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Bio-Qualitative Estimation of Diffused Air Pollution of a City in Northeastern Algeria by Using Epiphytic Lichens

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ABSTRACT

This research evaluates the overall air pollution in the Skikda region, the capital of petrochemicals in northeastern part of Algeria, we used a qualitative method based on the census and geographical distribution of the lichen flora corticolous according pink pollution in the study area combined with mapping. It is essential to know some biophysical factors, such as climate and the tree flora (lichen substrate or phorophyte) to better understand their influence on the distribution of lichens in different stations. Thus, 39 lichen species have been identified in 8 sites established as a zoning that takes into account their exposure to different sources of emanation. The census results of the lichen flora of the Skikda region and its periphery have shown that the number and rate of recovery is closely linked to the degree of pollution. This finding is remarkable in the field by reducing the number of species and their recovery rate when the overall pollution is diffuse is important.

Keywords: cartography, pollution, lichen, Skikda – Algeria.

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1.0 INTRODUCTION

For five decades, many methods for pollution studies have been developed. Some methods are qualitative approach to assess the extent of pollution from field observations. These qualitative approaches are exemplified by the works of Hawksworth (1970); Deruelle and al (1983);Van Haluwyn (1986). Quantitative methods had also been employed in pollution studies. These quantitative methods involve the use of mathematical modeling through the use of different parameters related to the lichen flora. Well known in quantitative approach to pollution studies may include the use of poleotolerance index (P.I) used by Trass (1973), atmospheric purity index (A.P.I) advocated by De Sloover (1964) which is the most used in the world. Maintaining air quality necessarily involves the detection and estimation of overall air pollution of this area of study Deruelle (1983b; 1984).

Establishing a mapping based on the areas of iso-pollutions and class sensitivity of lichen species in a pollution level of the area studied. As part of our research, we opted for mapping networks as a floristic approach based on the geographical distribution of lichen species. This floristic method or qualitative method is essentially based on the census of the lichen flora of the Skikda region in the northeastern part of Algeria. It provides information about different lichen species that live in this area and secondly to determine the lichen species most sensitive to pollution than is commonly called cash poleophobia, Posthumus (1983) and Lebrun (1990); Semadi (1997); Fadel (2011). It is important to note that these methods do not in any case to establish a direct correspondence with physical-chemical pollution measurements. They help assess the overall air pollution relative value of each area under study (Deruelle, 1984; Khallil *et al.*, 1998; and Joyeux *et al.* 1999).

The rationale for selecting epiphytic lichens as a bio-indicator of air pollution is linked to many issues. Firstly, the region of Skikda was devoid of pollution sensors. In addition, their installation costs quite expensive, these sensors require very stringent continuous readings. Secondly, lichens are generally plastic plant that is present everywhere. Each species has its own requirements and its distribution is influenced by the environment. In this paper, we highlight the special situation of Skikda that is conducive to the use of lichens. Thirdly, substratum climate and conditions are favorable for development of the lichen flora. The study region has favorable climate for the development of lichen vegetation. Some climatic factors, such as high relative humidity, a sizeable rainfall and favorable temperatures, are conducive to epiphyte flora. Phorophytes is abundant in this region producing a variety of vegetation conducive to lichens growth, i.e. *Fraxinus Angustifolia* (Vahl.), *Quercus suber* (L), *Olea europea* (L), and the Citrus genus.

