RESEARCH ARTICLE

Assessment of the relationship of air contamination and meteorological potential in the cities of Azerbaijan

Shakar Mammadova
Doctor
Baku State University
Republic of Azerbaijan
Email: mammadovashakar@gmail.com

Doi Serial https://doi.org/10.56334/sei/8.10.45

Keywords meteorological conditions, air temperature, index of air contamination, horizontal dissemination, recurrence percentage, foggy weather, stratification, southern cyclones

Abstract
The article studies the impact of meteorological conditions on the air contamination in the big cities of Azerbaijan. The ecological effect of such meteorological factors as air temperature, wind direction, wind speed, fog, dusty weather conditions etc. are studied by the seasons of year. Seasonal and yearly change of meteorological conditions intensifying and mitigating air contamination is studied and compared. Presence and change of concentration of harmful substances in the air of cities are in relationship with the prevalence of winds of different character and directions, responsible for the spread and movement of pollutants in urban environment. Potential of air contamination and index of air contamination are measured and compared on the example of Baku, Ganja, Sumgait and other cities of the country.

Citation. Mammadova Sh. (2025). Assessment of the relationship of air contamination and meteorological potential in the cities of Azerbaijan. *Science, Education and Innovations in the Context of Modern Problems*, *8*(10), 502–518. https://doi.org/10.56352/sei/8.10.45
Issue: https://imcra-az.org/archive/384-science-education-and-innovations-in-the-context-of-modern-problems-issue-10-vol-8-2025.html

Received: 05.03.2025 | Accepted: 01.07.2025 | Published: 05.08.2025 (available online)

Background

The environment of cities is seriously affected not only by human activities but also under the influence of climate factor. Since meteorological conditions of different territories are not the same due to their geographical location, the intensity of air pollution and also consequences of related negative processes may considerably differ as well. Rapid development of cities in the last decades resulted in stretching of urban areas for many kilometers longer compared to previous decades. Relatedly, differences in microrelief features within territory of a large urban area may entail variety in microclimatic properties of urban districts.

Meanwhile, climate components such as wind speed, direction of wind, synoptic condition, temperature, evaporation conditions, humidity, fog, cloudiness etc. typically have a serious influence on the intensity of air pollution and the spread of pollutants in the territory of big cities. In urban environment, the contribution of meteorological conditions to the medium level air pollution in some cases may equal 30% to 50% (Bezuglaya, Rastorguyeva, Smirnova, 1991). Character of air contamination is much different particularly regarding cities of different average yearly air temperature, potential evaporation, precipitation, and wind regime, since duration of presence of substances in the air as well as self-purification property of the natural environment are observed differently due to the mentioned parameters. Researchers may list air temperature, inversion of temperature, wind regime, precipitation, relative humidity, fog, intensity of solar radiation and cloudiness as the most affecting factors defining spread of harmful substances in the air (Sadigov, 2006). The property of dynamism of the atmosphere defines the intensity of spread of pollutants in the air. While in the stratosphere gases of man-made origin may remain even 2 to 4 months, the period is not the same for the troposphere and its lower parts, since humidity causes washing of many substances floating in the air as well as transformation of gases. Gaseous wastes are disseminated in the air and decrease in concentration, and solid substances are tend to sink on the surface after certain period of time. However, the process may go at different rates in urban environment in relationship with weather and meteorological condition (Newstadt, Van Don, et al. 1985). Transformation, migration, period of availability of pollutants in the air is considerably affected by favorability of meteorological condition as well as physical and chemical properties of the air (Pashayev, Guliyev, Safarov, 2007).

Rapid spread and dissemination of air pollution occur in close relationship with winds blowing over mountain, hilly and depressive surface. (Mirbabayev, 2005). In this regard, character and intensity of air pollution is different by geographical places where cities are situated.

In the cities of Azerbaijan, foggy weather typically intensifies the pollution of air and may result in heavier consequences. Industrial wastes often combine with fog drops, entailing smog process that is much hazardous to human health. While in urban areas high precipitation and humidity is observed during relatively cold season of a year, much heavier pollution is typical for the period from October to February. This happen when the concentration of chemical ingredients such as nitrogen oxide and carbon oxide is higher, mingling with dust and soot present in the air, entailing very adverse urban environment. The noted process usually may go rapidly if wind is not observed and the air temperature is close to zero. The foggy weather as well as denser smog complicates neutralization of such elements as hydrocarbon compounds.

In the regions with dry and warm climate, air pollution is typically much hazardous during summer period when high traffic causes the emission of large amount of nitrogen oxide. Photochemical air pollution may be observed as well. Moreover, relief peculiarities along with meteorological conditions should be remarked.

The above mentioned processes and factors substantiate the topicality of studying environmental aspects of microclimate regime of cities. Urban planning and reestablishment of architectural face of cities, as well as the spatial distribution of economic and social facilities in urban areas cannot be managed effectively without taking into consideration meteorological factors. From this view, consideration of study of relationship of synoptic processes and formation and spread of harmful pollutants in urban air is of scientific and practical importance.

The **purpose of this research** is to find out regularities of dependency between rate of air contamination and the meteorological conditions that are significantly variable for seasons of year in the territory of Azerbaijan's big cities.

Literature review

There is a broad range of literature on the role of meteorological factors in air pollution, carried out in different years.

Relatively early studies include exploration of forecasting of the air pollution potential by means of a multiple regression model (Van der Auwers, 1977). Some researchers suggest that in order to predict air pollution in cities it is necessary to know the dependence between the internal and external parameters, as given by the resistance law. An example of statistical processing of air pollution data in the planetary boundary layer is treated in terms of the external parameters (Yordanov, 1977). Impact of meteorological conditions on the traffic-related air pollutants was studied on the example of Los Angeles city (Witz, Moore, 1981). Relationship of climate and pollution has been studied on the example of Paris city (Escourrou, 1990). Role of urban climate in air pollution was investigated in detail for Shanghai city as well (Chao, 1990). Some other studies were devoted to the relationship between ozone concentrations and meteorological parameters (Xu J, Zhu Y, 1994). Among relevant literature, a study work on the relationship between synoptic, mesoscale and microscale meteorological parameters in Athens city can be found (Katsoulis, 1996).

In 2000es, many studies were dealing with the environmental impact of transport since high traffic caused serious health related problems in big cities. In this regard, the study of impact of meteorological conditions on local and seasonal variations in atmospheric nitrogen dioxide levels can be mentioned (Hargreaves, Leidi, Grubb, Howe, Muggleston, 2000). Studies on the forecasting of daily ozone concentrations in urban air are remarkable as well (Barrero, Grimalt, Cantón, 2006). The effects of meteorological conditions on atmospheric pollutant concentrations in a complex area were analyzed in the works devoted to air pollution in urban and suburban areas, where it was noted that unfavorable conditions may reduce the ability of the atmosphere to disperse pollutants and transport pollutants from other areas (Latini, Grifoni, Passerini, 2002).

