The Atmospheric Pollution of Baghdad City, Iraq

Salih Muhammad Awadh
Department of Geology, College of Science, University of Baghdad. Baghdad-Iraq

Abstract

The atmospheric pollution in Baghdad was investigated by using rainwater as a media for monitoring of pollution and also compared with the atmosphere pollution at reference stations of Al-Sulaimaniya in north of Iraq and Al-Rutbah in Western Desert of Iraq. Rainwater sampling carried out at period extended from Nov. 2007 to April 2008. Thirty five samples of rainwater were collected at seven monitoring stations at Baghdad which is industrialized (Abu-Graib, Al-Khadraa, Al-Qadissiya, Al-Saydiya, Al-Dora, Al-Talbia and Al-Sha'ab), in addition to four samples were collected from each of Al-Sulaimaniya and Al-Rutbah, a cities which are free from industrial pollution in purpose to use them as a comparative reference samples.

All samples of rainwater analyzed for Ca^{2+}. Mg^{2+}, Na^{+}, K^{+}, SO_4^{2-}, Cl^{-}, NO_3^{-}., pH, TDS and EC. The hydrochemical characterization showed high participation of Ca^{2+} (67%) and Mg^{2+} (18%) in cations and SO_4^{2-} (50%) and Cl^{-} (29%) in anions. The total ions mass showed the trend cations and anions as: $Ca^{2+} > SO_4^{2+} > Mg^{2+} > NO_3^{-} > Cl^{-} > Na^{+} > K^{+}$.

The pH values of rainwater in Baghdad range from 6.1 to 7.5 and in average of 6.7. These values obviously refer to high fluctuation of the gases and suspended particulates in Baghdad atmosphere in comparison with Al-Sulaimaniya and Al-Rutba. The pH values of rainwater in Al-Sulaimaniya range from 7 to 7.5 with average of 7.3, and in Al-Rutba range from 7.3 to 7.5 with average of 7.5 indicating low pH fluctuate and homogenize atmosphere.

The pH value in the rain water in Baghdad tends to be slight acidic nature at the beginning of the rainfall, but it appears to have less acidity after the washing processes of atmosphere. The $SO_4^{2+}/(NO_3^{-}+Cl^{-})$ hydrochemical function suggest that the natural processes beside the anthropogenic activity are sources of the acidity.

Keywords: Rainwater. Pollution. Hydrochemistry. Atmosphere. Baghdad.

الخلاصة

تم التحري عن التلوث الجوي لمدينة بغداد باستخدام ماء المطر الذي أستعمل كوسط لمراقبة التلوث، كما تم مظاهاته مع التلوث الجوي لمدينتي السليمانية في شمال العراق، والرطبة في الصحراء الغربية للعراق. أجريت عملية نمذجة ماء المطر في الفترة الممتدة من تشرين الثاني–2007 الى نيسان –2008. تم جمع 35 عينة ماء مطر من سبع محطات مراقبة (أبو غريب والخضراء والقادسية والسيدية والدورة والطالبية والشعب)، بالاضافة الى أربعة عينات جمعت من كل من السليمانية والرطبة واللتان تعتبران مناطق غير ملوثة صناعياً، إذ تم استخدام هذه العينات كعينات مرجعية لغرض المقارنة. تم تحليل Mg^{2+} و Ca^{2+} و Na^{+} و K^{+} و SO_4^{2-} و pH و NO_3^{-} و Cl^{-} و TDS و EC في جميع عينات ماء المطر. لقد بينت الصفات الهيدروكيميائية المساهمة العالية للكالسيوم (67%) والمغنيسيوم (18%) بالنسبة للأيونات الموجبة، وساهمت الكبريتات (50%) والكلورايد (29%) بالنسبة للأيونات السالبة. بينت الكتلة الأيونية الكلية بان ترتيب الايونات السالبة والموجبة من الاعلى الى الأدنى هو:

$Ca^{2+} > SO_4^{2+} > Mg^{2+} > NO_3^{-} > Cl^{-} > Na^{+} > K^{+}$

تتراوح قيمة الدالة الحامضية في ماء المطر في بغداد من 6.1 إلى 7.5 وهي بالمعدل 6.7 . من الواضح إن هذه القيم تشير الى تذبذب عالي في نسبة الغازات والجزيئات العالقة في جو بغداد أذا ما قورن بجو السليمانية

والرطبة. تتراوح قيمة الدالة الحامضية في ماء مطر السليمانية من 7 الى 7.5 وبمعدل 7.3 ، وفي الرطبة تتراوح هذه الدالة من 7.3 الى 7.6 وبمعدل 7.5 مشيرة بذلك الى تذبذب واطي في الحامضية وتجانس الجو. تميل الدالة الحامضية في ماء مطر بغداد لتكون ذات طبيعة واطئة الحموضة في بداية التساقط المطري، ولكنها تبدو لتكون أقل حامضية بعد عملية غسل الجو بالامطار. تبين الدالة الهيدروكيميائية $SO_4^{2+}/(NO_3^- + Cl^-)$ بأن مصدر الحامضية هو العمليات الطبيعية ألى جانب العمليات البشرية.

Introduction

Rainwater is usually the most clean available water source, and it is a good agent for washing suspended particulates, aerosols, pollutant gases and smoke from the atmosphere [1]. These washed materials descend downward, thereafter they distribute on the surface or and penetrate subsurface as solute matters. All rainwater components consider as a significant control factors of rain water chemistry [2]. Generally, the climate of Iraq is dry hot in summer, whereas it is rainy cold in winter. However the precipitation period in Iraq mostly starts not continuously in January and it finishes in May approximately [3].

