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Impact of the cement dust emitted from the South Cement Factory in Tafila/Jordan on plant diversity of the surrounding area

Sawsan A. Oran* and Hamad M. F. Abu Zahra

Department of Biological Sciences, Faculty of Sciences, University of Jordan, Amman- Jordan.

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Observations and analysis based on using scanning electron microscope (SEM) micrographs have been carried out to describe the impact of pollution caused by the emitted cement dust from the cement factory on the plant diversity of the surrounding area of Al-Rashadyah/ Tafila cement factory. Leaves of five selected species of *Crataegus aronia, Gundelia tournefortii, Anchusa strigosa, Lactuca orientalis* and *Astragalus bethlehmiticus,* from five localities within the study area based on their easily sampling and their availability in all localities during the period of collection were used for assessing the impact of the cement dust. A species of *C. aronia* was chosen as control species grown in Wadi Shuaib 200 km to the north of the study area. The results indicate that plants species grown near the cement factory are covered with higher amounts of dust accumulations than those grown at long distance from the factory. The analysis of SEM shows many different elements deposited on the leaves of all plants that have been sampled in the study area such as: calcium, potassium, aluminum and others, and it was found that calcium has the highest concentration than the other mineral salts.

Key words: Plant diversity, pollution, Tafila, Jordan.

INTRODUCTION

Plant diversity in Jordan faces the danger of degradation and loss of many plant species as a result of both adverse human impact and environmental factors. Moreover, these changes are occurring at natural rapid rate as results of human activities, such as land-use, climate change, nitrogen deposition, species introductions, increase in population, over exploitation of plant and animal species, pollution of soil, water and air. Biodiversity in Jordan is exposed to several threats leading to sharp decline in most of the Jordanian flora and the extinction of several species. Many species have been at risk, or were classified as threatened or endangered or even extinct on the regional and global levels. This situation resulted from various anthropogenic activities, as well as from a general lack of knowledge and awareness (Oran, 2005, 2014; AL-Eisawi, 2000, 2013; Al-Mohaisen et al., 2005). Yet serious attempts have been made to protect and conserve the plant genetic resources of the country. Many reserves have been established, but the laws and regulations governing

*Corresponding author. E-mail: oransaw@ju.edu.jo.

them are not always enforced and dozens of species are facing dramatic pressure (Oran, 1994; EPA, 2001). The plant diversity in Tafila governorate South of Jordan is very rich. A number of 383 species belong to 198 genera and 48 families were recorded (Oran, 2014).

Cement dust is one of the factors that affect plant biodiversity; it can settle on the surrounding vegetation and affect plant growth, directly by covering the leaf surface and indirectly through effects via the soil. The effects of dust on vegetation were reviewed by Farmer (1993) who provided a comprehensive review of the literature of the effects of dust on plants and their communities.

Kamel (1981) pointed out that dust emitted from the chimneys of cement kilns contains major concentrations (≥ 1%) of iron and trace amounts (≤ 0.1%) of manganese, cobalt, nickel, zinc and cadmium, which are known for their potential effect on air pollution. Other similar studies also dealt with the evaluating of the effects on plants growing around cement factories. Misra et al. (2000) investigated the responses of some common plants in Uttar Pradesh state/ India to cement dust pollution and to identify the tolerance to pollution of several species which are good collectors of cement dust and are resistant to pollution. Salami et al. (2002) studied the impact of cement dust emissions from West African Portland Cement Factory at Ewekoro in Southwestern Nigeria on the surrounding vegetation, from this study “it was found that chlorophyll contents leaf abundance, leaf area, woody species density and basal area increased significantly with increasing distance from the factory site”. Farmer (1993) explained the effects of dust pollution on vegetation types. Zvereva et al. (2008) investigated the general pattern of changes in species richness and diversity of vascular plants due to environmental contamination, and associated habitat changes imposed by point polluters and identified the sources of variation in the response of plant communities to industrial pollution at a global scale. Lisenko et al. (2012) suggested spectronephelometric methods to determine microphysical characteristics of dust in aspiration air and off- gases in cement plants. Edral and Demirtas. (2010) studied the effects of cement flue dust from a cement factory on stress parameters and diversity of aquatic plants; the toxicity and deficiency caused by cement dust pollution in wild plants growing around a cement factory was investigated by Mutlu et al. (2012); they determined the effects of cement dust pollution on contents of some significant essential elements (P, S, K, Ca, Fe and Cl) in wild plants using wavelength-dispersive spectrometer X- ray fluorescence (XRF) technique. The effects of the emissions of the Mergheb cement factory in North West Libya on the vegetation were evaluated. The impact of stack emissions of the factory on the abundance, frequency, density and number of species at each site surrounding the factory under the effect of wind direction was evaluated by Okasha et al. (2013). A study by assessed the potential of bioindicator/ biomonitor plants to determining pollution extent of toxic metals in plant leaves from the industrial area of the city Gaziantep in Turkey.

This study is focusing on analyzing and identifying the major pollutants emitted from the cement factory of Al-Rashadeyeh in Tafila governorate, south of Jordan, on the leaf surface of five local wild plant species collected from the surrounding area of the cement factory, and one plant species as a control from Wadi Shuaib area 200 km north of Al- Rashadeyeh cement factory, and its impact on the diversity of plant species.

MATERIALS AND METHODS

Five leaf samples for five plant species were collected randomly from the surrounding area of Al- Rashadeyeh cement factory (Map 1. A), occasional visits to the study area have been made and random collection of the species such as *Crataegus aronia*, *Gundelia tournefortii, Anchusa strigosa, Lactuca orientalis* and *Astragalus bethlehmiticus* was made. As far the control specimen *Crataegus aronia* leaf was collected from Wadi Shuaib which is 200 km north of the study area that is remote from the pollution area, as shown in (Map 1. B). It is good to know that leaf surface of *C. aronia, L. orientalis,* and *A. bethlehmiticus* is smooth and for *G. tournefortii* and *A. strigosa,* is hairy- spiny.

The scanning electron microscope (SEM) was used in this experiment for its ability to analyze small particles on the surface of the leaves. The type of SEM used is FEI Quanta 200 SEM at the Department of Geology in Yarmouk University. From each location, the location of each collected specimen from the factory is shown in Table 1; one leaf was selected at random from specimen collected. A 1 cm^2 size was cut from each of the leaves by a blade. A small drop of glue was placed on each stub. The leaf samples were placed on top of the glue and were pressed gently to be fixed on the stub.

Stubs with fixed specimens were analyzed under the SEM. Stubs were then placed in the SEM chamber. The high vacuum pressure was used to evacuate the chamber and high voltage was also used to turn the electron beam on for providing the best backscattered electrons (BSE) and X-ray microanalysis.

