

## Spatial and temporal analysis of Cobalt distribution in the groundwater of Akkar Plain at Tartous Governorate/ Syria

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### Abstract:

This research investigated Cobalt's seasonal and spatial distribution in the groundwater of 19 wells in Akkar Plain, Tartous Governorate, Syria.

Spatial analysis revealed that Agricultural Well 1 had the highest Cobalt concentration in the groundwater, with an average value of 0.107 mg/L. Conversely, the Karto 1 well had the lowest concentration at 0.054 mg/L.

The temporal analysis demonstrated that Cobalt concentrations were higher in spring than in autumn, with average values of 0.085 mg/L in spring and 0.075 mg/L in autumn. Of the four seasons, spring 2019 had the highest average Cobalt concentration at 0.141 mg/L, while spring 2020 had the lowest at 0.03 mg/L.

The variance distribution test indicated that the season factor was the most significant factor affecting the variance of Cobalt distribution among the studied factors (replicates, season, site, site\*season).

The excessive use of fertilizers is believed to be the main cause of Cobalt distribution in the groundwater. Other contributing factors include untreated sewage sludge, irrigation from Cobalt-contaminated water bodies, and the high levels of this metal in soils, either naturally or due to agricultural activities. All of these factors have led to an increase in Cobalt concentrations in the groundwater.

Groundwater Cobalt distribution in Akkar Plain decreased significantly during spring 2020 due to COVID-19 quarantine, highlighting human impact.

Thematic maps and statistical studies have shown that the distribution of Cobalt in the groundwater of Akkar Plain is widespread. The majority of the results indicate that the levels of Cobalt exceed the permissible limit for drinking water of 0.05 mg/L.

**Keywords:** Groundwater, Cobalt, Akkar Plain, Syria.

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## التحليل المكاني والزمني لانتشار الكوبالت في المياه الجوفية لسهل عكار في محافظة طرطوس/ سورية

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### الملخص:

تناول هذا البحث دراسة الانتشار المكاني والزمني للكوبالت في المياه الجوفية لـ 19 بئراً في سهل عكار في محافظة طرطوس، سورية.

أظهر التحليل المكاني أن البئر الزراعي 1 يحتوي على أعلى تركيز للكوبالت في المياه الجوفية، بمتوسط قيمة 0.107 مغ/ل، بينما كان لبئر كرتو 1 أدنى تركيز عند 0.054 مغ/ل.

أظهر التحليل الزمني أن تراكيز الكوبالت خلال الربيع كانت أعلى من تراكيزه خلال الخريف، حيث بلغ متوسط القيم 0.085 مغ/ل في الربيع و 0.075 مغ/ل في الخريف. وبالمقارنة بين الفصول الأربعة، سجل ربيع 2019 أعلى متوسط لتراكيز الكوبالت عند 0.141 مغ/ل، في حين سجل ربيع 2020 أدنى متوسط لتراكيز الكوبالت عند 0.03 مغ/ل.

أشار اختبار توزيع التباين إلى أن عامل الموسم هو العامل الأكثر تأثيراً على تباين انتشار الكوبالت بين العوامل المدروسة (المكررات، الموسم، الموقع، الموقع\*الموسم).

ويعتقد أن الاستخدام المفرط للأسمدة هو السبب الرئيسي لانتشار الكوبالت في المياه الجوفية. وتشمل العوامل المساهمة الأخرى حمأة مياه الصرف الصحي غير المعالجة، والري من المسطحات المائية الملوثة بالكوبالت، والمستويات العالية من هذا المعدن في التربة، إما بشكل طبيعي أو بسبب الأنشطة الزراعية. وقد أدت كل هذه العوامل إلى زيادة تراكيز الكوبالت في المياه الجوفية.

انخفض انتشار الكوبالت في المياه الجوفية في سهل عكار بشكل ملحوظ خلال ربيع عام 2020 بسبب الحجر الصحي بسبب فيروس كورونا، مما يسلط الضوء على التأثير البشري.

أظهرت الخرائط الغرضية والدراسات الإحصائية انتشاراً واسعاً للكوبالت في المياه الجوفية لسهل عكار، وتشير غالبية النتائج إلى أن مستويات الكوبالت تجاوزت الحد المسموح به لمياه الشرب وهو 0.05 مغ/ل.

