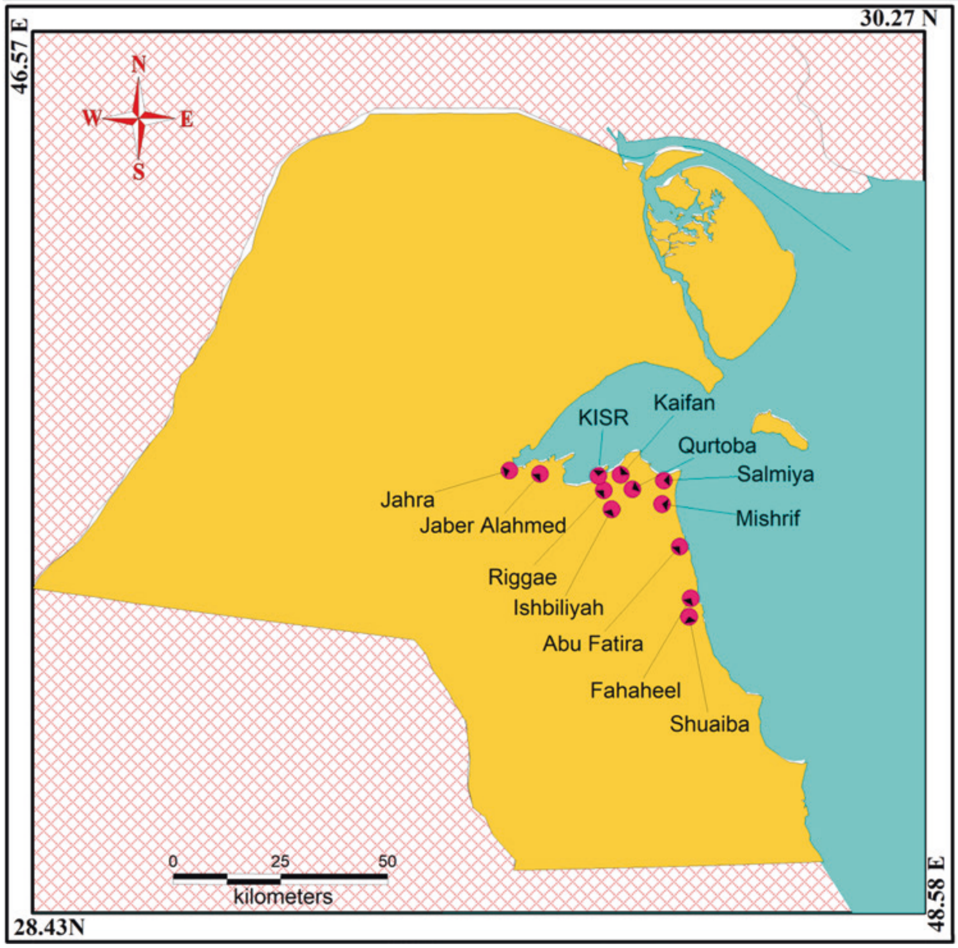

Fig. 1 Study area of the rainwater in industrial and residential regions of Kuwait

between the ions, Spearman correlation and principal component analysis (PCA) were adopted using SPSS. Acidic and neutralization potential (AP and NP), neutralization factor (NF), fractional acidity (FA), ionic ratios, and ammonium availability index (AAI) were calculated. The pollutants present in the rainwater are either natural or artificial and are referred to as marine and crustal enrichment factors. Marine contributions are assessed by sea salt and non-sea salt fractions (Keresztesi et al., 2020).

3 Results

See Figs. 2, 3 and Table 1. The average concentration of ions in the industrial region reflects the following order of dominance $SO_4^{2}- > Ca^{2+} > HCO_3- > Cl^- > NO_3- > Na^+ > K^+ > Mg_2^+ > NH_4^+ > NO_2^- > PO_4^{3}- > F^- > Br-$, whereas in the residential region, the order of dominance was as follows: $HCO_3^- > SO_4^{2}- > Ca^{2+} > Cl- > NO_3^- > Na^+ > K^+ > NH_4^+ > Mg_2^+ > NO_2- > F^- > PO_4^{3}- > Br^-$ (Fig. 2). Spearman correlation analysis and PCA indicated that Na^+ and Cl^- were highly correlated, reflecting the influence of sea spray and marine salts. The same was observed in PCA as first-factor loading with a variance of 55.46% and 45.96% (Table 1)

4 Discussion

The average pH of rainwater samples from residential and industrial regions is inferred to be alkaline due to suspended particulates in the atmosphere.

