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Application of Nemerow's Pollution Index (NPI) to assess the quality of bottled water available in Sulaymaniyah city.

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Abstract

A pollution index is a valuable tool used to assess the feature of water in a freshwater ecosystem. For this study, samples of bottled water from 10 different brands were collected, both local and imported, from various shops in Sulaymanyiah City between January and February 2023. The physical, chemical and bacteriological variables of the samples were studied. The main objective was to appraise the fittingness of these bottled water brands for drinking purposes using Nemerow's pollution index. To calculate the NPI, 15 parameters were measured, including turbidity, color, pH, electrical conductivity, total dissolved solids, total hardness, sodium, potassium, chloride, bicarbonate, sulfate, nitrate, phosphorus, and nitrite. The results were then compared to the drinking water guidelines set by the World Health Organization. The Nemerow's pollution index, derived from the measured parameters, indicated that the average NPI values ranged from 0.122 to 0.265 for all water samples. These values originated to be under the NPI limit set by the standards, suggesting a non-polluted status. Furthermore, all observed values were within the permissible limit, indicating that the bottled water brands investigated were of good quality.

Key words Brands, Values, Physiochemical parameters, Standards.

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Introduction

Drinking water refers to water that is sufficiently clean for consumption, with minimal risks in the short or long term. In numerous regions worldwide, people face insufficient contact with harmless water and must rely on sources that are contaminated with disease-carrying organisms, harmful pathogens, or high levels of toxins or suspended particles [1]. The inception of bottled water can be outlined back to 1970, and since its introduction, the market for this product has experienced substantial growth. By the late 1990s, the bottled water market had tripled in size compared to the soft drinks market [2]. Humans consume water from different sources and in various forms, and bottled water is one of these forms [3]. Bottled water consumption has increased significantly recently, primarily driven by the escalating contamination of water sources. Over the last three quarters, global bottled water drinking has increased steadily, establishing itself as the fastest-growing and most dynamic sector within the nutrition and drink industries [4]. Bottled water becomes a viable choice in regions where safe water is scarce or water treatment poses challenges. However, confirming the care of bottled water is crucial, and the monitoring of toxic and trace metal contaminants becomes necessary [5]. To safeguard their health, individuals resort to consuming bottled water, often spending substantial amounts of money to obtain it, under the assumption that it is cleaner and safer compared to boiled water [6]. Developing countries consider the reduction of waterborne diseases to be a primary objective for public health. Bottled water, offering various qualities, is now widely available and consumed globally. The highest drivers behind this increased consumption are the lack of safe and easily accessible drinking water, as well as the unappealing taste of chemicals, particularly chlorine, used in tap water purification. In developed countries like the cities in northern Iraq, consumers purchase bottled water as a healthier option compared to other beverages, aiming to improve their overall well-being and steer clear of epidemic diseases prevalent in the region, such as Cholera, Typhoid, and bacterial intestinal infections. These diseases often arise due to inadequate monitoring of disinfectant levels in water treatment stations and well water monitors, as well as the mixing of potable water with internal wastewater due to sporadic leaks. Therefore, the resolve of this study was to assess the characteristics of different brands of bottled water in Sulaymaniyah City using Nemerow Pollution Index (NPI) and compare the results against the guidelines established by the (WHO). The aim was to determine the care of the bottled water for human consumption.

Materials and Methods

Study area

The study took place in Sulaymaniyah City, which has an estimated population of 1.8 million. The city is situated at coordinates 35° 33' 25.36" latitude and 45° 26' 9.39" longitude, covering an approximate area of 17,023 square kilometers. It sits at an altitude of 847 meters above sea level. The residents of the city get their drinking water from multiple sources, including the Dokan Dam located 40 kilometers away, Sarchnar springs, and boreholes along the city's border. Alongside the tap water supply, the city offers convenient access to several brands of bottled water, primarily used for drinking purposes.