**الكلمات المفتاحية:** المياه الجوفية، الكوبالت، سهل عكار، سورية.

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يحتفظ المؤلفون بحقوق النشر بموجب

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## **Introduction:**

Groundwater is a valuable and renewable resource that serves as the primary source of drinking water, especially in developing countries. However, the depletion and degradation of groundwater affect its quantity and quality, posing a significant problem (**Kumar et al., 2018**). Despite advances in technology, heavy metals in drinking water still exceed recommended limits set by regulatory authorities worldwide. Drinking contaminated water is the primary source of measurable human exposure to heavy metals (**Rehman et al., 2018**). Cobalt is a crucial heavy metal, naturally occurring in the Earth's crust and living organisms in low concentrations. Human activities can increase their levels in the environment (**El Youssfi et al., 2023**). Cobalt is typically extracted from ores during the mining of other metals like Nickel and Copper (**Krasnykh et al., 1988**). Despite its natural content in the environment, Cobalt pollution has increased in recent years due to its diverse use in various branches of industry (**Biswas et al., 2013**), improper management of fertilizers (**Saaltink et al., 2014**), use of some pesticides (**Defarge et al., 2018**), and sewage sludge (**Li et al., 2014**).

Groundwater in Zahedan, Iran showed high Cobalt contamination (0.172-0.204 mg/L) due to agricultural activity (**Atashi et al., 2009**). Geological and human sources have contributed to high levels of Cobalt in drinking water in Abbottabad, Khyber Pakhtunkhwa, Pakistan (**Sarib et al., 2019**). An investigation of well water samples used for drinking in Gombe City, northeastern Nigeria, a major agricultural region, revealed Cobalt levels exceeding permissible values, reaching 0.42 mg/L (**Maigari et al., 2016**). During the survey of Basra City's aquatic environment in Iraq, Cobalt concentrations as high as 0.89mg/L were detected (**Al-Hassen and Al-Saad, 2012**). In the Syrian coastal basin, the presence of fractures, faults, and porous rock formations has made it easier for heavy elements such as Cobalt to be transported through surface and groundwater. As a result, some locations in the area have high concentrations of these elements (**Kassem and Sarhil, 2010**).

The standard permissible limit for Cobalt concentration in drinking water is 0.05 mg/L (**WHO, 1993**).

The main goal of this work is to investigate Cobalt concentration in the groundwater of Akkar Plain at Tartous Governorate/Syria during the spring and autumn seasons, with consideration for the permissible limit for drinking water.

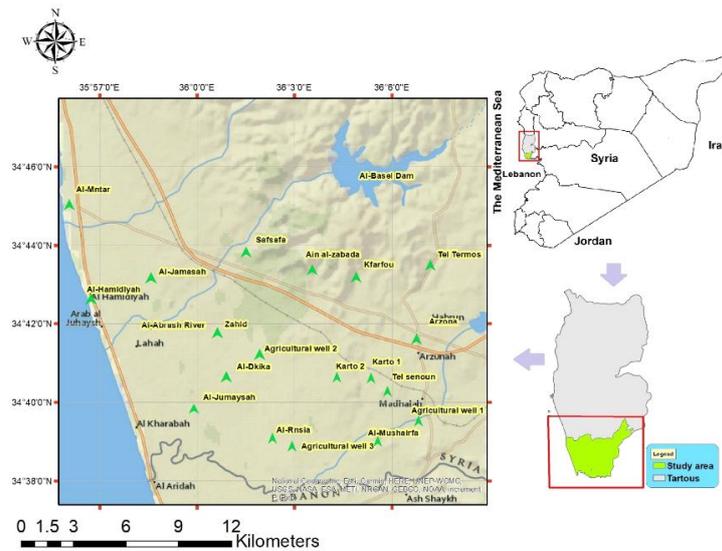
## **Material and methods:**

**Research materials:** To determine the monitoring points, a GPS device was used, and prepared maps using ArcMap 10.6.1 software. Water samples in tightly sealed sterile containers were collected and stored in an Ice-Storage Box Container. The pH of water samples was measured using a pH Electrode and a camera for documentation. To conduct analyses, an atomic absorption spectrometer (SpectrAA. 880) was used along with sterile tubes, distilled water, and standard solutions with a concentration of 1000 mg/L of Cobalt.

### **Research methods:**

#### **Research area:**

**Site:** The study area is located in Akkar Plain of Tartous Governorate (Syria), spanning between latitudes 34.64 and 34.75 north and longitudes 35.92 and 36.12. The total studied area is 186.4 km<sup>2</sup>, with an altitude ranging from 10 to 200 m above sea level. It is a major irrigated agricultural area in Tartous Governorate. The research area was determined using ArcMap after plotting monitoring points taken with GPS onto a map, as shown in Figure (1).



**Figure (1): Research area (Akkar Plain) and monitoring points**

Akkar Plain consists of a coastal area and a hilly region comprising basalt tuff, basalt, and limestone. The plain is crossed by several rivers, namely Al-Abrash, Al-Arous, Khalifa, Al-Ward, and Al-Kabir Al-Janoubi, and has dams like the Al-Basil Dam and Khalifa Dam for storing water for irrigation.

Groundwater is present in all geological layers, with an estimated 160 million m<sup>3</sup> available in the plain. There are thousands of licensed and unlicensed artesian and surface wells.