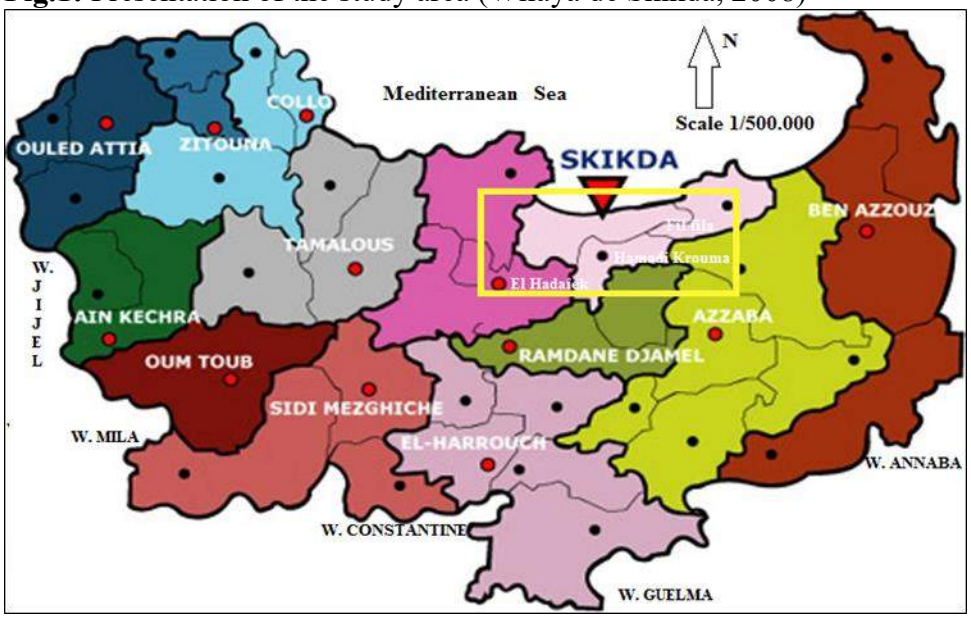
2.0 THE STUDY AREA

Our study area is within a quadrilateral including the town of Skikda wilaya capital with Stora and El Hadaiek outlying towns and Hamadi Krouma and spun yarn (Fig.1). It is located between latitudes 36 ° 5 'and 36 ° 30'N and longitudes 7 ° 15' and 7 ° 30 'E. The area is connected by a dense road network system. The study area is bounded by:

- To the north by the Mediterranean Sea.
- To the west by the massive mountains of Stora and the high coastal hills
- South and South -Is the valley of Oued Saf - Saf and coastal plains of Skikda at low altitudes.

Considering these boundaries with other wilayas, Skikda is located west of Annaba in the east of Jijel, in the northwest of Guelma and north - east of Constantine.

Fig.1: Presentation of the study area (Wilaya de Skikda, 2008)



3.0 DATA & METHODOLOGY

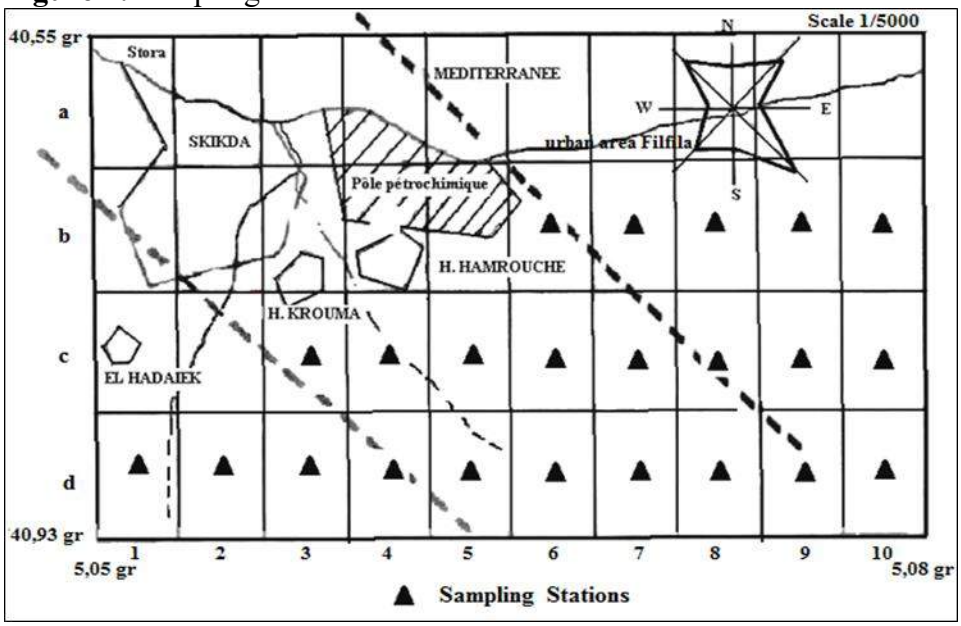
3.1. Floristic method

In this study, we opted for a mapping networks under floristic approach based on the geographical distribution of lichen species. This floristic method or qualitative method is based on the census of the lichen flora of the city of Skikda and peripheral municipalities. This floristic method allows us to identify the lichens that live in this area, and to determine the most sensitive species to pollution that is commonly known as poleophobia species Semadi (1983) Fadel (2014). Records of different species of lichens in the study area were already made by Metlaoui (2001) and completed by Hadjoudja (2012). The latter involves examining several trees of different ages and from different species. Four readings on each tree were taken. Two readings were performed on the side exposed to the pollution including one at the base and the other at a height from 01 to 1.5 m above the ground. Another two readings were performed on the opposite side. The determination technique of all species collected was performed in the laboratory using a binocular loupe and a microscope for cuts thallus. Some reagents such as potassium hydroxide in 10% Lugol, iodine and paraphenyl diamine were used for species identification.