Desertification (dryness and dust storms) strongly participates in increasing of suspended material in atmosphere which are eventually made Baghdad atmosphere dusty and much turbid. Dust storms reach Iraq coming from adjacent territories of west and north like Saudi Arabia, Jordan, Syria and Turkey (Figure-1). The long time dryness period in addition to the biological activities contributed in supply the suspended particulates to the atmosphere making the vision range limited, but after rainfall the atmosphere become clear (Figure-2). In the last three decades (1980s, 1990s and some of 2000s), obviously the atmosphere of Iraq has been changed from worse to worst because the absence of environmental management, but before many years the environmental managers were starting to application the environmental laws.

Beside the natural factors, the anthropogenic processes play an essential role in air pollution [4]. The Anthropogenic processes in Baghdad at the last decade are highly increased and seem to be a considered factor able to emit an effective pollutant gases to the atmosphere. Baghdad is a capital of Iraq and it expresses a large city, more than six million persons live in [3]. It contains many factories use diesel, kerosene and gasoline as fuel. Iraq has ten refineries and topping units, the largest of which are the 150,000 bpd Baji north of Iraq, 140,000 bpd Basra at south of Iraq and 100,000 bpd from Al-Dora plants at Baghdad [5]. After 2003 people started use a small electrical generations in their houses in order to obtain the electricity power, because the main electrical generation stations and the transportation cables were damaged by war and security situation [5]. These small generators in addition to the automobile continuously emit vary gases to the atmosphere [1], In addition to those above, there are many quarries of row building materials, plaster and brick factories around Baghdad [6]. Because the acidic precipitation has an adverse effect on ecosystem and human [2], therefore this work is an attempt to specify the chemical characterization of rainwater at Baghdad, which is the first one of this type in Iraq and expresses an additional contribution to atmospheric pollution of Iraq employs the rainwater as a hydrochemical tool for monitoring and determining the atmospheric pollution generated from natural constituents and anthropogenic pollutants.

Study area

Seven monitoring stations (Abu-Graib, Al-Khadraa, Al-Qadissiya, Al-Saydiya, Al-Dora, Al-Talbia, and Al-Sha'ab) in Baghdad were selected for collecting the rainwater samples. Two monitoring stations, the first at Al-Sulaymaniya (Kurdstan region-north of Iraq) and the second one at Al-Rutba in the mid of Western Desert of Iraq were also selected as a reference stations (Fiqure-3). Baghdad is the capital lies in the centre of Iraq. It is large city contains many factories such as the station of electricity power generation (south Baghdad in Al-Dora), oil refinery (in Al-Dora), state company of vegetable oil, painting and plating company, companies of high and heavy industries, company of liquid batteries industry, brick factories in the east of Baghdad, quarries of building material around Baghdad, incinerators, so much an ancient cars, vehicles and a huge of electrical generations in houses, therefore Baghdad atmosphere characterizes by dusty atmosphere. Gases can emit from vary and different sources like some industrial processes, cars and vehicles exhausts electrical generations and etc. [2].

Al-Sulaimaniya and Al-Rutba are cities lies north and west of Iraq respectively, smaller than Baghdad, and they appear to have relatively a fresh air because they devoid from industrial factories therefore considered as a reference stations for air pollution correlating.

Materials and methods

Rainwater samples were collected at seven stations in Baghdad. Also other samples of rainwater were collected from Al-Sulaimaniya and Al- Rutba for correlating (Figure-3). All rainwater samples were collected by glassy funnel of 25 cm diameter fitted on polyethylene bottle, previously rinsed by distilled water to avoid dry precipitation, fixed on the roof of building at the sampling stations.

The period of sampling extended from Nov. 2007 to April 2008. pH, T.D.S and E.C. were determined immediately by PH and conductivity meter (Table-1). All samples of the rain water have filtrated through filtration paper no.42. Cations (Ca^{++}, Mg^{++}, Na^{+}, K^{+}) and anions (Cl^{-}, CO_3^{-}, SO_4^{2-}, and NO_3^{-}) were determined in the filtrates (Table-2), whereas the precipitates (suspended particulates) are weighted in each sample (Table-1) and used for mineralogical studying by microscope and X.R.D techniques.

Hydrochemical characterization of rainwater

The amount of rainfall and period between of precipitation events are a control factor of chemical composition of individual rain event (7). The percent contribution of cationic components (Ca^{++}, Mg^{++}, Na^{+}, K^{+}) is 63% , whereas the percent of acidifying components (SO_4^{2-}, Cl^{-}, and NO_3^{-}) is 37% (Figure-4a). Ca^{++} and Mg^{++} are the dominant cations forming 62% and 16 % of the total cations (Figure-4b) and 40%, 11% of the total ionic mass respectively. The sulfates appear to be predominant anions forming 50 %, and it follows by nitrate 26% and chloride 24% (Figure-4c) of the total anions. Sulfates, chloride and nitrates contribute 18%, 9 % and 9% respectively of the total a ionic mass (Figure 4a). The distribution pattern of ionic components in the rainwater show the Ca^{2+} SO_4^{2-} and Mg^{2+} are dominated (Figure-4d). The equivalent ratio of $SO_4^{2-}/(NO_3^{-} + Cl^{-})$ is used as an index for evaluating the relative significance of these ions to the acidity and alkaline, and the degree of anthropogenic activities [2]. The $SO_4^{2-}/(NO_3^{-} + Cl^{-})$ variation use to discriminate between the natural and anthropogenic source. Figure-5 shows the both natural and anthropogenic sources.

