

## DESCRIPTION OF THE EFFECTS OF CHEMICAL AND BIOLOGICAL AIR POLLUTANTS BY MEANS OF AIR QUALITY INDICES

T. EÖTVÖS

*Department of Climatology and Landscape Ecology, University of Szeged, H-6701 Szeged, P.O.B. 653; Hungary  
E-mail: eotvostekla@gmail.com*

**Összefoglalás** – A környezeti levegő minősége alapvetően befolyásolja egészségünket és közérzetünket. A települési környezetek levegője ugyanakkor számos szennyező anyaggal terhelt. Ezek mérése és a mérési eredmények közérthető megjelenítése fontos mind a környezet közigazgatás, mind a civil oldal számára. A levegőminőség jellemzésére és közérthető közzétételére leggyakrabban levegőminőségi indexeket képeznek a mért szennyező anyag koncentrációkból. Az ilyen indexek megalkotása során a mért adatokat általában időben és terület szerint átlagolják, ezáltal az adatok fontos aspektusai veszhetnek el. Az eddig ismert valamennyi levegőminőségi indexre ugyanakkor egyöntetűen jellemző, hogy csak kémiai szennyező anyagok alapján készülnek, miközben egyes biológiai szennyező anyagok a kémiai szennyezők hatásait felerősíthetik és fordítva. A cikk tárgyalja a kémiai és biológiai szennyezők hatásait egyidejűleg figyelembe vevő index megalkotásának indokoltóságát. A közérthetőség érdekében megvizsgáljuk az eddigi indexálási gyakorlatok térinformatikai elemekkel történő kiegészítését is.

**Summary** – Human health is essentially influenced by air quality. Atmospheric air in residential areas contains many pollutants. The monitoring and the plain publishing of the measured values are important both for the authorities and the public. Air quality is often characterised by constructing air quality indices, and these indices are used to inform the public. The construction of an advanced air quality index is usually done by averaging the measured data usually in time and space; hereby important aspects of the data can be lost. All known indices contain only chemical pollutants, while certain biological pollutants can enhance the effects of the chemical pollutants and vice versa. In this paper we discuss the importance of integrating biological pollutants into air quality indices. In order to increase the efficacy of these indices to the civil society we aim to introduce geographic information system (GIS) methods into publishing air quality information.

**Key words:** air pollutants, air quality index, GIS, chemical air pollutants, biological air pollutants, pollen

### 1. INTRODUCTION

Atmospheric air is an aero-disperse system: in this gas-mixture solid and liquid particulates are present. Pure air contains nitrogen, oxygen, noble gases (such as Ar, Ne, He,), and carbon-dioxide, but this ideal composition does not exist in nature because it is always polluted by various components.

The pollutants can be classified in several ways according to their origin (natural or anthropogenic, chemical or biological), residence time (persistent, changing or considerably changing), formation mechanism (primary and secondary pollutants), phase (solid, liquid, gaseous), and their effect on human health (toxic, carcinogenic, allergic). The concentration of these pollutants has increased in the atmosphere with the development of technology, industry, transportation and the large-scale spread of the cultivation of industrial crops.

Therefore monitoring air quality has become very important due to the harmful effects on the biosphere and thus on human health. Measurements are being performed at monitoring stations placed in cities, run by environmental or public health authorities. Concentration of sulphur-dioxide, nitrogen-oxides, PM10, ozone and carbon-monoxide are the most often measured components. In addition – owing to the increasing frequency of allergic illnesses – the monitoring of pollen and measurement of its concentration has become increasingly important. The level of air pollution was attempted to be described in different ways to the civil society to make it understandable.

The aim of the study is twofold: firstly, to overview the current air quality indices, and to indicate the need to introduce a new type of air quality index to include the simultaneous effects of chemical and biological pollutants and, secondly, to use GIS methods in order to increase the efficacy of the air quality analysis.

## 2. CHEMICAL AND BIOLOGICAL POLLUTANTS AND THEIR EFFECT ON HUMAN HEALTH

People, animals and plants need clean air for the appropriate standard of living. In this case clean air means that the concentrations of air pollutants do not exceed certain threshold limits, which were established by empirical and/or experimental means.

The air quality requirements are put forth by legislation, while technical specifications contain the technological compliance in detail. In Hungary, the legislation is based on Act LIII 1995 on the General Convention of the Protection of the Environment. The Act, regarding the air quality protection, specifies the following:

- The protection of the air quality includes the atmosphere as a whole, its composition, the processes within, and the climate.
- The air is to be protected from all artificial impacts imposed by radiating, liquid, gaseous or solid substances affecting the quality of the air or imposing health damage or threatening the state of other elements of the environment via the air.
- At designing, implementing and operating activities or facilities and at processing and using products it is mandatory that the emission of air pollutants is minimal.

