**REPUBLIC OF AZERBAIJAN**

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**ABSTRACT**

of the dissertation for the degree of Doctor of Philosophy

**LICHENS OF SOME INDUSTRIAL CITIES OF AZERBAIJAN AND ASSESSMENT OF**

**BIOINDICATION FEATURES**

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**INTRODUCTION**

**The actuality of the subject.** The lichenoindication method has been used for several decades to assess the level of environmental pollution[[1]](#footnote-1). Numerous field and laboratory studies have shown that air pollution in industrial centers is a major factor in the destruction of lichens in cities[[2]](#footnote-2),[[3]](#footnote-3). There is no doubt that microclimate conditions (increased drought in the air, temperature changes, dew reduction and increase, weakening of solar radiation) have a negative impact on the distribution of lichens.

One of the most important problems of environmental is the selection of bioindicators and assessment of their tolerance. Among the most important pollutants carbon oxide, nitrogen oxide, sulphur dioxide, ozone, carbohydrates, aldehydes, heavy metals (Pb, Cu, Zn, Cd, Cr), ammonia, atmospheric dusts, radioactive isotopes, and other sulphur dioxide (SO2) are main pollutants in the atmosphere[[4]](#footnote-4).

The range of impacts of modern industrial centers to the nature is very wide. As a result of human economic activity, a special type of ecosystem - urboecosystems - emerges instead of natural plant groups[[5]](#footnote-5). This process has now become a catastrophic natural factor. As a result, it has led to qualitative changes in the relationship between nature and society.

“CITY EF­FECT” is one of the most pro­mi­sing prob­lems of mo­dern bio­logy and eco­logy. The his­tory of this prob­lem has be­en mo­re than 100 ye­ars. Bi­o­in­di­ca­ti­on fea­tu­res of many ci­ti­es such as Mos­cow (Slu­ka, Ab­ra­mo­va, 1984; Byaz­rov 2002), St. Pe­ters­burg (Ma­lis­he­va, 2003), Ye­ka­te­rin­burg (Pau­kov, 1997), Grozny (Za­kut­no­va, 1988), Lviv (Kuc­her­ya­viy, 1990), Yosh­kar-Ola (Sue­ti­na, 1997), Vol­ga (Liyv, 1984), Mad­rid (Qres­po, Bue­no, 1982), Ber­lin (Le­uc­kert, 1982), Lon­don (Havks­worth, Mc Ma­nus, 1982), Mu­nich (Mac­her, 1987), Pa­ris (De­rul­le, Qar­sia Scha­ef­fer, 1983), Pra­gue (Lis­ka, Vez­da, 1990), Ham­burg (Ger­many, John, 1989) we­re in­ves­ti­ga­ted. In re­cent ye­ars, re­se­arch in this area has ac­ce­le­ra­ted sig­ni­fi­cantly. The­se re­se­arc­hes are very im­por­tant for ur­ban plan­ning. Dif­fe­rent spe­ci­es of lic­hens are va­lu­ab­le bi­o­in­di­ca­tors for de­ter­mi­ning the deg­ree of air pol­lu­ti­on be­cau­se they ha­ve dif­fe­rent po­leo­to­le­rant pro­per­ti­es.

The results of many researches on the study of the theory and practice of the problem of lichenoindication through lichens have been published in England, America, the Baltics[[6]](#footnote-6),[[7]](#footnote-7). Despite the fact that the taxonomic structure of the lichens in Azerbaijan has been sufficiently studied by Sh.O.Barkhalov, V.S.Novruzov, S.M.Alverdiyeva, A.A.Bayramova, D.Sh.Ganbarov and others, there is little information about the possibility of using it as bio-monitoring. The efficient use of natural resources and the problem can be solved only on the basis of the study of natural processes. In this regard, it is important to study the species composition of lichens in natural and anthropogenic ecosystems. Although lichens are widespread in nature, they are not inexhaustible, and a number of species have become extinct as a result of human intervention[[8]](#footnote-8). A number of species have already been included in the International Red Books, including the 2nd edition of the Red Book of Azerbaijan[[9]](#footnote-9).

The role of lichens as a bioindicator of environmental pollution is great. The bioindication method has some advantages over physical-chemical methods, as it does not require expensive equipment and devices. The results are obtained by continuous observation, without interfering with the vital processes of the organism. At the same time it is possible to characterize a large area[[10]](#footnote-10).

Dif­fe­rent spe­ci­es of lic­hens re­act dif­fe­rently to at­mosp­he­ric air pol­lu­ti­on. The fac­tor of dif­fe­ren­tia­ti­on of spe­ci­es com­po­si­ti­on in ur­ban con­di­ti­ons is en­vi­ron­men­tal pol­lu­ti­on. Pol­lu­ti­on in su­burbs is not the ma­in fac­tor of dif­fe­ren­tia­ti­on (li­mi­ting fac­tor). In this re­gard, the dis­tur­ban­ce of the eco­lo­gi­cal ba­lan­ce is al­so ref­lec­ted in the so­ci­al and eco­no­mic de­ve­lop­ment of so­ci­ety. This pro­cess is typi­cal for the de­ve­lo­ped ci­ti­es of Azer­bai­jan - Gan­ja, Min­gac­he­vir, Yev­lakh, Dash­ka­san, Ga­zakh, Shir­van.

The susceptibility of lichens to air pollution is due to the fact that their water enters not only from the substrate, but also through chemicals in the atmosphere. Some lichens are intolerant to small amounts of pollutants in the air. Others, on the contrary, live in settlements in anthropogenic conditions. It is possible to determine the degree of contamination through licnehs[[11]](#footnote-11),[[12]](#footnote-12),[[13]](#footnote-13).

Taking into account the urgency of the problem, the dissertation work on “Assessment of lichenobiota and bioindication features of some industrial cities of Azerbaijan” was completed.

**Object and subject of the research.** Lichens distributed on different substrates were taken as an object of research.

**Pur­po­se and ob­jec­ti­ves of re­se­arch.** It con­sists of de­ter­mi­ning the spe­ci­es com­po­si­ti­on and dist­ri­bu­ti­on pat­terns of lic­he­no­bio­ta in so­me in­dust­ri­al ci­ti­es of Azer­bai­jan, as­ses­sing the bi­o­in­di­ca­ti­on fea­tu­res in ur­boe­cosys­tems. The fol­lo­wing tasks ha­ve be­en set to ac­hie­ve the pur­po­se:

- Identification and environmental assessment of major pollution sources in some industrial cities;

- Provision of characteristics of lichenobiota of the studied cities (Ganja, Mingachevir, Yevlakh, Gazakh, Dashkesen, Shirvan);

- Compilation of lichenoindication maps of Ganja, Yevlakh, Mingachevir, Gazakh, Dashkasan, Shirvan cities and their ecological substantiation;

- Identification of road transport pollutants and explanation of the mechanism of impact on the lichens;

- Identification of sensitive epiphytic lichens by analysis of existing approaches and identification of optimal methods that can be applied to lichenobiota of the urboecosystem;

- Spa­ti­al dist­ri­bu­ti­on of so­me spe­ci­es of lic­hens and de­ter­mi­na­ti­on of the­ir dist­ri­bu­ti­on in Gan­ja, Min­gac­he­vir, Yev­lakh, Dash­ka­san, Ga­zakh, Shir­van ci­ti­es as a who­le;

**Re­­se­­arch met­hods.** The re­se­arc­hes we­re per­for­med by rou­te and sta­tio­nary met­hods. At the sa­me ti­me, flo­ris­tic, flo­ris­tic-syste­ma­tic, areo­lo­gi­cal, bo­ta­ni­cal-ge­og­rap­hi­cal, phyto­ce­no­lo­gi­cal, sta­tis­ti­cal met­hods we­re ta­ken in­to ac­co­unt. Po­leo­to­le­ran­ce in­dex (PI) was cal­cu­la­ted, sen­si­ti­vity sca­le of the spe­ci­es was com­pi­led. Vi­tal forms and eco­lo­gi­cal gro­ups of lic­hens, oc­cur­ren­ce fre­qu­ency of spe­ci­es, ge­ne­ral dist­ri­bu­ti­on pat­terns and do­mi­nant synu­sia de­pen­ding on the type of subst­ra­te we­re de­ter­mi­ned, the struc­tu­re of samp­le si­tes was com­pa­red and analy­zed.

