Inductively Coupled Plasma (ICP)

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Abstract

- The crushed powder from defined dust particle size fractions was analyzed using inductively coupled spectrometry plasma (ICP) for major and trace elements.
- The ICP was used for the determination of concentrations of trace elements and six major elements: (Al, Fe, Mg, Ca, Na, and K) and five minor elements (Ba, Cr, V, Ti, and Pb). They are quoted in part per million (ppm).
- Maps showing high and low concentrations of ICP among Kuwait.

ICP (Inductively Coupled Plasma) Spectrometry Analysis

The crushed powder from defined dust particle size fractions was analyzed using ICP to identify major and trace elements. The reason for using ICP to analyze major elements was

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because some samples had less weight than needed (7 g) for analysis by XRF, while only 2 g (± 0.05) of powder is used in the ICP method. The method used for dissolved sediment samples for ICP involved open evaporation of the sample with hydrofluoric acid, together with nitric acid (HNO_3), in a platinum crucible.

The ICP was used to determine the concentrations of trace elements and six major elements: (Al, Fe, Mg, Ca, Na, and K) and five minor elements (Ba, Cr, V, Ti, and Pb). The amounts are quoted in parts per million (ppm) (Fig. 5.1).

Iron (Fe)

Iron (Fe) plays a major role in the biochemical reactions within a marine environment and acts as a major feeder to microorganisms (e.g., phytoplankton, cyanobacteria). The average amount of iron within fallen dust varies from 13,000 to 57,000 ppm. The distribution of areas with higher concentrations of iron indicates the effect of northeastern wind coming from the Zagros Mountains. The southern coastal areas had the highest concentrations of iron. There were some areas with high iron concentrations in a straight line from Bubiyan Island in the northeast toward Arafat in the southeast. The lowest concentration of iron in Kuwait was recorded in March and September, while the highest was in December (Figs. 5.1 and 5.2).

Areas with high ICP concentration	Areas with low ICP concentration
Um Eish	Um Niqa
Salmiya	Ratqah
Shuaiba	Dibdibah
Khiran	Sulaybiyah
Parts of Bubiyan Island	Wafra farms

Aluminum (Al)

Aluminum as an element is a major indication of higher concentrations of alkali and plagioclase feldspar minerals. The average amount of aluminum within fallen dust varies from 3000 ppm to more than 80,000 ppm (average: 41,246 ppm). The distribution of areas with higher concentrations of aluminum is sporadic and without trend. September was an exceptional case; the Western Desert areas had lower concentrations than the coastal areas. The lowest concentration in Kuwait was in September, while the highest was in December (Figs. 5.3 and 5.4).

Areas with high ICP concentration	Areas with low ICP concentration
Salmi Abdulli Um Niqa Um Rimam Shuaiba	Subiyah Abdulli Roudhatain Kabd Wafra farms

Barium (Ba)

Barium (Ba) as an element is a major indication of higher concentrations of alkali and plagioclase feldspar minerals. The average amount of aluminum within fallen dust varies from 3000 ppm to more than 80,000 ppm (average: 41,246 ppm). The distribution of areas with higher concentrations of Ba was found mainly in three locations: Abdulli, Shuaiba, and northern Kuwait Bay in Sabah Al-Ahmed National Reserve. The lowest concentration in Kuwait was

recorded in June, while the highest was in March and September (Figs. 5.5 and 5.6).

Areas with high ICP concentration	Areas with low ICP concentration
Abdulli Um Eish Salmiya Shuaiba Burqan	Bubian Island Ubayriq Dibdibah Khur Fawaris Khiran

Calcium (Ca)

Calcium (Ca) as an element is a major indication of higher concentrations of plagioclase feldspars and heavy minerals. The average amount of calcium within fallen dust varies from 1247 ppm to more than 115,500 ppm (average: 48,318 ppm). The higher distribution areas cover most of Kuwait, but, on average, the northern areas had higher concentrations than southern Kuwait. The lowest concentration in Kuwait was in June, while the highest was in December (Figs. 5.7 and 5.8).