Related regulations (no. 21/2001 Government Regulation; no. 17/2001 Regulation, Ministry of Environment; no. 14/2001 Joint Regulation: Ministry of Environment, Ministry of Health, Ministry of Agriculture and Rural Development; no. 7/2003, Joint Regulation: Ministry of Environment, Ministry of Economy) are in compliance with the Regulations and Directives of the European Union concerning Clean Air Protection.

We can define air pollution as follows: gases, solid particles and aerosols that change the natural composition of the atmosphere. They can be harmful to human health, living organisms, soil, water and other elements of the environment. Of the classification possibilities listed in the introduction, we discuss air pollutants according to their origin.

According to their origin, they can come from natural and anthropogenic sources. The natural sources are forest fires, prairie fires, volcanic activity, flora and fauna. Hence H<sub>2</sub>S, SO<sub>2</sub>, HCl, NO<sub>x</sub>, CO, CO<sub>2</sub>, CH<sub>4</sub>, NH<sub>3</sub>, dust, pollen, fungus spore, bacteria are natural pollutants. All human activities are anthropogenic sources of pollutants. These pollutants are basically the same as the natural ones except maybe the biological pollutants; besides, some specific organic compounds (CFC's, dioxin, benzene, etc.) and soot and ash.

Though all the here-mentioned components are well-known pollutants, regular daily monitoring is limited to only some of them. Furthermore, some of them are typically not

influencing the air quality of residential areas on a daily basis, due to their impact mechanism. Considering these, the paper deals with the following compounds: CO, SO<sub>2</sub>, NO<sub>x</sub>, O<sub>3</sub>, dust (PM10, soot, ash), and of the biological pollutants the pollen of ragweed (*Ambrosia*).

### 3. CHEMICAL POLLUTANTS: CO, O<sub>3</sub>, SO<sub>2</sub>, NO<sub>x</sub>, DUST (PM10, SOOT, ASH)

Most of the indices consider these five pollutants, which are also the most frequently measured ones.

*Carbon-monoxide* is extremely poisonous for people and animals. Breathing it in, it attaches to haemoglobin and squeezes out oxygen. Haemoglobin becomes carbon-monoxide haemoglobin, which causes lack of oxygen in the nervous system and heart muscle. Acute poisoning brings on headache, heavy breathing, heart problems, in serious case unconsciousness and even breath paralysis. Survivors usually suffer from slowly healing nerve injuries. In fresh air acute poisoning never happens. Chronic symptoms are headache, dizziness, insomnia, heart ache, nervous system symptoms and increase of heart attack frequency. In fresh air carbon-monoxide leaves the organism. Elderly people, pregnant women, people who work in polluted air are most exposed.

*Sulphur-dioxide* is harmful to people and animals if they inhale it. SO<sub>2</sub> is adsorbed to the mucous membrane, of which the acidic reaction has irritant effect. If it enters the bloodstream, haemoglobin becomes sulfo-haemoglobin; hereby it hinders taking oxygen. Clean air restores health. Acute effects are lung, nose and throat mucous membrane irritation, and asthmatic spasm. In fresh air it does not occur. In chronic case respiratory illnesses (bronchitis) occur. Children, elderly people as well as children and adults suffering from asthma are the most endangered.

*Nitrogen-oxides* irritate the mucous membrane, cause coughing, nausea, headache, dizziness and acute poisoning. These symptoms disappear in a few hours then some hours later pneumonia, pneumoedema may develop. In fresh air acute poisoning does not occur. Nitrogen-dioxide has twofold impact mechanism. Attached to the mucous membrane, it forms nitrous or nitric acid, which damages the tissues locally. If it enters the bloodstream, haemoglobin is oxidized to methemoglobin, thus it becomes unable to carry oxygen to the organs. Therefore, longer exposure reduces resistance ability against infections, aggravates asthmatic diseases, causes frequent respiratory illnesses, and, later on, decreased lung-functions occur. Children and people who suffer from asthmatic illnesses, cardio-vascular diseases and respiratory diseases are the most endangered.

*Ozone* is strongly poisonous to human health. Eyes, nose and throat mucous membrane are irritated. It causes coughing and headache if the time of exposition is short. In chronic cases it contributes to asthma and reduces lung capacity. People suffering from asthma, other respiratory diseases, furthermore those with heart problems, elderly people and manual workers are the most endangered.