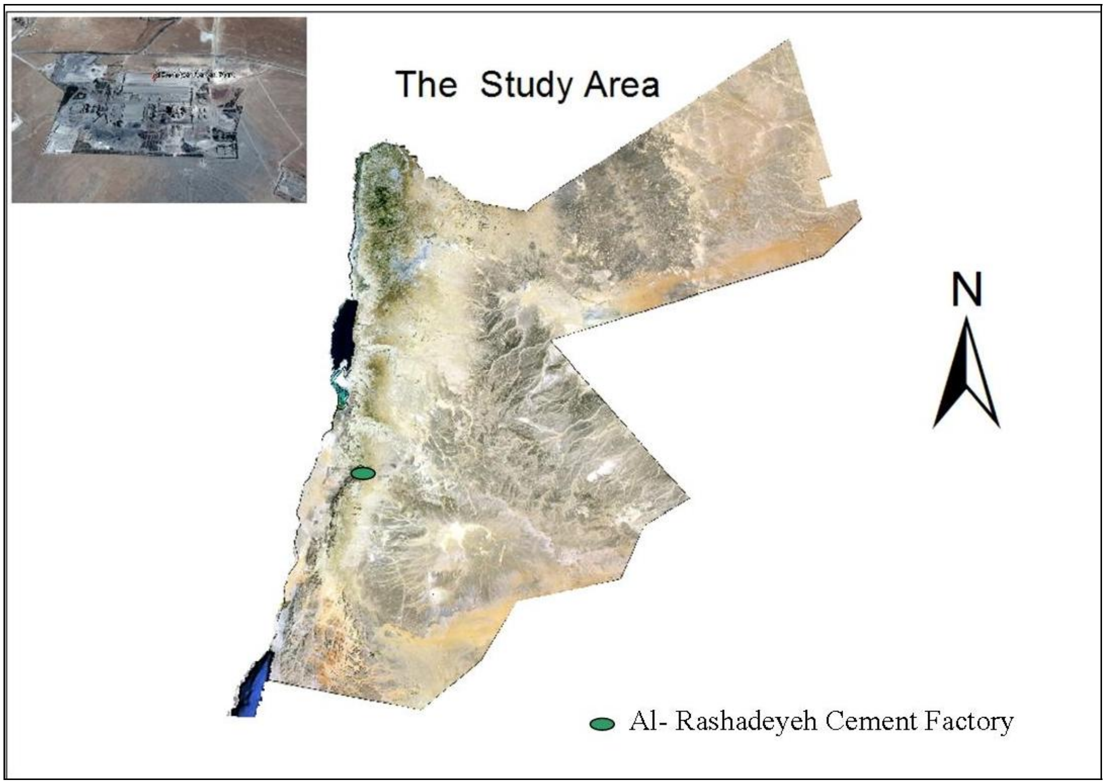
In microanalysis the area of analysis and parameters are set and the software of the SEM controls the data analysis. The X-ray microanalysis of the particles determines which elements are present on the surface of the leaf and places all elements detected in a spectrum. No test has been made to test the elements binding capabilities for the leaves of the different studied plant species; calculations of element composition are then provided for every specimen and finally a digital micrograph is given. In this study different magnifications were set according to the sample used.

RESULTS

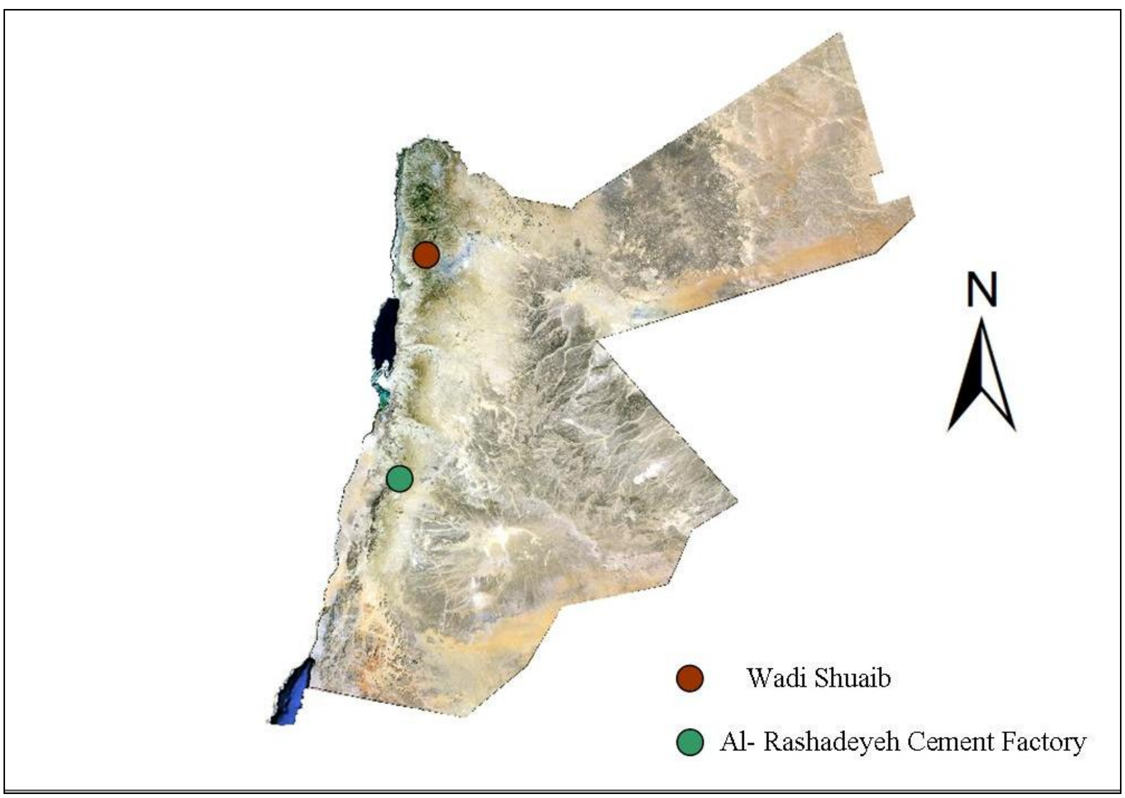
Dust observation

Scanning electron microscopy (SEM) analysis

It can be observed from Figures 1 to 6 that there is a considerable amount of cement dust accumulated in all of the five plant species that have been collected and



Map 1A. Showing Al- Rashadeyeh cement factory.



Map 1B. Showing Al- Rashadeyeh cement factory and Wadi Shuiab area.

Table 1. Leaf identification and sampling information for the SEM analysis.

Leaf number	Leaf Identification	Location
1	*Crataegus aronia*	Locality (1) 50 m North of the factory
2	*Gundelia tournefortii*	Locality (2) 100 m East of the factory
3	*Anchusa strigosa*	Locality (3) 500 m West of the factory
4	*Lactuca orientalis*	Locality (4) 750 m South of the factory
5	*Astragalus bethlehmiticus*	Locality (5) 1000 m North East of the factory
6 (control sample)	*Crataegus aronia*	Wadi Shuaib

