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Particles Matters Accumulation and Anatomical Leaf Properties of Three Tree Species Growing in the Industrial Area in Jeddah, Saudi Arabia

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Abstract. Particles matters accumulation and anatomical leaf properties of Camphor (*Cinnamomum camphora*), Henna (*Lawsonia inermis*), and Bougainvillea (*Bougainvillea spectabilis)* trees growing in the industrial zone in Jeddah - Saudi Arabia and Hada Al-Shame area (control) was done. The leaf properties of all tree species growing in the industrial and control showed that each stoma had a raised edge over the guard cell region. The guard cells appeared more shrunken on the polluted leaves as compared with unpolluted leave. The results indicated that the most deposition particles on leaf surfaces of all tree species were: soot (C) and soil dust with characteristic matrix elements (Si, Al, Mg, Ca, K); fuel oil particles rich in Al, Si, Ca, and Pb; coal ash particles containing C, Al, Si, K, Ca, S; and Pb. As a result, leaves of those plant species may be used as bio-indicators for the assessment of particular matters in the industrial areas.

Keywords: Particles matters; anatomical leaf properties; Air Pollution; Industrial areas.

Introduction

Plants can be used as a useful bio-indicators for the assessment of environmental pollution in the industrial areas (Tomasevic *et al*., 2004; Madejón *et al.,* 2004, 2006; Gautam *et al.,* 2005; Mingorance and Oliva, 2006). Several studies were carried out using plants as bio-accumulators or bio-indicators in environmental investigations (Celik *et al*., 2005; Aksoy and Demirezen, 2006; Yilmaz *et al*., 2006; Akguc *et al*., 2008; Maletsika and Nanos 2013; Saadullah, *et al.,* 2014).

Particular matters in variety of forms such as dust particles, globules, aggregates etc., accumulate on leaf surfaces of industrial areas plants including higher plants. Keskin and Ili (2012) indicated that the chemical composition of particular matters on leaf surfaces of *Pinus nigra* Arn. subsp. *pallasiana* (Lamb.) Holmboe showed distinct differences between the regions.

The particulate matters have a negative mechanical effect where it covers the leaf blade reducing light penetration and blocking the opening of stomata. These impediments influence strongly the process of photosynthesis which rate declines sharply. Christodoulakis and Fasseas (1990) showed no significant changes in *Laurus nobilis* (a resistant xerophyitc plant) leaf structure exposed to air pollutants in Athens and under the action of pollutants, plants develop different morphological and anatomical changes.

Iqbal and Shafig (2001) indicated that the cement dust had a significant effect on the growth and structure of some plant species compared with non polluted plants, and toxic compounds such as fluoride, magnesium, lead, zinc, copper, sulphuric acid and hydrochloric acid found to be emitted by cement manufacturing factories. Farmer (1993) reported that cement dust pollutants block the stomata, reduction in number of annual crops.

The high dust deposition on the leaf surface in urban and industrial area have been reported by Rao and Pal (1979) and Shetye and Chaphekar (1980). They concluded that high dust deposition on leaf surface at road side with heavy vehicular traffic may be due to spray of unborn oil residue of diesel or petrol on the leaf surface. According to Prajapati and Tripathi (2008) dust interception and its accumulation in different plant species not only depends upon the sources and amount of pollutants in the environment but also depends on morphological characters of plants like leaf size, texture, hair, length of petiole and weather condition and wind direction. Bhatnagar *et al*. (1985) reported that a very high dust fall on the leaves of all the nine plants under study growing in industrial in comparison to those growing in nonindustrial area. Lerman (1972) suggested that continuous application of cement dust clog the stomata, so interfering with gaseous exchange. Wang *et al.* (2015) reported that the rainfall caused a considerable increase in the accumulation of particles on the leaf surfaces at a high particular matters concentration, which resulted from the wet deposition of particular matters, and balanced the amount of particular matters on the leaf surfaces over a longer period.

The purpose of this study was to assesses the accumulation of particular matters on leaf surfaces and anatomical leaf properties of Camphor (*Cinnamomum camphora*), Henna (*Lawsonia inermis*), and Bougainvillea (*Bougainvillea spectabilis)* trees growing in the industrial zone in Jeddah - Saudi Arabia and Hada Al-Shame area.