**The main provisions of the defense.**

1. The lic­hen flo­ra of Gan­ja, Ga­zakh, Min­gac­he­vir, Yev­lakh, Dash­ka­san, Shir­van was for­med un­der the inf­lu­en­ce of comp­lex eco­lo­gi­cal fac­tors. The de­ci­si­ve ro­le among them is the anth­ro­po­ge­nic trans­for­ma­ti­ons of the ur­ban en­vi­ron­ment. The na­tu­re of the de­ve­lop­ment of epiphy­tic lic­hens de­ter­mi­nes the cha­rac­te­ris­tics of the func­tio­nal use of the area;
2. Ur­ba­ni­za­ti­on of the natural environment of Ganja, Gazakh, Mingachevir, Dashkasan, Yevlakh, Shirvan affects the composition of lichenobiota;
3. It is cor­re­la­ted with the le­vel of con­di­ti­on of the epiphy­tic lic­hens of the city high­way. Maps com­pi­led using the lic­he­no­in­di­ca­ti­on met­hod can be app­li­ed in the de­sign of ur­ban and su­bur­ban are­as.
4. Lic­­he­­no­­lo­­gi­­cal maps are comp­lex in­di­ca­tors of en­vi­ron­men­tal pol­lu­ti­on of in­dust­ri­al ci­ti­es;
5. The structure and composition of the lichen synusia of the studied cities provide an assessment of atmospheric pollution.

**Sci­en­ti­fic no­velty of the re­se­arch.** As a re­sult of lic­he­no­in­di­ca­ti­on re­se­arc­hes con­duc­ted for the first ti­me in the re­gi­on, mo­del are­as we­re se­lec­ted in Gan­ja, Min­gac­he­vir, Yev­lakh, Dash­ka­san, Shir­van, Ga­zakh ci­ti­es, the spe­ci­es com­po­si­ti­on of ur­ban lic­he­no­bio­ta was stu­di­ed, to­le­rant spe­ci­es re­sis­tant to at­mosp­he­ric pol­lu­tants and wi­desp­re­ad spe­ci­es we­re se­lec­ted, are­as ex­po­sed to anth­ro­po­ge­nic inf­lu­en­ces we­re se­lec­ted, the cau­ses of air pol­lu­ti­on we­re cla­ri­fi­ed by appl­ying the car­tog­raphy met­hod and sci­en­ti­fic exp­la­na­ti­on of the anth­ro­po­ge­nic trans­for­ma­ti­on of lic­he­no­bio­ta was pro­vi­ded. As a re­sult, ten­dency to­wards an inc­rea­se in the anth­ro­po­ge­nic lo­ad and dec­rea­se in the spe­ci­es di­ver­sity and abun­dan­ce of lic­hens we­re ob­ser­ved.

It was found out that 29 species in Ganja, 32 in Gazakh, 22 in Yevlakh, 18 in Mingachevir, 20 in Shirvan, 34 in Dashkesan have been toxitolerant and recommended as biological monitors.

For the first time, 29 families, 41 genera and 68 species have been identified for industrial cities. Of these:

1. Ganja city -16 family, 16 genera, 29 species
2. Dashkesan city - 21 family, 25 genera, 34 species
3. Yevlakh city -11 family, 11 genera, 22 species
4. Mingachevir city - 11 family,13 genera, 18 species
5. Shirvan city -14 family, 14 genera, 19 species
6. Gazakh city - 20 family, 23 genera, 31 species

**Theo­re­ti­cal and prac­ti­cal sig­ni­fi­can­ce of the re­se­arch.** It is ne­ces­sary to se­lect in­di­ca­tor spe­ci­es for dif­fe­rent so­ur­ces of pol­lu­ti­on, use lic­hens as bio­mo­ni­to­ring of the en­vi­ron­ment, pro­vi­de bio­morp­ho­lo­gi­cal cha­rac­te­ris­tics, de­ter­mi­ne the eco­lo­gi­cal sus­tai­na­bi­lity of spe­ci­es, the­ir ro­le in the phyto­ce­no­sis, iden­tify re­so­ur­ce so­ur­ces and crea­te fo­re­cast maps, as well as ef­fi­ci­ent use of na­tu­ral re­so­ur­ces.

The obtained data allow to analyze the air condition of the studied cities and on this basis to develop measures to improve air quality.

The results of the study of lichens in the territory of Ganja city can be used in compiling the regional lichenoflora, specifying the ecology, geography and habitats of different species, as well as in developing a system of measures for rare lichen species.

The results obtained are considered the basis for predicting technogenic impacts harmful to the environment and human health.

Re­se­arch ma­te­ri­als can be used in the te­ac­hing of bio­logy, bio­logy-te­ac­hing, che­mistry-bio­logy, eco­logy and en­vi­ron­men­tal pro­tec­ti­on fa­culty spe­cia­li­ti­es, and in­for­ma­ti­on on spe­ci­es com­po­si­ti­on can be used in the te­ac­hing of re­le­vant sec­ti­ons of bo­tany.

**App­­ro­­ba­­ti­­on and app­li­ca­ti­on.** Ba­sed on the re­sults of the re­se­arch, se­ven sci­en­ti­fic ar­tic­les, three con­fe­ren­ce ma­te­ri­als and fi­ve the­ses we­re pub­lis­hed in ac­cor­dan­ce with the dis­ser­ta­ti­on to­pic. Of them two ar­tic­les and three the­ses we­re pub­lis­hed ab­ro­ad. The ma­in pro­vi­si­ons of the dis­ser­ta­ti­on we­re pre­sen­ted and dis­cus­sed in In­ter­na­tio­nal sci­en­ti­fic con­fe­ren­ce on “Ac­tu­al prob­lems of Bio­logy and Che­mistry” (Gan­ja, 2015; 2016; 2019); Sympo­si­um on euroa­si­an bio­di­ver­sity (Ba­ku, 2015; Minsk, 2017); at the XXI Re­pub­li­can Sci­en­ti­fic Con­fe­ren­ce of Doc­to­ral Stu­dents and Yo­ung Re­se­arc­hers (Ba­ku, 2017), at the Con­fe­ren­ce “New Chal­len­ges in Bo­ta­ni­cal Re­se­arch” de­di­ca­ted to the 90th an­ni­ver­sary of aca­de­mi­ci­an Va­hid Ja­lal og­lu Ha­ji­yev or­ga­ni­zed by the Ins­ti­tu­te of Bo­tany of ANAS and the So­ci­ety of Azer­bai­jan Bo­ta­nists (Ba­ku, 2018), at the con­fe­ren­ce de­di­ca­ted to the 120th an­ni­ver­sary of V.I.Ul­ya­nis­hev (Ba­ku, 2018), Sci­en­ti­fic Con­fe­ren­ces of Gan­ja Sta­te Uni­ver­sity (2015; 2016; 2017; 2018), Sci­en­ti­fic se­mi­nar and Sci­en­ti­fic Co­un­cil of the Ins­ti­tu­te of Bo­tany of ANAS.

**The organization where the dissertation work is performed.** The dissertation work was carried out at the Department of Botany of Ganja State University.

**The struc­tu­re and to­tal vo­lu­me of the dis­ser­ta­ti­on.** The dis­ser­ta­ti­on con­sists of 139 pa­ges - int­ro­duc­ti­on, 7 chap­ters, conc­lu­si­on, 28062 cha­rac­ters, inc­lu­ding prac­ti­cal re­com­men­da­ti­ons, a list of li­te­ra­tu­re with 222 tit­les.

**CHAPTER I. PHYSICAL GEOGRAPHICAL CHARACTERISTICS OF THE RESEARCH AREA**

A brief description of the natural-geographical features of the study area was given, the relief, climatic conditions, hydrology, soil and vegetation cover of the area were analyzed.

**CHAPTER II. RESEARCH MATERIALS AND METHODS**

The research was conducted in Ganja, Mingachevir, Dashkasan, Yevlakh, Gazakh, Shirvan and its environs in 2014-2019.

Rou­ting and sta­tio­nary met­hods, as well as flo­ris­tic, flo­ris­tic-syste­ma­tic, areo­lo­gi­cal, bo­ta­ni­cal-ge­og­rap­hi­cal, phyto­ce­no­lo­gi­cal, sta­tis­ti­cal met­hods used in bo­tany we­re used in the re­se­arch (Gross­he­im, 1948). Po­leo­to­le­ran­ce in­dex was stu­di­ed in Es­to­nia (Liv, 1988), Ka­zan (Go­lub­ko­va, 1978), the Bal­tics (Trass, 1988), Grozny (Za­kut­no­va, 1988) and Ast­rak­han (Pi­li­pen­ko, 2008). It is known that lic­hens are an in­di­ca­tor of air pol­lu­ti­on and can be used in the en­vi­ron­men­tal mo­ni­to­ring system of the re­gi­on.