A series of researches dealing with the impact of meteorological condition on air pollution were conducted by Turkish scientists who investigated the studied problem on the example of cities of Turkey. The relationship between monitored outdoor air quality data and meteorological factors, such as wind speed, relative humidity ratio and temperature was statistically analyzed on the example of Trabzon city. The study was carried out with using the code SPSS. The results were obtained through multiple linear regression analysis. It was revealed that for some months there is a moderate and weak level of relation between the SO_2 level and the meteorological factors in Trabzon (Cuhadaroglu, Demirci, 1997). The authors suggest that air pollution concentrations and meteorological data should be evaluated statistically in order to correlate them (Demirci & Cuhadaroglu, 2000).

Statistical methods are preferred in a series of other studies as well. Authors of such statistical analysis mention that the pollution concentrations on previous day of assessment may serve as the most important factor contributing to heighten air pollution concentrations. According to them, statistical models prove that weather variables such as temperature and pressure should be regarded as the most significant factors affecting air pollution in the cities with dry climatic condition (Hosseinibalam, Hejazi, 2012).

The results of this research are nearly compliant with another one carried out on the example of Erzurum city of Turkey. In the work where statistical model is proposed, the result includes a suggestion that daily traffic-related pollutant concentrations are not only influenced by daily meteorological parameters but also by the pollutant concentration of previous day in Erzurum (Ocak, Turalioglu, 2008). In this study, the relationship between daily CO (carbon monoxide), NO_x (nitrogen oxides), O_3 (ozone) concentration with the pollutant concentration of previous day and meteorological factors (wind speed, temperature, relative humidity) in 1995-1997 winter seasons was statistically analyzed using the stepwise multiple linear regression analysis.

Determination and parameterization of some air pollutants as a function of meteorological parameters was a subject of the work carried out on the example of Kayseri city of Turkey (Kartal, Ozer, 1998).

Relationship between monitored air pollutant concentrations such as SO_2 and the total suspended particles (TSP) data and meteorological factors such as wind speed, temperature, relative humidity and atmospheric pressure was investigated on the example of Elazığ city of Turkey. The authors of relevant research studied the relationship for months of October, November, December, January, February, and March during the period from 2003 to 2005. Moderate and weak level of relation between the air pollutant concentrations and the meteorological factors was identified as a result of linear and non-linear regression analysis (E.Akpinar, S.Akpinar, Fehmi Öztop, 2009).

The investigation carried out towards Szczecin city of Poland deals with the use of the volumetric method (Lanzoni VPPS, Italy) and an automatic weather station (Vaisala, Finland) in order to study the relationship between presence of biological particles and non-biological pollutants in the atmosphere and the incidence of adverse reactions affecting human health (Puc, Bosiacka, 2011). This study demonstrates different effects of ambient air pollution and meteorological factors on pollen concentration of selected taxa in the atmosphere. Statistical correlation between pollen concentration and air pollution factors was found to be a consequence of the relation between the latter and meteorological conditions.

A study, devoted to the dependence of urban air pollutants on meteorological conditions in Great Cairo area, revealed that wind direction has an influence not only on pollutant concentrations but also on the correlation between pollutants (Elminir, 2005). As the author revealed, the pollutants associated with traffic were at highest ambient concentration levels when wind speed was low. At higher wind speeds, dust and sand from the surrounding desert was entrained by the wind, thus contributing to ambient particulate matter levels. It found that the highest average concentration for NO_2 and O_3 occurred at humidity<or=40% indicative for strong vertical mixing. For CO, SO_2 and PM_{10} the highest average concentrations occurred at humidity above 80%.

It is known that there are favorable conditions for photochemical processes in the Absheron peninsula (Gorchiev, Agaev, 1982; Mammadova, Ahmadov, Babayeva, 2012). High intensity of solar radiation may lead to photochemical processes that entail the formation of more toxic secondary products (for example oxidation of sulfuric gas). Sh.Ahmadov and M.Huseynli (2005), who studied the hazard of air pollution in condition of photochemical processes remark that the availability of two inversions (near the Earth surface and elevating) in cities may entail presence of upper and lower stratums of contamination that are not mixed. As they explain, in the upper layer formed at the height of 200–400 m, active photochemical gases are photochemically transformed, creating secondary and much hazardous compounds, whereas in the lower layer, photochemical processes are not observed because the upper stratum impedes intrusion of ultraviolet rays onto the Earth surface.

At present, in industrial cities of Azerbaijan, 65-70% of the pollutants are emitted from motor transport (Hasanov, 2003). This is because the old industrial enterprises do not operate with full output or have stopped their activity. Since the number of vehicles has been increased recently in the cities, territorial coverage of vehicle related environmental pollution has been extended as well. Thus, high traffic is observed not only in the city centers as it used to be before but all core and suburban districts of urban areas where high density of moving cars and even traffic jams are observed. Relatedly, study of the ecological effect of climate and meteorological factors under the new conditions is of high practical importance because related studies have not been implemented in detail in recent decades in the country.

Methodology

In this research, the relationship between meteorological conditions and air pollution in the big cities of Azerbaijan was studied upon determining of contamination potential of the atmosphere (CPA) based on reviewing meteorological factors. This potential includes the meteorological parameters that define vertical and horizontal dissemination of pollutants in the urban atmosphere. The challenges in application of this method are related to limited opportunities because of less number and coverage of meteorological points where required meteorological data are to be accessed. Therefore indicators of meteorological potential for the larger territory do not provide highly accurate information, and bear general character. However, reference on the method of defining CPA is preferred in the implementation of a series of researches, like those carried out by Y.Bezuglaya, as well as in the measurements led at General Geophysics Observation after A.Voyeykov (Saint-Petersburg, Russia) in the past. The presented study was carried out based on the method offered by Y.Bezuglaya as well as with considering similar methodological approaches previously used towards forecasting of CPA (Abdullayev, Mammadova 2001; Mirbabayev, 2005; Afandiyev, Mammadova, 2013).

The study conducted by us through the application of the mentioned method allows define relationship between meteorological parameters and air contamination. According to this method, CPA is measured based on the following formula:

$$CPA = R_S + R_t \qquad (1)$$

where R_S is a recurrence of wind of 1m/sec of speed, and R_t is a recurrence of foggy days.

Meteorological self-purification potential of the atmosphere equals sum of recurrence of rainy days of ≥ 0.5 mm of precipitation and recurrence of winds ≥ 6m/san of speed:

$$SCPA = R_o + R_v \qquad (2)$$

where R_o is a recurrence of rainy days of 1 ≥ 0.5 mm of precipitation, while R_v is a recurrence of winds ≥ 6m/san of speed.