Acidic- alkaline characterization

All pH values at the nine monitoring stations indicate slight acidic nature of rainwater as compared to the reference level of 5.6 [8]. The average pH value of all monitoring stations are higher than 5.6 (Table-1). The average values of pH at all stations could be arranged from lowest to highest as following: Al-Dora (6.3) < Al-Khdraa (6.6) Al-Saydiya (6.7) < Al- (6.7) < Abu-Graib (6.8) < Al-Talbia (7.0) < Al-Sha'ab (7.2). The higher average of pH recorded in Al-Sulaimaniya (7.3) and in Al-Rutba (7.5) (Table-1). The pH of natural precipitation is generally controlled by the dissolved CO_2, and it is greatly influenced by the addition of acidic components (SO_2+NO_x) generated by civil and industrial activities [9]. The seven stations at Baghdad are normally influenced by anthropogenic activities. The much acidic precipitation has been recorded at Al-Dora (pH=6.3) (Figure-6). This attributed to the different gases especially SO_2, NO_3 and CO_2 which emit from four chimneys of the electrical station. The highest value of pH was recorded at Al-Sha'ab (7.6) (Figure-6d). Generally the first rainfall event at 2 Nov. 2007 and 11 Jan. 2008 characterized by low pH (6.3) at Al-Khadraa (Figure-6a), 6.5 at Abu-Graib (Figure-6b), 6.9 at Al-Sha'ab (Figure-6d), 6 at Al-Dora (Figure-6g) and 6.7 at Al-Talbia (Figure-6h), whereas relatively appear to be high at Al- Qadyssiya (7.1) (Figure-6c) and 6.9 at Al-Saydiya (Figure-6f). This attributes to the nature of type of the suspended particulates [2].

The lowest concentration of SO_4^{2-} and NO_3^{-} found at Al-Khadraa, whereas the highest found at Al-Dora (Table-2 and Figure-6i). Also the TDS and EC appear to have highest value at Al-Dora (Table-1, Figure 7d), but the lowest value was recorded at Al-Khadraa (Table-1, Figure-7a). Mostly the rate of suspended particulates was high at the first rainfall event, thereafter decreases during other alternated rainfalls (Figure-8). The typical pattern can be seen at Al-Sha'ab (Figure-8g).

Mineralogy of suspended particulates

The microscopic study of the suspended particulates showed a presence of very fine grains of flaky shapes as suspended particulates in Baghdad atmosphere. This shape appears to be an essential factor made those particles as a suspended dust in the atmosphere. Fine grains of calcite and clay minerals beside the plant fibers are dominated. The natural constituent appear mixed with industrial wastes like carbon ash and originated from combustion the fossils fuel, and stripes of plastic material derived from industrial wastes (Figure-9). All those constituents are light and eventually descend downward to the earth surface with rainwater during precipitation. XRD technique permit that the calcite, orthoclase, clay minerals and rare gypsum the major constituents of the suspended particulates. The monitoring stations may be arranged from highest to lowest calcite content as following:

Abu-Graib, AL-shaab, Al-Talbia, Al-Qaissiya, Al-Dora, Al-Kadraa. This feature is concordant and fit with Ca^{2+} content (Table-2). The clay minerals appear to be found in Al-Qaissiya.

Discussion and conclusions

The pH of natural precipitation is controlled by CO_2 and it also is greatly influenced by the additional acidic compounds like SO_2 and NO_x generated by civilian and industrial activities [9]. Acidic pollution in the atmosphere like H_2SO_4 and HNO_3 mainly originated from combustion of fossils fuels in automobiles, building for heating and the industry [10; 11; 12]. The pH values of rainwater at all monitoring stations tend toward acidic rather than alkaline. The rainfall in Al-Dora characterized by slight acidic nature, this ascribe to industrial reasons (The highest value of SO_4^{2-} and NO_3^- is recorded in Al-Dora) which belong to the acidic gases emitted from electrical station and refining factory in Al-Dora. These gases disperse randomly at all directions, thereafter, dissolve within rainwater causing acidity. Wind direction plays an essential role in transportation of pollutant gases. Sometime winds change its direction toward Al-Saydiya, and because Al-Saydiya and Al-Qadissiya are closely near of Al-Dora, therefore the pH tend to be acidic rather than alkaline. Barrie, 1985 [13] estimated from his observations in Canada that on the average, 60% of sulfates in rainwater originated from in-cloud SO_2 oxidation, and only 40% was due to the uptake of sulfate particulates. Mineralogical study reveals no gypsum and any minerals may generate such these anions. This reflect the gas role that appears daily in Al-Dora sky. The major atmospheric acidity of Abu-Graib, Al-Talbia and Al-Sha'ab come from automobile exhausts, but this acidity appear to have diluted by dissolving the earth alkali metals ($Ca^{2+}$and Mg^{2+}) in the rainwater. The highest concentration of Ca^{2+} was recorded at Abu-Graib coming from anthropogenic sources. Abu-Graib lies closely near the cement and plaster factories including limestone crushing which generate fine dust move upward and dispersed according to the wind direction. Ca^{2+} and Mg^{2+} in rainwater caused alkalinity [14]. Ca^{2+} Mg^{2+} and SO_4^{2-} are the dominant ions in the rainwater of Baghdad, The Ca^{2+} Mg^{2+} cations are mostly originated from eroded surface rocks and soil which mainly calcareous and the Ca^{2+} partly from human activities during crushing and calcinations of the raw materials (marly limestone) required for the cement industry. The SO_4^{2+} and NO_3^- ions are mainly originated of industrial processes. The order abundance of cations and anions in the rainwater at Baghdad was generally $Ca^{2+} > SO_4^{2+} > Mg^{2+} > NO_3^- > Cl^- > Na^+ > K^+$. The rainfall event causes temporary diluting the atmosphere. The pH value appears to be slight acidic nature at the beginning of rainfall because the washing and dissolving processes of a huge suspended particles and gases that accumulated during dry seasons, but it tends changing toward alkaline nature attributed to the atmospheric washing. Also the Ca^{2+}, Mg^{2+}, K^+ are originated from calcite, orthoclase and clay minerals which were derived from surface soil and ascend upward by air or by dust storms. Baghdad atmosphere chemically seems inhomogeneous. Al-Khadraa atmosphere appears the best and characterizes by lowest TDS value, but Al-Dora atmosphere contains highest TDS value (Table-1 and Figure-7) which has highly affected by industrial activites and fluctuated pH. The two references stations at Al-Sulaimaniya and Al-Rutba have approximately not fluctuated pH and the lowest value of TDS. This ascribes to the constancy of atmospheric constituents and unpolluted. Depend on pH values, the studied areas could be arranged according to the rate of their pollution from highest to lowest as Baghdad>Al-sulaymania>Al-Rutba. The $SO_4/(NO_3+Cl)$ function suggest that the anthropogenic source beside the natural sources are responsible the acidity. Acid rain causes the rapid chemical weathering of rocks and may leach toxic metals such as Pb out of soil [15]. The nature of rainwater at Baghdad has acidity make it an affective solvent especially on buildings that limestones have been built, Also it will effect on soil with time changing its chemical and mineralogical composition.