A comp­re­hen­si­ve study of lic­hens sho­uld inc­lu­de in­for­ma­ti­on not only on the lic­he­nof­lo­ra of the study area, but al­so on the lo­cal and bio­lo­gi­cal cha­rac­te­ris­tics of ne­arby ur­boe­cosys­tems. On the ot­her hand, a com­pa­ra­ti­ve analy­sis sho­uld be con­duc­ted on re­gio­nal backg­ro­unds. In many ca­ses, the choi­ce of such are­as is prob­le­ma­tic. The shown app­ro­ac­hes sho­uld be ade­qua­te to the en­vi­ron­men­tal va­ria­bi­lity of the ur­boe­cosys­tem we are stud­ying. We ha­ve ta­ken Goy-Gol Na­tio­nal Park and Korc­hay Sta­te Na­tu­re Re­ser­ve as a cle­an re­gio­nal backg­ro­und. The­se ob­jects we­re used as a so­ur­ce of in­for­ma­ti­on to as­sess anth­ro­po­ge­nic trans­for­ma­ti­ons of re­mo­te are­as. This al­lo­wed to ac­hie­ve suc­cess­ful re­sults in the con­text of clus­ter app­ro­ac­hes.

As a re­sult of anth­ro­po­ge­nic lo­ad analy­sis of the dist­ri­bu­ti­on of epiphy­tic lic­hens in ur­ban parks and gar­dens, a sen­si­ti­vity sca­le of the spe­ci­es has be­en com­pi­led. Spe­ci­es are di­vi­ded in­to sen­si­ti­ve (he­te­rop­ho­bia), mo­de­ra­tely sen­si­ti­ve (mild) and re­sis­tant (he­me­rop­hil) gro­ups.*Ever­nia pru­nast­ri, Ra­ma­li­na fas­ti­gia­ta, Ra­ma­li­na di­la­ce­ra­ta, Ra­ma­li­na fra­xi­nea, Par­me­lia sa­xa­­ti­lis* be­long to the first ca­te­gory. Mo­de­ra­te-sen­si­ti­ve spe­ci­es *Me­la­nel­la lau­ra, Le­ca­no­ra sam­bu­ci* and etc. are fo­und in parks and flo­ors of the cent­ral parts. Re­sis­tant (to­le­rant) spe­ci­es *Xhan­to­ria pa­rie­ti­na, Physcia or­bi­cu­la­­ris, Physcia stel­la­ris, Physco­nia gri­sea, Physco­nia dis­tor­ta* and etc. are spre­ad in all parts of the park.

Ma­te­ri­als were implemented in linden (*Tilia cordata* L.), maple (*Acer platanopolics* L.), common pine (*Pinus* *sylvestris* L.), plane (*Platanus orientalis* L.), ash-tree (*Fraxinus excelsior* L.), pear (*Pyrus communis* L.) and other trees. The city’s plan system is divided into square meters (1km) and geobotanical description of the lichen groups within it was given:

1.With the help of a system of sample sites, the species composition of lichenobiota of Ganja, Mingachevir, Dashkasan, Yevlakh, Gazakh, Shirvan and its environs was studied, and the vital forms and ecological groups of lichens spread in these areas were determined;

2.Lichen species were identified in and around cities and the occurence frequency of species was studied;

3.General distribution patterns of different lichen species and vital forms depending on the substrate type were identified;

4.Types of lic­he­nosy­nu­sia we­re de­ter­mi­ned, the pre­sen­ce of lic­hens in dif­fe­rent phyto­ce­no­ses and dif­fe­rent subst­ra­tes was as­ses­sed, do­mi­nant synu­sia was de­ter­mi­ned;

5.Comparative characteristics of different industrial centers and built sample areas were given. According to the methodology of lichenoindication studies[[14]](#footnote-14), the map of cities is divided into square points.

A plan map was used in the re­se­arch ci­ti­es to cla­rify the dist­ri­bu­ti­on cha­rac­te­ris­tics of the lic­hens. A fra­me was used to cal­cu­la­te the co­ve­ra­ge of the epiphy­tic lic­hens[[15]](#footnote-15). The di­men­si­ons of the fra­mes can be dif­fe­rent: 5x10 cm; 10x10 cm; 20x20 cm.

The nomenclature of taxa was given according to modern catalogs (Hauck, Dulamsuren 2016)[[16]](#footnote-16). In the studied cities, a 20x20 cm experiment was performed on each tree and the poleotolerance index (PI) was calculated using the following formula. The average value PI was conducted for each tree trunk studied, and then for each sample area13. In the studied urban areas, the IO value was correlated with the average concentration of sulphur oxide in the air and calculated by the poleotolerance index:

Here, *a* – degree of tolerance of lichen species in urban environment;

*c-* the degree of cover of species (by point);

*n-* quantity of species;

*C-* average total coverage of all species.

The occurrence of each species was determined on a five-point scale: 1 point -0-20%; 2 points-21-40%; 3 points-41-60%; 4 points-61-80%; 5 points-81-100%.

Cover was assessed on the following 5-point scale [100]: 1 point-1-5%; 2 points-6-20%; 3 points-21-40%; 4 points-41-65%; 5 points-66-100%.

Poleotolerance index was studied in Estonia (Liv, 1988; Martin, 1982), Kazan (Golubkova, 1978), Southern Baltic (Trass, 1988), Grozny (Zakutnova, 1988) and Astrakhan (Pilipenko, 2008).

**CHAPTER III. PROBLEM OF USING LICHENS AS AN INDICATOR**

The­re is a ne­ed to crea­te spe­ci­al in­for­ma­ti­on systems - mo­ni­to­ring system to as­sess anth­ro­po­ge­nic chan­ges of the con­di­ti­on of the en­vi­ron­ment. To de­ter­mi­ne the deg­ree of im­pact of en­vi­ron­men­tal pol­lu­tants on in­dust­ri­al fa­ci­li­ti­es, it is im­por­tant to know the res­pon­se of bio­lo­gi­cal fa­ci­li­ti­es to pol­lu­tants. For this pur­po­se, lic­hens we­re se­lec­ted as the ma­in ob­ject for bio­lo­gi­cal mo­ni­to­ring[[17]](#footnote-17), [[18]](#footnote-18).

The chap­ter pro­vi­des a cri­ti­cal analy­sis of the li­te­ra­tu­re on the use prob­lem of lic­hens as an in­di­ca­tor, the analy­sis of re­sults of re­se­arch on the study of the the­ory and prac­ti­ce of the lic­he­no­in­di­ca­ti­on prob­lem.

**CHAPTER IV. LICHENOBIOTA OF URBOECOSYSTEMS OF SOME INDUSTRIAL CITIES**

As a re­sult of the de­ve­lop­ment of li­te­ra­tu­re and fi­eld re­se­arch ma­te­ri­als, the ta­xo­no­mic com­po­si­ti­on of the lic­he­no­bio­ta of ur­boe­cosys­tems of Gan­ja, Min­gac­he­vir, Yev­lakh, Dash­ka­san, Ga­zakh, Shir­van was dis­co­ve­red. It was de­ter­mi­ned that the lic­he­no­bio­ta of the stu­di­ed ur­boe­cosys­tems con­sists of 68 spe­ci­es be­lon­ging to 41 ge­ne­ra on 29 fa­mi­li­es.

*Physcea­ce­ae* (11 spe­ci­es), *Le­ca­no­­ra­­ce­ae* (10 spe­ci­es), *Ca­lop­la­ca­ce­ae* (5 spe­ci­es), *Art­ho­nia­ce­ae* (3 spe­ci­es) pre­do­mi­na­te in lic­he­no­bio­ta of ur­boe­cosys­tems. Each of *Le­ci­dea­ce­ae, Pyre­nu­la­ce­ae, Me­gas­po­ra­ce­ae* fa­mi­li­es was rep­re­sen­ted with two spe­ci­es. 12 fa­mi­li­es are mo­noty­pe and rep­re­sen­ted with one spe­ci­es. Analy­sis at the ge­nus le­vel shows that *Le­ca­no­ra* ( 9 spe­ci­es), *Te­losc­his­tes* (4 spe­ci­es), *Physcia* (3 spe­ci­es), *Ca­lop­la­ca* (5 spe­ci­es) pre­do­mi­na­te.