Meanwhile, study and determination of the meteorological potential of the atmosphere (MPA) is required as well in order to conduct comparison between MPA and CPA that may further allow the rate of hazard of environmental pollution in a certain (urban) area. MPA is an indicator reflecting complex of meteorological factors defining the concentration of pollutants in the air and related self-purification process. Study of this potential is based on the quantity and quality data for previous years. Usually researches in practice are carried with using modeling method. In this case, a complex of such affecting factors as urban architecture, relief, wind, air temperature, seasons of a year, precipitation, amount of solar radiation etc. can be taken into consideration in forecasting of air pollution. Meanwhile, as we think, specification of the CPA method is needed in order to gain higher accuracy in assessing meteorological potential of cities with limited territory.

As the prior studies conducted by us (Mammadova, 1998, 2007, 2010) show, the major factors defining MPA in the environments of cities of Azerbaijan are wind, cloudiness and precipitation.

Taking into consideration the above mentioned formula, the following formula is proposed by us for the first time to define MPA:

$$MPA = R_s + R_i / R_o + R_v \qquad (3)$$

Meteorological potential is measurable in relation to years, seasons and months. The results of measurements gained based on this formula allow compare CPA and MPA. According to this method, while CPA is < 1, the recurrence of self-purification process is stronger than the recurrence of processes responsible for contamination, and eventually, this leads to the dissemination of pollutants as well as the mitigation of effect of pollutants. If MPA is > 1, this means the process of contamination is heavier compared to self-purification potential of the atmosphere that may accelerate contamination process in urban environment in the end.

To measure the index of air contamination (IAC) in cities, the following formula is used (Fetisova L., Korotkova N., Fetisova N., 2011):

$$I_i = \left[\frac{q_{avei}}{ACL_{cci}} \right] \qquad (4)$$

where I_i is index of air contamination, $q_{ave\,i}$ is average concentration of certain pollutants, and $ACL_{cc\,i}$ is daily allowed concentration limit in average for those pollutants.

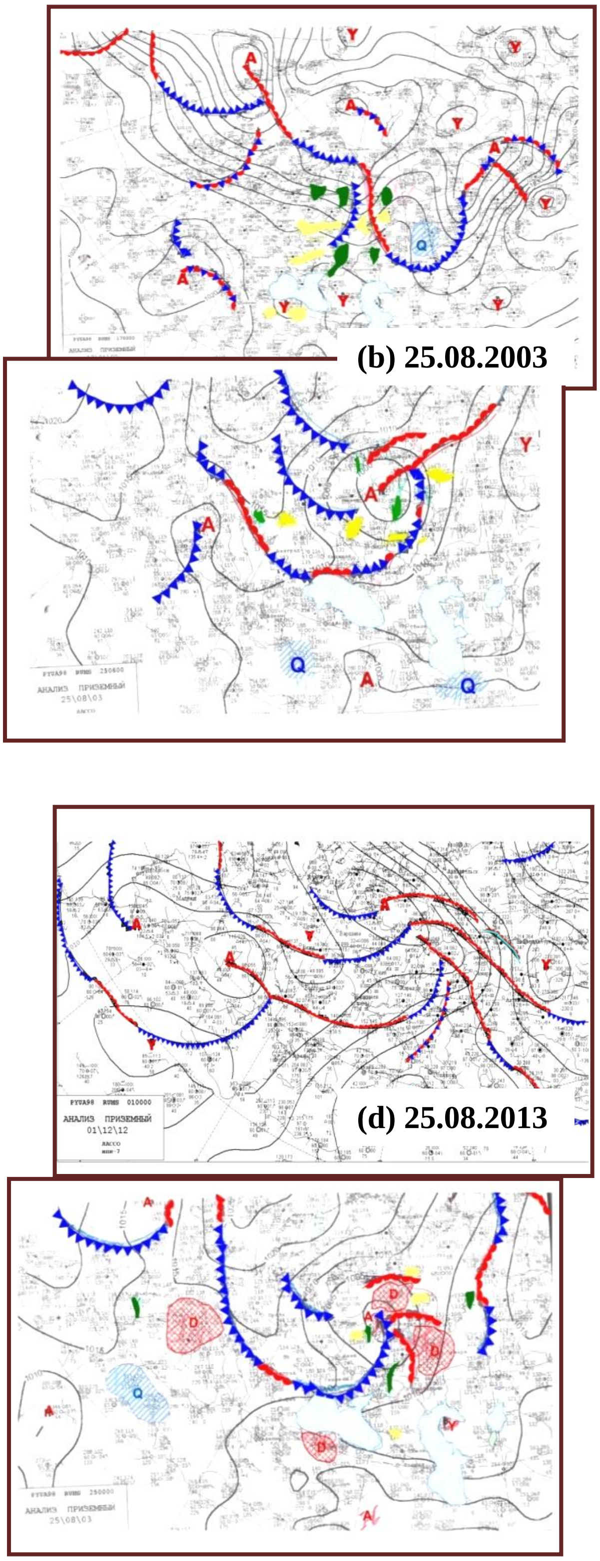
Analysis of meteorological condition

Analysis of meteorological condition with studying available data proves the presence of considerable differences in the natural environment of Azerbaijan's cities (Madatzade, 1973; Ayyubov, 1987; .Ayyubov, Musayev, Karimov, 1997; Pashayev, Sultanov, Huseynov, 2005, et. al).

Differences in meteorological conditions, typical for the regions of Azerbaijan are driven by the various air masses as the most influential factors among others. Very different air masses may cover the territory of Azerbaijan all year round and affect natural and climatic conditions of the regions of the country. Winds of various types and directions are observable in the country's territory as well. The local climate is considerably influenced by air masses moving from different baric centers such as Scandinavian anticyclones, Azores High, subtropical anticyclone, southern cyclone, continental anticyclones, Central Asian anticyclone, as well as local atmospheric processes. Prevalence of winds of monsoon regime, breezes, foehns, dry and warmer winds called "ag yel" and "gara yel" and also Catabatic winds into the air basin of the country is associated with thermobaric conditions present here. Big cities such as Ganja, Mingachevir, Lankaran, Nakhchivan and many others located in different regions of the country are under the impact of these winds as well. Yearly percentage of windless weather makes 48% in Baku, 38% in Nakhchivan, 37% in Ganja, 34% in Mingachevir and Lankaran, and 11% in Sumgait.

The highest average annual temperature in Azerbaijan is observed in the Kura-Araz lowland, where relatively large cities such as Mingachevir, Shirvan, Yevlakh, Kurdamir, Imishli are located. The south-eastern pre-Caspian coastal part of the Shirvan plain (where Shirvan and Salyan cities are located) is much warmer with the average yearly temperature at 14.5°C and more. The average temperature in the lowland areas is 14-14.6°C as usual. In Nakhchivan city, the average yearly temperature is close to 13,6ºC. Corresponding indicators for the larger cities of the country are shown on Table 1.

Below, the description of some synoptic conditions, adverse in terms of air contamination in the regions and cities of Azerbaijan is given (Figure 1).