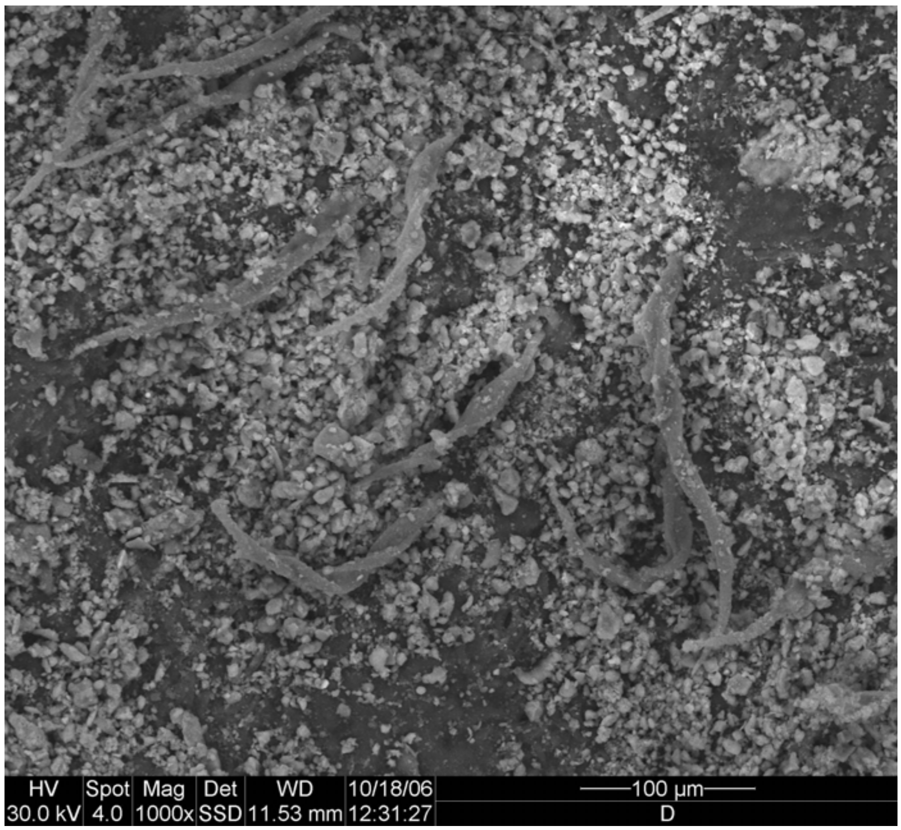


Figure 1. SEM micrograph for *Crataegus aronia* (leaf 1) taken from locality 1.

sampled comparing to the control plant *C. aronia* which was collected from Wadi Shuaib and has almost a clean surface.

Localities 1, 2, 3 and 4, which were 50, 100, 500 and 750 m North, East, West and South of the cement plant, respectively tend to have the highest concentration of dust particles, due to the fact they are the closest to the cement factory, and subjected to traffic. This is followed by locality 5 which is about 1000 m North-East of the factory.

Therefore leaf sampling from all these localities shows that particle concentrations on leaves collected from these localities will decrease from locality 1 to 2 to 3 to 4 and to 5.

X- Ray microanalysis

The particles deposited on the leaves are from the air and the surroundings, analysis of the particles will provide information about the particulate air pollutants in the area sampled. The higher the concentration of particles in the area, the higher the concentration of particles on the leaf surface will be. The weight percentage and the chemical composition of the particles on the leaf surface are represented in Tables 2 to 7.

The X- ray microanalysis illustrated that the leaves had a wide range of particle concentrations and they are represented as weight percentage in the tables provided with each graph (Graphs 1 to 6), these are ranged from a

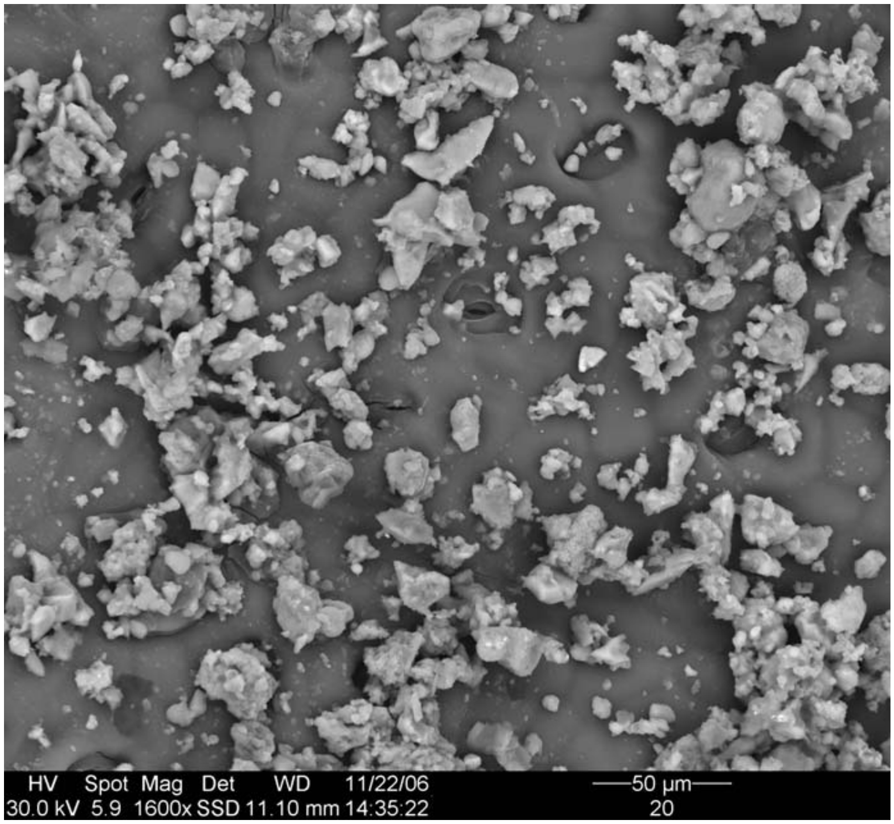


Figure 2. SEM micrograph for *Gundelia tournefortii* (leaf 2) taken from locality 2.

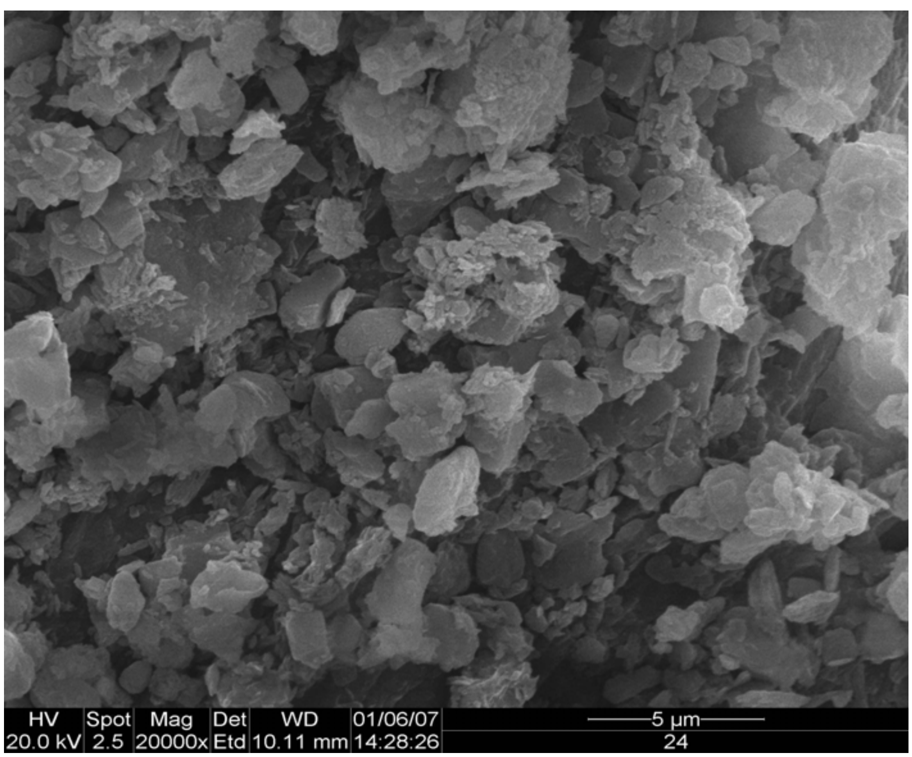


Figure 3. SEM micrograph for *Anchusa strigosa* (leaf 3) taken from locality 3.