The elevated concentrations of $SO_4^{2}-$ in the industrial region are anthropogenic due to emissions from oil refineries, industries, and traffic (Keresztesi et al., 2020). High concentrations of Cl^- and Na^+ are observed in a few samples collected near coastal areas, especially in industrial areas, indicating sea salts in the rainwater. The AP/NP ratio in the study area ranged between 1.39 and 1.14, indicating the samples' weak acidic character. The highest

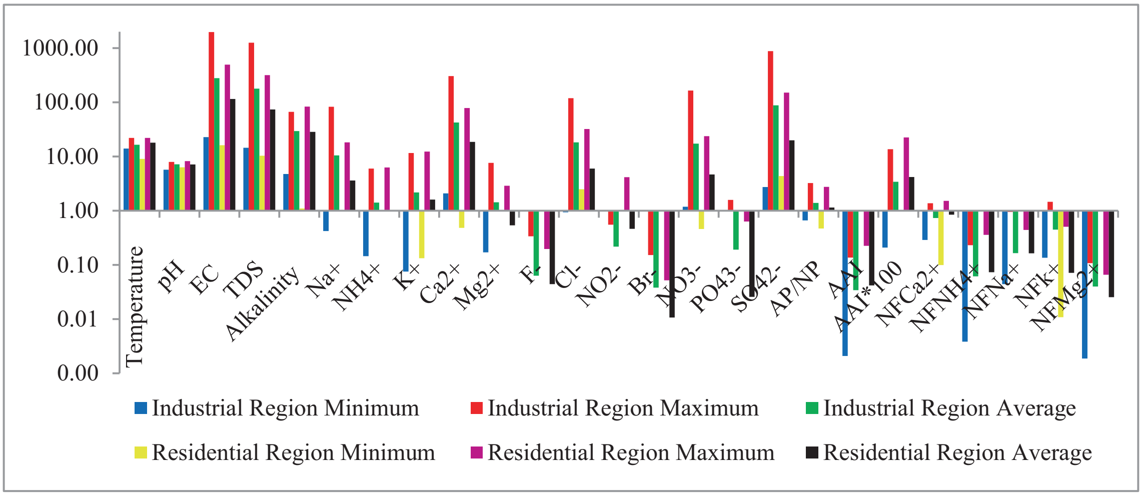

Fig. 2 Analytical representation of rainwater chemistry data

Fig. 3 Enrichment factors with respect to crustal and seawater sources

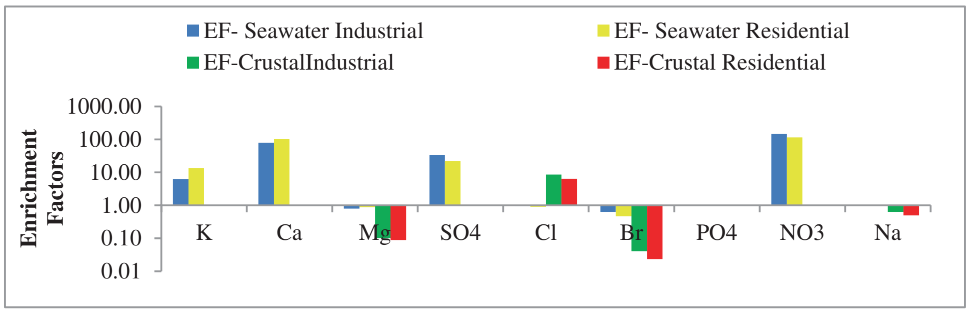

Table 1 Principal component analysis data of rainwater samples in industrial and residential regions

Parameters	Industrial				Residential				
	1	2	3	4	1	2	3	4	5
pH	0.14	0.81	–0.05	–0.32	0.21	–0.09	0.89	–0.01	0.08
Temperature	0.13	–0.08	0.88	–0.29	0.04	–0.35	0.17	–0.10	0.75
Electrical Conductivity (EC)	0.97	0.21	0.06	0.01	0.86	0.07	0.44	0.10	–0.04
HCO_3–	0.42	0.62	0.41	–0.3	0.57	0.01	0.75	0.10	0.09
Na^+	0.97	0.22	–0.01	0.01	0.93	0.01	0.21	–0.003	0.03
NH_4^+	0.90	–0.1	–0.2	0.07	0.03	0.97	0.05	–0.01	–0.13
K^+	0.90	0.22	0.04	–0.07	0.87	–0.09	0.02	0.46	–0.06
Ca^{2+}	0.96	0.23	0.11	0.02	0.86	–0.1	0.30	–0.07	0.19
Mg^{2+}	0.30	0.83	0.19	0.29	0.89	0.11	0.28	0.18	–0.13
F–	0.89	0.28	0.20	0.22	0.82	–0.21	0.09	–0.32	0.22
Cl	0.96	0.27	0.02	0.05	0.90	–0.03	–0.08	0.23	0.07
NO_2^-	–0.19	0.37	0.77	0.34	–0.04	0.93	–0.1	–0.07	0.10
Br–	0.64	0.49	–0.11	0.02	–0.02	0.29	–0.02	0.26	0.75
NO_3^-	0.99	0.12	0.03	0.03	0.82	0.21	0.36	–0.09	–0.01
PO_4^3–	0.15	–0.12	–0.08	0.88	0.07	–0.07	0.05	0.94	0.12
SO_4^{2-}	0.98	0.11	0.04	0.01	0.96	–0.04	0.14	–0.07	–0.11
Variance (%)	**55.16**	**15.59**	**10.54**	**8.18**	**45.96**	**13.47**	**12.30**	**8.79**	**8.12**
Cumulative variance (%)	**55.16**	**70.75**	**81.29**	**89.46**	**45.96**	**59.43**	**71.73**	**80.52**	**88.64**