(a) 17.01.2002 (b) 25.08.2003

(c) 01.12.2012 (d) 25.08.2013

Fig. 1. Air masses entailing heavy air pollution in the cities of Azerbaijan

The Figure 1a reflects the condition of anticyclone that was observed in 17.01.2002. The shown condition must be regarded as environmentally adverse since prevalence of an area of high pressure favours spreading of pollutants in the air. As seen from the picture, an area of low pressure and less gradient was prevalent in the country's territory. Such a condition often can be seen at present as well. Availability of the noted condition usually leads to sustainable stratification in the air causing extension of the areal of contamination and the rate of environmental pollution. Analysis of synoptic condition clearly indicates to the availability of windless weather in the territory, as a result of which meteorological conditions facilitate the spread of pollutants in the air.

The Figure 1b shows the presence of air conditions typical for south-western edge of south cyclones. The situation reflected in the picture was observed in 25.08.2003. As seen, the territory is under the influence of lower pressure zone (cyclone) in the south, as well as under the influence of a high pressure zone (anticyclone) in the north-east. The observed weather condition is weakly cloudy and affected by weak south-east winds. This specific weather condition is characterized by the presence of unfavorable environmental condition because of availability of sustaining stratification that means no significant change in synoptic processes is expected in the upcoming hours. The described synoptic conditions contribute to the spread of polluting ingredients in the whole territory of the country as well as its cities.

Analysis of synoptic condition, observed in 01.12.2012 and given in the map-scheme 1c, shows that the territory is under the influence of a zone of high pressure. While anticyclonic baric system and less-gradient pressure prevails, and the speed of sources of pollution is limited, there is a unfavourable condition for the conveyance of pollutants in the air as a result of which dependant dusts is available at higher concentration. Relatedly, meteorological condition is adverse in terms of spread of pollutants in the atmosphere.

Another example for adverse meteorological condition is shown in Figure 1d (observed in 25.08.2013). As seen from this picture, the territory is under the influence of low zone of pressure (cyclone) in the south, and affected by a zone of high pressure (anticyclone) in the north-east. According to this map-scheme, the territory is prevailed by fragmented clouds as well as weak winds blowing from south-east. The meteorological condition is characterized by the presence of continuing stratification, i.e. no change in synoptic processes is expected during the upcoming hours and period. The described synoptic condition facilitates spread of pollutants in the cities. High rate of air contamination is observed.

Analysis of meteorological conditions of the cities of Azerbaijan was carried out by us on the basis of review of the literature and summarization of perennial statistical data in order to study the influence of meteorological factors on air pollution and assess contamination potential of the atmosphere by seasons. The key parameters are given on the Tables 1,2,3 and 4.

Table 1

Yearly average air temperature in the cities of Azerbaijan (ºC)

City	Year					
	2000	2001	2002	2003	2004	2005
Baku	15	15,2	14,8	14	14,8	15,3
Lankaran	15	16,9	15	14,3	14,9	14,3
Mingachevir	16	16,4	15,7	15	15,9	15,1
Shaki	13,2	14,1	12,7	12,3	13,2	13,6
Sumgait	15,1	16,1	14,9	14,1	15,1	15,5
Ganja	**	**	14,3	13,8	**	**

Table 2

Speed of wind in the cities of Azerbaijan (m/sec)

Cities	2000	2001	2002	2003	2004	2005
Baku	24,4	19,7	35	29,7	28,5	21,4
Lankaran	111,4	82,8	86,3	103	96,7	69,9
Nakhchivan	15,2	**	**	**	**	**
Mingachevir	27	22	21	41,3	26,1	25,2
Shaki	63,6	52,5	79,3	83,3	66,3	52,1
Sumgait	17,5	16,6	26,3	20,5	20,2	15,8
Ganja	**	**	25,4	23,5	**	**

Table 3

Annual average precipitation in the cities of Azerbaijan (mm)

Cities	2000	2001	2002	2003	2004	2005
Baku	12,75	14,75	12	11,6	12,3	10
Lankaran	1,5	1,3	1,4	1,5	1,6	1,6
Nakhchivan	1,7	**	**	**	**	**
Mingachevir	2,5	2,6	2,3	2,1	2,5	2,2
Sheki	1,5	1,6	1,6	1,4	1,8	1,6
Sumgait	4,9	4,8	4,7	3	3,8	4,3

Table 4

Recurrence of winds of different directions in the cities of Azerbaijan (2006)

Direction	Cities						
	Baku	Sumgait	Ganja	Mingachevir	Sheki	Nakhchivan	Lankaran
North	22	19	2	10	5	14	5
North-west	11	39	25	11	20	8	20
East	-	1	3	7	-	5	2
South-east	1	16	13	11	10	20	19
South	5	10	2	12	14	7	10
South-west	12	3	12	3	33	4	8
West	1	1	2	12	18	4	2
Windless	48	11	37	34	-	38	34

Baku and Sumgait cities are situated in Absheron-Gobustan region, the west part of Azerbaijan. Here average yearly air temperature equals 14-15ºC. The monthly air temperature in average is 3-4ºC for January and 24-26ºC for July. The annual precipitation is 100-250 mm. Fog, snowfall and snowstorm is repeated with less frequency.

In Great Baku area, speed of wind rarely may reach 40 m/sec. Breezes are typical for pre-Caspian Sea only. During winter, foehns may enter the territory of Baku from south-west and west, causing rise of temperature as 6-8ºC as much. In Absheron and its surrounding areas, winds typically blow from north-west, north and north-east during winter and summer. Average annual precipitation is 200-300 mm in Gobustan and 245 mm in Baku. Medium yearly precipitation is 14.2ºC. In northern part of Absheron Peninsula, north-west, north-east and south winds prevail.

Fog and dusty weather may be observed but not so often in Baku. Foggy weather is observed mostly in early spring and colder period, whereas blizzard is typical for winter. Dusty weather is seen mainly in warmer period. All these climate events are unfavorable in terms of spread of pollutants. In average, 4 times foggy weather are observed in January, as well as 5 foggy conditions during both February and March. The process is less observable from June to September.

Along with a regular fog, so-called a dry fog may also happen in Baku. The main role in this process is played by the Caspian Sea and industrial enterprises, responsible for the presence of smog, dust parcels and soot in the air. Wastes of aerosol, emitted from industrial and other facilities facilitate arising of much denser fog. Foggy weather is seen in the air of Baku more often compared to other cities.

Beside with this, motor vehicles contribute to arising of smog considerably, causing increase in amount of aerosols and ions in the air. This process happens mostly during summer months. Under the influence of high temperature some part of heavy ions rise toward higher layers of the atmosphere in summer. As usual, light ions are reduced in amount as less as 35-40%, whereas heavy ions usually increase as much as 145-155% since light ions may become heavy upon merging with water that exists in the air.

Moreover, ions widely accumulated under clouds may contribute to reflection of electromagnetic rays since they may serve as reflectors in this process. Such highly contaminated air in condition of electromagnetic radiation may entail disturbances in human behavior, dullness, insomnia, fatigue, weakening of memory etc.