3.2. Presentation of the meshing and the choice of sampling stations

For four decades the region Wilaya has been known induced pollution by industrial development and commercial activities related to many infrastructures (port, road and rail) that led to urban growth uncontrolled denaturing transition between urban, industrial, and agricultural areas. They were also the cause of many including that of air pollution, responsible for various pollutants from combustion emitted from diffused source that confuses different emission foci represented by urban cities (Skikda, Hadaiek, Hamrouche Hamoudi, Hamadi Krouma and Fil fila), mobile homes consist of traffic and petrochemical industrial zone (Inspection de l'environnement, 2004).These different sources of emissions are included in the study site located in a quadrilateral of 60 Km^2. It is divided into a grid of 40 meshes (1.5 x 1) Km or 0.003 gr 0.015 gr in longitude and latitude. The coordinates of each mesh are specified by a number in abscissa and by letter in ordered. The base maps used in our research are of Algeria maps at 1 / 25,000 (type 1960) Skikda N° 7 - 8 published by the National Geographic Institute (I.G.N) and the use of satellite images. We have established a zoning based on exposure to different emanations of various pollution sources and their locations in relation to urban and the industrial areas (Fig. 2).

Figure 2: Sampling stations



Most of the sites is about three quarters of the study area is characterized plains and hills. The rest of the area is located in the foot-hills. Each site includes several stitches. Each cell comprises at least one sampling station. In general, the choice of stations is determined by environmental factors (microclimate, abundance of phorophytes and homogeneity of vegetation) but also by topographical factors. In this research, we considered a coherent ecological system taking into account individual stations, represented both by roadside trees or isolated trees and secondarily by citrus orchards and trees of urban parks. Site 1 is the one that is most exposed to various pollutants emanating from industrial areas and urban cities of Skikda and Hamadi Krouma. Against the site by 8 the least exposed to pollution is removed by a straight line at about ten kilometers from sources of emanation. It should be noted that the surveyed sites are geographically distributed heterogeneously. They are distributed as follows:

- 50% of them are located in the coastal area populated by several porophytes *Fraxinus angustifolia* (Vahl.), *Pinus pinaster* (Ait.) and *Cupressus sempervirens* (L)

- 40% in the area inhabited by subcoastal phorophytes such as *Olea europea* (L), *Casuarina equistifolia* (L), *Cupressus sempervirens* (L) and fruit tree orchards of citrus Citrus genus;

- 10% in the mountainous area remains the main phorophyte represented by *Quercus suber* (L).

4.0 FINDINGS & DICUSSIONS

The inventory of lichens allowed us to know their distribution according altitudinal gradient, exposure, substrate and sites that are more or less exposed to pollution. At the study area, 39 species were identified. The nomenclature identification is adapted from Ozenda and Clauzade (1970), and Jahns (1989), Roux *et al.* (2006). Some species followed by "sp" mention with the number 1 and 2 are different but belong to the same genus which have not been identified. Given that our work focuses on the distribution of lichens according to the pollution gradient, we do not submit a complete list of lichens.

4.1. Global geographic distribution of lichen vegetation

Several authors, such as Semadi (1983), Lebrun (1990) and Fadel *et al.* (2011) found that the geographical distribution of lichens is influenced by three factors: type of substrate, climate and the degree of air pollution.

4.1.1 Site 1: Urban city of Skikda

This site is located southwest of the largest petrochemical pole. It includes three b_1 mesh; b_2; b_3. On this site we selected five sampling stations mainly composed by roadside trees represented by the species Fraxinus angustifolia (Vahl.). Note that we also explored some of the walls and roofs of houses.

Altitude: 05 -20 m
Exposure: South / West
Slope: 00-05%
Substrate: *Fraxinus angustifolia* (Vahl.)
Recovery: 00-05%
Number of species: 02

4.1.2 Site 2: Suburban area of Skikda

Site 2 is located in the suburban zone of Skikda more exactly to the southwest of the center. It also links with the urban area of Hamadi Krouma. It includes two mesh c_2; c_3 which are located 3 sampling stations also composed of roadside trees belonging to the genus *Fraxinus angustifolia* (Vahl.) and afforestation *Cupressus sempervirens* (L.)