It was fo­und that lic­he­no­bio­ta of ur­boe­cosys­tems of Gan­ja city con­sists of 29 spe­ci­es be­lon­ging to 16 fa­mi­li­es, 16 ge­ne­ra, lic­he­no­bio­ta of ur­boe­cosys­tems of Min­gac­he­vir city – 18 spe­ci­es be­lon­ging to 11 fa­mi­li­es, 13 ge­ne­ra, lic­he­no­bio­ta of ur­boe­cosys­tems of Yev­lakh city – 22 spe­ci­es be­lon­ging to 11 fa­mi­li­es, 11 ge­ne­ra, lic­he­no­bio­ta of ur­boe­cosys­tems of Ga­zakh city – 31 spe­ci­es be­lon­ging to 20 fa­mi­li­es, 23 ge­ne­ra, lic­he­no­bio­ta of ur­boe­cosys­tems of Dash­ka­san city – 34 spe­ci­es be­lon­ging to 21 fa­mi­li­es, 25 ge­ne­ra and lic­he­no­bio­ta of ur­boe­cosys­tems of Shir­van city – 19 spe­ci­es be­lon­ging to 13 fa­mi­li­es, 13 ge­ne­ra.

**CHAPTER V. SOCIO-ECONOMIC CHARACTERISTICS OF SOME INDUSTRIAL CITIES AND EVALUATION OF BIOINDICATION FEATURES OF URBOECOSYSTEMS**

The chapter consists of 5 sections. The sections identifies socio-economic characteristics of Ganja, Mingachevir, Yevlakh, Gazakh, Dashkasan and Shirvan cities, main atmospheric pollutants and their sources and assess bioindication features of urboecosystems.

**5.1. Assessment of bioindication features of Ganja city urboecosystems.** The main limiting factor in the city of Ganja is the Ganja DET.AL aluminum complex, motor transport and industrial centers. The main atmospheric air pollutants are Ganja Metal Casting and uninterrupted combustion plant, Electrolysis, Neon Flour Mill, Automobile factories, Royal LLC concrete, glass, brick plants. The role of road transport in urban air pollution is high.

Sul­fur gas, nit­ro­gen oxi­des, fluo­ri­des, ozo­ne and he­avy me­tals ha­ve the grea­test im­pact on the li­fe of lic­hens in Gan­ja. SO2 is the do­mi­nant fac­tor. SO2 pro­vi­des the spre­ad of epiphy­tic lic­hens. It was fo­und that 0,08 – 0,1 mml3 of sul­fur dio­xi­de dis­rupts the pro­cess of pho­tosynt­he­sis. Brown spots are ob­ser­ved in the chlo­rop­last of lic­hens. At low pH, chlo­rophyll aci­di­fi­es when the hu­mi­dity is 3,4. When the pH is 2-3, it turns in­to a phe­ophy­tin. The inc­rea­se in hu­mi­dity en­han­ces the dis­so­lu­ti­on of SO2 and the aci­dic en­vi­ron­ment. For this rea­son, lic­hens are not re­sis­tant to high hu­mi­dity. Ho­we­ver, they are re­sis­tant to high con­cent­ra­ti­ons of SO2 in dry air. At the sa­me ti­me, it is known that yo­ung thal­lo­mes are mo­re sen­si­ti­ve than ol­der thal­lo­me.

The relative purity index of the atmosphere in the study area is given in Table 1. Then the points system was calculated using a special scale. When the relative purity coefficient is high, the air is clean.

**Table 1**

**Relative purity index of the atmosphere in the study area**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Area | Point score of bark-like lichens | Point score of leaflike lichens | Point score of shrublike lichens | Relative atmospheric pollution |
| Railway H.Aliyev avenue, connection of hospital No.3 | 3 | 1 | 0 | 0,20 |
| Asphalt plant with observed industrial pollution. | 3 | 1 | 0 | 0,20 |
| Aluminum factory | 6 | 1 | 0 | 0,40 |
| Machine building factory | 7 | 1 | 0 | 0,30 |
| Concrete plant | 7 | 1 | 0 | 0,43 |
| Central park | 15 | 1 | 0 | 0,60 |
| Gulustan park | 10 | 1 | 0 | 0,57 |
| Damiryolchular park | 10 | 1 | 0 | 0,30 |
| Equipment building factory | 9 | 1 | 0 | 0,40 |
| New Ganja park | 12 | 1 | 0 | 0.63 |

The regularities of the spread of lichens in the territory of Ganja city are given in Table 2.

As a re­sult of the inc­rea­se in anth­ro­po­ge­nic lo­ad, the spe­ci­es di­ver­sity of lic­hens, the pro­jec­ti­ve co­ver of dif­fe­rent spe­ci­es and lic­he­nosy­nu­sia dec­rea­se. Analy­sis of tre­es co­ve­red with lic­hen thal­lo­mes shows that the num­ber of lic­hens in ar­ti­fi­ci­al grou­pings dec­rea­ses sharply. It ma­kes up 37 spe­ci­es in parks and si­de­walks, the ave­ra­ge pro­jec­ti­ve co­ve­ra­ge of lic­hen synu­sia is low in na­tu­ral grou­pings in the city. The num­ber of tre­es in the city park that are not co­ve­red with lic­hen is lo­wer than in the na­tu­ral ve­ge­ta­ti­on gro­ups of the city. In the city park, the ave­ra­ge num­ber of lic­hen-co­ve­red tre­es is 55% and no mo­re than 15% as op­po­sed to plant gro­ups.

**Table 2**

**Species diversity of lichens in different areas of Ganja city**

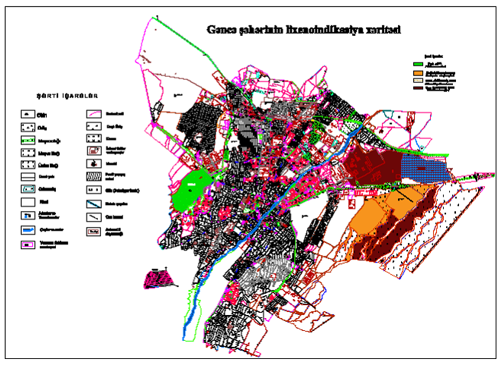
|  |  |  |  |
| --- | --- | --- | --- |
| Plant groups | Number of species | Average projective coverage of lichenosynusia% | Percentage of trees not covered with lichens |
| Pine alleys  Plane alleys (city)  Riverside greenery  Parks and sidewalks  Greenery inside settlement  Side of highways | 22  15  40  37  35  24 | 19.4  14,5  9.5  3  2,4  2.1 | 23  150  52  65  69  70 |

The city of Gan­ja is one of the ci­ti­es of the re­pub­lic with a high le­vel of man-ma­de pol­lu­ti­on, whe­re lar­ge in­dust­ri­al en­terp­ri­ses are lo­ca­ted. Unu­sed was­tes of in­dust­ri­al en­terp­ri­ses, as well as hou­sing and com­mu­nal ser­vi­ces are disc­har­ged in­to the ur­ban en­vi­ron­ment in so­lid, li­qu­id and ga­se­o­us form and cau­se pol­lu­ti­on of the at­mosp­he­re, so­il sur­fa­ce and gro­und­wa­ter. Ac­cor­ding to the Azer­bai­jan Sta­te Hydro­me­teo­ro­logy Cen­ter, pol­lu­ti­on with dust and smo­ke in Gan­ja is 9,2 ti­mes hig­her than nor­mal, pol­lu­ti­on with sul­fur dio­xi­de is 2,2 ti­mes hig­her, and pol­lu­ti­on with hydro­gen sul­fi­de is 8 ti­mes hig­her than nor­mal. The pol­lu­ti­on in­dex in the city is 13,5. The ave­ra­ge an­nu­al dust con­cent­ra­ti­on in the at­mosp­he­re is 4,62 mg/m3, and 5,8 mg/m3 in the cent­ral and eastern part of the city. Ro­ad trans­port was­te alo­ne pol­lu­tes the city’s at­mosp­he­re by 42,9%, inc­lu­ding 90,9% of trans­port was­te is car­bon dio­xi­de, 57,6% - nit­ro­gen oxi­des and 97.6% - car­bohyd­ro­gens. Ac­cor­ding to the Azer­bai­jan Gas Clea­ning Ter­ri­to­ri­al Ins­pec­to­ra­te, only 17 en­terp­ri­ses in the city ha­ve 734 so­ur­ces of ha­zar­do­us was­te. Of the­se, 425 do not ha­ve tre­at­ment fa­ci­li­ti­es. The­re­fo­re, the at­mosp­he­re of Gan­ja city is inc­lu­ded in the list of ci­ti­es ric­her in che­mi­cal ele­ments. In ge­ne­ral, the city’s air ba­sin con­ta­ins sul­fur, nit­ro­gen, hydro­gen sul­fi­de, alu­mi­num com­po­unds, fluo­ri­ne, le­ad, zinc, cop­per and va­ri­o­us dust com­po­unds. In­dust­ri­al en­terp­ri­ses alo­ne re­lea­se 7,749 thou­sands tons of so­lids, 27999 tons of gas and li­qu­id was­te in­to the at­mosp­he­re per ye­ar.