The process of collecting and examining water samples

Ten different bottled water brands were selected for the present investigation. Between January and February 2023, random samples of 10 bottles were collected from a variety of stores and supermarkets spread throughout Sulaymaniyah City. The samples were taken to the lab in a cool box after being collected. Until analysis was done, all samples were kept in their original containers and kept cool at 4°C. The bottled water containers had capacities of either 0.5 or 1 liter. To create a composite sample for each brand, two identical samples of bottled water were mixed. Additionally, the sampled water was categorized as either a natural spring, a natural mineral, or purified water. The specific brands and sources of bottled water utilized in this study are detailed in Table (1). The analysis encompassed several physical, chemical, and biological limits, including Turbidity (was carried out by using Photo Flex/Photo Flex Turb.WTW Company-by Photo Flex/Photo Flex Turb.WTW Company-Germany) and Most Probable Number (MPN) test. These parameters were evaluated using the standard methods outlined in the investigation of water and wastewater [7]. The department of natural resources within the faculty of agricultural engineering sciences, containing the laboratory of higher education, was employed for the consequent analyses Germany), Color (was assessed using photoLab spectral model (82362 Weilheim) WTW Company-Germany, pH (was performed by pH Multi 340i/SET Multiparameter-Instrument WTW Company-Germany, EC, and TDS (were executed by Cond 330i, 82362 Weilheim WTW Company-Germany, Total hardness, Na^+, K^+, Cl^-, SO_4^{2-}, HCO_3^- (were identified through titrimetric methods), NO_3^-, PO_4^{2-}, NO_2 (were carried out

Table (1) Displays the varieties and origins of the bottled mineral water utilized in the current investigation.

Bottled water brands	Water type	Source of water
KANi Sard	Natural spring water	Sulaymaniyah-Iraq
Slemani	Natural mineral water	Sulaymaniyah-Iraq
Jaam	Natural spring water	Sulaymaniyah-Iraq
Life	Natural spring water	Duhok-Iraq
Pak	Natural spring water	Sulaymaniyah-Iraq
Roma	Natural spring water	Sulaymaniyah-Iraq
Jiyan	Natural spring water	Sulaymaniyah-Iraq
Gole	Natural spring water	Sulaymaniyah-Iraq
Pinar	Natural mineral water	Turkey
Uludag	Natural spring water	Turkey

Evaluation of the Nemerow's Pollution Index (NPI) for samples of bottled water

The Nemerow Pollution Index (NPI) refers to a method for assessing pollution that was developed by [8]. This index has been studied by [9, 10]. The NPI is a simplified pollution index that can be calculated using the following equation :

$$\mathrm{NPI} = \frac{\mathrm{Ci}}{\mathrm{Li}}$$

Here, Ci represents the observed concentration of the *i*th parameter in milligrams per liter (mg L^{-1}), and Li represents the permissible limit for the *i*th parameter based on the guidelines provided by [11] for analogous parameters. The average pollution index, NPI_{avg}, can be calculated as well.

$$\mathrm{NPI_{avg}} = \frac{1}{m}\sum_{i=1}^{m} \mathrm{NPI}_i$$

Ideally, the NPI_{avg} should be equal to or less than one. Pollution classification is classified into 4 stages based on water quality standards. The interpretation of calculated NPI_{avg} values can be originated in Table (2)

Table (2) Presents Nemerow's Pollution Index (NPI) along with the criteria for assessing the status of water quality.

Nemerow's pollution index	Water quality Status
$0 < NPI_{avg.} < 1$	Good condition
$1 < NPI_{avg.} < 5$	Slightly polluted
$5 < NPI_{avg.} < 10$	Moderately polluted
$NPI_{avg.} > 10$	Extremely polluted

It is significant to remind that the units of Ci and Li should be the same. Each NPI value shows the comparative pollution contributed by a single parameter and does not have any units. The Li values for different water quality limits are given in mg L^{-1} according to the (WHO) guidelines for analogous parameters. If the NPI value exceeds 1.0, it indicates the existence of impurities in the water, suggesting the need for treatment before use.

Results and discussion

This study provides an analysis of the physical, chemical, and biological composition of examined bottled water, with results summarized in Table (3). The measurements presented in the table represent averages of three replicates for each brand of bottled water during the study period. Bottled water brands' results were compared to international standards, specifically the 2011 (WHO) standards.