The groundwater-bearing layers present in the Upper Cretaceous, Pliocene, and Quaternary are fed primarily by the infiltration of rainwater and irrigation water through soil pores. Additionally, they are fed by the seepage of water through karst, cracks, and voids located in rocks of a basaltic nature that are abundantly cracked. Groundwater flows towards the west and southwest, draining into riverbeds and through sectors that expose it under the surface of the sea. It is worth noting that groundwater levels in some areas of the plain may reach depths of less than 3 meters, and may touch the surface of the earth in winter, forming permanent swamps (Al-Asaad et al., 2019).

**Soil (Al-Dayaa and Darwish, 1989; GCSAR 2019):**

Plain soil is semi-planar and wavy sedimentary, it is either:

- Sandy texture: spread along the coastal strip, more than 150 cm deep, poor in organic matter and elements due to its excess drainage and high permeability, containing CaCO<sub>3</sub>, basic pH, high sand content, devoid of structure. Factors limiting production include sea currents (wind drift), excess drainage, and poor nutrients. It is spread in Al-Hamidiyah and Al-Mntar
- Clay texture (the most common): deep, the percentage of clay exceeds 50% in some sites; its color ranges from red to brown to black, rich in nutrients, basic pH, and poor drainage. Factors limiting production: high clay content, high groundwater level, salinity, poor CaCO<sub>3</sub>. It is spread in (Kartto, Arzona, Zahid, Al-Dkika, Al-Rnsia, Al-Jamayah, and Al-Jumaysah).

Hills soil: medium depth, from 50 - 100 cm, heavy to medium consistency, its color also ranges from red to brown to black. It is located in some locations on a limestone base and in others on a basalt base. The factors determining production include the high percentage of CaCO<sub>3</sub> and clay in some sites, in addition to inclination, exposure to erosion, and the presence of stones. It is spread in (Safsafa, Tel senoun, Tel Terms, Kfarfu, Ain al-zabda, and Al-Mushairfa).

**Climate:**

The temperature in Akkar Plain varies between 20.5° to 28.5° in summer and 8° to 17° in winter. The average humidity level throughout the year ranges from 60% to 76%. Monthly rainfall data from the Ministry of Agriculture and Agrarian Reform in Syria is available for the period between 2000 and 2020 and is shown in Figure (2). The average annual rainfall in Akkar Plain during this period was 841mm, which usually falls between October and May.

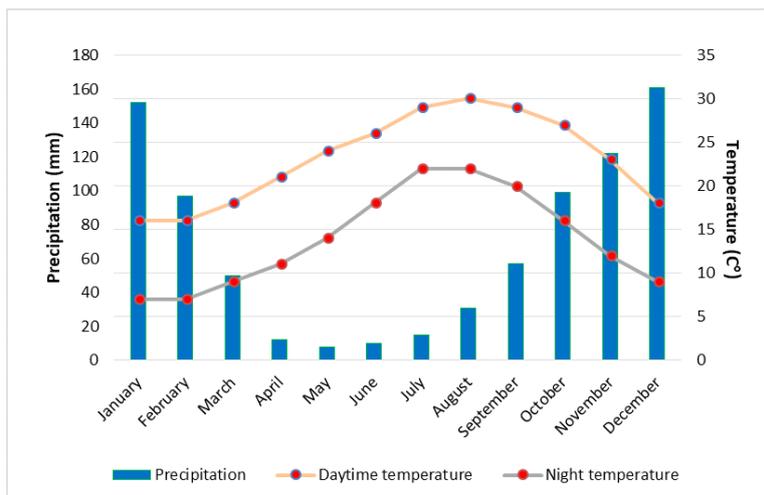


Figure (2): Average monthly rainfall and temperature distribution in the research area (2000-2020)

**Land uses:**

The land use divisions in the research area are shown in Figure (3). The majority of the dominant plain’s lands (>85%) is used for agriculture. Crops like wheat, corn, and tobacco, as well as vegetables like tomatoes, cucumbers, parsley, zucchini, peppers, beans, peas, and eggplant are commonly grown. Fruit trees like olives, citrus fruits, figs, pomegranates, and peaches are also a part of the area's agriculture. Protected agriculture is also widely practiced in the region. Residential clusters make up only 7.48% of the total area of the plain. Water bodies like rivers (such as Al-Abrash River and Al-Kabeer Al-Janoubi River), dams (such as Al-Basil dam), water canals, and swamps comprise around 4.07% of the total area of the plain, while the remaining percentage (<2%) is made up of bare soil and forests (Ministry of Agriculture 2008; Salman *et al.*, 2023a; Salman *et al.*, 2023b).