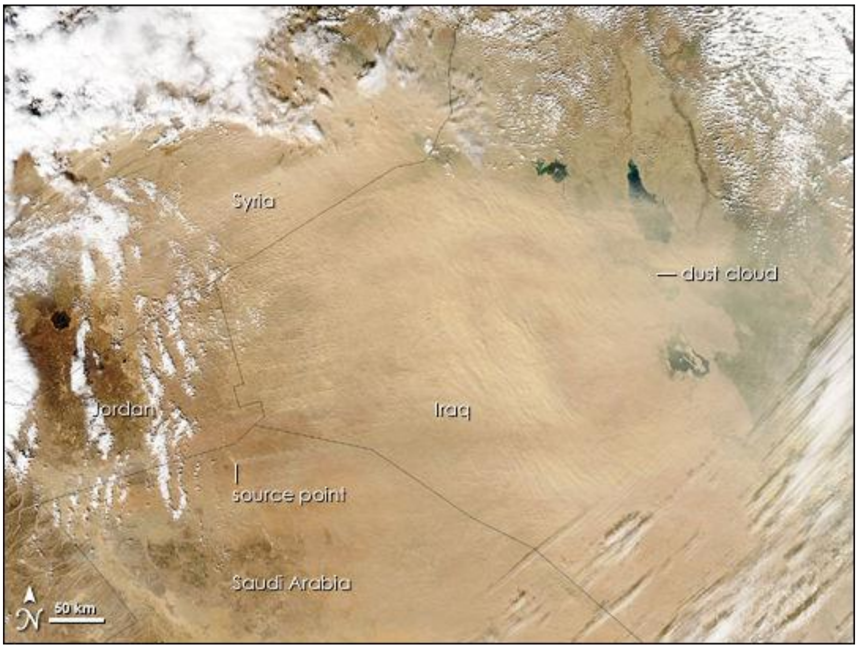

Fig.1: Satellite image shows dust storm covers the western south part of Iraq progresses toward Baghdad coming from adjacent western territories of Iraq.

Fig.2: photo of Al-Dora city after rainfall event shows a clear atmosphere. The four chimneys of electrical stations are appeared.