Materials and Methods

Study area

This study was conducted at Jeddah city industrial area, which is situated between 21°24′37″N latitude and 39°14′30″E longitude and the control area (the Agricultural Research Station, Hada Al-Sham, King Abdulaziz University at a distance of 120 km north-east of Jeddah) which situated between 21°47′50″N latitude and 39°43′33″E longitude in the West of Saudi Arabia.

Plant Materials

Three plant species with the same age, namely Bougainvillea (*Bougainvillea spectabilis*), Camphor (*Cinnamomum camphora*) and Henna (*Lawsonia inermis*) were selected for this study, as they were common in Jeddah industrial area (polluted) and the control area (unpolluted).

Determinated characteristics

Sampling time was done at the end of March, 2014 (this date is the end of the active working of the industrial factories in Jeddah). The particles matters accumulation and anatomical leaf properties of the 3 plant species were assessed in polluted and control.

The anatomical leaf properties study was done by using the Scanning Electron Microscopy. For Scanning Electron Microscopy (SEM) studies the samples (leaves) were cut as small pieces and placed on the double side carbon tape on aluminum stub and dried in air. All samples were sputtered with a 15 nm thick gold layer (JEOL JFC- 1600 Auto Fine Coater). The specimens were examined with a scanning electron microscope Quanta FEG 450, FEI, Amsterdam, Netherland. The microscope was operated at an accelerating voltage of 20 kV, according to (Dykstra, 1993 and Hayat, 2000). Then, the samples were photographed by the SEM.

The analyses of presence atmospheric particles on leaf surfaces were carried out by FESEM method, observing the presence and shape of the particles, followed by EDS analyses to determine elemental composition of the particles on leaf surfaces, as described by Tomasevic, *et al.* (2004).

Experimental Design

A completely randomized design with 4 replications were used to study each plant species separately where the industrial zone of Jeddah (polluted area) and the Hada Al-Shame (control area) were the treatments.

Results and Discussion

Anatomical leaf properties

Based on the leaf characteristics, the three different plants species were recorded as fallow:

Camphor

Anatomical leaf properties of Camphor trees growing in the industrial (polluted) and control (unpolluted) areas showed stomata with normal structure (Fig. 1a, b). Each stoma had a raised edge over the guard cell region, which is typical for plant (Carpenter, 2005). The guard cells appeared more shrunken on the polluted leaves as compared with unpolluted leaves (Fig. 1a, b).

The study showed that the stomata of Camphor plant leaves growing in the control area (unpolluted) were not plugged by particulates as compared with the plants growing in the industrial area (polluted) (Fig. 1c, d). Although the particles were present on the leaf surface of the plants growing in the industrial are. At industrial area the particles were abundant and clumped together, whereas they were less frequent and more scattered on leaves from the control area (unpolluted) (Fig. 1c, d).

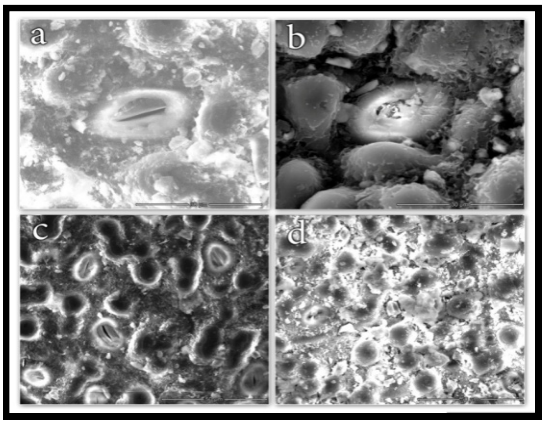

Fig. (1). Anatomical leaf properties of Camphor trees from an industrial (polluted) and control (unpolluted) areas (a) unpolluted showing stomata with normal structure; (b), polluted showing the damage in the stomata structure; (c), unpolluted showing leaf surface with normal sunken shape of the stomata; (d), polluted showing the complete blockage of stomata with pollutants.

Henna

The Anatomical leaf properties of Henna trees growing in the industrial (polluted) and control (unpolluted) areas (Fig. 2a, b) showed that each stoma had a raised edge over the guard cell region, which is typical for plant (Carpenter, 2005). The guard cells appeared more shrunken on the polluted leaves as compared with unpolluted leaves (Fig. 2 a, b).

The study showed that the stomata of Henna plant leaves growing in the control area (unpolluted) were not plugged by particulates as compared with the plants growing in the industrial area (polluted) (Fig. 2 c, d). Although the particles were present on the leaf surface of the plants growing in the industrial area. At industrial area the particles were abundant and clumped together, whereas they were less frequent and more scattered on leaves from the control area (unpolluted) (Fig. 2 c, d).