Altitude: 05 -10 m
Exposure: South / Southwest
Slope: 00-5%
Substrate: *Fraxinus angustifolia* (Vahl.) and *Cupressus sempervirens* (L.)
Recovery: 05-10%
Number of species: 04

4.1.3 Site 3: Industrial area and the urban area of Hamadi Hamrouche

This site includes the petrochemical pole,the urban area of Hamadi Hamrouche and the small industrial park. It is formed by three meshes b_4; b_5; c_4 articulated around the main road (R.N n° 44, connecting Skikda towards Annaba). It includes four sampling stations.

Altitude: 05- 10 m
Orientation: North - East and South West / urban city of Skikda
Slope: 03-5%
Substrate: *Olea europea* (L) and *Fraxinus angustifolia* (Vahl.)
Recovery: 5 - 10%
Number of species: 02

4.1.4 Site 4: Coastal Plain Safsaf

This site is homogeneous in its composition. It is occupied mainly by citrus orchards. It is located in the coastal plain. It includes b_6 meshes; b_7; b_8 where three sampling stations are located. It includes b_6 meshes; b_7; b_8 where three sampling stations are located.

Altitude: 05 -10 m
Exposure: East / petrochemical industry
Slope: 00- 05%
Substrate: orangery and Citrus genus *Pinus pinaster* (Ait.)
Recovery: 30 - 40%
Number of species: 24

4.1.5 Site 5: Portion of the coastal plain of sub Safsaf

This site consists mainly of perennial crops represented by different species of the genus Citrus. The plant species Casuarina equistifolia (L.) is the boundary of the various groves. This site includes c_5 meshes; c_6; c_7; d_4; d_5; d_6; d_7 which are located five sampling stations.

Altitude: 05-15 m
Exposure: South - East / petrochemical pole of the city of Skikda
Slope: 05-10%
Substrate: Citrus genus and *Casuarina equistifolia* (L.)
Recovery: 15 - 20%
Number of species: 18

4.1.6 - Site 6: Urban city of Hadaiek

Site 6 covers four meshes represented by c_1; d_1; d_2; d_3 which are located four sampling stations.

Altitude: 10-15 m
Exposure: South-west / the petrochemical pole and the urban fabric of Skikda
Slope: 8-12%
Substrate: *Fraxinus angustifolia* (Vahl.) and *Cupressus sempervirens* (L.)
Recovery: 30 - 40%
Number of species: 16

4.1.7 - Site 7: Verger of locality "Pontous"

This site covers three d_8 meshes; d_9; d_{10} which are distributed three sampling stations.

Altitude: 25- 30 m
Exposure: Southeast / petrochemical pole and the city of Skikda
Slope: 03-05%
Substrate: Genus Malus and *Casuarina equistifolia* (L.).
Recovery: 10 - 20%
Number of species: 10

4.1.8 - Site 8: Locality "Sedaa Rassou" and the forests of Jebel Abu Fare

Site 8 is farthest from the petrochemical pole and urban Skikda of Hammoudi Hamrouche and Hamadi Krouma. This site includes eight b_9 meshes; b_{10}, c_8; c_9; c_{10} occupied by an oak forest more or less degraded. Given the homogeneity of this website only four sampling stations were selected.

Altitude: 40 to 50 m
Exposure: Northeast and Southeast / petrochemical industry
Slope: 05-10%
Substrate: *Quercus suber* (L.)
Recovery: 50 - 60%
Number of species: 19

The analysis of the representation of different species, gives a glimpse of the lichen landscape of our study area. It varied depending on its location but also depending on the substrate on which it lives. This landscape seems to dominate in the following species.

4.2. Spatial distribution networks based pollution rose

The diversity of lichen species, their recovery can be explained by the existence or absence of pollution; however, we must not omit the role of other factors (climatic, orographic and substratum) that have a role in the distribution of lichens, Semadi *et al.* (1993); Rahali (2002); Fadel *et al.* (2009). If we consider the relationship of lichen vegetation and pink pollution, we notice that the lichen species are distributed in a pollution gradient defined by reducing the number of species and decreasing recovery rate (Tab.1).