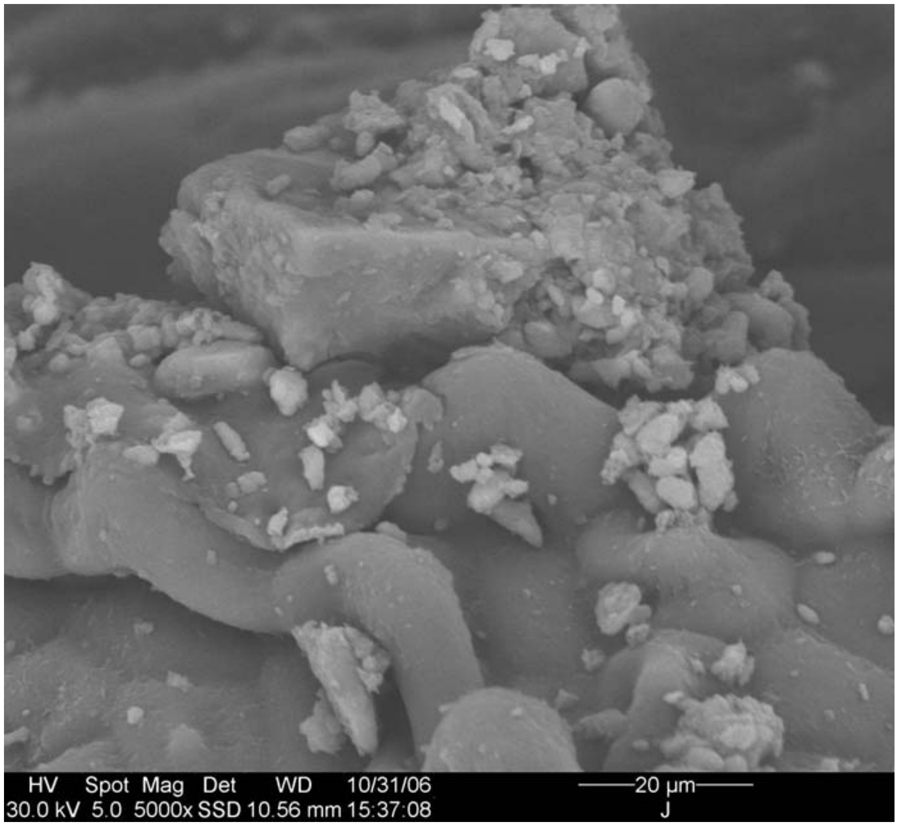


Figure 4. SEM micrograph for *Lactuca orientalis* (leaf 4) taken from locality 4.

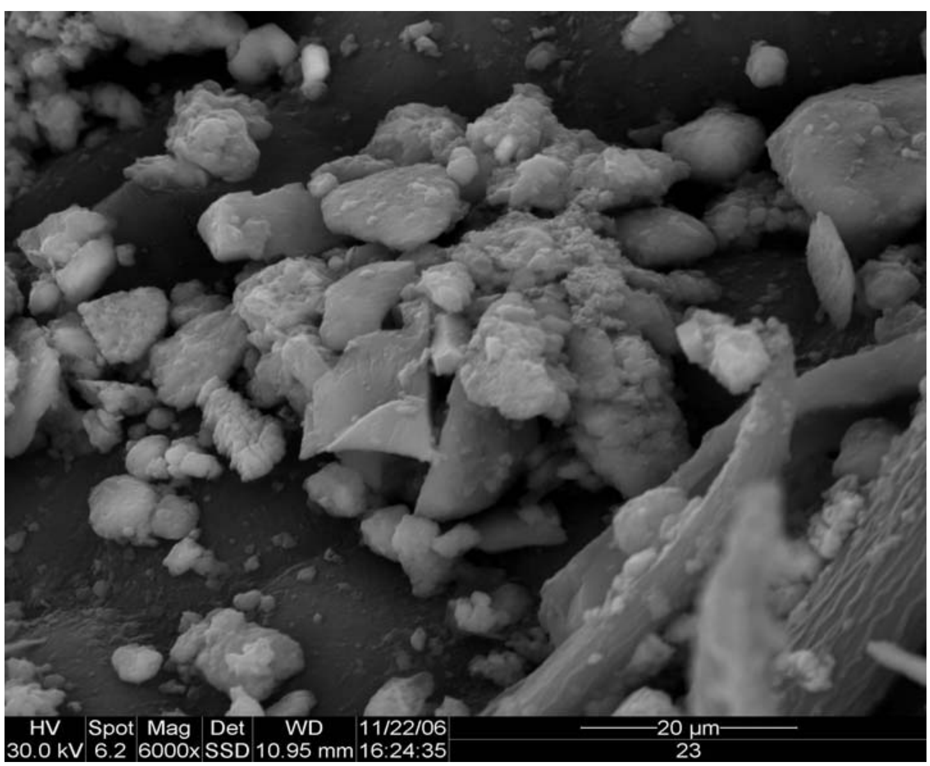


Figure 5. SEM micrograph for *Astragalus bethlehmiticus* (leaf 5) taken from locality 5.

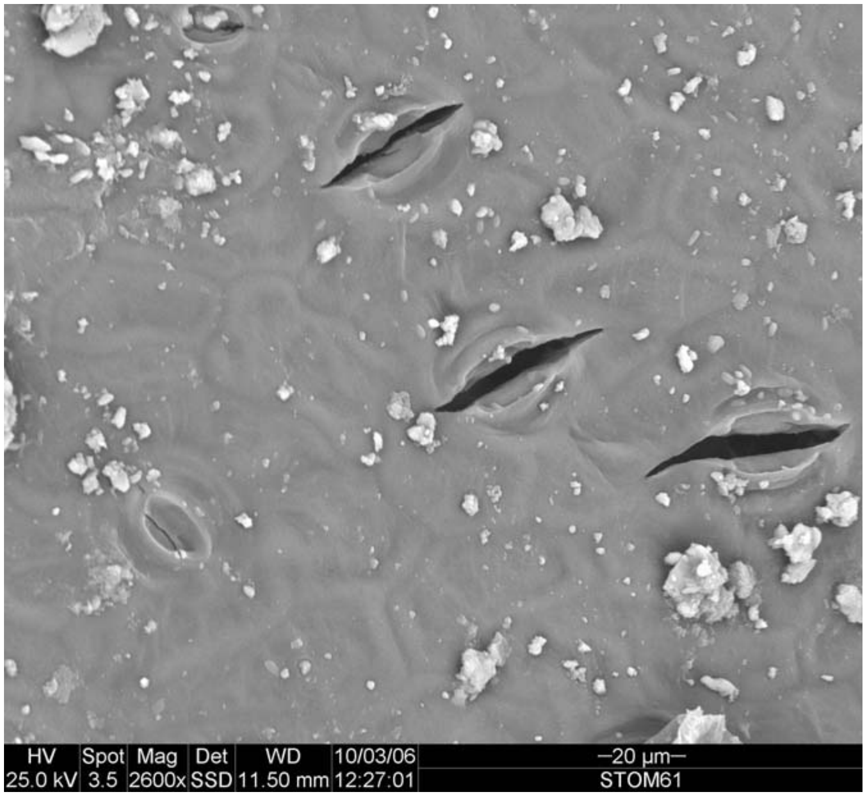


Figure 6. SEM micrograph for *Crataegus aronia* (leaf 6, control sample) collected from Wadi Shuaib.