Dusty weather is another adverse condition typical for the weather of Baku. Compared to many regions of Azerbaijan, dusty weather is often observed here particularly in windy condition. The mentioned process arises upon availability of higher concentration of dust, sand and other particles, elevated from the surface of the Absheron peninsula due to heavy winds.

In the city, recurrence of north and north-east winds from November to March., i.e. during colder period is 22-48%, while the average perennial air temperature makes 5.5-16.5ºC for the same period. The recurrence of south and south-west winds equals 7-40% as well as for the warmer period 22-48%, while the average perennial air temperature is 23.5-26.5ºC.

Data on carbon dioxide in average for the period from 2001 to 2009 were compared with air temperature, direction and speed of wind (Table 5).

Table 5

Average monthly data on air temperature, speed of wind and carbon oxide

in Baku city (2001-2009)

Month	Temperature, ºC	Speed of wind, m/sec	Carbon oxide, mg/m^3
I	5.5	2.4	1.9
II	5.2	3.2	1.9
III	7.5	3.6	1.2
IV	11.9	3.1	1.6
V	17.6	2.5	1.6
VI	23.4	3.7	1.5
VII	25.8	2.9	1.7
VIII	26.5	2.3	1.6
IX	22.4	2.4	1.6
X	16.9	2.7	1.4
XI	11.3	2.7	1.3
XII	5.7	2.8	1.2

As seen from Table 5, the concentration of carbon dioxide tended to rise in relationship with air temperature and speed of wind. The figure was fixed as higher during June and July due to slowness of blowing winds in condition of higher air temperature.

Table 6

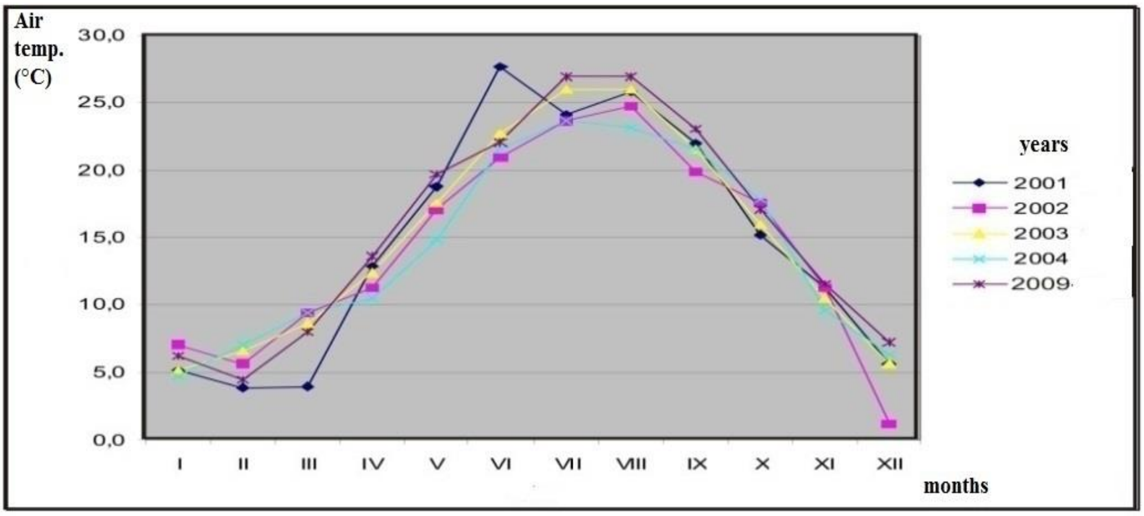
Average yearly data on air temperature, speed of wind and carbon dioxide

in Baku city (2001-2009)

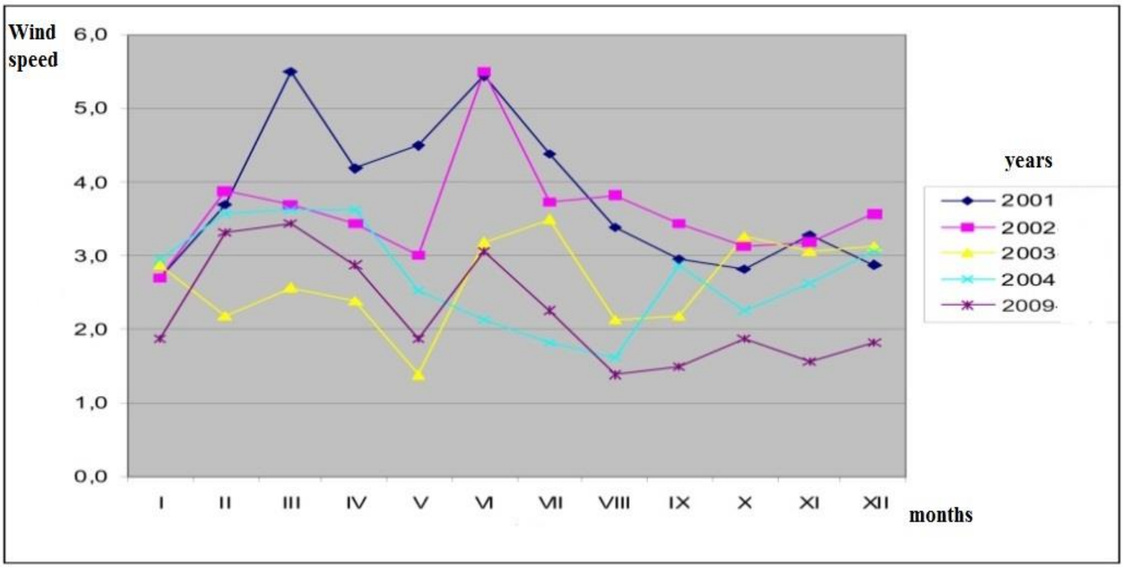
Year	Temperature, ºC	Speed of wind , m/sec	Carbon dioxide, mg/m³
2001	15.1	3.6	1.4
2002	14.8	3.4	1.4
2003	14.9	2.6	1.5
2004	14.9	2.3	1.3
2005	15.4	2.1	1.6
2006	15.5	3.1	1.4
2007	14.7	2.9	1.5
2009	15.9	3.2	1.6

As shown on Table 6, the concentration of carbon dioxide grew compared to the first half of 2000es. During the same period, harmful elements in the composition of rain drops were risen as 20% as much.