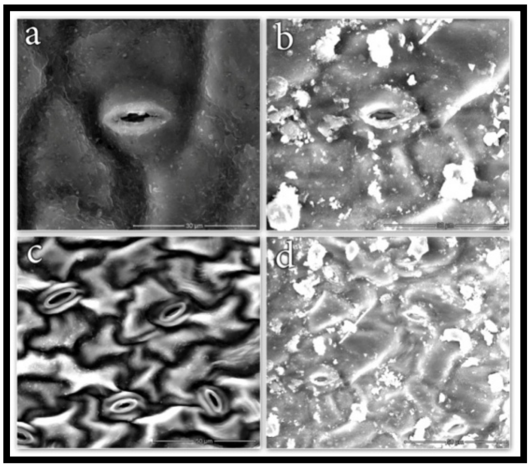

Fig. (2). Anatomical leaf properties of Henna trees from an industrial (polluted) and control (unpolluted) areas (a) unpolluted showing stomata with normal structure; (b), polluted showing the damage in the stomata structure; (c), unpolluted showing leaf surface with normal sunken shape of the stomata; (d), polluted showing the complete blockage of stomata with pollutants.

Bougainvillea

The leaf properties of Bougainvillea trees growing in the industrial (polluted) and control (unpolluted) areas (Fig. 3a, b) showed that each stoma had a raised edge over the guard cell region, which is typical for plant (Carpenter, 2005). The guard cells appeared more shrunken on the polluted leaves as compared with unpolluted leaves (Fig. 3a, b).

The study showed that the stomata of Bougainvillea plant leaves growing in the control area (unpolluted) were not plugged by particulates as compared with the plants growing in the industrial area (polluted) (Fig. 3c, d). Although the particles were present on the leaf surface of the plants growing in the industrial are. At industrial area the particles were abundant and clumped together, whereas they were less frequent and more scattered on leaves from the control area (unpolluted) (Fig. 3c, d).

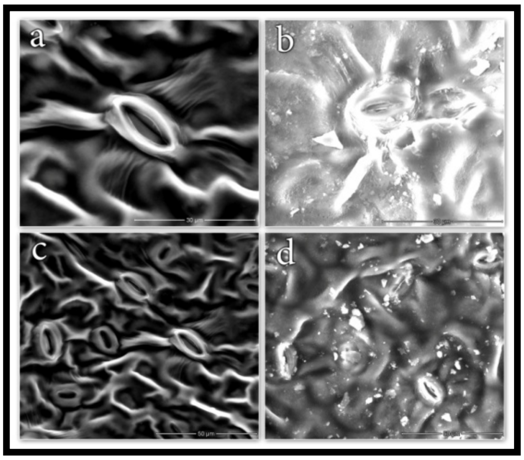

Fig. (3). Anatomical leaf properties of Bougainvillea trees from an industrial (polluted) and control (unpolluted) areas (a) unpolluted showing stomata with normal structure ; (b), polluted showing the damage in the stomata structure; (c), unpolluted showing leaf surface with normal sunken shape of the stomata; (d), polluted showing the complete blockage of stomata with pollutants.

The above results for all tree species are in agreement with those of Pal *et al*. (2002) that showed leaf stomata of trees growing at sites of high pollution load appeared to have smaller size, reduced aperture size, and destructed guard cells. Modification of the frequency and sizes of stomata as a response to the environmental stress is an important manner of controlling the absorption of pollutants by plants (Gostin, 2009). Also, Gostin (2009) reported the decrease in stomatal size in *Lotus corniculatus, Trifolium montanum, T.pratense, and T.repens.* Saquib *et al.* (2010) reported that the air pollution stress around the thermal power plant lead to the significant reduction in stomatal conductance. The results obtained by Youssef, *et al.,* (2013) reported that the trees of *Ligustrum japonicum* and *Olea europea* (*Oleacea*e) growing under industrial areas showed stomata closed completely with pollutants particles and consequently expected to affect the physiological operations inside the plant cell. Iqbal, *et al*. (1996) reported that the smaller size of stomata and the decrease in stomata aperture may operate as a defense mechanism against inhibitory action of pollutants on photosynthesis.

Morphological characters of the particles matters

The results of morphology and chemical composition of the particles deposited on leaf surfaces of the three different plant species growing in the industrial (polluted) and control (unpolluted) areas were recorded in the present study.