Table 2. X-ray spectrum of particles for leaf 1.

Element	Weight % (Wt %)
O	53.66
Na	0.51
Mg	1.5
Al	1.85
Si	6.36
S	1.22
K	1.23
Ca	31.91
Fe	1.76
Total	100

Table 3. X-ray spectrum of particles for leaf 2

Element	Weight % (Wt %)
O	55.53
Mg	2.39
Al	3.87
Si	9.74
K	1.08
Ca	23.67
Ti	0.53
Fe	3.19
Total	100

minimum of 0.17% (leaf 4), to 55.53% (leaf 2).

Graph 1 determines which elements are presented in the particles found on the surface of leaf 1 and places them in a spectrum. It is clear from this graph that calcium (Ca) is the highest element found and has a high weight percentage followed by silicon (Si) then sulfur (S), oxygen (O), aluminum (Al), potassium (K) and magnesium (Mg) (Table 2).

Table 3, shows the elemental composition data and provides a spectrum for each element found in dust particles on the surface of leaf 2. The weight percentage for all of the elements is arranged as follows:
Ca > Si > Al > Mg > K > Fe > Ti.

The elemental composition in Table 4 for leaf 3 based on weight percentage is arranged as follows: Ca > Si > Al > Fe > Mg > K > Cu.

In the same way the graph in Table 5 also shows the arrangement of the elemental composition in leaf 4 as follows: Ca > Si > S > K > Al > Mg > Fe > Na > Ti. Both graphs in Tables 6 and 7 provide the elemental composition and the spectrums for leaves 5 and 6,

Table 4. X-ray spectrum of particles for leaf 3.

Element	Weight % (Wt %)
O	54.14
Mg	2.04
Al	4.83
Si	17.19
K	1.07
Ca	16.27
Fe	3.7
Cu	0.76
Total	100

Table 5. X-ray spectrum of particles for leaf 4.

Element	Weight % (Wt %)
O	51.76
Na	1.24
Mg	2.22
Al	3.78
Si	15.98
S	1.61
K	2.96
Ca	18.49
Ti	0.17
Fe	1.81
Total	100

Table 6. X-ray spectrum of particles for leaf 5.

Element	Weight% (Wt %)
MgO	4.72
Al_2O_3	12.17
SiO_2	40.39
K_2O	0.88
CaO	32.34
TiO_2	0.84
Fe_2O_3	8.65
Total	100

showing their appearance based on weight percentages as follows respectively:

(i) Ca > Si > O > Al > Fe > Mg > K > Ti.
(ii) Ca > O > C > P > Si > Al > Mg.

Moreover the results on Tables 2 to 7, shows that the concentration of the different recorded elements were higher on the leaves of smooth surface than the leaves of hairy- spiny surface.

Table 7. X-ray spectrum of particles for the control sample.

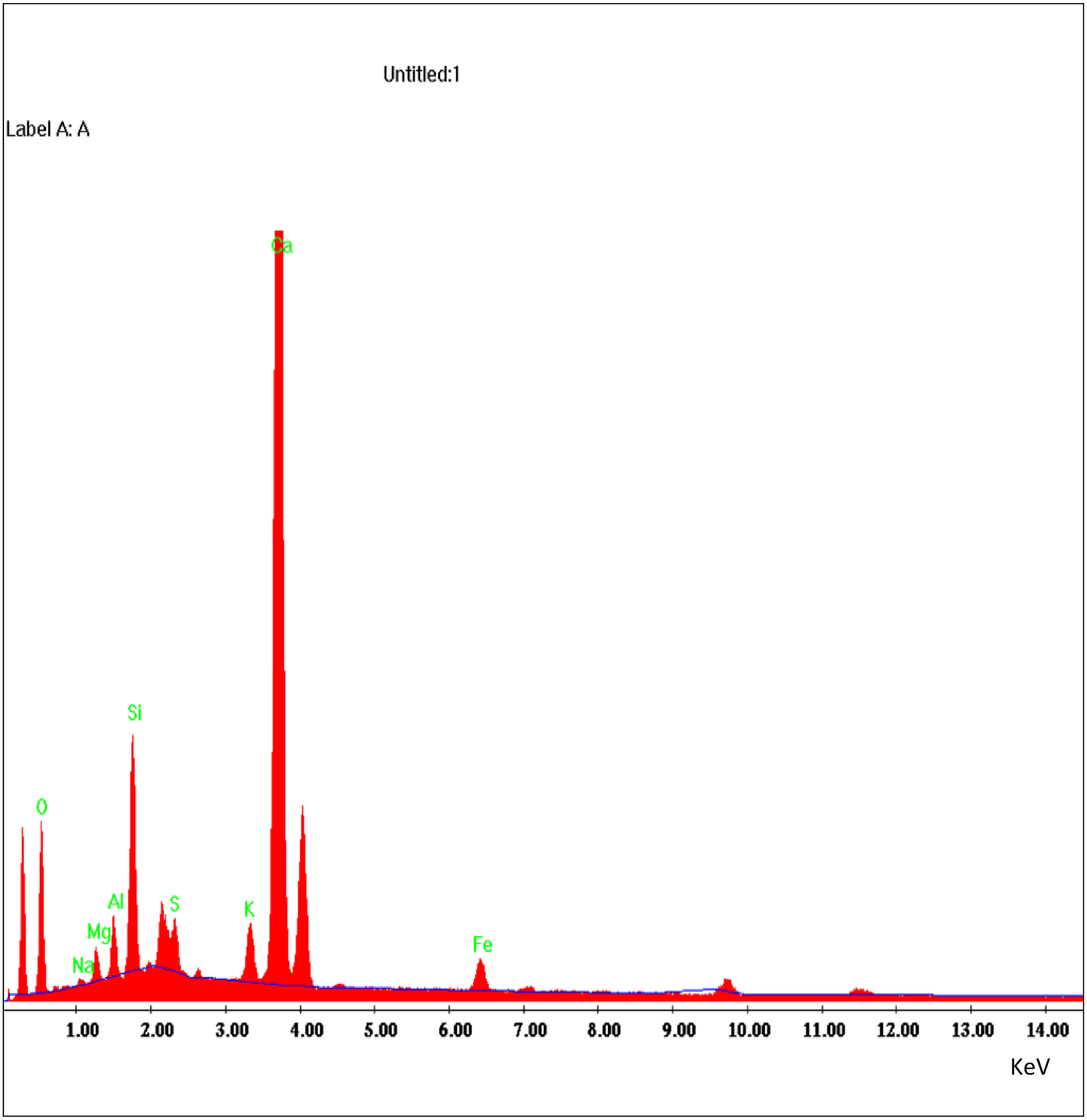
Element	Weight % (Wt %)
C	7.33
O	51.33
Mg	0.9
Al	0.73
Si	1.01
P	0.6
Ca	38.09
Total	100

DISCUSSION

The study area or the area surrounding Al- Rashadeyeh cement factory in Tafila south of Jordan is considered as a Mediterranean mountainous area dominated by *Juniperus phoenicea* degraded forests and a nearby natural reserve called “Dana”, which is the safe heaven of many local wild plant species in Tafila area. The establishment of the cement factory in that important natural site was unwise decision made by the authorities; however, the cement dust would be the major pollutant in the area surrounding Al- Rashadeyeh cement factory and would affect the human and other living communities. It can block the stomata of leaf surface, might affect the photosynthesis, respiration, transpiration, and may cause leaf injury symptoms, as a result of that the productivity of these plants would be declined and consequently a reduction in vegetation growth, abundance and species loss. The inhibition of all these processes depending on particle size and concentration of dust that will affect stomata functions.