Ac­­cor­­ding to the da­ta of 2017, pol­lu­tants of 20871,40 tons (CO2, CH, NO, etc.) we­re re­lea­sed in­to the at­mosp­he­re of Gan­ja city by mo­tor trans­port. The num­ber of en­terp­ri­ses pol­lu­ting the at­mosp­he­re in Gan­ja city is 31, the num­ber of so­ur­ces of pol­lu­ti­on is 56. Ha­zar­do­us subs­tan­ces of 3834,174 tons we­re re­lea­sed in­to the at­mosp­he­re. Spe­ci­es of lic­hens adap­ted to such a pol­lu­ted en­vi­ron­ment are di­vi­ded in­to 3 gro­ups ac­cor­ding to the deg­ree of to­le­ran­ce: cos­mo­po­li­tan spe­ci­es, spe­ci­es that are se­lec­ti­ve aga­inst cer­ta­in pol­lu­tants, in­to­le­rants. The ran­ge of anth­ro­po­ge­nic ano­ma­li­es was de­ter­mi­ned by imp­le­men­ting ob­ser­va­ti­ons at a dis­tan­ce of 43 km in the di­rec­ti­on of Gan­ja-Goy-Gol by the li­ne­ar-tran­sect met­hod. The im­pact of anth­ro­po­ge­nic ano­ma­li­es on ve­ge­ta­ti­on con­ti­nu­es 30 km east, 20 km west, 12 km north and so­uth, 10 km so­uth-east. De­pen­ding on the con­di­ti­on of the test spe­ci­es, the ran­ge of im­pact of anth­ro­po­ge­nic ano­ma­li­es can be con­si­de­red to be 25-30 km[[19]](#footnote-19). As a re­sult of the analy­sis of the col­lec­ted ma­te­ri­als, the in­di­ca­ti­on of at­mosp­he­ric pol­lu­ti­on of Gan­ja city was cal­cu­la­ted on the ba­sis of the to­le­ran­ce in­dex (TI) using the met­hods de­ve­lo­ped by Es­to­ni­an lic­he­no­lo­gists[[20]](#footnote-20). Ac­cor­ding to the le­vel of oc­cur­ren­ce of to­le­rant spe­ci­es, a lic­he­no­in­di­ca­ti­on map of Gan­ja city was com­pi­led (Map-sche­me 1).

The city of Gan­ja is di­vi­ded in­to fo­ur pol­lu­ti­on zo­nes:

The first zo­ne – T.I. = 9.0-10.0 - zo­ne ex­po­sed to strong im­pact of nit­ro­gen anhyd­ri­de, nit­ric oxi­de, sul­fur dio­xi­de gas and ot­her at­mosp­he­ric pol­lu­tants. This inc­lu­des Aze­ra­lu­mi­ni­um, an oil and fat plant, an equ­ip­ment-ma­king plant and the cent­ral part of the city, whe­re a ma­jor high­way pas­ses. No lic­hen is fo­und in the cent­ral part of this zo­ne. *Ca­lop­la­ca ce­ri­na, Pha­e­ophy­sia or­bi­cu­la­ris* we­re re­gis­te­red at a dis­tan­ce of 2500m, *Xant­ho­ria pa­rie­ti­na, Physco­nia gri­sea* at a dis­tan­ce of 1500m to the west, *Clo­do­nia fur­ca­ta* on the gro­und, *Can­de­la­ri­el­la aurel­la* on the rock. No lic­hen spe­ci­es was re­gis­te­red up to 3000 m on the ro­ofs of the hou­ses to­wards Aze­ra­lu­mi­num.



**Map-scheme 1. Lichenoindication map of Ganja city**

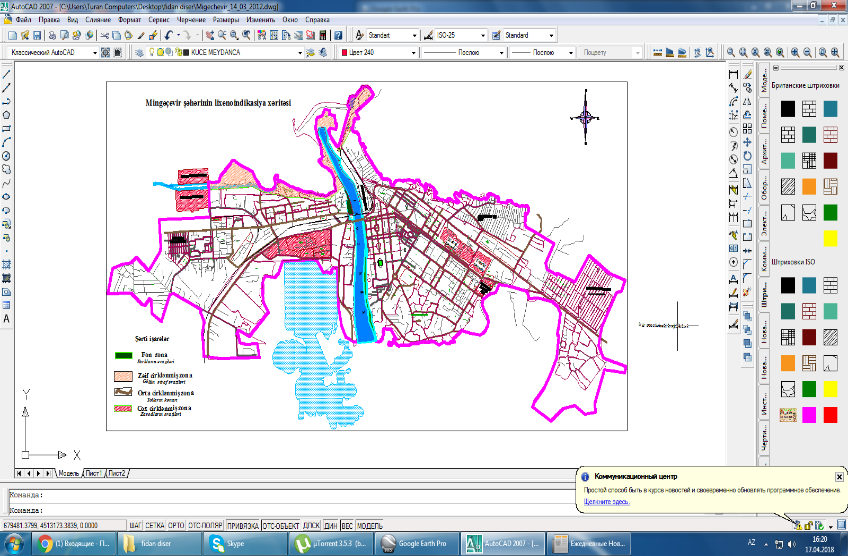
The second zone - TI = 6,0- 9,0 the central part of the city under the influence of industrial enterprises and the area within a radius of 2-4 km, as well as the lower part of the Ganja railway station, a radius of 1 km is considered a pollution zone. No lichens are encountered in the central streets and sidewalks. However forms specific lichen synusia consisting of the *Candelaria concolor- Caloplaca lactea, Candelariella aurella– Caloplaca elegans* on the roofs of houses located in the opposite direction to industrial enterprises. The thallome of the whitish-gray *Physconia caesia* are observed between two synusia forming a yellowish-pink сover.

Third zo­ne - TI = 3,0- 6,0 *Xhant­ho­ria pa­re­ti­na, Le­ca­nia di­me­ra, Le­ca­no­ra at­ra, Physco­nia gri­sea, Ca­lop­la­ca cit­ri­na, Par­me­lia sa­xa­ti­lis* spe­ci­es are fo­und in orc­hards at a dis­tan­ce of 4 km along Bag­ban­lar sett­le­ment and the banks of the Gan­ja Ri­ver.

The fourth zone - TI = 1,0- 3,0 covers an area of 5-6 km around the city. *Cladonia furcata, C.foliaceae, Tonini candida, Collema crispum, Diploschistes scruposus* and etc. species are encountered among the steppe vegetation in the soil.

**5.2. Evaluation of bioindication features of urboecosystems of Mingachevir and Yevlakh cities.** The city of Mingachevir was built in connection with the construction of a hydroelectric power plant on the Kura River. It received the status of a city on November 11, 1948. It is located 323 km from Baku. It is 17 km from the Baku-Tbilisi railway. The national airport is located 30 km from the Yevlakh region, and the international airport is located 80 km from the city of Ganja.

The lic­he­no­bio­ta of Min­gac­he­vir is al­most uns­tu­di­ed. Ta­king in­to ac­co­unt the bi­o­in­di­ca­ti­on fea­tu­res of lic­hens, the­re is a ne­ed to study the bio­lo­gi­cal di­ver­sity of lic­hens of Min­gac­he­vir city. Ac­cor­ding to the le­vel of oc­cur­ren­ce of to­le­rant spe­ci­es, a lic­he­no­in­di­ca­ti­on map of Min­gac­he­vir city was com­pi­led (Map-sche­me 2).