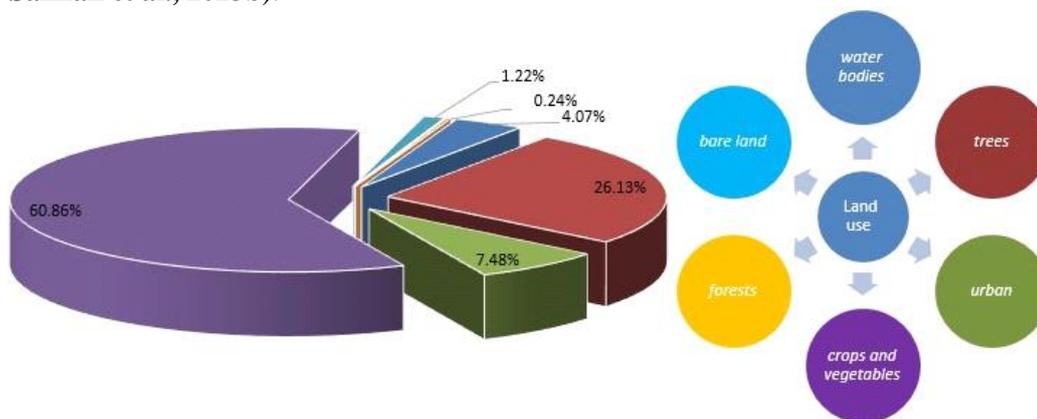


Figure (3): Land use Chart in the research area

**Monitoring points, groundwater sampling protocol, and analysis methods:**

Groundwater samples were collected in Akkar Plain from 16 drinking water monitoring wells and 3 agricultural wells during the spring and autumn seasons in 2019 and 2020. The sampling locations are indicated in Figure (1).

To ensure that no stagnant water was collected, the well was run for at least 5 minutes before samples were taken. The samples were collected in sealed polyethylene sterile plastic containers that were washed with well water before filling. Each sample had a volume of 100 ml, with three replicates taken for each sample. The samples were stored in plastic containers with ice, and the name, number, and date of sampling were recorded. The pH of the water samples was measured using a pH electrode. To measure the concentration of Cobalt, the water was filtered to remove impurities and the filtrate was collected in sterile glass tubes. The concentration of Cobalt was determined using a flame atomic absorption spectrometer device in the Department of Soil Sciences laboratories at the Faculty of Agriculture of Damascus University. Standard Cobalt solutions were prepared at concentrations of 1, 2, and 5 ppm, then solutions of unknown concentration were measured.

**Mapping:**

Groundwater Cobalt distribution maps were created using ArcMap 10.6.1 software at a 1:50,000 scale.

**Statistical analysis:**

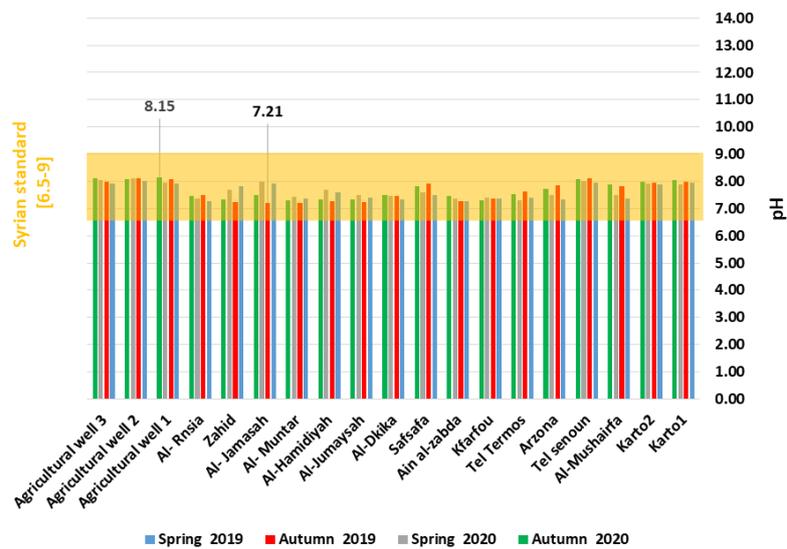
ANOVA test was conducted as a factorial experiment, using a completely randomized block design. Afterward, the least significant difference (LSD) test was performed to determine any significant differences between the means at a 5% confidence level. The F test and variance distribution test were also carried out to determine the percentage effect of the studied factors, which included replications, site, season, and site\*season. All of the tests were conducted using the MiniTab 14 statistical program.

**Results and discussion:**

**pH values:**

**Figure (4)** shows the measured pH values of water samples taken from various wells in Akkar Plain during the four research seasons. The minimum pH value of 7.21 was recorded in the Al-Jamasah well water sample during the autumn season of 2019, and the maximum pH value of 8.15 was recorded in the water sample of Agricultural well 1 during the autumn season of 2020. It is worth noting that the pH values of well water were found to be within the limit allowed for drinking water as per the **Syrian standard** [6.5-9], and the pH values were moderately to alkaline.