Dust emitted from the chimneys of the cement factory contains major concentrations of Fe, Co, Ni, Zn, Cd and Pb; these elements are transported with the particulates and are known for their effect on air pollution as reported by previous studies, but this current analysis shows that dust particles deposited on leaf surface contains major concentrations of Ca, Si, O, K, Al and Mg, these elements are known to be the components of the plant cells, but at the same time Si, Al, K and part of O and Ca are the main components of clay and limestone, which are the raw materials for cement production and could come to the plants from the soil itself.

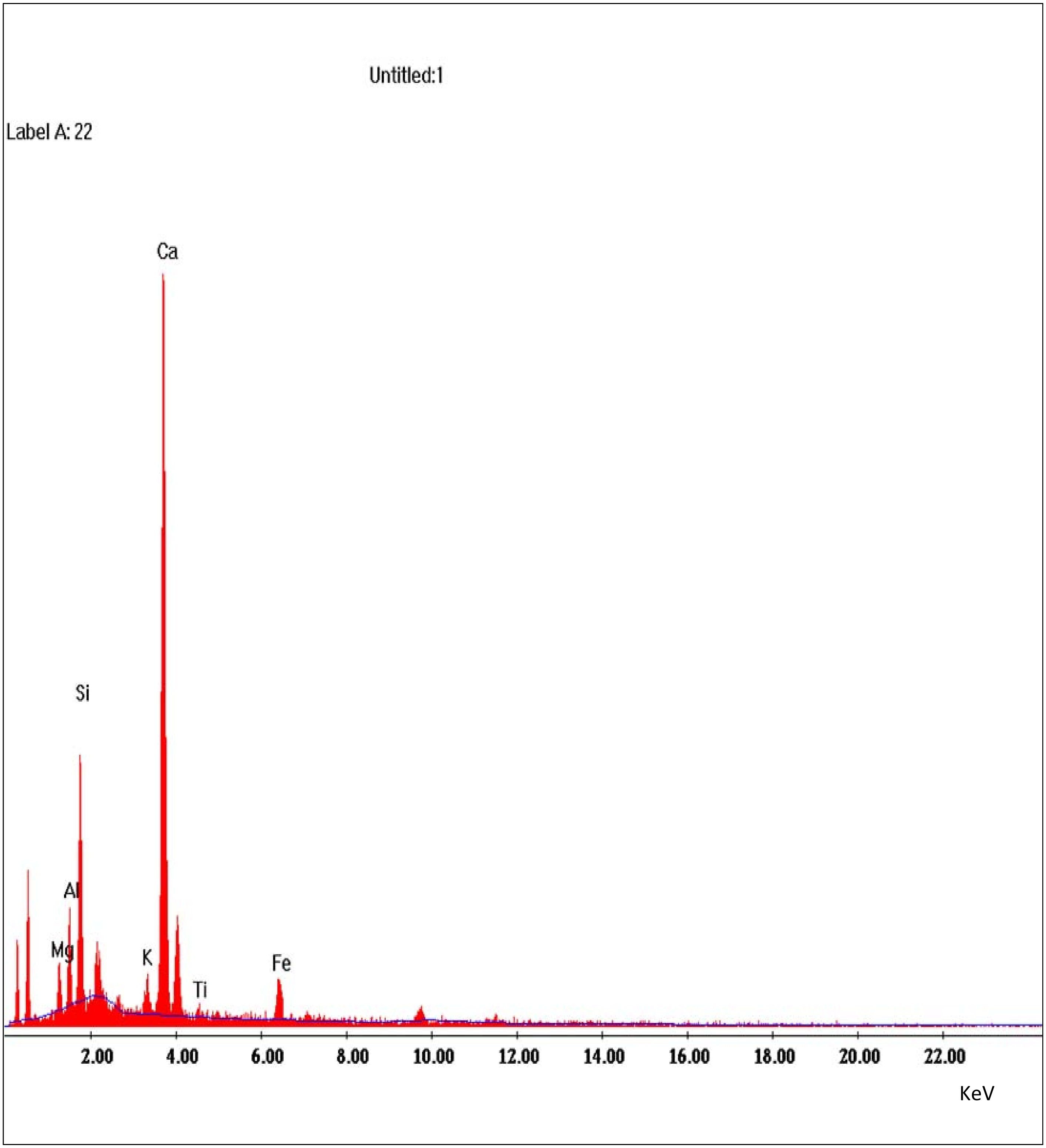
It is worth mentioning that the direction of prevailing wind in Jordan is usually coming from west to east, north to south; occasionally the wind changes direction from east to west and thus easterly wind specially in the cold days of the year or hottest days of the year since the wind is coming from dry- cold desert in winter and dry- hot weather in the summer time, similarly in parts of changing seasons in the year within the period between spring and summer, the prevailing wind is changing direction from south to east carrying lots of dusty winds



Graph 1. X-ray spectrum of particles for leaf 1.