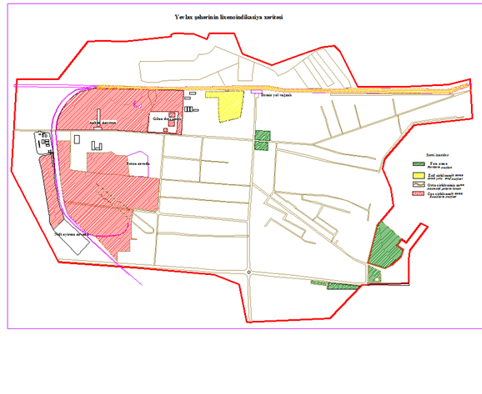
**Map-scheme 2. Lichenoindication map of Mingachevir city**

**Yevlakh** - The city of Yevlakh is located on the right bank of the Kura River, 293 km from Baku, in a plain area. (The south-eastern of the Ganja-Gazakh plain, the north-western edge of the Karabakh and Shirvan plains, the city of Yevlakh is on the Ancient Silk Road). The climate is characterized by temperate-hot semi-desert and dry steppe with dry winters.

Sin­ce March 2004, a num­ber of in­dust­ri­al fa­ci­li­ti­es in the city ha­ve be­en re­const­ruc­ted or bu­ilt. “Ta­mir” ATSC has be­en re­const­ruc­ted, whe­re trac­tors of dif­fe­rent brands are as­semb­led and re­pai­red. “La­la-Teks­til” se­wing, “Ar­fa” fur­ni­tu­re fac­to­ri­es, “Gi­lan” le­at­her pro­ces­sing, “Dan” brick fac­to­ri­es, “Gi­da” LLC can­nery and ot­her new pro­duc­ti­on en­terp­ri­ses al­so ope­ra­te. Yev­lakh is al­so a trans­port hub. The na­tio­nally im­por­tant Ba­ku-Tbi­li­si ra­il­way, Ba­ku-Ga­zakh high­way, Ba­ku-Sup­sa, Ba­ku-Tbi­li­si-Cey­han oil, Ga­zakh-Ags­ta­fa, Ba­ku-Er­zu­rum gas pi­pe­li­nes al­so pass thro­ugh Yev­lakh. Yev­lakh Airport, which ser­ves do­mes­tic flights al­so lo­ca­ted in Yev­lakh. The pas­sing of the Ba­ku-Tbi­li­si-Kars ra­il­way, which has be­en un­der const­ruc­ti­on in re­cent ye­ars, al­so pro­mi­ses sig­ni­fi­cant pros­pects for Yev­lakh.

The le­vel of oc­cur­ren­ce of spe­ci­es in anth­ro­po­ge­nic and na­tu­ral ecosys­tems of Min­gac­he­vir and Yev­lakh is not the sa­me. Che­mi­cal analy­sis of the spe­ci­es fo­und in tho­se ci­ti­es re­vea­led a cor­re­la­ti­on bet­we­en po­le­to­le­ran­ce and SO2. As a re­sult of eco­bio­morp­ho­lo­gi­cal analy­sis, fi­ve gro­ups of vi­tal forms of lic­hens we­re iden­ti­fi­ed. Po­le­to­le­rant spe­ci­es for Min­gac­he­vir and Yev­lakh ha­ve be­en iden­ti­fi­ed on the ba­sis of rou­te re­se­arc­hes.

Ac­cor­ding to the level of occurrence of tolerant species, a lichenoindication map of Yevlakh was compiled (Map-scheme 3).



**Map-scheme 3. Lichenoindication map of Yevlakh city**

**5.3. Evaluation of bioindication features of urboecosystems of Gazakh and Dashkasan cities.** One of the main pollutants for the city of Gazakh is the highway connecting Azerbaijan with Georgia, Russia and Turkey.

In to­tal, 27 spe­ci­es of lic­hens we­re fo­und for Ga­zakh city. Most of them are fo­und in tree bark, subst­ra­te, ro­of co­ver. From the spe­ci­al gro­up of lic­hens, fi­ve spe­ci­es are ob­ser­ved in ar­ti­fi­ci­al subst­ra­tes, conc­re­te, ce­ment, brick, ro­of co­ver and 5 nit­rop­hi­lic lic­hens we­re re­cor­ded on the­se subst­ra­tes. It was de­ter­mi­ned that the­re is a cor­re­la­ti­on bet­we­en the lic­he­nof­lo­ra and deg­ree of air pol­lu­ti­on ac­cor­ding to the amo­unt of nit­ro­gen oxi­de and the na­tu­re of the lic­hens. The oc­cu­ren­ce of each spe­ci­es was cal­cu­la­ted ba­sed on the ra­tio of area whe­re the spe­ci­es was fo­und in the samp­le area to the to­tal area. In ad­di­ti­on, the per­cen­ta­ge of tre­es that do not ha­ve a lic­hen thal­lo­me was cal­cu­la­ted in each plant gro­up. It was de­ter­mi­ned that 28 spe­ci­es are fo­und in Ga­zakh city and 31 spe­ci­es in Dash­ka­san. Spe­ci­es of *Anaptych­ya, Aca­ros­po­ra, Art­hopy­re­nia, Me­la­nea, Le­ci­del­la Eve­ri­na, Ra­ma­li­na* ge­ne­ra fo­und in the na­tu­ral flo­ra are not pre­sent in ur­boe­cosys­tems. Lic­he­no­in­di­ca­ti­on map of Ga­zakh and Dash­ke­san ci­ti­es ac­cor­ding to the le­vel of oc­cur­ren­ce of to­le­rant spe­ci­es was com­pi­led (Map-sche­me 4-5).

|  |  |
| --- | --- |
|  |  |
| **Map-scheme 4. Lichenoindication map of Gazakh city** | **Map-scheme 5. Lichenoindication map of Dashkesan city** |

As a re­sult of stud­ying the lic­he­no­bio­ta of Ga­zakh and Dash­ka­san ci­ti­es, the fol­lo­wing we­re iden­ti­fi­ed:

- The biodiversity of lichens in cities is declining;

* Spe­ci­es di­ver­sity is dec­li­ning from the outskirts of the city to the cen­ter. For­ma­ti­on abun­dan­ce of *So­re­dia* ge­nus ex­po­sed to at­mosp­he­ric pol­lu­ti­on is inc­rea­sing in ur­ban are­as. In are­as 2.5 km away from the city, the­re are no are­as that ha­ve not be­en ex­po­sed to one or anot­her anth­ro­po­ge­nic im­pact in the ur­ban lands­ca­pe.

- Species *Xanthoria parietina* is a permanent resident of urban greenery.

Based on the above, the poletolerance index was calculated. Poletolerance index of Gazakh and Dashkasan cities is equal to IP = 3.

**5.4. Eva­lua­ti­on of bi­o­in­di­ca­ti­on fea­tu­res of Shir­van city ur­boe­cosys­tems.** Sul­fur gas, nit­ro­gen oxi­des, fluo­ri­des, ozo­ne, he­avy me­tals ha­ve the grea­test im­pact on the li­fe ac­ti­vity of lic­hens of Shir­van city. SO2 is con­si­de­red the do­mi­nant fac­tor. SO2 de­ter­mi­nes the pre­va­len­ce of epiphy­tic lic­hens. It was fo­und that 0.08 - 0.1 mml3 dis­rupts the pro­cess of pho­tosynt­he­sis (Met­ho­do­logy of mea­su­re­ment, 2008). Brown spots are ob­ser­ved in the chlo­rop­last of lic­hens. When the pH is low, chlo­rophyll is aci­di­fi­ed when the hu­mi­dity is 3,4. When the pH is 2-3, it turns in­to a phe­ophy­tin [Trass, 1968]. Inc­rea­sed hu­mi­dity en­han­ces the dis­so­lu­ti­on of SO2 in aci­dic en­vi­ron­ments. For this rea­son, lic­hens are not re­sis­tant to high hu­mi­dity. Ho­we­ver, they are re­sis­tant to high con­cent­ra­ti­ons of SO2 in dry air.

As a result of studying the lichenobiota of Shirvan city, the following was determined.

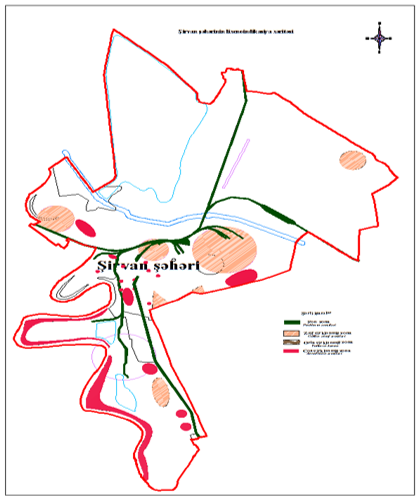
* Biodiversity of lichens is decreasing in cities;
* Species diversity is declining from the outskirts of the city to the center. Formation abundance of Soredia, which is exposed to atmospheric pollution, is increasing in urban areas. (There are no areas that have not been exposed to anthropogenic influences to one degree or another in the urban landscape 2.5 km away from the city).