The bold values represents the variance and cumulative variance of each factor of principal component analysis neutralization potential was mainly from Ca^{2+}, K^+, and Na^+ in the industrial region, whereas in residential, Ca^{2+} was predominant, followed by Na^+. Although $SO_4^{2}-$ is responsible for maintaining acidic pH, the samples were neutralized by Ca^{2+}, Na^+, and K^+. FA is far from the unity in both regions, indicating that neutralizing ions are dominant. The AAI was calculated as the ratio of ammonium ion concentration to the sulfate and nitrate. From Fig. 2, it was evident that irrespective of the regions, NH_4^+ does not play a significant role in neutralization as AAI is <100 (Singh & Gupta, 2017). EFs were calculated to determine the crustal and seawater (Fig. 3) sources using the reference elements Ca^{2+} and Na^+ (Yuan et al., 2020). Mg^{2+} could be from marine sources as EF concerning seawater is higher than crustal (Szep et al., 2019). EF, with respect to Cl^-, indicated that the contribution is predominantly from crustal sources. The EF of Ca^{2+} shows a mean value of 79.93 and 102 in both regions indicating the terrestrial sources by weathering, road dust, and local cement factories (Keresztesi et al., 2020).

Ca^{2+} is correlated to most of the ions, which reflects the crustal. The correlation between ions identified that rainwater tends to be more alkaline. The attribution of Mg^{2+} could be from marine sources (Szep et al., 2019). In industrial regions, pH was influenced by Mg^{2+}, whereas in residential regions, HCO_3. The overall PCA analysis of the residential and industrial region data shows that similar processes were observed in both regions as the dissolution of ions is primarily from the same sources except for the industrial emissions, oil refineries, etc., which is again governed by the wind directions and speed. Therefore, rainwater chemistry is determined to be chiefly governed by anthropogenic sources by traffic, refineries, or petrochemical plants (Keresztesi et al., 2020).

5 Conclusion

This study assessed the chemical attributes in Kuwait rainwater from industrial and residential regions. The spatial representation of the ions substantiated the crustal and anthropogenic influences. Furthermore, the neutralizing ions played a significant role in altering the acidic nature of rainwater dominated by anthropogenic activities and hence recommended for harvesting as the ions in the rainwater were within the permissible limits.

References

Boga, R., Bodor, Z., Bodor, K., Tonk, S., Deak, G., Pernyeszi, T., & Nita, I.-A. (2019). The influence of evapotranspiration and wet deposition on the variations of PM10 concentration in the ciuc basin. *Present Environment and Sustainable Development, 13*, 33–44. https://doi.org/10.2478/pesd-2019-0003

Chenchouni, H., Chaminé, H. I., Khan, M. F., Merkel, B. J., Zhang, Z., Li, P., Kallel, A., & Khélifi, N. (2022). *New Prospects in Environmental Geosciences and Hydrogeosciences*. Springer, Cham. https://doi.org/10.1007/978-3-030-72543-3

IAEA/GNIP. (2014). *Precipitation sampling guide* (V2.02). http://www.iaea.org/water

Keresztesi, Á., Nita, I. A., Boga, R., Birsan, M. V., Bodor, Z., & Szép, R. (2020). Spatial and long-term analysis of rainwater chemistry over the conterminous United States. *Environmental Research, 188*, 109872. https://doi.org/10.1016/j.envres.2020.109872

Singh, D. K., & Gupta, T. (2017). Role of ammonium ion and transition metals in the formation of secondary organic aerosol and metallo-organic complex within fog processed ambient deliquescent submicron particles collected in central part of Indo-Gangetic Plain. *Chemosphere, 181*, 725–737. https://doi.org/10.1016/j.chemosphere.2017.04.080

SMEWW. (2017). *Standard methods for the examination of water and waste Water* (23rd edn.). https://www.awwa.org/Store/Standard-Methods-for-the-Examination-of-Water-and-Wastewater-23rd-Edition/ProductDetail/65266295

Szep, R., Bodor, Z., Miklossy, I., Nița, I. A., Oprea, O. A., & Keresztesi, A. (2019). Influence of peat fires on the rainwater chemistry in intra-mountain basins with specific atmospheric circulations (Eastern Carpathians, Romania). *Science of the Total Environment, 647*, 275–289. https://doi.org/10.1016/j.scitotenv.2018.07.462

Yuan, Y., Alahmad, B., Kang, C. M., Al-Marri, F., Kommula, V., Bouhamra, W., & Koutrakis, P. (2020). Dust events and indoor air quality in residential homes in Kuwait. *International Journal of Environmental Research and Public Health, 17*(7), 2433. https://doi.org/10.3390/ijerph17072433