Camphor

The morphological characters of the particles obtained from the scanning electron microscopy from the industrial (polluted) leaf surfaces of Camphor showed that the particles were in different sizes and shape, which strongly covered the leaves. Also, the particles on the leaves from control (unpolluted) were in different sizes and shape, but distributed in small area (Fig.4a & c).

The scanning electron microscopy micrographs and corresponding EDS spectrums and chemical composition of leaves of Camphor from the industrial (polluted) and control (unpolluted) areas are shown in Table 30 and Fig.4b & d, respectively. The chemical composition of the particles deposited on leaves of this species indicated that the most abundant particles were: soot (C) and soil dust with characteristic matrix elements (Si, Al, Mg, Ca, K, Na); fuel oil particles rich in Al, Si, Ca, and Pb; coal ash particles containing C, Al, Si, K, Ca; and produced from the local industrial processes.

The concentrations of C content decreased on the leaves collected from control area as compared with industrial area. The concentration of O, Mg, Al, Si, and Ca increased on the leaves collected from polluted area as compared with unpolluted area. The Na, Pb and K were found only on the surface of leaves collected from polluted area (Table 29).

The particles morphology and chemical composition on the leaves of Camphor indicated by the SEM-EDAX procedure, it may be suggested that particles deposited on the leaves mostly originated from the traffic within the industrial zone and local industries.

Table (30). FESEM-EDS analytical data (average wt. %) on particles constituting on leaves of Camphor trees growing in the industrial (polluted) and control (unpolluted) areas.

Location	Elemental percentage (%)								
	C	O	Na	Mg	Al	Si	Pb	K	Ca
Control (unpolluted)	40.09	20.57	--	00.38	01.04	02.09	---	---	00.74
Industrial area (polluted)	75.18	33.60	00.78	01.09	04.06	08.75	07.56	00.55	03.51

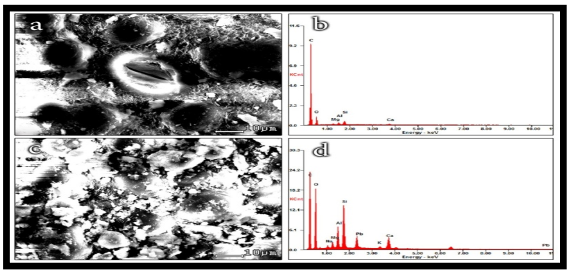

Fig. (4). Scanning electron micrographs and EDS spectrums of particulate matters on the leaves of Camphor trees growing in the control area (a, b) and in the industrial area (c, d).

Henna

The morphological characters of the particles matters obtained from the scanning electron microscopy from the industrial (polluted) leaf surfaces of Henna showed that the particles were in different sizes and shape on both leaves collected from control (unpolluted) and polluted areas and distributed in small area (Fig.5a and c).

The scanning electron microscopy micrographs and corresponding EDS spectrums and chemical composition of leaves of Henna from the industrial (polluted) and control (unpolluted) areas are shown in Table 31 and Fig.5b & d, respectively. The chemical composition of the particles deposited on leaves of this species indicated that the most abundant particles were: soot (C) and soil dust with characteristic matrix elements (Si, Al, Mg, Ca, K, Na); fuel oil particles rich in Al, Si, Ca, and Pb; coal ash particles containing C, Al, Si, K, Ca, S; and Pb. The concentrations of C content not significantly different between polluted or the control areas. Under the control area the concentrations of O, Al, Si and S were significantly higher than in the industrial zone. These results might be due to the effect of the fuel (gasoline) used in the agricultural machines in the Agricultural Research Station and the wind strength and directions especially for the Si concentrations (Dmuchowski and Bytnerowicz, 2009). The other particles of Na, Mg, Pb, Cl, K and Ca were significantly higher in the tree leaves in the industrial zone from the control area due to the industrial emissions pollutants.

The present particles on the Henna leave might been due to the pollutants produced from the industries and the near traffic.

Table 31. FESEM-EDS analytical data (average wt. %) on particles constituting on leaves of Henna trees growing in the industrial (polluted) and control (unpolluted) areas.