Turbidity and color, important parameters for drinking water, were within permissible levels according to (WHO) standards. Turbidity ranged from less than 0.01 to 0.21 NTU, while color ranged from 4.3 to 7.5 Hazen units Table (3). The pH amounts of the bottled water samples, ranging from 6.91 to 7.81, indicated that they were close to neutral to sub-alkaline in nature and fell within the permissible limits set by (WHO). pH is an important factor in determining the suitability of water for various purposes [12]. Electrical conductivity (EC) measurements showed slight variation, ranging from 63.31 to 293.75 µs cm^{-1}. All samples were within the acceptable range for drinking water. EC is an imperative sign of water quality as it reflects the quantity of dissolved material in the water. Differences in EC values between bottled water brands can be attributed to differences in ionic composition, soil composition, and mineral content in different water sources. The increase in conductivity of water is accompanied by an increase in the total dissolved solid (TDS), which means that there close relationship between EC and TDS [13].

TDS in the studied bottled water ranged from 64 to 298 mg L^{-1}, which can affect the taste of the water. Very low TDS ranks may result in an unappealing taste, while great TDS levels can impact the taste as well [14]. Total hardness (TH) values, ranging from 16 to 306 mg L^{-1} Table (3), are also important for determining water quality for domestic, industrial, or agricultural purposes [15]. TH levels for all bottled water brands were within acceptable limits set by (WHO). Bottled water brands analyzed had low concentrations of sodium (Na^{+}) and potassium (K^{+}), with Na^{+} ranging from 2.51 to 40.09 mg L^{-1} and K^{+} ranging from 0.25 to 2.33 mg L^{-1}. These values were under the acceptable limits set by (WHO) for drinking water Table 3. Additionally, the concentrations of chloride (Cl^{-}), bicarbonate (HCO_3^{-}), sulfate (SO_4^{2-}), nitrate (NO_3^{-}), phosphorus (PO_4^{2-}), and nitrite (NO_2^{-}) ions mg L^{-1} in all brands of bottled water were lower than allowable limits set by (WHO) Table (3).

Regarding bacterial contamination, the attendance of indicator microorganisms such as coliform bacteria indicates fecal contamination and the potential presence of pathogens [16]. Coliform bacteria (MPN) are a frequently used bacterial sign of sanitary features of foods and water [17]. However, in this study, the total coliform bacteria in all the samples were undetectable (Table 3), aligning with (WHO) guidelines that recommend the absence of detectable coliform bacteria in any 100 ml sample of water intended for drinking [18].

Table (3) Displays the measured values of the parameters studied in numerous brands of bottled water compared to the standard guidelines set by [11].

Parameters	Bottled water brands										
	KANi Sard	Slemani	Jaam	Life	Pak	Roma	Jiyan	Gole	Pinar	Uludag	WHO
Turbidity (NTU)	> 0.01	> 0.01	> 0.01	0.21	> 0.01	> 0.01	> 0.01	> 0.01	> 0.01	> 0.01	5
Color (Hazen)	6.1	7.5	7.5	6.2	7.3	7.2	5.5	7.4	6.7	4.3	15
pH	7.51	7.26	7.51	7.55	7.81	7.57	7.46	7.22	7.03	6.91	6.5-8.5
EC (µs cm^{-1})	293.75	183.12	241.05	190.92	172.17	220.04	198.54	198.58	73.78	63.31	1000
TDS (mg L^{-1})	298	184	244	193	173	222	201	201	74	64	500
TH (mg L^{-1})	120	231	90	99	100	306	52	85	16	23	500
Na^+ (mg L^{-1})	40.09	3.07	3.09	2.51	38.43	3.54	3.57	7.32	4.92	3.15	200
K^+ (mg L^{-1})	0.38	1.43	1.22	0.35	0.25	0.32	1.14	2.33	1.53	0.62	12
Cl^- (mg L^{-1})	18.1	2.7	6.5	11.5	18.2	35.3	3.2	8.4	3.6	1.3	250
HCO_3^- (mg L^{-1})	120	70	65	60	150	100	76	60	61	26.6	200
SO_4^{2-} (mg L^{-1})	8.57	12.02	11.01	16.84	8.27	13.05	9.71	10.03	7.92	2.83	250
$NO3^-$ (mg L^{-1})	9.88	3.18	1.51	0.75	2.03	1.25	3.23	1.71	0.89	0.47	50
PO_4^{2-} (mg L^{-1})	0.4	0.5	0.5	0.4	1.2	0.5	0.3	0.3	0.3	0.4	5
NO_2 (mg L^{-1})	0.04	0.02	0.03	0.03	0.05	0.05	0.02	0.04	0.04	0.05	3
MPN (cell/100 ml)	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	100

This study examines the water quality limitations required for drinking water, as indicated in Table (3). The NPI (Nemerow's Pollution Index) method is used to conclude the NPI values based on these standard parameters. If the NPI value exceeds 1.0, it suggests the existence of contaminations in the bottled water, requiring treatment before consumption. The NPI values for various pollutants in different bottled water brands are presented in Table (4).