During autumn, the pH values were higher than spring due to increased temperatures. This leads to an increase in the dissolving mineral oxides present in soil layers, which raises the pH (**Al-Obaidi, 2008**).



**Figure (4): Results of pH levels in various well water samples from Akkar Plain**

**Cobalt (Co) distribution:**

Table (1) shows the average concentration of Cobalt measured by a flame atomic absorption spectrometer in groundwater samples taken from specific monitoring points in the research area during the four seasons: spring 2019, autumn 2019, spring 2020, and autumn 2020.

**Table (1): Average Cobalt concentrations in the groundwater of Akkar Plain during the research seasons**

Site	Groundwater Co* concentration mg/L			
	Spring 2019	Autumn 2019	Spring 2020	Autumn 2020
Karto1	0.144 <sup>def</sup>	0.031 <sup>ij</sup>	0.002 <sup>m</sup>	0.039 <sup>f</sup>
Karto2	0.133 <sup>fgh</sup>	0.027 <sup>j</sup>	0.005 <sup>lm</sup>	0.118 <sup>a</sup>
Al-Mushairfa	0.136 <sup>efg</sup>	0.041 <sup>i</sup>	0.009 <sup>kl</sup>	0.051 <sup>e</sup>
Tel senoun	0.096 <sup>j</sup>	0.076 <sup>efg</sup>	0.020 <sup>j</sup>	0.098 <sup>b</sup>
Arzona	0.163 <sup>bc</sup>	0.024 <sup>i</sup>	0.007 <sup>lm</sup>	0.076 <sup>c</sup>
Tel Termos	0.133 <sup>fgh</sup>	0.134 <sup>a</sup>	0.022 <sup>ij</sup>	0.023 <sup>j</sup>
Kfarfou	0.119 <sup>hi</sup>	0.080 <sup>def</sup>	0.045 <sup>ef</sup>	0.017 <sup>j</sup>
Ain al-zabda	0.180 <sup>a</sup>	0.056 <sup>b</sup>	0.027 <sup>hi</sup>	0.081 <sup>c</sup>
Safsafa	0.143 <sup>def</sup>	0.086 <sup>de</sup>	0.060 <sup>b</sup>	0.064 <sup>d</sup>
Al-Dkika	0.170 <sup>ab</sup>	0.072 <sup>fg</sup>	0.050 <sup>de</sup>	0.121 <sup>a</sup>
Al-Jumaysah	0.117 <sup>i</sup>	0.089 <sup>d</sup>	0.038 <sup>g</sup>	0.078 <sup>c</sup>
Al-Hamidiyah	0.151 <sup>cde</sup>	0.031 <sup>ij</sup>	0.030 <sup>h</sup>	0.100 <sup>b</sup>
Al- Muntar	0.157 <sup>bcd</sup>	0.091 <sup>d</sup>	0.057 <sup>bc</sup>	0.096 <sup>b</sup>
Al- Jamasah	0.154 <sup>cd</sup>	0.074 <sup>fg</sup>	0.013 <sup>k</sup>	0.097 <sup>b</sup>
Zahid	0.122 <sup>ghi</sup>	0.087 <sup>de</sup>	0.005 <sup>lm</sup>	0.092 <sup>b</sup>
Al- Rnsia	0.120 <sup>hi</sup>	0.117 <sup>c</sup>	0.073 <sup>a</sup>	0.064 <sup>d</sup>
Agricultural well 1	0.171 <sup>ab</sup>	0.153 <sup>a</sup>	0.041 <sup>fg</sup>	0.064 <sup>d</sup>
Agricultural well 2	0.182 <sup>a</sup>	0.069 <sup>g</sup>	0.052 <sup>cd</sup>	0.041 <sup>f</sup>
Agricultural well 3	0.090 <sup>j</sup>	0.131 <sup>b</sup>	0.006 <sup>lm</sup>	0.060 <sup>d</sup>
LSD <sub>0.05</sub>	0.015	0.011	0.005	0.008
Indicative value mg/L	0.05			

\* Average of three replicates for Co concentration.

Averages followed by similar letters in the same column indicate that there is no significant difference between them at the significance level of 0.05.