Location	Elemental percentage (%)										
	C	O	Na	Mg	Al	Si	S	Pb	Cl	K	Ca
Control	53.91	39.41	--	00.38	00.90	00.53	00.33	---	--	---	01.44
Industrial area	57.01	29.58	04.30	00.92	00.39	00.33	---	04.85	4.20	01.51	03.51

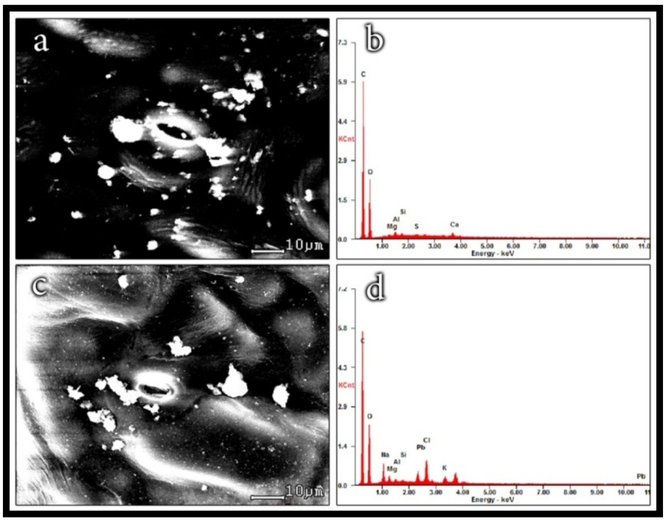

Fig. (5). Scanning electron micrographs and EDS spectrums of particulate matters on the leaves of Henna trees growing in the control area (a, b) and industrial area (c, d).

Bougainvillea

The morphological characters of the particular matters obtained from the scanning electron microscopy from the industrial (polluted) leaf surfaces of Bougainvillea showed that the particles were in different sizes and shape on both leaves collected from control (unpolluted) and polluted areas and distributed in small area (Fig.6a & c).

The scanning electron microscopy micrographs and corresponding EDS spectrums and chemical composition of leaves of Bougainvillea from the industrial (polluted) and control (unpolluted) areas are shown in Table 32 and Fig.6b & d, respectively. The chemical composition of the particles deposited on leaves of this species indicated that the most abundant particles were: soot (C) and soil dust with characteristic matrix elements (Si, Al, Mg, Ca, K); fuel oil particles rich in Al, Si, Ca, and Pb; coal ash particles containing C, Al, Si, K, Ca, S; and Pb. The obtained results showed no significant differences between the concentrations of C, O, Mg and Ca on the leaves of the trees grown in the control or the industrial areas, while the concentrations of Al, Si, S, P and Pb were significantly higher under the industrial zone than the control area, but S, Cl and K were higher in the control area than the industrial zone with significantly values (Table 30). These results reflected the industrial emissions effects and the used fuel in Hada Al-Sham area effects besides the genotype × environment interaction.

The high accumulated polluted particles on the Bougainvillea leaves might bean due to the industrial and traffic emissions in the industrial zone and the machine fuel emissions and chemical fertilizers and chemical pesticides used in the Agricultural Research Station in Hada Al-Sham.

Table (32). FESEM-EDS analytical data (average wt. %) on particles constituting on leaves of Bougainvillea trees growing in the industrial (polluted) and control (unpolluted) areas.

Location	Elemental percentage (%)										
	C	O	Mg	Al	Si	S	P	Pb	Cl	K	Ca
Control	58.42	26.47	01.21	00.57	01.06	00.38	--	---	04.21	06.83	00.84
Industrial area	62.83	23.35	01.38	00.84	01.55	--	00.28	01.41	02.74	04.55	01.07

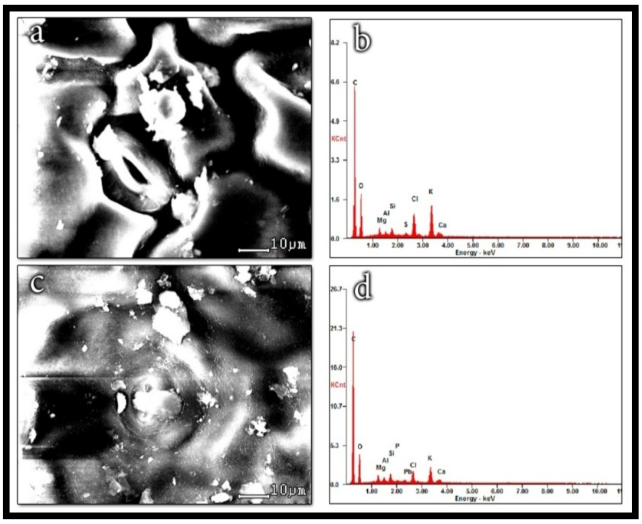

Fig. (6). Scanning electron micrographs and EDS spectrums of particulate matters on the leaves of Bougainvillea trees growing in the control area (a, b) and industrial area (c, d).