*Xhantorina parentina* is a permanent resident in urban greenery. Sensitive species are not resistant to atmospheric pollution.

*Xhan­to­ria pa­ri­en­ti­na, Par­mer­li­op­sis am­bi­gua, Physcia pul­ve­ru­len­ta, Ph.ci­lia­ta, Ph.stel­la­ris, Physco­nia gri­sea, Pha­e­ophy­cia ci­lia­ta, Can­de­la­ri­el­la vi­tel­li­na are the most com­mon ur­ban lic­hen nit­rophy­tes:* Eco­lo­gi­cal ac­ti­vity of *Ca­lop­la­ca ce­ri­na, C. ho­lo­car­pa, Le­ca­no­ra ha­ge­nii, P(4) Pha­e­ophys­cia or­bi­cu­la­ris* and etc.spe­ci­es and wi­de ran­ge of the­ir oc­cu­ren­ce are­as are clo­se to the spe­ci­es of Min­gac­he­vir and Yev­lakh ci­ti­es.

Bi­o­in­di­ca­ti­on features of lichens, purity index of Shirvan city atmosphere and poleotolerance indices were calculated according to H.H.Trassa (1968). The city of Shirvan and suburban areas are divided into 3-zone, 4-zone and 7-zone areas according to the species diversity of lichens[[21]](#footnote-21).

According to the level of occurrence of tolerant species, a lichenoindication map of Gazakh city was compiled (Map-scheme 6).

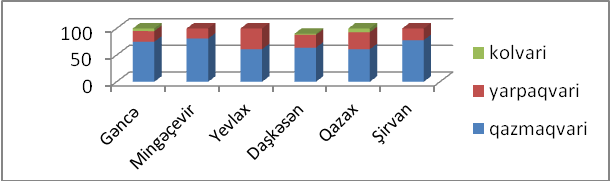


**Map-scheme 6. Lichenoindication map of Shirvan city**

There are similarities in the species composition, depending on the nature of the adaptation of the lichen flora of the studied cities to pollutants. The urban flora of the western region of Azerbaijan is compiled based on the analysis of materials on the example of 6 cities.

A com­pa­ra­ti­ve analy­sis of the lic­he­no­bio­ta of the­se ci­ti­es re­vea­led that the fresh air in­di­ca­tors subs­tan­tia­te the oc­cur­ren­ce of shrub­li­ke forms in the city. Shrub­li­ke forms are not fo­und in Min­gac­he­vir, Yev­lakh and Shir­van. Fo­ur shrub­li­ke forms in Dash­ka­san, two in Ga­zakh are fo­und. In Dash­ka­san and Ga­zakh ci­ti­es, le­af­li­ke forms pre­do­mi­na­te. The­se in­di­ca­tors show that the at­mosp­he­re of the­se ci­ti­es has a mo­de­ra­te le­vel of to­xic and ga­se­o­us emis­si­ons.

In general, Shirvan, Mingachevir, Ganja and Yevlakh are the main cities in terms of pollution. The percentage of forms in the surveyed cities is given in diagram 1.

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**Diagram 1. Percentage of the studied cities according to the vital forms**

Ac­cor­ding to the di­ag­ram No. 1, bark­li­ke vi­tal forms in Gan­ja city ma­ke up 75%, le­af­li­ke 20%, shrub-li­ke only 5%. Bark­li­ke and le­af­li­ke forms are 81%, 19% in Min­gac­he­vir city, 61%, 39% in Yev­lakh, 78%, 22% in Shir­van, res­pec­ti­vely. No shrub­li­ke lic­hens are fo­und in all 3 ci­ti­es. It is 64%, 24%, 12% in the city of Dash­ka­san, res­pec­ti­vely, and 61%, 32%, 7% in the city of Ga­zakh.

The analy­sis of the are­as ex­po­sed to the le­vel of pol­lu­ti­on re­vea­led cer­ta­in re­gu­la­ri­ti­es. As the anth­ro­po­ge­nic lo­ad inc­rea­ses, the amo­unt of lic­hens dec­rea­ses. At the sa­me ti­me, dif­fe­rent morp­ho­lo­gi­cal de­for­ma­ti­ons are ob­ser­ved at the le­vel of oc­cur­ren­ce of dif­fe­rent spe­ci­es, as well as in the lic­hen thal­lo­mes.

No “nor­mal” zo­ne was fo­und in any mo­del area. Ho­we­ver, the num­ber of “Lic­hen de­serts” has inc­rea­sed. *Art­ho­nia ra­dia­ta, Can­de­la­ri­el­la aurel­la, Can­de­la­ri­el­la vi­tel­li­na, Ca­lopl­qa­ca ce­ri­na, Cup­he­li­um ti­gi­la­re, Physco­nia gri­­sea* can be con­si­de­red mo­del spe­ci­es for all are­as with si­mi­lar so­ur­ce of con­ta­mi­na­ti­on (sulp­hur anhyd­ra­te and ot­her sulp­hur com­po­unds, nit­ro­gen oxi­des and ot­her he­avy me­tal com­po­unds). There are taxonomic and biomorphological differences between the contaminated areas and the lichenobiota of the relatively “clean” areas. It is important to carry out planning work in the industrial cities of Azerbaijan, to take special measures to improve the environmental situation.

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**CHAPTER VI. ECOLOGICAL-SENOTICAL FEATURES**

**AND GEOGRAPHICAL STRUCTURE OF LICHENS**

**OF STUDIED CITIES**

Lic­he­no­bio­ta of Gan­ja, Ga­zakh, Min­gac­he­vir, Yev­lakh, Dash­ka­san, Shir­van ci­ti­es inc­lu­des 8 ge­og­rap­hi­cal ele­ments. The ma­in pla­ce con­sists of mul­ti­re­gio­nal spe­ci­es, bo­re­al, ne­mo­ral ge­og­rap­hi­cal ele­ments.

An in­teg­ral part of the analy­sis of lic­he­no­bio­ta is the com­bi­na­ti­on of spe­ci­es with si­mi­lar dist­ri­bu­ti­ons in ge­og­rap­hi­cal ele­ments. Analy­sis of ge­oe­le­ments al­lows to re­ve­al in­for­ma­ti­on abo­ut the area, ori­gin of spe­ci­es and mig­ra­ti­on rou­tes. The­re is no com­mon app­ro­ach among lic­he­no­lo­gists on the clas­si­fi­ca­ti­on and de­ter­mi­na­ti­on of ge­oe­le­ments. Ge­og­rap­hi­cal ele­ments of lic­he­no­bio­ta are de­ter­mi­ned on the ba­sis of mo­dern ha­bi­tats. Alt­ho­ugh many met­hods ha­ve be­en known for the ge­oe­le­ments of hig­her plants, the clas­si­fi­ca­ti­on of the­se ele­ments for lic­hens has not be­en re­sol­ved.

As a result of the analysis of geoelements in some industrial cities (Ganja, Mingachevir, Yevlakh, Dashkasan, Gazakh, Shirvan) the classification system of 68 species was compiled according to M.P. Tomin[[22]](#footnote-22). Of these, holarctic (6), polyarctic (8), boreal (6), panboreal (8), nemoral (14), Mediterranean (14), multiregional (8) and species with unknown habitats (7) are divided into geoelements.

# **CHAPTER VII. ABSTRACT OF LICHENOBIOTA OF**

# **INDUSTRIAL CITIES OF AZERBAIJAN**

Flo­ra’s abst­ract is ba­sed on many ye­ars of re­se­arch and li­te­ra­tu­re. The lic­hen flo­ra of so­me in­dust­ri­al ci­ti­es of Azer­bai­jan (Gan­ja, Min­gac­he­vir, Yev­lakh, Dash­ka­san, Ga­zakh, Shir­van) con­sists of 29 fa­mi­li­es, 41 ge­ne­ra and 68 spe­ci­es[[23]](#footnote-23). The no­menc­la­tu­re of ta­xa was gi­ven ac­cor­ding to mo­dern li­te­ra­tu­res such as Hawks­worth, Da­vid (Blin­ko­va, 2005; Ha­le, 1967); San­tes­son (Rand­la­ne, 2013), Ess­lin­ger (Blan­co, 2004; Ertz, 2011; Ess­lin­ger, 2004). Vo­lu­me of ge­nus is gi­ven ac­cor­ding to San­tes­son (Skye, 1968), Ess­lin­ger (Ess­lin­ger, 2009), Ca­non (Bun­gartz, 2007; Can­non, 2007), Check­list (Cho­ba­nog­lu, 2011; Cop­pins, 2005; Cres­po, 2011).