Areas with high ICP concentration	Areas with low ICP concentration
Salmi Ratqah Bubian Island Khiran Um Eish	Jal Al Zur Ubayriq Kabd Ahmadi Wafra farms

Fig. 5.1 Average iron (Fe) content in ppm within fallen dust in Kuwait (2010)

Fig. 5.2 Fe content in ppm within fallen dust in Kuwait (2010)

Chromium (Cr)

Chromium with iron plays a major role in the biochemical reactions within marine environments and acts as a major feeder to microorganisms (e.g., phytoplankton, cyanobacteria). The average amount of chromium within fallen dust

varies from 28 to 2128 ppm. The chromium higher distribution areas are similar to that of iron. Bubiya Island and areas around Kuwait Bay were the highest areas of chromium. The lowest concentration in Kuwait was in December, while the highest was in September (Figs. 5.9 and 5.10).

Fig. 5.3 Average aluminum (Al) content in ppm within fallen dust in Kuwait (2010)

Areas with high ICP concentration	Areas with low ICP concentration
Bubiyan Island	Salmi
Abdulli	Liyah
Jal Al Zur	Burqan
Salmiya	Qurain
Atraf	Wafra farms

Potassium (K)

Potassium (K) as an element is a major indication of higher concentrations of alkali feldspar minerals. The average amount of potassium within fallen dust varies from 848 ppm to more than 178,600 ppm (average: 18,035 ppm). The higher distribution areas of potassium are associated with major wind corridors in western (Salmi) and northeastern areas (Bubiyan and Subiyah) in Kuwait. The lowest concentration in Kuwait was in June, while the highest was in September and December (Figs. 5.11 and 5.12).

Areas with high ICP concentration	Areas with low ICP concentration
Parts of Bubiyan Island	Shuaiba
Um Eish	Wafra farms
Salmi	Sulaybiyah
Kabd	Ratqah
Khur Fawaris	Liyah

Magnesium (Mg)

The presence of magnesium (Mg) as an element indicates higher concentrations of heavy minerals. The average amount of magnesium within fallen dust varies from 1247 ppm to more than 115,500 ppm (average: 48,318 ppm). Magnesium's higher distribution areas are in the northern and northeastern sides of Kuwait more than in the south and far west. The lowest concentration in Kuwait was in September, while the highest was recorded in March (springtime with low wind activity) (Figs. 5.13 and 5.14).

Areas with high ICP concentration	Areas with low ICP concentration
Abdulli	Salmi
Subiyah	Ubayriq
Um Eish	Sulaybiyah
Atraf	Burqan
Kabd	Wafra farms

Sodium (Na)

The presence of sodium (Na) as an element indicates higher concentrations of alkali feldspar minerals and salt content within dust samples. The average amount of sodium within the fallen dust varies from 941 ppm to more than 62,700 ppm (average: 9091 ppm). The sodium higher

Fig. 5.4 Al content in ppm within fallen dust in Kuwait (2010)

distribution areas are associated with major wind corridors in northwestern areas (Um Al Madafi), with low concentrations in farms and preserved areas with dense vegetation. The lowest concentration in Kuwait was in March, while the highest was in June (Figs. 5.15 and 5.16).

Areas with high ICP concentration	Areas with low ICP concentration
Bubian Island	Salmi
Ratqah	Abdulli
Um Al Madafi'	Urayfijan
Liyah	Khur Fawaris
Salmiya	Wafra farms

Fig. 5.5 Average barium (Ba) content in ppm within fallen dust in Kuwait (2010)

Lead (Pb)

The presence of lead (Pb) and magnesium (Mg) as elements indicates higher concentrations of heavy minerals within the dust. The average amount of lead within fallen dust varies from 6 ppm to more than 8500 ppm (average: 2168 ppm). Lead's higher distribution areas cover the northeastern sides of Kuwait more than the south and far west, which might offer some indications regarding the source areas, especially the Mesopotamian Floodplain and the Zagros Mountains. The lowest concentrations in Kuwait were in December and September, while the highest was in March. Furthermore, there is another trend: a high lead concentration that extends from Um Al Madafi toward Atrah in Kuwait (Figs. 5.17 and 5.18).