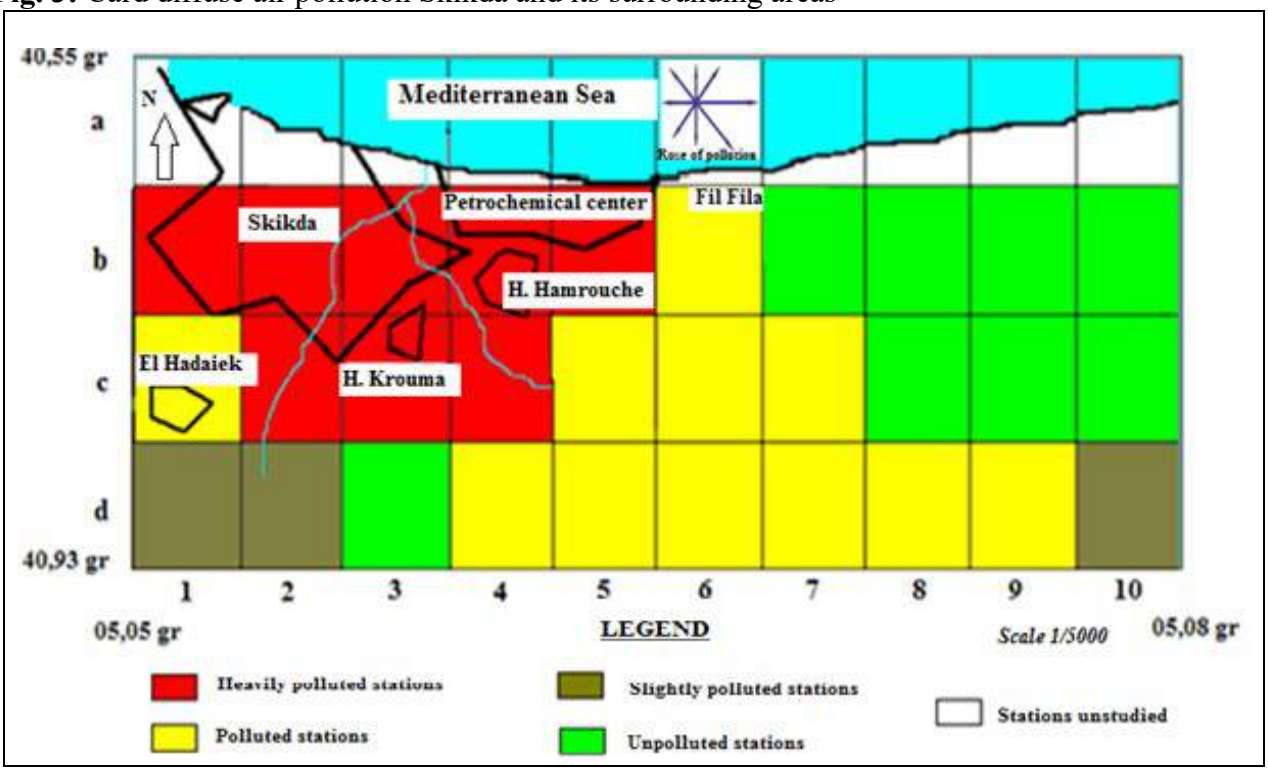
Table 1.0: Distribution of the lichen flora according to the gradient of the pollution

STUDY LOCATION	CORRESPONDING MESH	NUMBER OF SPECIES	RECOVERY RATE (%)
Site 1 Heavily polluted	b_1 ; b_2 ; b_3.	*02*	*00 – 05*
Sites 2 & 3 Polluted	c_2; c_3; c_4; b_4; b_5	*02 - 04*	*05 - 10*
Sites 5 & 7 Slightly polluted	c_5 ; c_6 ; c_7; d_4 ; d_5 ; d_6 ; d_7 ; d_8, d_9, d_{10}	*10 - 18*	*10 - 20*
Sites 4, 6 & 8 Unpolluted	b_6 ; b_7 ; b_8 ; b_9 ;b_{10}; c_1; c_8, c_9, c_{10}; d_1 ; d_2 ; d_3	*16 - 24*	*>30*

The table reveals that sites 1 and 2 and 3 contain few species (2 - 4). Their recovery rate is low from 0 to 10%. These sites are highly urbanized and industrialized are diffused sources of global atmospheric pollution of our study area. They are heavily polluted. Sites 5 and 7 located in the sub coastal area near the petrochemical zone and the urban area of Hamrouche Hamoudi are in the corridor of the pink pollution generated by prevailing winds from the northwest. Ecological conditions are favorable for development of lichen where we counted between 10 and 18 species. Their recovery rate is relatively low barely exceeding 20%, making them slightly polluted sites.