**Table (2): Results of the variance distribution test for Cobalt (Co)**

Source	DF	SS	MS	% Variance	P
Replicate	2	0.0002	0.0001	0.09	0.06
Site	18	0.0450	0.0025	1.99	0.00
Season	3	0.3612	0.1204	95.78	0.00
Site*Season	54	0.1435	0.0027	2.11	0.00
Error	150	0.0058	0.0000		
Total	227	0.5557			

**Spatial statistical analysis:** The results indicate significant differences of Cobalt among the sites during the seasons ( $p$ -value $<$ 0.05) as shown in **Table (1)**. In the spring of 2019, the water at Agricultural well2 in the village of Al-Dkika had the highest value of average Cobalt concentration (0.182 mg/L), while Agricultural well3 in the village of Al-Rnsia recorded the lowest average Cobalt concentration at (0.09 mg/L). In the autumn of 2019, Agricultural well1 in the village of Al-Mushairfa recorded the highest average Cobalt concentration (0.153 mg/L), while Arzona well had the lowest value of Cobalt concentration with an average of (0.024 mg/L). In the spring of 2020, Al-Rnsia well had the highest average Cobalt concentration (0.073 mg/L), while Karto 1 well had the lowest value (0.002 mg/L). In the autumn of 2020, the highest average Cobalt concentration was recorded in Al-Dkika well (0.121 mg/L), while Kfarfou well had the lowest value with an average of (0.017 mg/L). **Figure (5)** shows it has been determined that there are significant differences in the levels of Cobalt found in the groundwater across the various sites in Akkar Plain ( $p$ -value $<$ 0.05). The LSD value, at a confidence level of 0.05, was 0.033. Agricultural Well 1 had the highest average Cobalt concentration, with a value of 0.107 mg/L, while Karto 1 well water had the lowest average concentration of 0.054 mg/L. The differences in Cobalt levels between the sites can be attributed to various sources of pollution, including agricultural, industrial, natural, or human.

It can be noted that most of the measured values for Cobalt in the tested wells exceed the permissible value of drinking water (0.05 mg/L). This could be attributed to the excessive use of chemical fertilizers containing Cobalt as a plant nutrient (**Regulation EU, 2019**). In this research, heavy metals were measured in a widely used fertilizer and pesticides in Akkar Plain to determine their Cobalt content; it was found that the concentration of Cobalt in the fertilizer was 0.975 mg/kg. Additionally, the pesticides used in this area contained high levels of Cobalt in their composition, with a concentration of 1.27 mg/L. The uncontrolled

spread of household sewage pits due to a lack of sewer and agricultural drainage networks in most of the areas of the plain may also contributed to the presence of Cobalt in groundwater. It is possible also that the reason behind the widespread distribution of Cobalt in groundwater is the dependence on water bodies as a source of irrigation. During this study, Cobalt concentrations increased in both the Al-Abrash River and Al-Basil Dam due to the large number of pollution sources that flow directly into their waters, such as sewage and olive press waste. The measured concentrations during the four seasons were 0.188, 0.142, 0.062, and 0.097 mg/L, respectively, for the Al-Abrash River and 0.14, 0.071, 0.032, and 0.069 mg/L, for the Al-Basil Dam. The presence of basalt in the rocks and soil of the Akkar Plain region (UN-ESCWA and B. G. R., 2013) may be a natural factor contributing to the spread of Cobalt in the groundwater. Soil samples collected from the study sites revealed high concentrations of Cobalt, with average values ranging from 1.119 to 12.964 mg/kg.

**Temporal statistical analysis:** there are significant differences in Cobalt concentration in groundwater among the four seasons of study ( $p$ -value $<0.05$ ). The LSD value was at a confidence level of 0.05 (0.009). The highest average Cobalt concentration in the groundwater of the Akkar Plain was recorded in spring 2019, with a value of 0.141 mg/L. On the other hand, the lowest average concentration was observed during the spring of 2020, with a value of 0.03 mg/L. The average concentration of Cobalt was recorded during the autumn of 2019, with a value of 0.077 mg/L, and the average concentration of Cobalt during the autumn of 2020 was recorded with a value of 0.073 mg/L. When comparing the average Cobalt concentrations between spring and autumn, the results show that there is a significant difference ( $p$ -value $<0.05$ ) with an LSD value of 0.011 at a confidence level of 0.05. Specifically, the average Cobalt concentration during the autumn seasons in 2019 and 2020 was found to be 0.075 mg/L, while the average concentration during the spring seasons was 0.085 mg/L as shown in **Figure (6)**. The discrepancies between the spring and autumn seasons could be attributed to the distinct amounts of fertilizers applied and variations in rainfall between the two seasons. In the spring, rainfall washes traces of fertilizers and pesticides from the soil, carrying the leachate rich in Cobalt and delivering it directly to the groundwater. In the autumn, the decrease in water turbidity leads to a decrease in the amount of materials capable of adsorbing mineral elements on its surface, which contributes to the elements remaining in their dissolved form and their concentrations in the water rising.

**Variance Distribution Test:** According to the variance distribution test results, which aimed to determine the percentage impact of the studied factors on Cobalt spread in the groundwater of the Akkar Plain, the season factor had the most influence on the variance and was responsible for 95.78%. The interaction between the site and season contributed to 2.11%, followed by the site factor at 1.99%. Finally, the replicates had the least effect at 0.09%, **Table (2)**.