Table (4) Nemerow's Pollution Index results for bottled water brands.

Parameters	NPI values									
	KANi Sard	Slemani	Jaam	Life	Pak	Roma	Jiyan	Gole	Pinar	Uludag
Turbidity	0.002	0.002	0.002	0.042	0.002	0.002	0.002	0.002	0.002	0.002
Color	0.41	0.50	0.50	0.41	0.49	0.48	0.37	0.49	0.45	0.29
pH	0.94	0.91	0.94	0.94	0.98	0.95	0.93	0.90	0.88	0.86
EC	0.29	0.18	0.24	0.19	0.17	0.22	0.20	0.20	0.07	0.06
TDS	0.60	0.37	0.49	0.39	0.35	0.44	0.40	0.40	0.15	0.13
TH	0.24	0.46	0.18	0.20	0.20	0.61	0.10	0.17	0.03	0.05
Na^+	0.20	0.02	0.02	0.01	0.19	0.02	0.02	0.04	0.02	0.02
K^+	0.03	0.12	0.10	0.03	0.02	0.03	0.10	0.19	0.13	0.05
Cl^-	0.07	0.01	0.03	0.05	0.07	0.14	0.01	0.03	0.01	0.01
HCO_3^-	0.60	0.35	0.33	0.30	0.75	0.50	0.38	0.30	0.31	0.13
SO_4^{2-}	0.03	0.05	0.04	0.07	0.03	0.05	0.04	0.04	0.03	0.01
NO_3^-	0.20	0.06	0.03	0.02	0.04	0.03	0.06	0.03	0.02	0.01
PO_4^{2-}	0.08	0.10	0.10	0.08	0.24	0.10	0.06	0.06	0.06	0.08
NO_2	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.02
NPI_{avg}	0.265	0.224	0.214	0.195	0.254	0.256	0.192	0.206	0.155	0.122

Based on the results, the turbidity and color NPI values range from 0.002 to 0.042 and 0.29 to 0.50 Table (4). Figure (1) shows that all brands of bottled water are within acceptable NPI for turbidity and color values. The pH NPI amounts fall within the permissible range of 0.86 to 0.98 for all bottled water brands, Table (4) and Figure (2)

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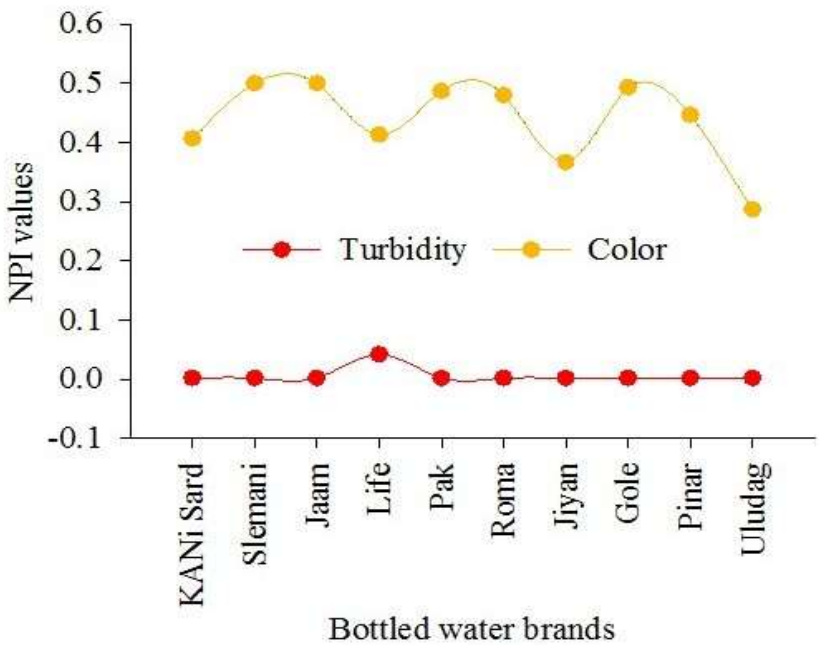

Figure 1: The variation of NPI values of turbidity and color.