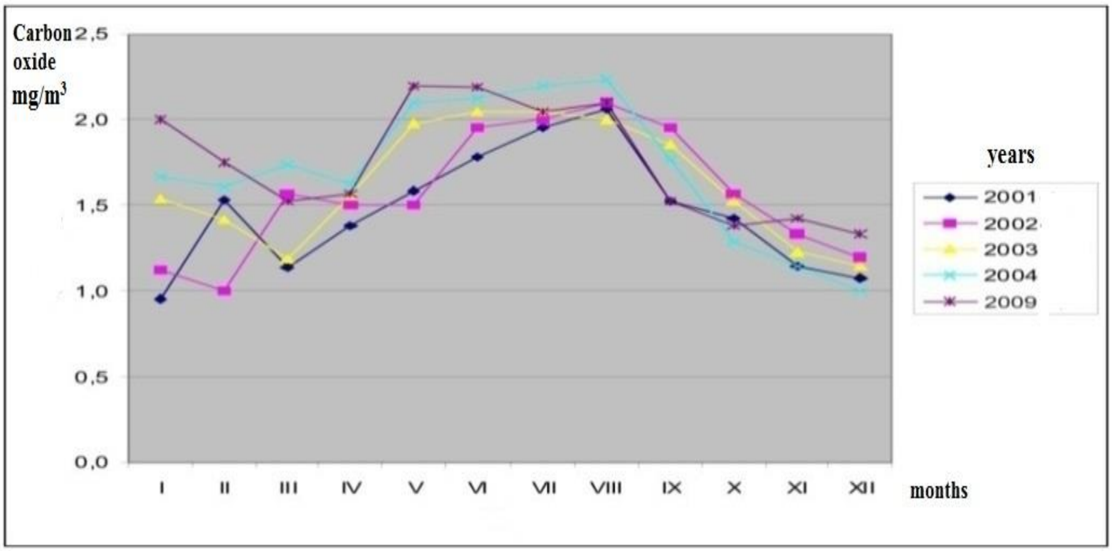
Changes in the amount of carbon oxide depending on average air temperature and speed of wind is given in the following three pictures. As seen, warmer period of a year typically facilitate arising and spread of carbon oxide at higher concentrations in the air, meaning that amount of carbon oxide in the air is directly proportional with air temperature. Relationship of the amount of carbon oxide and the speed of wind is inversely proportional.


Air temp. (°C)
30,0
25,0
20,0
15,0
10,0
5,0
0,0
I II III IV V VI VII VIII IX X XI XII
months
years
2001
2002
2003
2004
2009

(a)


Wind speed
6,0
5,0
4,0
3,0
2,0
1,0
0,0
I II III IV V VI VII VIII IX X XI XII
months
years
2001
2002
2003
2004
2009

(b)



(c)

Fig. 2. Changing concentration of carbon oxide (c) in the air in relationship with average monthly temperature (a) and speed of wind (b) for different years

Ganja, the second largest city of Azerbaijan is situated in Ganja-Gazakh region, the west part of the country. Climate of Ganja is formed under the influence of air masses entering the territory of the country from different directions.

The average temperature in Ganja is 12-14°C, as well as making 1°C in January and 24-25°C in July. Annual precipitation is 246 mm. Snow cover is not durable. Western winds play an influential role in the area. Warm and dry winds called garayel is common from April to October. Medium yearly air temperature is 13.1°C.

In Ganja, winds of 0-1 m/sec of speed are observed during 91 days a year. Frequency of such winds is higher during the period of September to December (8-10 days), and is less common in other months (6-7 days). Average frequency of winds of 6 m/sec of speed makes up 10 days, and they are observed mostly in March, April, June and August (5-6 days). Recurrence of the noted winds is lesser in October, November, December and January, varying from 2 to 3 days only. The annual number of days with precipitation at 0,1 mm in condition of low cloudiness makes up 51 days a year, and are observed mostly in summer and rarely in autumn.

Analysis carried out by us shows that air pollution in Ganja (as well as in many other cities of the country) is driven mostly under the effect of local atmospheric processes (30-35%) and also tropical air masses (25-27%). Air pollution in the air of Ganja city can be forecasted when the presence of tropical air masses (37%) and southern cyclones (31%) in winter seems probable in advance. In summer, air pollution occurs most often in condition of the prevalence of local atmospheric processes and continental air mass (26-28%). In autumn, contamination can be observed at lesser level when south cyclones invade the area (9%). Roles of responsible air masses are shown on Table 7.

Table 7

Recurrence of atmospheric processes in Ganja city (9%)

Atmospheric processes	Recurrence percentage in a year	Recurrence percentage by seasons			
		Winter	Spring	Summer	Autumn
Local atmospheric processes	36	20	27	28	25
Tropical air masses	27	37	28	14	21
Continental air mass	21	24	24	28	24
Southern cyclones	16	31	27	23	19

Air pollution in the air basin of Ganja may occur under the high impact of temperature inversion that in some cases arise due to local condition of anticyclone observable from November to March as usual. The inversion zone in Ganja city like other areas of Lesser Caucasus is located at 200-600 m of altitudes, and may happen in condition of anticyclone.

When tropical air masses favoring air pollution are available in the city of Ganja, pollution level here and the adjacent areas can be fixed at high level. This can be observed both in winter and summer. Due to occurrence of high atmospheric pressure, various emitted gases, dust, soot, gaseous particles, etc. may be accumulated in sub-inversion stratum, causing high air contamination.

Under the influence of subtopic anticyclones, flows of tropical air masses of south-west direction may move to the air space of Azerbaijan as well as of Ganja city and favor contaminated environment at different levels, depending on seasons of year. In the course of the mentioned process, environment of fog and weak rain weather may occur that intensifies air pollution. This typically happens in autumn and summer seasons.

In general, air pollution in Ganja is often associated with continental air masses formed over Western Siberia and Kazakhstan as well as northern part of the Caucasus. With annual recurrence rate at 21%, movement of these air masses towards the territory of Ganja is more frequent situated summer (28%). Passing mainly through the northern Caucasus, continental air masses intrude the air basin over Caspian Sea, and then move from north-east and north to the area where Ganja is situated. The process is observed in all seasons. In warmer period, air masses are relatively transformed while they are on the south of Russia and northern Caucasus, as a result of which usually environmental situation in the city air becomes better.

The impact of southern cyclones on the meteorological conditions of Ganja city should be noted as well. With annual recurrence rate at 16%, southern cyclones intensify air contamination particularly in winter (31%). Moving of southern cyclones into the territory of the country as well as Ganja city is observed almost all year round. Depending on the synoptic situation on the Caucasus and Minor Asia, cyclones of the Mediterranean Sea move to Azerbaijan through different ways and cause air to change as well as air pollution. Southern cyclones cause to occasional rains (in spring and autumn), and also fog during morning and night hours, due to which pollution of the atmosphere is intensified.

In the eastern part of the Kura-Aras lowland where Shirvan city is situated, the average annual temperature is 14-15°C. The figures are 2-4°C in January, and 25-27°C in July. Average annual precipitation is 200-250 mm. Most rainy period is August. Breezes are prevailing winds in the east, and west winds may be seen mostly in summer. Fogs may be seen relatively often. In summer, long-term dry weather is observed. Winds of different direction with a speed of up to 12 m/sec can be observed in Kura depression. Dry and warm Agyel winds blow in summer when the temperature may reach 35-40°C, and relative humidity varies between 15 and 30%. In some cases, the speed of Agyel may be recorded at about 10-15 m/sec. In the central parts of the Kura-Aras lowland, north-west (in winter) and south-east (in summer) winds dominate.