*Dust particles* can irritate and hurt eye and upper respiratory tracts. Dust particles bigger than 10 µm are purified by the epithelium of the respiratory tracts; while dust particles smaller than 10 µm (PM10) can enter the lungs. The chemical composition, physical properties and concentration of the dust determine the effect on the respiratory system. Breathing in dusty air aggravates the state of people with asthma; reduces the ability of resistance against infections and toxic materials. Dust particles can adsorb viruses, bacteria, fungus, toxic materials and so help them to enter the organs. Those

suffering from respiratory or cardio-vascular diseases as well as elderly people are the most endangered.

#### 4. BIOLOGICAL POLLUTANTS: RAGWEED POLLEN

Ambrosia is one of the most common and most thoroughly studied weed in Hungary. It is supposed to have come from the south part of North-America and by the second half of the 19<sup>th</sup> century four American species have already become acclimatized in Europe. These are the short (or common) ragweed (*Ambrosia artemisiifolia* = *Ambrosia elatior*), the giant ragweed (*Ambrosia trifida*), the perennial ragweed (*Ambrosia psilostachya*) and the silver ragweed (*Ambrosia tenuifolia*). *Ambrosia elatior* is the most widespread species of these. In Europe, the ragweed pollen pollution is the highest in the Carpathian Basin, sometimes with two orders of magnitude higher than the second Northern Italy and the third Rhone valley.

In Hungary, only *Ambrosia elatior* can be found of the four species of ragweed mentioned above. During the 1920s, it only existed in Southern Transdanubia, since then it has spread in the whole country. Local climate promotes its quick expansion. Thus blooming and pollen emission is significant. Pollen can survive in the soil for a long time – even decades. The main blooming period is between July and October, but it is most intensive in August.

*Ambrosia* is dangerous not only for people sensitive to allergy but it can cause severe damage in agriculture as well. It occurs in large quantities along roads, railway embankments, uncultivated fields; it displaces other plants (field crops, for example lucerne). It is hard to eradicate because it does not have natural competitors, since it is a new species in the country.

Allergy is an abnormal reaction against materials, which can be found in the environment and are normally harmless to human health. The immune system of a patient sensitive to allergy exaggerates the reaction against certain materials and perceives them harmful. These materials are the allergens. About 30% of the Hungarian population has some type of allergy, two-third of them has pollen-sensitivity, and at least 60% of this is caused by ragweed (Járai-Komlódi, 1998; Makra *et al.*, 2004, 2005, 2006, 2007). About 50-70% of the allergic patients have ragweed-sensitivity (Mezei *et al.*, 1992). The number of patients registered with allergic illnesses doubled and the number of cases of allergic asthma became four times higher by the late 1990s compared to the situation 40 years ago.

When a patient with allergic illness is in touch with the allergen, the following process occurs:

1. The human body, reacting against the allergen, produces specific antibodies; namely, protein molecules. These are IgE (immunoglobulin E) molecules.
2. These antibodies attach to special cells. These can be found in the respiratory organs and intestines, where allergens can enter easily.
3. Many chemical compounds are forming; one of them is histamine, which is important in the developing of an allergic reaction.
4. Breathing in chemical compounds can cause nose and eye itching, in more serious cases asthmatic asphyxia, or urticaria, furthermore, mouth and stomach symptoms, diarrhoea can develop.

Extreme concentrations of chemical compounds can cause severe symptoms all over the body: nettle-rash, low blood pressure or even unconsciousness. This group of symptoms is called anaphylaxis.

## 5. INTRODUCTION TO AIR QUALITY INDICES

The first attempts to formulate air quality state in relation to pollutant levels appeared in the 1960s.

It usually meant that concentration intervals were defined for some pollutants, and these intervals had a detailed description. In this paper the categories of two air pollution indices are shown. Pollutant Standard Index (PSI) seems more complex in a sense that a numerical scale is defined for the concentration intervals, and these numbers indicate, which category the actual air quality falls in (*Table 1*).

*Table 1* Pollutant Standard Index (PSI)

| PSI<br>value | O <sub>3</sub> |        | PM                        |                          | CO                | SO <sub>2</sub>    |
|--------------|----------------|--------|---------------------------|--------------------------|-------------------|--------------------|
|              | 8 hours        | 1 hour | PM2.5,<br>24 hours, (ppm) | PM10,<br>24 hours, (ppm) | 8 hours,<br>(ppm) | 24 hours,<br>(ppm) |
| 50           | 0.07           | –      | 15                        | 50                       | 4                 | 0.03               |
| 100          | 0.08           | 0.12   | 65                        | 150                      | 9                 | 0.12               |
| 150          | 0.10           | 0.16   | 100*                      | 250                      | 12                | 0.25               |
| 200          | 0.12           | 0.20   | 150*                      | 350                      | 15                | 0.30               |
| 300          | 0.40 (1 hr)    | 0.40   | 250*                      | 420                      | 30                | 0.60               |
| 400          | 0.50 (1 hr)    | 0.50   | 350                       | 500                      | 40                | 0.80               |
| 500          | 0.60 (1 hr)    | 0.60   | 500                       | 600                      | 50                | 1.00               |