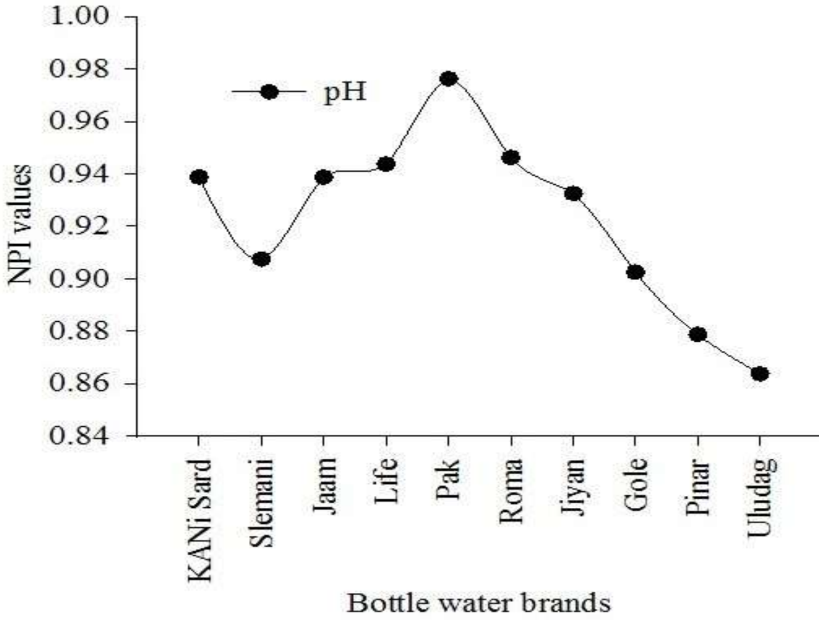

Figure 2: The variation of NPI values of pH.

The electrical conductivity values (EC NPI) levels of 0.06 to 0.29 across all water samples, Table (4) and Figure (3) illustrate the various ranges of NPI EC values. The observed NPI values for TDS range from 0.13 to 0.60, Table (4). However, the NPI TDS values are within the allowable limit Figure (3). The NPI ranges for total hardness (TH) 0.03 to 0.61 and NPI TH values in all brands of bottled water fall below the range Table (4), and Figure (3). The NPI ranges for sodium and potassium 0.01 to 0.20 and 0.02 to 0.19 are respectively Table (4), and Figure (4) demonstrates that all brands of bottled water fall within the permissible range of NPI Na^+ and K^+ values. Chloride levels 0.01 to 0.14 in all water brands are recorded below the permissible NPI limit Table (4) and Figure (4).

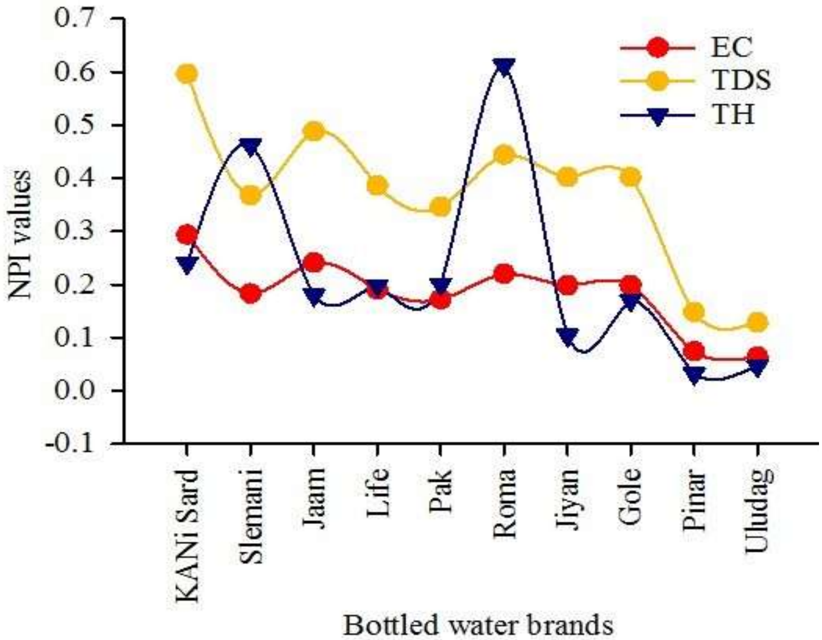

Figure 3: The variation of NPI values of EC, TDS, and TH.