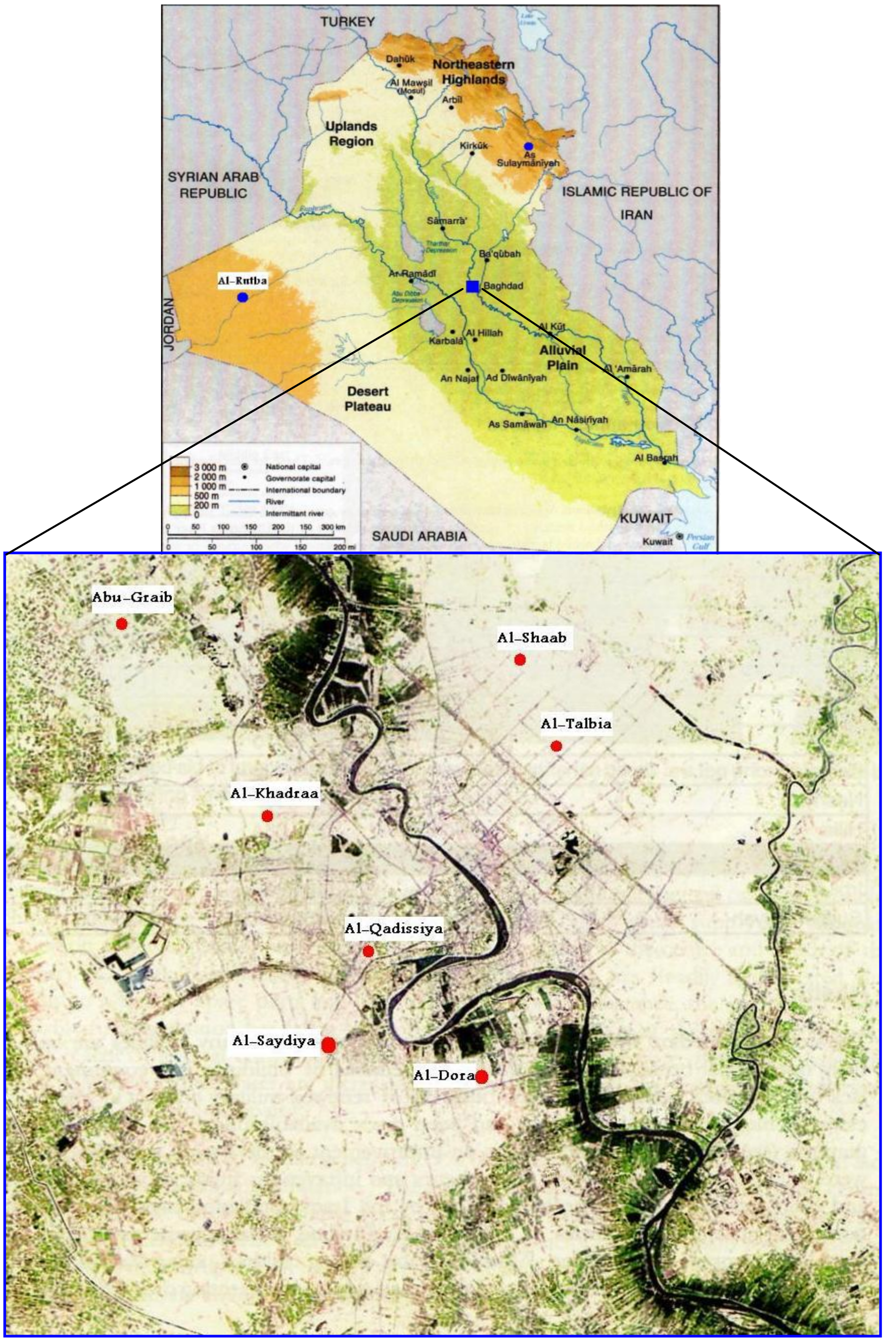

Fig.3: Location map of the study area shows the seven monitoring stations. (Spot image, August 2002: False color composite, band 4, 3 and 1.image courtesy of digital globe, ele.3200m)

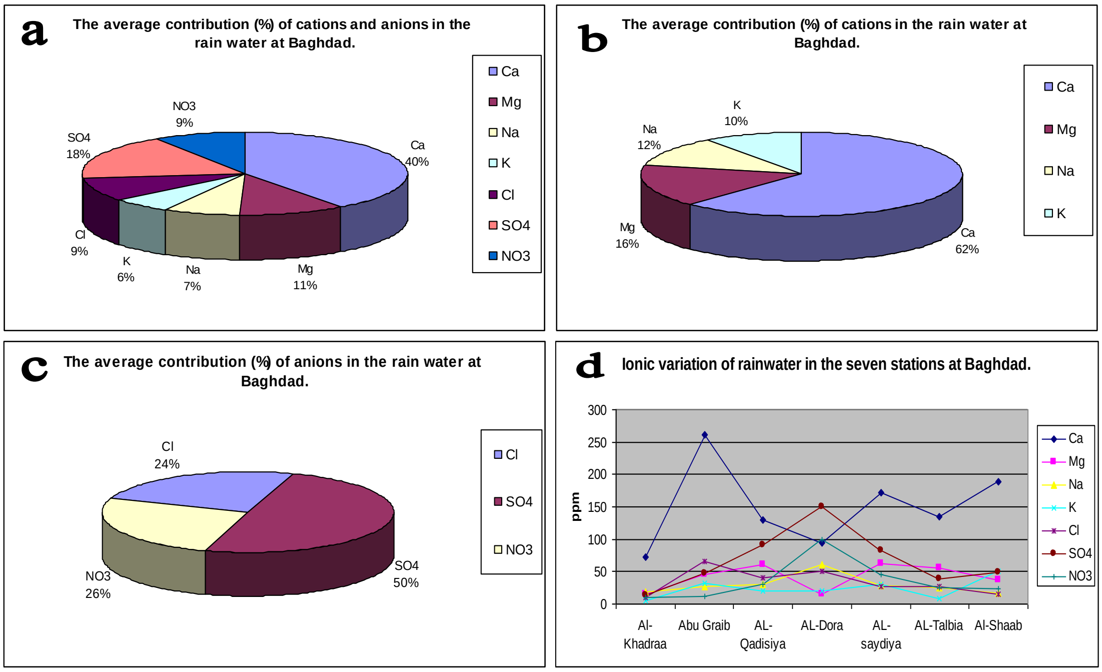

Fig. 4: The contributions (%) of ions in the rain water at Baghdad.

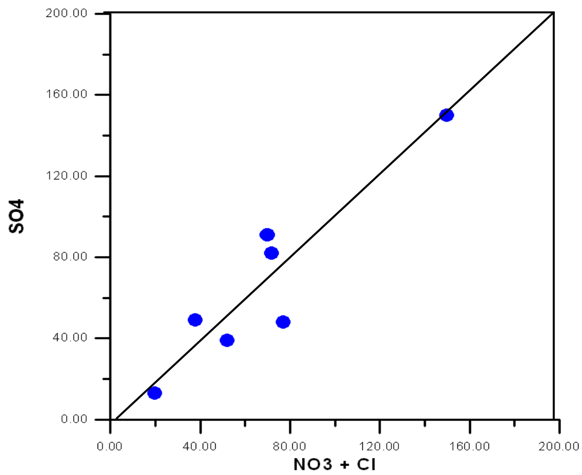

Fig. 5: Variation diagram between SO_4^{2-} and (NO_3^-+ Cl^-).