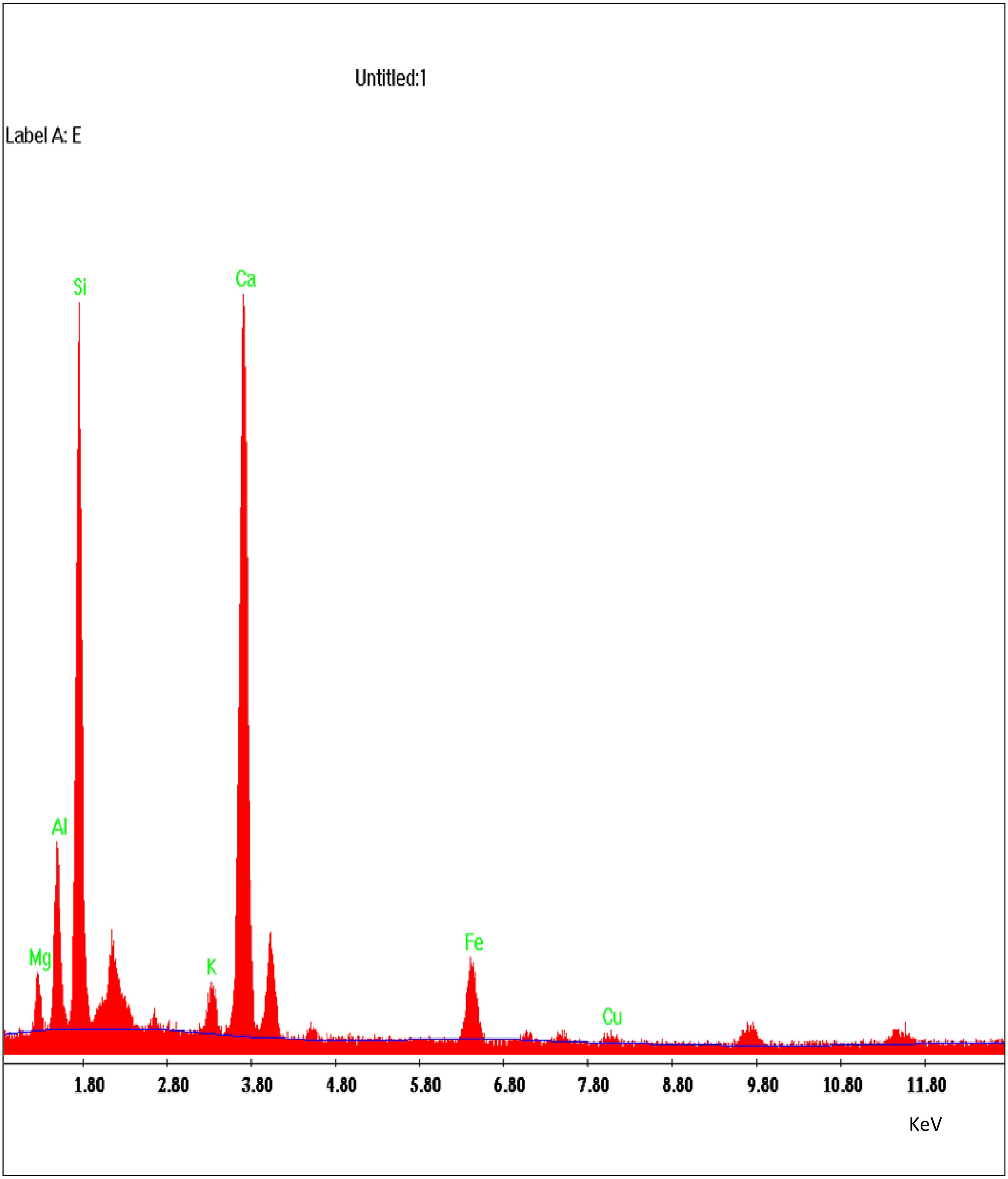
that is known locally and regionally as " *Khamaseen* winds". As mentioned previously the dominant prevailing wind is westerly and northerly changing occasionally through easterly and southerly. Therefore the directions of prevailing winds have influence on the deposition of dust particles in the study area.

The results of this small scale study would asses the impact of the types of dust emissions or pollutants on leaf surface of local wild plant species that probably affect the survival of wild local plant species and also will be affecting the diversity of endemic species and those of economic value.