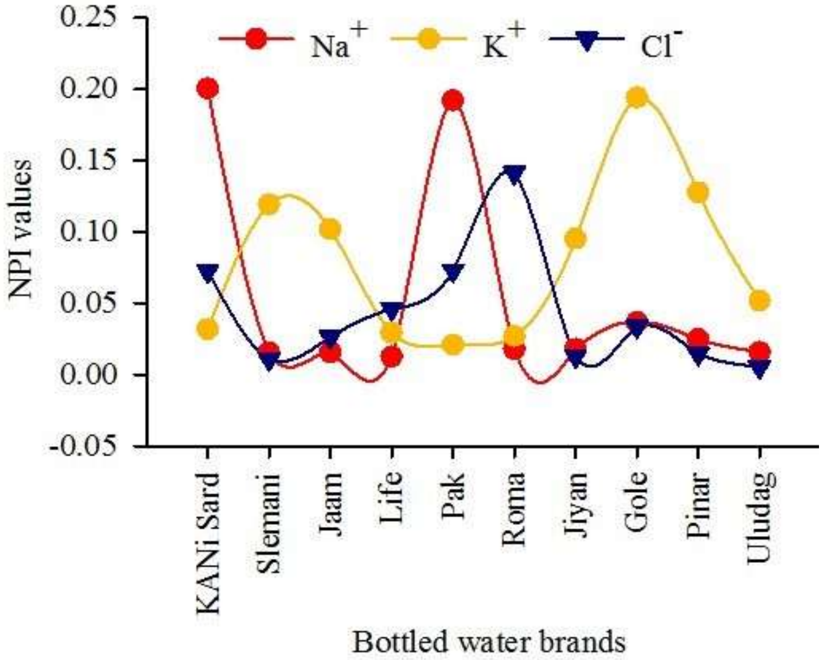

Figure 4: The variation of NPI values of Na^+, K^+, and Cl^-.

The NPI range for bicarbonate 0.30 to 0.75, Figure (5) indicates that the NPI amounts for various HCO_3^- concentrations do not exceed the limited range Table (4). The NPI rates for SO_4^{2-}, NO_3^-, PO_4^{2-}, and NO_2 concentrations are all below one, suggesting that the concentrations in all brands of bottled water comply with the allowable limits set by (WHO), Table (4) and Figure (6). The NPI values for total coliform bacteria in all studied water brands are zero and fall within the permissible NPI range Table (4). Overall, the NPI rates for all studied concentrations are not greater than one, indicating that the bottled water brands are suitable for drinking according to (WHO) standards

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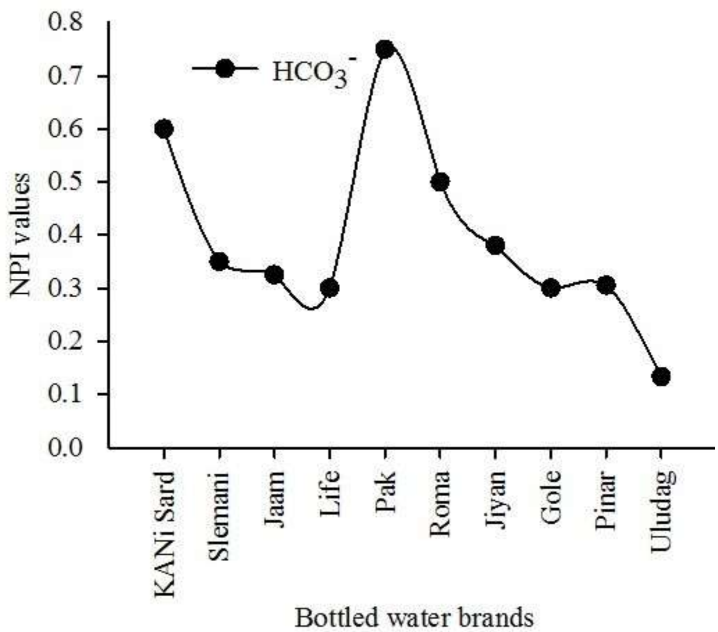

Figure 5: The variation of NPI values of HCO_3^-.