Mingachevir city is situated in Jeyranchol-Bozdagh area, where cold air masses may blow mainly from the west and in some cases from the east. In winter foehns are seen whereas in summer usually dry weather prevail as usual. The average annual temperature in the region is 12-14°C (0-1°C in January, and 23-25°C in July), and the annual precipitation is 300-400 mm, falling mostly in spring. Fog is rarely common. The average yearly temperature is 14.8°C in the city.

In Lankaran plain where Lankaran city is located, the average annual temperature is 11-14°C (1-4°C in January and 22-26°C in July). The annual amount of precipitation varies from 600 to 1700 mm. Highest amount of rainfall is fixed in autumn. Fogs take place often. Usually, there is no continuous snow cover during cold period. Breezes and Catabatic winds are typical for the region. Average rainfall in Lankaran makes 1111 mm, and average temperature is 14.1°C.

Sheki city is situated in the southern foothills of Greater Caucasus. The average annual temperature here is 11-12°C, making 0-1°C in January and 22-24°C in July. The annual precipitation is about 500-700 mm. Fogs are common in warmer period. Catabatic winds with a speed of 0-1 m/sec prevail in the area. Average annual amount of precipitation is 692 mm.

Nakhchivan city is situated in the region of the same name where climate is severe. Dry and very warm summer and very colder winter is present here. Daily air temperature varies sharply in the area. Average annual air temperature in Nakhchivan is 12.9°C, and rainfalls make up 251 mm. Higher precipitation is fixed in spring. In some cases, Catabatic winds, and also winds of southeastern and northeast directions may be available. Dry Agyel winds are observed here as well. The temperature in the region equals 35-40°C, and relative humidity is 15-30%. Winds typically are 0-6 m/sec to 10-15 m/sec in speed.

Results

Changes in data on the emitted pollutants in relationship with meteorological-climatic conditions (wind speed and direction, humidity, rainy days, etc.) were defined. Meteorological and climatic conditions of big cities in Azerbaijan play a certain role in the spread of wastes released from industrial enterprises and vehicles of transport. Key factors affecting air pollution are average annual air temperature in cities, average annual speed and direction of winds. It has been revealed that contamination rates are higher if meteorological factors changes weakly (speed and direction of wind). Favoring role of the temperature factor in transport related air pollution is much higher in summer season. This is due to high temperature, responsible for higher concentration of harmful substances in the air that complicates purification of the air as well as living conditions.

Studies show that the highest of concentration of contaminants emitted into the atmosphere from motor vehicles (sources of lower altitude) is observed when wind speed is 0–1 m/sec. In regard to industrial and other facilities (sources of higher altitude), the maximum amount of pollutants released into the atmosphere happen when wind speed is 6 m/sec.

In the air of Baku, meteorological factors have an influence on the spread of ingredients that exceeds the allowed concentration limits, defined in the country. Often this concentration is higher even a few times. In the air of city, the concentration of carbon oxide of technogenic origin typically is much higher in summer period and directly proportional with air temperature and inversely proportional with wind speed.

The carried study allowed to measure index of air contamination (IAC) in the air of cities of Azerbaijan based on the formula (4) shown above.

It was defined that yearly index of IAC in the air of Great Baku varies from 2.25 to 10.1 depending the geographical position of the area of measurement, as well as responsible meteorological factors. In Baku, IAC is higher in August (7.7) and also in July (5.7) and June (5.4). The higher figures of IAC are observed also in January (5.3), December (5.0) and November (4.9). In other word, the most adverse meteorological conditions in terms of air contamination usually are present in warmer and higher seasons of a year. April is not ecologically unfavorable month in Baku as well. March, February and May are the month of lower IAC. The situation is related considerably to directions and speed of winds. As comparison with other cities shows, the IAC is highest in Baku.

According to results of the study, the average chemical composition of precipitation, falling in Baku is composed of ions of sulphate ions (19,5%), nitrate ions (9,5%), ammonium (1,0%), chloride (11,0%), hydrocarbon (20,5%), phosphate (0,02%), calcium (8,73%) and magnesium (3,75%). More than half of these identified elements are emitted from transport. The amount of harmful elements in the composition of rain drops falling in Baku is higher than that of observed in other cities. HCO_3^-, SO_4^{2-}, Ca^{2+}, Cl^- and NO_3^- were identified as the most pollutant components of a raindrop in Baku.

In Baku, warm season have an accelerating effect on the presence of carbon oxide in the air, since presence of this gas in the air is directly proportional with air temperature. Meantime, the higher wind speed, the lower concentration of carbon oxide is in the air.

Dusty weather as unfavorable phenomena occurs in average 7 times a year in Baku. It is mostly responsible for widespread of wastes in the air, and not for only sand parcels but other elements as well. Solid and gaseous wastes are typically carried from polluted places to cleaner areas in dusty weather. Transport wastes are spread mostly this way.

In Sumgait city, the highest IAC is available in July (12.0), as well as in May (10.8), August (10.6) and September (10.6). In this term, most favorable situation is observed in winter – December, January and February (3.8 for each).

North-western and western winds may cause harmful wastes to move towards the residential areas of Sumgait. However, the highest amount of pollution happens in warm season, like it is observed in Baku city. The process happen particularly related to prevalence of anticyclone as well as the weakly windy weather.

The analysis of the data shows that local air circulation processes in Ganja city and its surrounding areas are observed relatively often (36%) during a year. High pollution happens less frequently in winter (20%), and is observed mostly in spring and summer (55%). The level of pollution becomes higher in windless condition and weakly windy weather typical for summer and spring. In Ganja, though western (30%) and eastern (24%) winds are the most responsible winds for the spread of pollutants in the air, polluting ingredients usually do not excess allowed concentration limit.

During February and October, meteorological factors accelerating air contamination are equal to meteorological factors facilitating self-purification in the air of Ganja city. During cold season meteorological processes favouring pollution of the atmosphere exceed meteorological processes responsible for dissemination of pollutants. From April to October, i.e. in the period of 7 months, meteorological processes leading to pollution of the atmosphere may last 214 days. Meteorological conditions facilitating air contamination are available mainly in January, February, November and December.

Measurements show that in Ganja city, IAC is typically higher in the period of May–October (2.9–3.3), and is highest in August and July like in Baku. Meanwhile, this indicator is lower during January (1.9) and February (2.0), as well as relatively lower during February (2.0) and March (2.3). However, in some cases IAC may reach 5.5 to 5.8, and this also may happen in warmer period.

In Mingachevir city, the ICA is higher in warm season of year since the highest figures are fixed from June to September, making 4.1–4.2. Positive meteorologically conditions are available in April and May (3.1). In Shirvan city, IDA does not change considerably all year round due relatively less amount of emitted gases in the air. ICA for the city was fixed as 0.43. In Mingachevir and Shirvan cities, recurrence percentage of winds of north and northeast direction is 16-30%, as well as 25-35% in warm season.