Tomašević and Aničić, (2010) Using a scanning SEM-EDAX, studded the morphological and chemical composition of deposited particles on urban tree leaves of common deciduous trees: *Aesculus hippocastanum* and *Tilia spp.* and indicated that the most abundant particles were soot and dust with minor constituents such as Pb, Zn, Ni, V, Cd, Ti, As, and Cu. The effect of particles matter accumulation on vegetation depends on the dust quantity, the duration of its presence, the dust's chemical composition and the plant species (Maletsika and Nanos, 2011). The particles matter accumulation on plant leaves may cause blocking of stomata and shading of photosynthetic tissue, and, as a result, reduction of leaf photosynthetic and transpiration capacity (Maletsika and Nanos, 2011).

Hirano, *et al.,* (1995) reported that the effect of dusts deposited on cucumber and kidney bean plants was related to particle size: as the particle size decreased, it caused more shading to plant parts. The results of Grantz *et al.,* (2003) indicated that increased particles matter dust deposition on vegetation may negatively affect carbon assimilation, due to shading and reduced stomatal conductivity. Several Studies show that under polluted conditions, plants develop different morphological and anatomical changes (Inamdar and Chaudahri, 1984; Iqbal, 1985; Karenlampi, 1986; Gupta and Ghouse, 1988; Bhatti and Iqbal, 1988; Veselkin, 2004; Prajapati, 2012). The result of high dust deposition on the leaf surface in urban and industrial area have been reported by Tomašević and Aničić (2010) and Rahul and Jain (2014). They concluded that high dust deposition on leaf surface at road side with heavy vehicular traffic may be due to spray of unburnt oil residue of diesel or petrol on the leaf surface. Saravana and Sarala (2012) reported very high dust fall on the leaves of all plants under study growing in industrial in comparison to those growing in nonindustrial area.

Conclusion

1. As anatomical leaf properties under the industrial conditions, the results showed that the guard cells were more shrunken on the polluted leaves compared with unpolluted leaves in the 3 plant species.
2. Also, the particles were abundant and clumped together on the leaf surface of the plants growing in the industrial area.
3. The concentrations of C, O, Mg, Al, Si and Ca increased on the leaves collected from the polluted area as compared with unpolluted area.
4. Na, Pb and K were found only on the surface of leaves collected from the polluted area.

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تراكم الجسيمات والصفات التشريحية لأوراق ثلاثة أنواع من الأشجار تنموا في المنطقة الصناعية بجدة، المملكة العربية السعودية

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المستخلص. تم دراسة تراكم الجسيمات والخصائص التشريحية للأوراق أشجار الكافور (*Cinnamomum camphora*)، والحناء (*Lawsonia inermis*)، والجهنمية (*Bougainvillea spectabilis*) النامية في المنطقة الصناعية بمدينة جدة، المملكة العربية السعودية ومنطقة هدا الشام (مقارنة). وأظهرت النتائج أن خصائص الورقة وجميع أنواع الأشجار التي تنمو في المنطقة الصناعية ومنطقة المقارنة أن كل ثغر له حافة مرتفعة على منطقة الخلية الحارسة. كما ظهرت الخلايا الحارسة منكمشة أكثر على الأوراق الملوثة مقارنة بالأوراق غير الملوث. وأشارت النتائج إلى أن معظم الجسيمات المترسبة على سطوح الأوراق في جميع أنواع الأشجار هي: السخام (الكربون) وغبار التربة المحتوي على عناصر (السليكون، والألومنيوم، والمغنيسيوم، والكالسيوم، والبوتاسيوم)؛ جزيئات زيت الوقود الغنية في الألومنيوم، والسليكون، والكالسيوم، والرصاص؛ جسيمات الرماد الفحم التي تحتوي على الكربون، والألومنيوم، والسليكون، والبوتاسيوم، والكالسيوم، والكبريت؛ والرصاص. وبناءً على ذلك، يمكن استخدام أوراق تلك الأنواع النباتية كمؤشرات حيوية لتقييم الجسيمات في المناطق الصناعية.

الكلمات المفتاحية: الجسيمات، الصفات التشريحية للورقة، تلوث الهواء، المناطق الصناعية.