**Figure 7** shows thematic maps that illustrate the variation in Cobalt distribution in groundwater across the Akkar Plain during four study seasons. In spring 2019, Cobalt distribution was high in all locations due to the high rainfall, which led to a rise in groundwater levels. The high groundwater level facilitated the mixing of pollutants from various sources, such as agriculture, industry, and sewage, and thus Cobalt moved from the soil to groundwater. During the autumn seasons of 2019 and 2020, Cobalt was distributed in most sites due to the decrease in water turbidity during the autumn, which means a decrease in the amount of materials capable of adsorbing metallic elements on its surface, which contributes to the elements remaining in their dissolved form and their concentrations in the water increasing. In spring 2020, a decrease in Cobalt distribution was observed in most sites due to the quarantine measures taken during the COVID-19 outbreak. During this period, all human activities, whether agricultural or industrial, were stopped in the region.

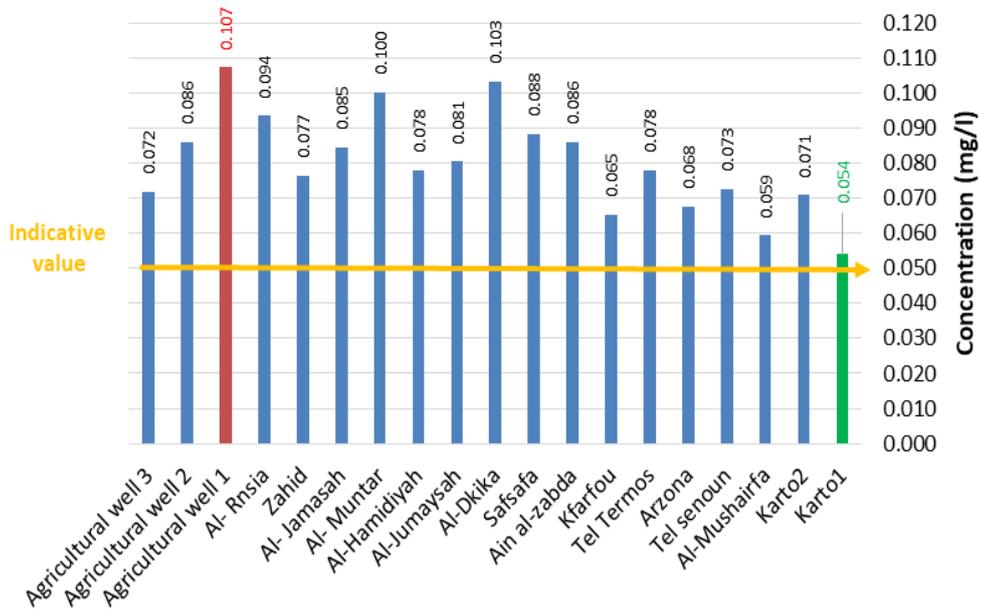


Figure (5): Average Cobalt concentrations in groundwater of Akkar Plain at different sites