The carried studies show that air contamination in Baku is at medium level, whereas it is moderate in Sumgait, Ganja and Mingachevir, and lower in other cities. Air contamination is observed at very low level in Nakhchivan city.

Statement of conflict

The author declare that there is no any conflict of interest.

References

1. Abdullayev, R.B., Mammadova, Sh.I. (2001). Role of synoptic processes in the analysis of the ecological state of the atmosphere in Ganja city. Proceedings of Baku State University, series of natural sciences, No. 3, 140-147.
2. Ahmadov, Sh.A., Huseynli, M.A. (2005). Radiation regime of the atmosphere. Baku. 206 p.
3. Akpinar, E.K., Akpinar, S., Öztop, H.F. (2009). Statistical analysis of meteorological factors and air pollution at winter months in Elaziğ, Turkey. Journal of Urban and Environmental Engineering. Vol. 3, No.1, 7-16.
4. Ayyubov, A.J. (1987). Climate of resorts and rest places of Azerbaijan SSR. 93 p. Baku.
5. Ayyubov, A.J., Musayev, Z.F., Karimov, A.A. et al. (1997). Climate of Baku and Absheron Peninsula and human health. 1997, 124 p. Baku.
6. Barrero, M.A., Grimalt, J.O., Cantón, L., (2006). F of daily ozone concentration maxima in urban atmosphere. Chemometrics & Intelligent Laboratory System, 80, 67-76.
7. Bezuglaya, E.Yu., Rastorguyeva, G.P., Smirnova, I.V. (1991). What an industrial city breathes? (in Russian). Leningrad.
8. Chao, Z. (1990). Urban climate and air pollution in Shangai. Energy Buildings 15, pp. 647–656.
9. Cuhadaroglu, B., Demirci, E. Influence of some meteorological factors on air pollution in Trabzon city. Energy and Buildings. Volume 25, Issue 3, 1997, 179-184.
10. Demirci, E. & Cuhadaroglu, B. (2000). Statistical analysis of wind circulation and air pollution in urban Trabzon. Energy Buildings 31, 49–53.
11. Elminir H.K., (2005). Dependence of urban air pollutants on meteorology. The Science of the Total Environment, Nov. 1, 350, 225-237.
12. Escourrou, G. (1990). Climate and pollution in Paris. Energy Buildings, 15, pp. 673–676.
13. Fetisova, N.V., Korotkova, N.A., Fetisova, N.A. (2011). Methods of estimation and forecasting of air pollution (in Russian). 48 p.
14. Gorchiyev, A.A., Agaev, T.D. (1982). Studies on high-altitude air temperature inversions with different lower boundaries in a two-kilometer height layer of the atmosphere over the Absheron peninsula (in Russian). Proceedings of Academy of Sciences of Azerbaijan SSR, series of Earth sciences. No. 5, 34-42.
15. Hasanov A.A. (2003). Problems of ecology of Azerbaijan. Elm. Baku. 339 p.
16. Hargreaves, P.R., Leidi, A., Grubb, H.J., Howe, M.T., Mugglestone, M.A., (2000). Local and seasonal variations in atmospheric nitrogen dioxide levels at Rothamsted, UK, and relationships with meteorological conditions. Atmospheric Environment, 34, 843-853.
17. Hosseinibalam, F., Hejazi, A. (2012). Influence of meteorological parameters on air pollution in Isfahan. 3rd International Conference on Biology, Environment and Chemistry. IPCBEE. Vol. 46, 7-12. IACSIT Press, Singapore.
18. Kartal, S. & Ozer, U. (1998). Determination and parameterization of some air pollutants as a function of meteorological parameters in Kayseri, Turkey. Air and Waste Management Association 48, 853–859.
19. Katsoulis, B.D. (1996). The relationship between synoptic, mesoscale and microscale meteorological parameters during poor air quality events in Athens, Greece. The Science of the Total Environment, 181, 13-24.
20. Latini, G., Grifoni, R.C. & Passerini, G. (2002) Influence of meteorological parameters on urban and suburban air pollution. Air Pollution X, Transaction: Ecology and the Environment 53.
21. Mammadova Sh.I., Ahmadov Sh.A., Babayeva Kh.S. (2012). Role of climate condition in the pollution of the atmosphere. Proceedings of Azerbaijan Engineering Academy, 118-126.
22. Mammadova, Sh.I. (1998). Study and forecasting of anthropogenic pollution of air basin in Ganja city and its suburban area. Candidate thesis, 144 p.
23. Mammadova, Sh.I., Abdullayev, R.B. (2007). Role of meteorological conditions in the pollution of atmosphere of large cities of Azerbaijan. Proceedings of Scientific Conference devoted to Prof. M.Museyibov. Baku State University, 123-125.
24. Mammadova, Sh.I. (2010). Meteorological conditions of cities of Azerbaijan and the environmental problems caused by pollution in the atmosphere // Proceedings of Baku State University, series of natural sciences, No. 4, 165-171.
25. Madatzadeh, A.A. (1973). Natural and synoptic climatic seasons of the East Caucasus. 132 p. Baku.
26. Mirbabayev, M.Y. (2005). Ecology of air space. Baku: Nafta-Press. 286 p.
27. Newstadt, F.T. & Van Don, H. et al. (1985). Atmospheric turbulence and modeling of impurity distribution (in Russian). Gidrometeoizdat. 351 p.
28. Ocak S., F. Turalioglu S. (2008). Journal of International Environmental Application & Science. Effect of Meteorology on the Atmospheric Concentrations of Traffic Related Pollutants in Erzurum, Turkey. Vol. 3 (5): pp. 325-335.
29. Pashayev, A.M., Guliyev H., Safarov, S.H. (2007). Physical bases of atmospheric processes. 415 p. Baku.

30. Pashayev, A.M., Sultanov, V.Z., Huseynov, N.Sh. et al. (2005). Climate characteristics of Nakhchivan Airport. 199 p. Baku.
31. Puc M., Bosiacka B. (2011). Effects of meteorological factors and air pollution on urban pollen concentrations. Polish Journal of Environmental Studies. Vol. 20, No. 3. pp. 611-618.
32. Sadigov, A.R. (2006). Ecology and environmental protection. Baku: Taknur, 268 p.
33. Yordanov, D. (1977) A statistical analysis of air pollution data in terms of meteorological conditions. Boundary-Layer Meteorology 11(1), pp. 27–32.
34. Van der Auwers, L. (1977) Forecasting the air pollution potential by means of a multiple regression model, In: Proc. Eighth Int. Technical Meeting on Air Pollution Modeling and its Application, Amsterdam, 38–54.
35. Witz S., Moore A.B., (1981). Effect of meteorology on the atmospheric concentrations of traffic-related pollutants at a Los Angeles site. JAPCA 31, 1098-1101.
36. Xu, J, Zhu, Y. (1994). Some characteristics of ozone concentrations and their relations with meteorological factors in Shangai. Atmospheric Environment, 28, 3387-3392.