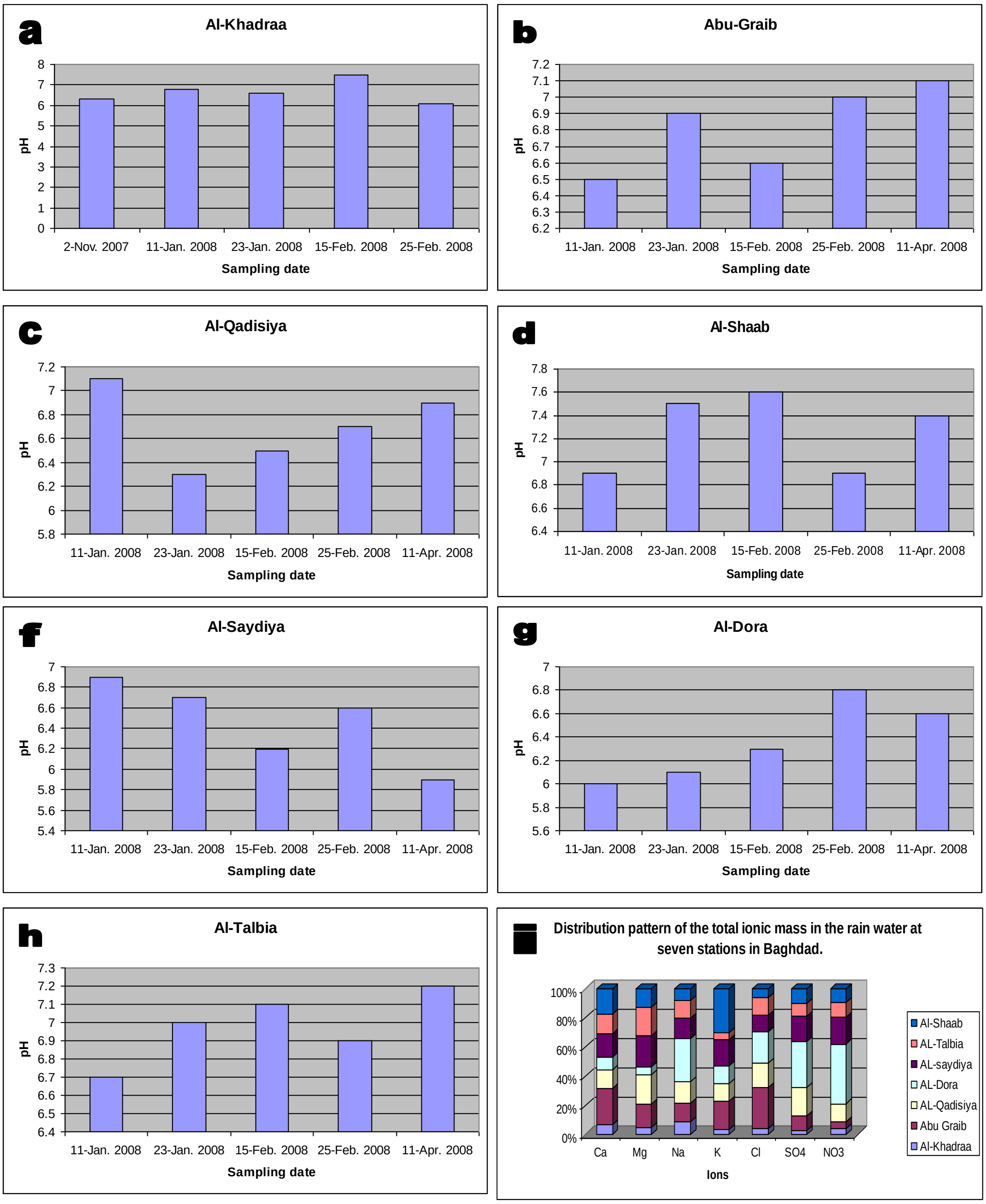

Fig. 6: The pH values and total ionic mass in the rain water of seven monitoring stations in Baghdad.