Areas with high ICP concentration	Areas with low ICP concentration
Bubiyan Island	Ratqah
Subiyah	Ubayriq
Abdulli	Dibdibah
Um Al Madafi	Burqan
Atrah	Wafra farms

Titanium (Ti)

The average amount of titanium within the fallen dust varies from 4 ppm to 8873 ppm (average: 2328 ppm). The presence of titanium as an element indicates higher concentrations of heavy minerals within dust. The titanium distribution was higher in areas around Kuwait Bay, western areas, and the southern coastal zone of Kuwait, indicating higher concentrations than in the northern and central areas of Kuwait. The lowest concentration in Kuwait was in summer, during September and June, while the highest was in December and March (Figs. 5.19 and 5.20).

Areas with high ICP concentration	Areas with low ICP concentration
Subiyah	Bubiyan Island
Um Rimam	Abdulli
Salmiya	Um Eish
Shuaiba	Burqan
Ubayriq	Wafra farms

Fig. 5.6 Ba content in ppm within fallen dust in Kuwait (2010)

Vanadium (V)

The average amount of vanadium (V) within fallen dust varies from 11 to 153 ppm (average: 2328 ppm), which is the lowest concentration (in addition to thallium [TL]) of all the detected elements within dust fallout. The presence of vanadium as an element indicates higher concentrations of heavy minerals within dust. The highest distribution of vanadium was present around the coastal zone and north-eastern areas of Kuwait. The lowest concentration in Kuwait

was in December, while the highest was in March (Figs. 5.21 and 5.22).

Areas with high dust fallout concentration	Areas with low ICP concentration
Bubiya Island	Ratqah
Subiyah	Ubayriq
Abdulli	Dibdibah
Salmiya	Burqan
Um Rimam	Wafra farms

Fig. 5.7 Average calcium (Ca) content in ppm within fallen dust in Kuwait (2010)

Fig. 5.8 Ca content in ppm within fallen dust in Kuwait (2010)

Fig. 5.8 (continued)

Fig. 5.9 Average chromium (Cr) content in ppm within fallen dust in Kuwait (2010)

Fig. 5.10 Cr content in ppm within fallen dust in Kuwait (2010)

Fig. 5.11 Average potassium (K) content in ppm within fallen dust in Kuwait (2010)

Fig. 5.12 K content in ppm within fallen dust in Kuwait (2010)

Fig. 5.12 (continued)

Fig. 5.13 Average magnesium (Mg) content in ppm within fallen dust in Kuwait (2010)

Fig. 5.14 Mg content in ppm within fallen dust in Kuwait (2010)

Fig. 5.15 Average sodium (Na) content in ppm within fallen dust in Kuwait (2010)

Fig. 5.16 Na content in ppm within fallen dust in Kuwait (2010)

Fig. 5.16 (continued)

Fig. 5.17 Average lead (Pb) content in ppm within fallen dust in Kuwait (2010)

Fig. 5.18 Pb content in ppm within fallen dust in Kuwait (2010)

Fig. 5.19 Average titanium (Ti) content in ppm within fallen dust in Kuwait (2010)

Fig. 5.20 Ti content in ppm within fallen dust in Kuwait (2010)

Fig. 5.20 (continued)

Fig. 5.21 Average vanadium (V) content in ppm within fallen dust in Kuwait (2010)

Fig. 5.22 V content in ppm within fallen dust in Kuwait (2010)

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