Sites 4, 6, and 8 to specific ecological conditions (climatic, orographic and substratum) are so far from sources of fumes away from all forms of pollution. The diversity of phorophytes are also the source of abundant lichen species of these sites, some 19 to 24 species were observed. The rate of recovery is above 30% to some of them up to 60%. These sites include several species susceptible to pollution such as *Diploïca canescens* (Dicks.) Massal. ; *Parmelia caperata* (L.) Ach. ; *Parmelia perlata* (Huds.) Vain. ; *Parmelia soredians* Nyl. ; *Parmelia tiliacea* (Hoffm.) Ach.

Fig. 3: Card diffuse air pollution Skikda and its surrounding areas



The polluted areas shown in the map (Fig. 3) include b_1 mesh; b_2; b_3; b_4; b_5; c_2; c_3; c_4 as moderately to highly polluted. They are located in the hallway of the pink pollution generated by prevailing winds from the northwest. These include the industrial area and transport the pollutants emitted by different units to deposit them in stations located in her direction. On the other hand, sites that are low or not polluted are located far from sources of emissions from industrial units and sources of urban emissions. They are located off the hallway through which the prevailing winds from the northwest. They are located in the southeast of the mesh, southwest and northeast. These findings are supported by previous studies on the bio-quantitative estimation using the methods of the atmospheric purity, poleotolerance index and analytical monitoring of air pollution total hydrocarbons (Fadel 2007 & 2014).

4.3. Poleophobia scale of the lichen flora of the study area

Lichens are distributed according to the level of the pollutions. This distribution allowed us to establish a scale of poleophobia as the principal species that is sensitive to pollution. These classifications are delineated below.

(a) ***Very resistant species, located in urban and industrial areas***

- *Caloplaca* sp_1
- *Pertusaria albescens* (Huds.) M.Choisy
- *Phlyctis agelaea* (Ach.) Flot.
- *Physcia biziana* (Massal.) Zahlbr.
- *Physconia grisea* (Lamk.) Poelt
- *Xanthoria parietina* (F) Fr Th

(b) ***Moderately resistant species, located in the little urbanized suburban areas***

- *Caloplaca* sp_1
- *Caloplaca* sp_2
- *Candelariela* sp
- *Collema nigrescens* (Huds.) DC.
- *Pertusaria hemisphaerica* (Flörke) Erischs
- *Pertusaria Hymenea* (Ach.) Schaer.
- *Phaeophyscia hursita* (Mereschk.) Moberg
- *Physconia pulverulacea* Moberg

(c) ***Poleophobia species located in rural areas away from sources of emissions***

- *Diploïca canescens* (Dicks.) Massal.
- *Parmelia caperata* (L.) Ach.
- *Parmelia perlata* (Huds.) Vain
- *Parmelia soredians* (Nyl.).
- *Parmelia tiliacea* (Hoffm.) Ach

5. CONCLUSION

Our study was directed on the qualitative bio-estimation of a global and diffuse atmospheric pollution of the city of Skikda and its periphery using lichen flora as bio-indicator. We identified all the arboreal lichen flora of all the stations studied. During this phase we also collected all the data needed to study the biophysical environment of our study area. It is imperative to identify some biophysical factors, such as climate and the tree flora (lichen substrate or phorophyte) to better understand their influence on the distribution of lichens in different stations. The census results of the lichen flora of the Skikda region showed that the number and rate of recovery is closely linked to the degree of pollution. Previous works by Gilbert *et al.* (1970), and Semadi *et al.* (1997) point in the same direction. They appreciate the degree of pollution directly from field observation. The same finding is remarkable to know when pollution is high, the number of species decreases and

their recovery rate. The quality card air obtained allowed to demonstrate that all sampling sites located within moderately to highly polluted sites are located in the corridor of pollution generated rose by prevailing winds North West. These pass through the industrial area and transport the pollutants emitted by different units to deposit them in stations located in that direction. Sites that are located in peripheral urban fabric sites are heavily polluted. The sites contained in the meshes which are near major roads are moderately or highly at polluted. Only sites that are poorly or not polluted are located away from sources of emissions from industrial units and sources of urban emissions.

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