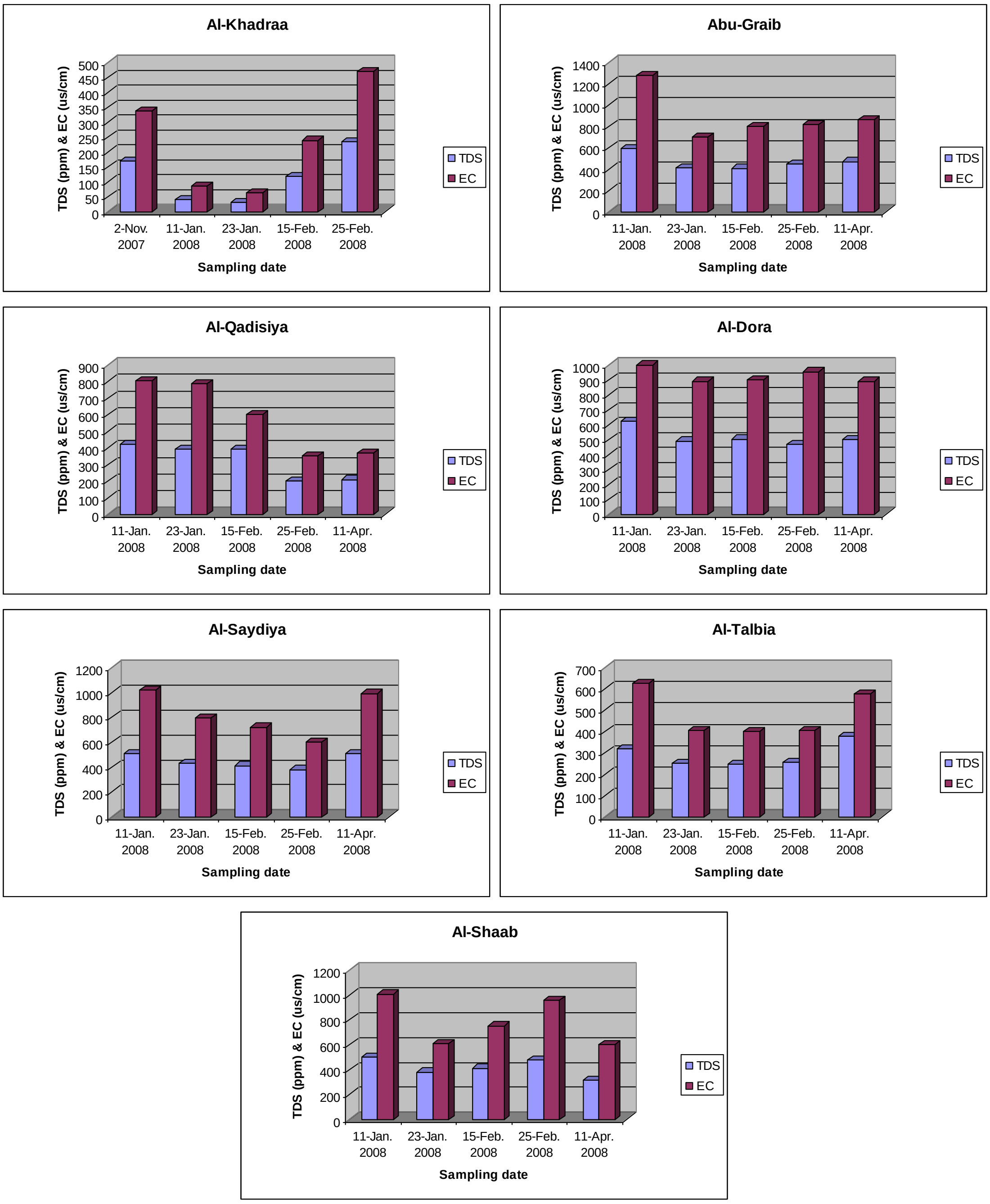

Fig. 7: The TDS and EC versus sampling dates at the seven monitoring stations of Baghdad.

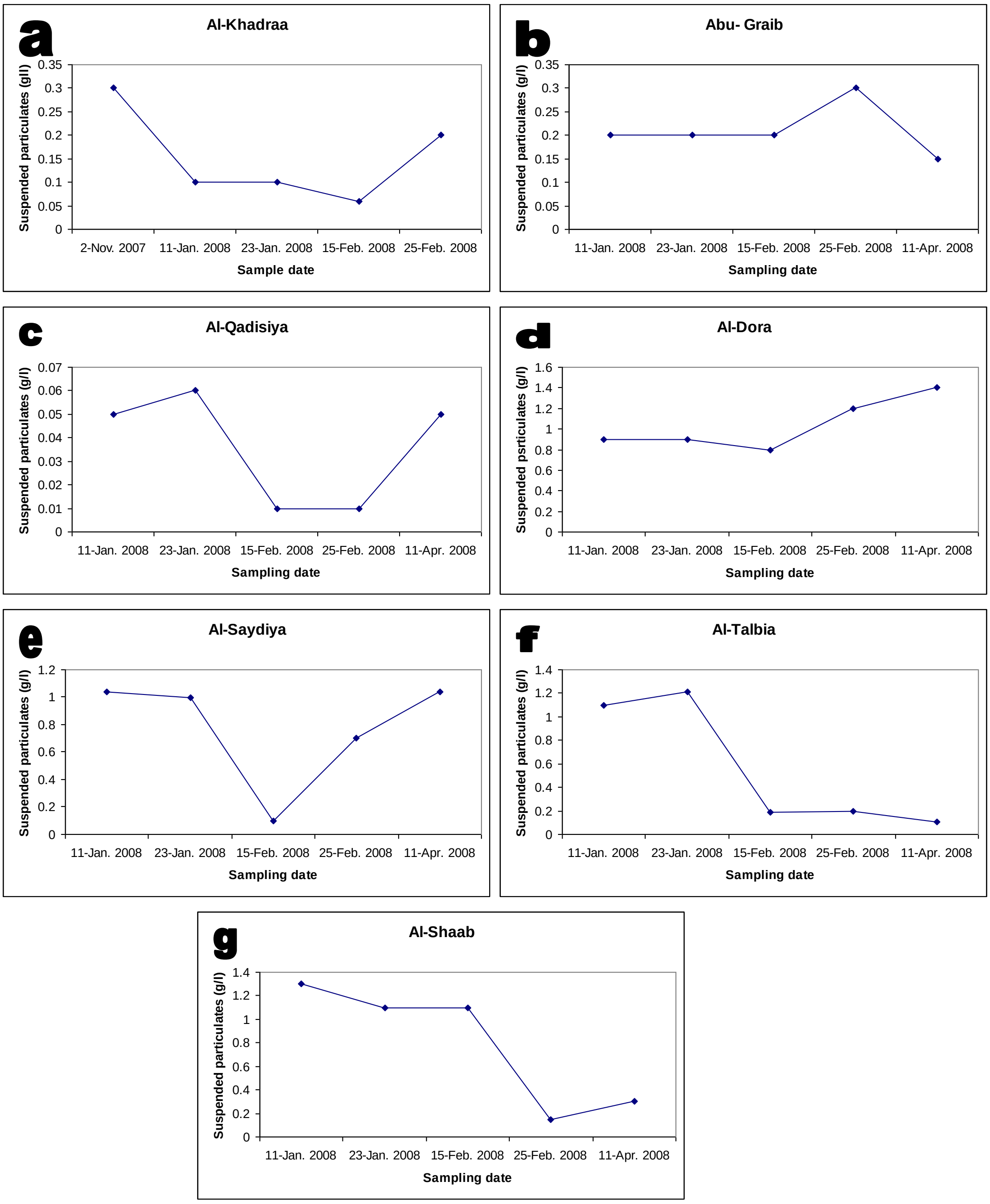

Fig. 8: The distribution patterns of the suspended particulates at the seven monitoring stations of Baghdad.