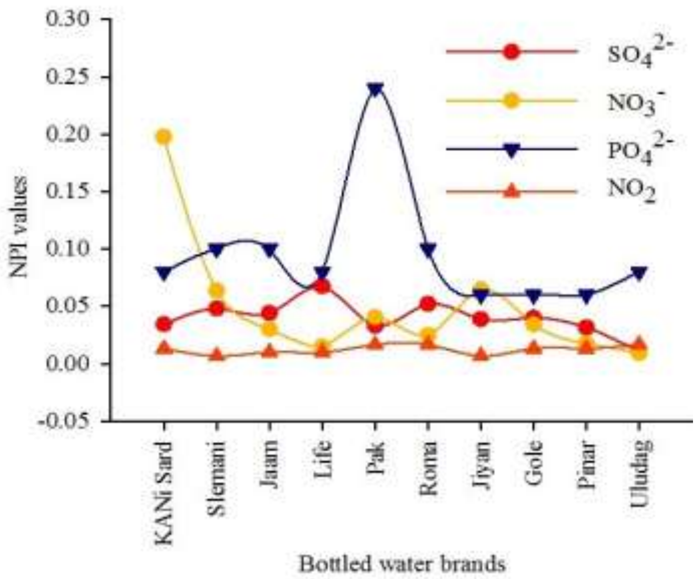

Figure 6: The variation of NPI values of SO_4^{2-}, NO_3^-, PO_4^{2-}, and NO_2.

Conclusion

The Nemerow Pollution Index (NPI) method was used to assess the quality of bottled water for human consumption in Sulaymaniyah city, using a selection of ten different monitoring brands. The investigation confirmed the accuracy and appropriateness of the assessment approach used. The results showed that the studied bottled water samples met the safety requirements for human consumption, as the values of various parameters did not exceed the established international standards of the World Health Organization (WHO) for drinking water. Differences in physical, chemical and biological properties have been observed between different brands of bottled water, reflecting differences in the natural environment, composition of water sources and treatment and purification methods used in production. It was found that the NPI values for various parameters were consistently below the permissible thresholds, indicating that the bottled water brands are free of contamination. The evaluation of the Nemerow Pollution Index average (NPIavg) showed that the tested bottled water samples in the city of Sulaymaniyah had values ranging from 0.122 to 0.265, indicating favorable conditions and suitability for use as a drinking water source.

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مجلة جامعة كركوك للعلوم الزراعية

تطبيق مؤشر Nemerow للتلوث (NPI) لتقييم نوعية المياه المعبأة المتوفرة في مدينة السليمانية.

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• تاريخ استلام البحث05/2024/01 وتاريخ قبوله 2024/02/07.

الخلاصة

مؤشر التلوث هو أداة قيمة تستخدم لتقييم خصائص المياه في النظام البيئي للمياه العذبة. في هذه الدراسة، تم جمع عينات من المياه المعبأة من 10 ماركات تجارية مختلفة، محلية ومستوردة، من محلات تجارية مختلفة في مدينة السليمانية بين كانون الثاني/يناير وشباط/فبراير 2023. تمت دراسة الخصائص الفيزيائية والكيميائية والبكتريولوجية للعينات. كان الهدف الرئيسي هو تقييم مدى ملاءمة هذه الماركات التجارية للمياه المعبأة لغرض الشرب مستخدما مؤشر التلوث Nemerow (NPI). لحساب NPI، تم قياس 15 متغير، بما في ذلك العكورة واللون ودرجة الحموضة والتوصيل الكهربائي والمواد الصلبة الذائبة الكلية و والعسرة الكلسة والصوديوم والبوتاسيوم والكلوريد والبيكربونات والكبريتات والنترات والفوسفور والنيتريت. تمت مقارنة النتائج بالمعدلات الطبيعية لمياه الشرب التي وضعتها منظمة الصحة العالمية. و أشار مؤشر التلوث Nemerow، المشتق من االمتغيرات المقاسة، إلى أن متوسط قيم NPI تراوح من 0.122 إلى 0.265 لجميع عينات المياه. هذه القيم كانت أقل من حدود NPI الذي حددته المعايير، اي ان جميع القيم كانت ضمن الحدود المسموحة بها، مما يشير إلى أن ماركات المياه المعبأة التي تم فحصها كانت غير ملوثة وذات جودة جيدة.

الكلمات المفتاحية: العلامات التجارية، القيم، المتغيرات الفيزيائية والكيميائية، المعايير.