Wit­hin a genus, species are listed in alphabetical order. For each species, information on the growth area, ecology, brief botanical characteristics, geographical distribution in the research areas are provided.

**RESULTS**

1. It was determined that 68 species of lichens belonging to 29 families and 41 genera were distributed in the studied industrial cities. Of them 29 species belonging to 16 families, 16 genera are found in the urboecosystems of Ganja city, 22 species belonging to 11 families, 11 genera in Yevlakh, 18 species belonging to 11 families, 13 genera in Mingachevir city, 31 species belonging to 20 families, 23 genera in Gazakh, 34 species belonging to 21 families, 24 genera in Dashkasan city, 19 species belonging to 13 families, 13 genera in Shirvan city.

2. It was cle­ar that the lic­he­no­bio­ta of ur­boe­cosys­tems is do­mi­na­ted by *Physcea­ce­ae (11 spe­ci­es), Le­ca­no­ra­ce­ae (10 spe­ci­es), Te­losc­his­ta­ce­ae (5 spe­ci­es), Art­ho­nia­ce­ae (3 spe­ci­es)*.Each of *Le­ci­dea­ce­ae, Pyre­nu­la­ce­ae, Me­gas­po­ra­ce­ae* fa­mi­li­es was rep­re­sen­ted with two spe­ci­es. 12 fa­mi­li­es are mo­noty­pe and rep­re­sen­ted with one spe­ci­es. Analy­sis at the ge­nus le­vel shows that *Le­ca­no­ra (9 spe­ci­es), Te­losc­his­tes (4 spe­ci­es), Physcia (3 spe­ci­es), Ca­lop­la­ca (5 spe­ci­es)* are rep­re­sen­ted.

3. Bark-li­ke forms pre­do­mi­na­te in the stu­di­ed are­as (54 spe­ci­es, 79,5%). Ten spe­ci­es (14,7%) ac­co­unt for le­af­li­ke forms, fo­ur spe­ci­es (5,8 %) for shrub­li­ke forms. He­me­rop­hob (45%) spe­ci­es, me­di­um re­sis­tant (35%), he­me­rop­hils (20%). As the le­vel of in­dust­ri­al use of ci­ti­es inc­rea­ses, the num­ber of he­me­rop­hobs of me­di­um-re­sis­tant spe­ci­es inc­rea­ses, he­me­rop­hil spe­ci­es dec­rea­ses. Ba­sed on the I.P in­dex, high le­vels of air pol­lu­ti­on we­re fo­und in the study are­as.

4. It was fo­und that the oc­cur­ren­ce of shrub-li­ke forms of lic­hens in the stu­di­ed ci­ti­es is an in­di­ca­tor of the deg­ree of air pu­rity. No shrub-li­ke forms we­re fo­und in Gan­ja, Min­gac­he­vir, Yev­lakh and Shir­van, 4 shrub-li­ke forms are re­gis­te­red in Dash­ka­san and 2 in Ga­zakh. In Gan­ja city, bark-li­ke forms ma­ke up 75%, le­af­li­ke - 20%, shrub­li­ke only - 5%. Res­pec­ti­vely, 81%, 19% in Min­gac­he­vir city, 61%, 39% in Yev­lakh city, 78%, 22% in Shir­van and shrub­li­ke lic­hens are not fo­und in all 3 ci­ti­es. In the city of Dash­ka­san it is 64%, 24%, 12%, res­pec­ti­vely, and in the city of Ga­zakh - 61%, 32%, 7%.

5. It was discovered that an increase of 4% of large amounts of organic and inorganic wastes to the atmosphere in Ganja, Yevlakh, Mingachevir railway stations: dust-50%, carbon oxide-21%, sulfur oxide-21%, nitrogen oxide-5% and others (alkaline and acid vapors, fluoride compounds, hydrocarbons, hydrogen sulfide, acetone, gasoline vapors, ammonia) has formed “Lichen deserts” in the territory of these cities.

6. It has be­en fo­und that the bio­di­ver­sity of ur­ban lic­hens is dec­li­ning from the outskirts of the city to the cen­ter. In­dust­ri­al ci­ti­es and su­bur­ban are­as are di­vi­ded in­to 3-zo­ne, 4-zo­ne and 7-zo­ne are­as ac­cor­ding to the spe­ci­es di­ver­sity of lic­hens. *Xhan­to­ria pa­ri­en­ti­na, Par­mer­li­op­sis am­bi­gua, Physcia pul­ve­ru­len­ta, Ph ci­lia­ta, Ph stel­la­ris, Physco­nia gri­sea, Pha­e­ophy­cia ci­lia­ta, Can­de­la­ri­el­la vi­tel­li­na* are the most com­mon ur­ban lic­hens.

7. Ba­sed on oli­go­rithm mo­di­fi­ca­ti­on fo­ur re­gio­nal sca­les of epiphy­tic lic­he­no­bio­ta (CT) ha­ve be­en de­ve­lo­ped in com­mon pi­ne, small-lea­ved lin­den, ori­en­tal pla­ne, Cas­pi­an ho­ney­lo­cust. Me­di­um pro­jec­ti­ve co­ver of spe­ci­es and to­xip­ho­bia in­dex (TI) on clus­ter to­xip­ho­bia (CT) we­re de­ter­mi­ned, at­mosp­he­ric air qua­lity of the stu­di­ed ci­ti­es was di­vi­ded in­to 4 zo­nes ac­cor­ding to the re­sults of lic­he­no­in­di­ca­ti­on mo­ni­to­ring: re­la­ti­vely sa­tis­fac­tory (ACH + 22), in­ten­si­ve (15-21), cri­ti­cal (ACH = 10-15) and cri­sis (ACH = 10-6).

8. The si­mi­la­rity of the spe­ci­es com­po­si­ti­on of lic­hens in the stu­di­ed ci­ti­es is de­ter­mi­ned by 2 fac­tors ba­sed on the na­tu­re of clus­te­ring: na­tu­ral-cli­ma­tic con­di­ti­ons and anth­ro­po­ge­nic fac­tors. Anth­ro­po­ge­nic fac­tors ha­ve be­en fo­und to play a de­ci­si­ve ro­le in re­du­cing spe­ci­es com­po­si­ti­on in a clus­ter si­te that dif­fers ac­cor­ding to na­tu­ral and cli­ma­tic con­di­ti­ons.

**PRODUCTION PROPOSALS**

It is con­si­de­red ad­vi­sab­le to imp­le­ment cont­rols on so­me harm­ful emis­si­ons from cars, inc­lu­ding le­ad, sul­fur, so­lid par­tic­les, ben­zapy­re­ne, polycyc­lic aro­ma­tic hydro­car­bon al­dehy­des.

* Ta­king mea­su­res to re­du­ce emis­si­ons of spe­ci­al harm­ful com­po­unds in en­terp­ri­ses.
* *Xant­ho­ria pa­rie­ti­na, Par­me­lia sul­ca­ta, Par­me­li­op­sis am­bi­gua, Physcia pul­ve­ru­len­ta, Physcia ci­lia­ta, Physcia te­nel­la, Physcia stel­la­ris, Physco­nia dis­tor­ta, Pha­e­ophys­cia ci­lia­ta, Can­de­la­ri­el­la vi­tel­li­na* are re­com­men­ded for bi­o­in­di­ca­ti­on, nit­rophy­te spe­ci­es such as *Ca­lop­la­ca ce­ri­na, C.ho­lo­car­pa, Le­ca­no­ra ha­ge­nii, Xant­ho­ria pa­rie­ti­*na for anth­ro­po­ge­nic chan­ges in en­vi­ron­men­tal con­di­ti­ons in phyto­ce­no­ses.
* Com­pa­ri­son of lic­he­no­bio­ta of con­ta­mi­na­ted are­as with the bio­morp­ho­lo­gi­cal struc­tu­re of na­tu­ral are­as re­ve­als ta­xo­no­mic and bio­morp­ho­lo­gi­cal dif­fe­ren­ces. It is im­por­tant to carry out plan­ning work in the in­dust­ri­al ci­ti­es of Azer­bai­jan, to ta­ke spe­ci­al mea­su­res to imp­ro­ve the en­vi­ron­men­tal si­tua­ti­on.

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