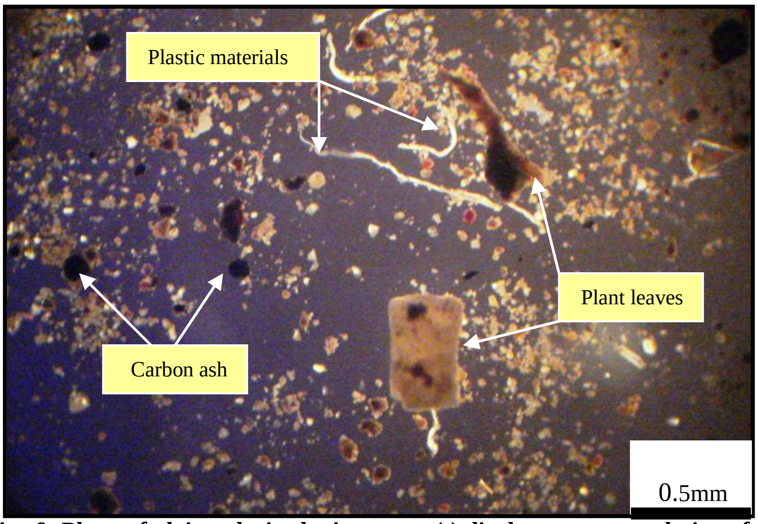

Fig. 9: Photo of plain polarized microscope (-) displays an accumulation of fine grain of calcite and clay minerals as well as the organic matters and plastics.

Monitoring station	date	pH	average pH	TDS ppm	EC us/cm	suspended particulate g/l

Table 1: The results of pH, TDS (ppm), EC(us/cm) and suspended particulates (g/l) in nine monitoring stations.

Al-Khadraa	2-11-2007	6.3	6.6	170	338	0.3
	11-1-2008	6.8		41	87	0.1
	23-1-2008	6.6		30	64	0.1
	15-2-2008	7.5		117	239	0.06
	25-2-2008	6.1		234	470	0.2
Abu-Graib	11-1-2008	6.5	6.8	690	1276	0.2
	23-1-2008	6.9		410	699	0.2
	15-2-2008	6.6		406	800	0.2
	25-2-2007	7.0		450	820	0.3
	11-4-2008	7.1		470	860	0.15
Al-Qadissiya	11-1-2008	7.1	6.7	420	805	0.05
	23-1-2008	6.3		393	786	0.06
	15-1-2008	6.5		390	600	0.01
	25-2-2008	6.7		200	350	0.01
	11-4-2008	6.9		209	371	0.05
Al-Dora	11-1-2008	6.0	6.3	620	299	0.09
	23-1-2008	6.1		490	890	0.9
	15-2-2008	6.3		503	900	0.8
	25-2-2008	6.8		470	953	1.2
	11-4-2008	6.6		499	890	1.4
Al-Talbia	11-1-2008	6.7	7.0	320	625	1.1
	23-1-2008	7.0		250	405	1.21
	15-2-2008	7.1		245	400	0.19
	25-2-2008	6.9		255	403	0.2
	11-4-2008	7.2		378	575	0.11
Al-Shaab	11-1-2008	6.9	7.2	500	1005	1.3
	23-1-2008	7.5		380	607	1.1
	15-2-2008	7.6		410	751	1.1
	25-2-2008	6.9		478	953	0.15
	11-4-2008	7.4		315	599	0.3
AL-Saydiya	11-1-2008	6.9	6.7	509	1019	1.04
	23-1-2008	6.7		429	795	1.0
	15-2-2008	6.2		410	720	0.1
	25-2-2008	6.6		380	600	0.7
	11-4-2008	5.9		510	991	1.04
Al-Sulaimaniya	5-1-2008	7.0	7.3	6	15	0.0
	7-2-2008	7.5		38	79	0.01
	12-2-2008	7.5		63	128	0.02
	3-4-2--8	7.0		60	120	0.01
Al-Rutba	10-1-2008	7.3	7.5	101	225	0.1
	15-2-2008	7.5		71	110	0.07
	23-2-2008	7.6		48	76	0.5
	3-4-2008	7.7		51	82	0.1

Table 2: Ionic concentrations in in the rain water.

Station	Ca2+			Mg2+			Na+			K+			Cl-			SO4 --			NO3-		
	min.	av.	max.	min.	av.	max.	min.	av.	max.	min.	av.	max.	min.	av.	max.	min.	av.	max.	min.	av.	max.
Al-Khadraa	30	73	180	14	15	16	8	10.5	13	5	5.6	7	8	10.3	12	10	13	16	8	10	15
Abu-Graib	200	262	300	38	45	51	23	27	31	30	32	33	60	65	67	42	48	52	10	12	14
Al-Qadissiya	92	130	140	53	60	65	25	30	34	17	20	27	31	40	49	85	91	98	20	30	37
Al-Dora	80	95	120	13	15	20	51	60	75	18	20	22	45	50	55	131	150	169	94	100	170
Al-Talbia	110	135	152	40	56	61	20	25	30	8	8.5	10	23	25	27	32	39	50	20	25	43
Al-Shaab	166	188	225	34	37	43	16	17	20	38	50	61	11	15	22	27	49	62	19	23	29
AL-Saydiya	140	172	210	50	63	71	25	29	31	22	30	35	13	27	32	41	82	95	30	45	60
average	**151**			**40**			**28**			**24**			**33**			**67**			**35**		
Al-Sulaimaniya	4.2	6.6	8.0	4.1	5.0	6.3	5.0	5.5	6.3	2.0	2.5	3.4	3.4	6.0	7.9	3.1	5.4	6.6	2.	2.1	3.0
Al-Rutba	38	40	59	8	10	17	5	5	5	5	10	17	5	5	5	3	3	3	3	3	3

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