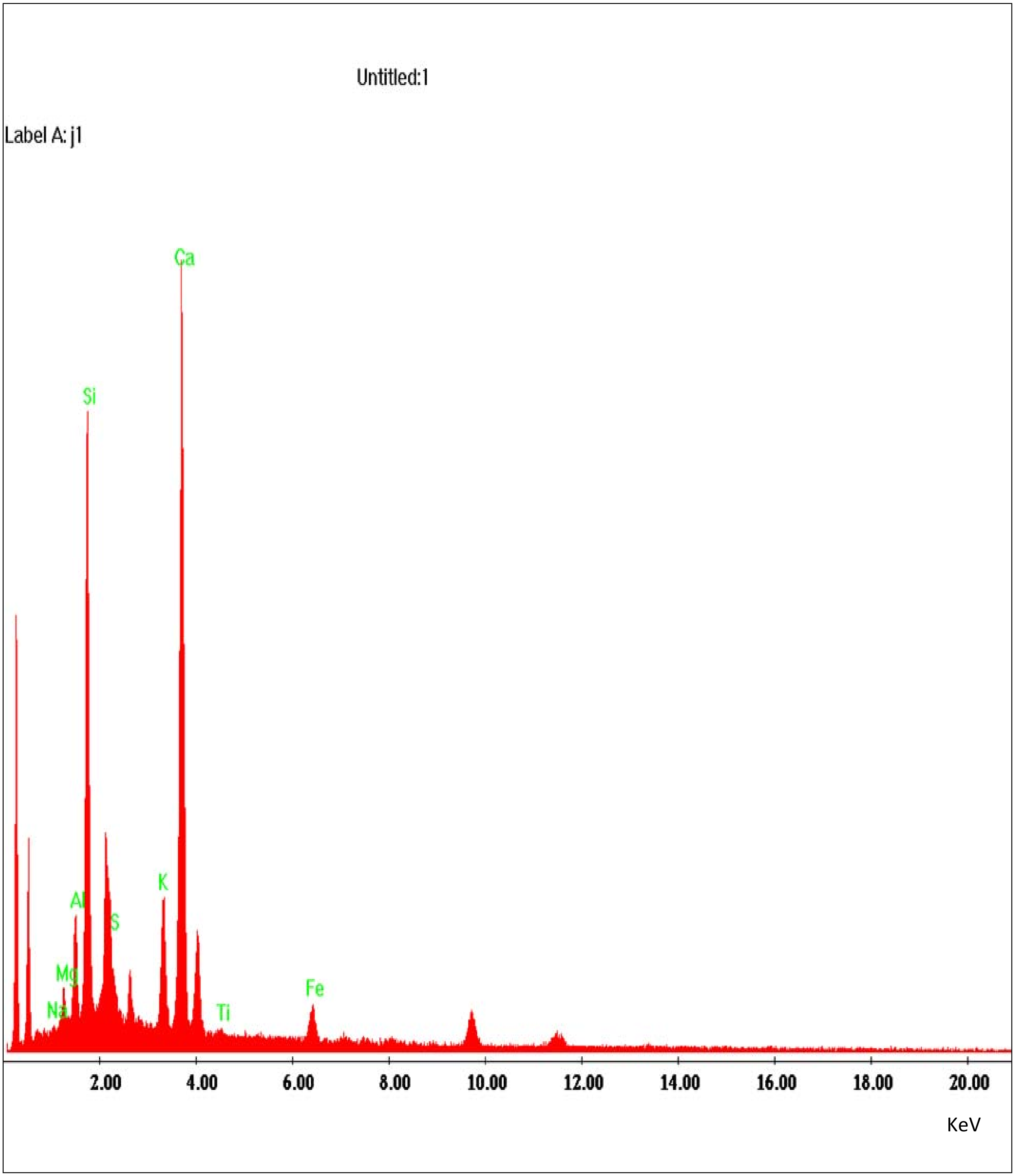


Graph 2. X-ray spectrum of particles for leaf 2

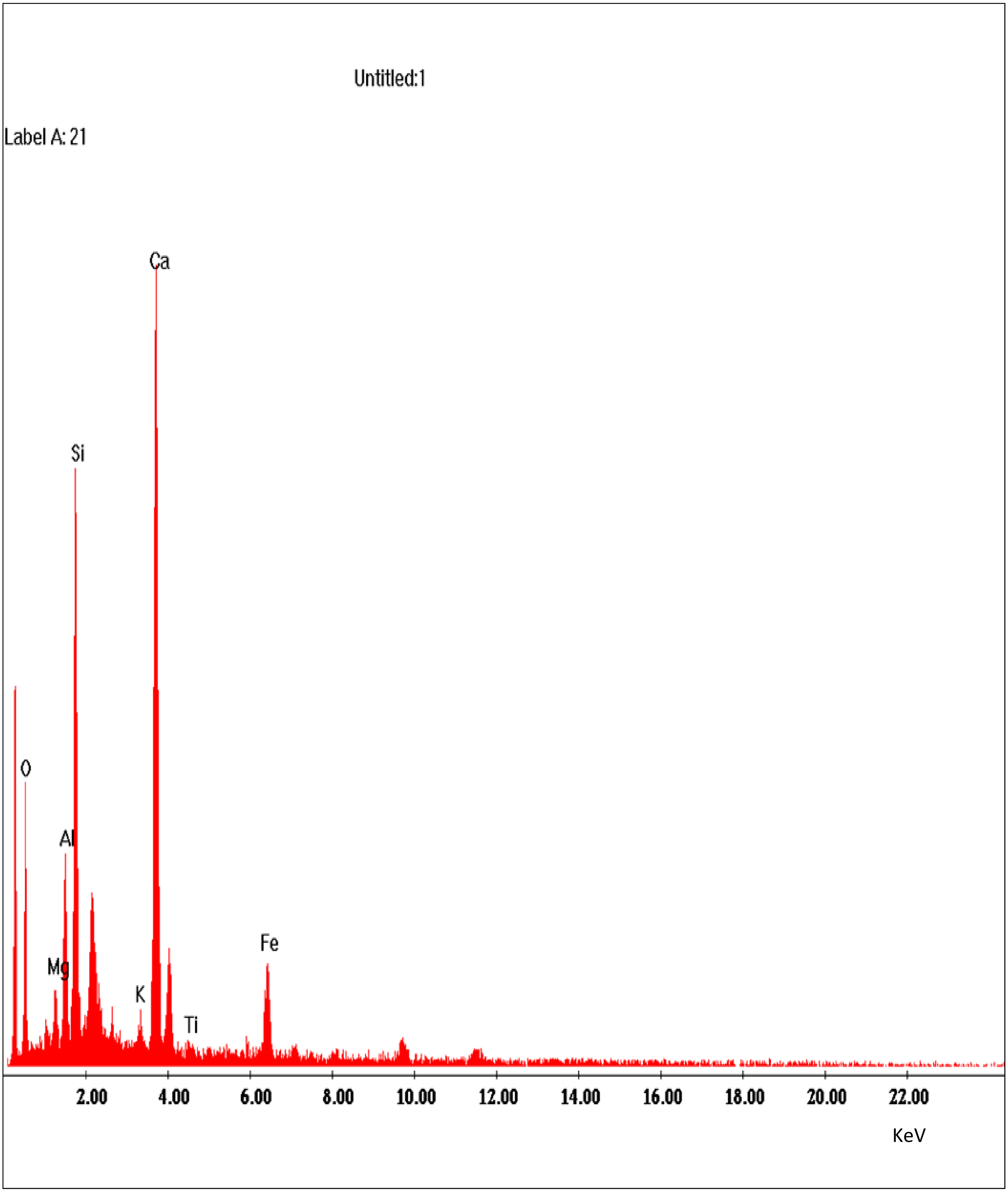
Moreover, this study is hopefully explaining the un-safe situation for the plant species and other kinds of living organisms that are eventually affected by this pollution and are exposed to the air pollutants emitted from the



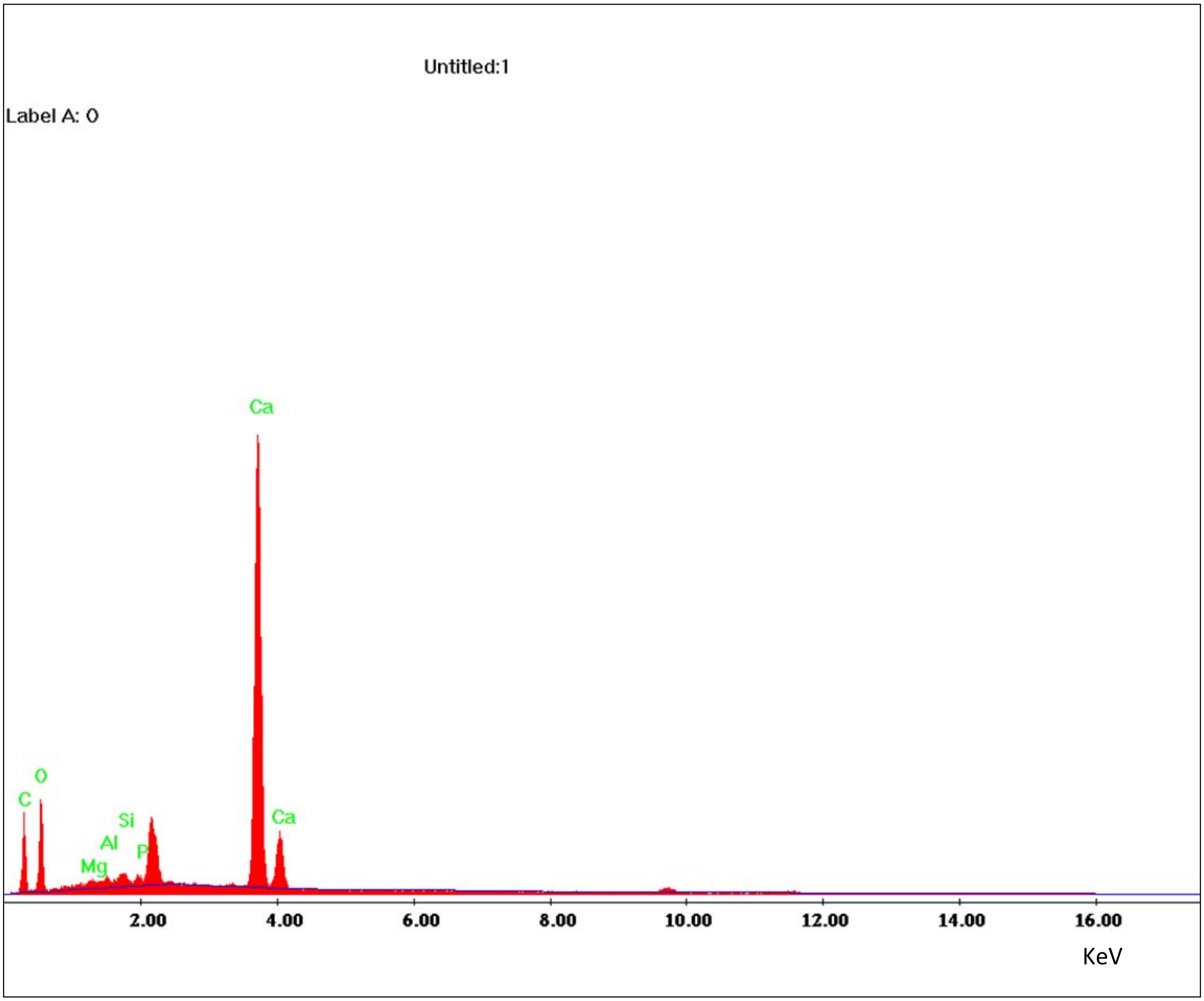
Graph 3. X-ray spectrum of particles for leaf 3.



Graph 4. X-ray spectrum of particles for leaf 4.



Graph 5. X-ray spectrum of particles for leaf 5.



Graph 6. X-ray spectrum of particles for the control sample.

neighboring Al- Rashadeyeh cement factory in south of Jordan, and as result decline and probably degrade wild plant species of the area.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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