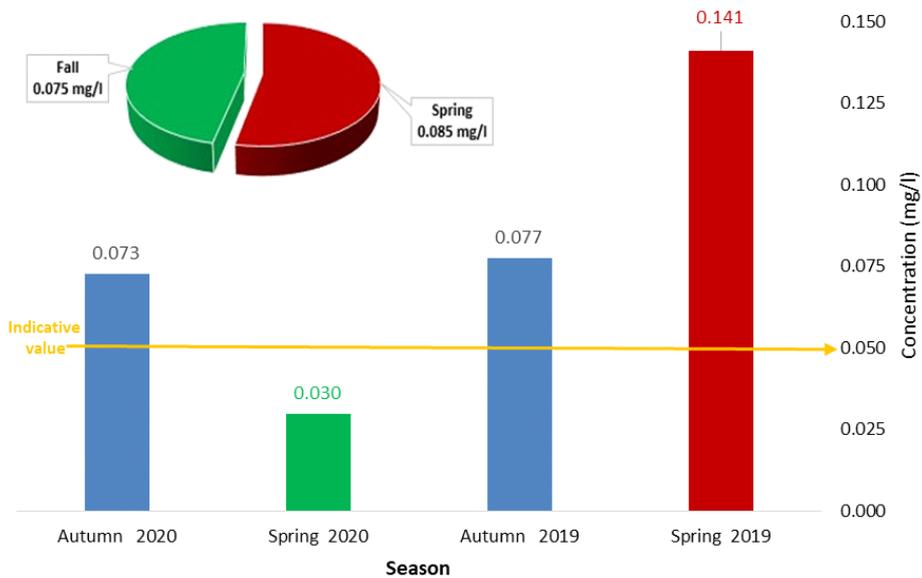
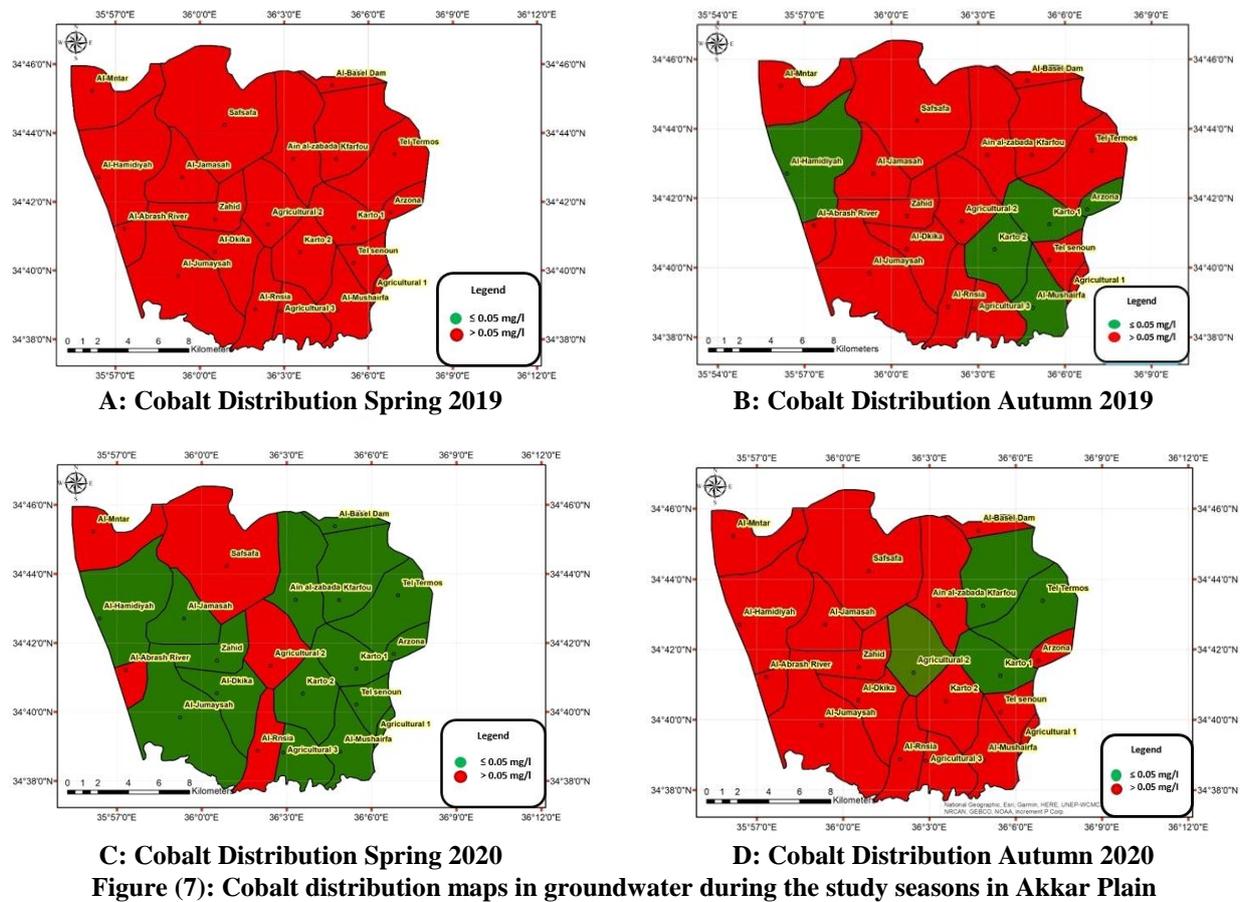


Figure (6): Average Cobalt concentrations in groundwater of Akkar Plain during different Season



## Conclusions:

Cobalt is widely present in Akkar Plain's groundwater. Results show that most of the samples collected have Cobalt concentrations higher than the permissible limit of 0.05 mg/L for drinking water.

Agricultural Well 1 had the highest Cobalt concentration of 0.107 mg/L. Karto 1 well had the lowest concentration of 0.054 mg/L. Cobalt concentration was higher in spring than in autumn. Spring 2019 had the highest average Cobalt concentrations among all seasons. Spring 2020 had the lowest. Season factor had the most significant impact on Cobalt distribution variance among studied factors.

Cobalt in Akkar Plain's groundwater is primarily caused by excessive use of Cobalt-containing fertilizers, untreated sewage sludge, irrigation from Cobalt-contaminated water bodies, and human activities. The COVID-19 quarantine led to a decrease in Cobalt concentration in spring 2020.

To prevent further pollution, it is recommended to take the following steps: monitor the sources of pollution, raise awareness, and promote eco-friendly agriculture in coastal plains with high groundwater levels. It is also important to follow the fertilizer guidelines provided by the Syrian Ministry of Agriculture, establish a sewage network in the area, and regularly maintain and restore the agricultural drainage network in the Akkar Plain. These measures will help to reduce pollution and protect the environment.

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