Proposed PSI values (*EPA*)

*Mayer et al.* (2004) developed statistical air stress indices and an impact-related air quality index (DAQx). Their sensitivity depending on emissions and air mass exchange conditions was investigated by test calculations based on air pollution data

The Air Quality Index (AQI) is introduced by the *EPA* (USA). This is a system of quantifying the quality of the ambient air we breathe. The AQI reading for a given day is based on the critical pollutants and upon pollutants with high readings. The major air pollutants used to determine the AQI are ground-level ozone, particulate matter, carbon monoxide, sulphur dioxide and nitrogen dioxide. The Air Quality Index is divided into six categories ranging from good to hazardous. Good is green, and ranges from 0-50. The next level is moderate, which is yellow and ranges from 51-100. The third level is unhealthy for sensitive groups, and is orange. It ranges from 101-150. The fourth level is unhealthy, which is red and ranges from 151-200. Very unhealthy is purple, and ranges from 201 to 300. The hazardous level, rarely seen in the United States, is black and has an AQI of 301+ (*Table 2*).

The components considered, the thresholds and the descriptions are different in most countries. The paper of *Shooter and Brimblecombe* (2007) is a good summary of air quality indices.

In the more complex indices there are previously defined parameters (or only one parameter), which are weighted on the basis of the strength of their effects on human

health. They are averaged in time, the place of the monitoring station is considered and by means of mathematical methods a single value is constructed of the data.

Table 2 Air Quality Index (AQI) (EPA)

| AIR QUALITY GUIDE              |           |  |  |
|--------------------------------|-----------|--|--|
| Air quality                    | AQI       | Caution – Ozone  | Caution–<br>very small particles<br>(PM <sub>2.5</sub> )   |
| Good                           | 0 – 50    | No health impacts are expected when air quality is in this range.  | No health impacts are expected when air quality is in this range.  |
| Moderate                       | 51 – 100  | Unusually sensitive people should consider limiting prolonged outdoor exertion.  | No health impacts are expected when air quality is in this range.  |
| Unhealthy for sensitive groups | 101 – 150 | Active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion.  | People with respiratory disease or heart disease, the elderly, and children should limit prolonged exertion.   |
| Unhealthy                      | 151 – 200 | Active children and adults, and people with respiratory disease, such as asthma, should avoid prolonged outdoor exertion; everyone else, especially children, should limit prolonged outdoor exertion. | People with respiratory disease or heart disease, the elderly, and children should avoid prolonged exertion; everyone else should limit prolonged exertion.  |
| Very unhealthy                 | 201 – 300 | Active children and adults, and people with respiratory disease, such as asthma, should avoid all outdoor exertion; everyone else, especially children, should limit outdoor exertion.                 | People with respiratory disease or heart disease, the elderly, and children should avoid any outdoor activity; everyone else should avoid prolonged exertion |
| Hazardous                      | > 300     | Everyone should avoid all outdoor exertion.  |  |

Current EPA Air Quality Index and Clean Air Campaign Health Advisory

There is no unified strategy for constructing an air quality index. In every country or even within a country in different cities the value of the air quality index is acquired by different methods. There are suggestions for making simple air quality indices but in practice they are not characteristic. Even simple air quality indices need skills in mathematical statistics (*Bruno and Cocchi, 2002*).

## 6. DRAWBACKS OF CURRENT AIR QUALITY INDICES

Some objections can be raised against current air quality indices. They are not unified so it is hard to compare them. Though the descriptions are easy to understand for everyone and more or less compatible but the content behind the descriptions may be different due especially to the components considered.

Each of the complex indices considers different components but none of them include biological pollutants (for example ragweed pollen). However, their consideration could be very important because e.g. pollen, especially that of ragweed, through its irritant effect on the mucous membrane may intensify the effects of chemical pollutants.

When creating complex indices, at least temporal and spatial averaging needs to be performed, respectively. Objection can be raised against the temporal averaging of compounds that have no long term effects (for instance CO), since the modified data may not indicate severe short term exposures.

## SUGGESTIONS TO SOLVE THE PROBLEMS

There are two suggestions to solve these problems. One of them is to supplement the current and studied air quality parameters with pollen. Pollen levels would be considered as a multiplier function according to the actual concentration, thus the cumulative effects would appear in air quality indices.

In order to eliminate the lost data caused by averaging in time and space, we suggest using GIS methods. The indices used in this way should consider only the cumulative effects of the actually measured pollutant concentrations at a single location, and the GIS would display these indices at a certain time. In this way human health effects of all the pollutants show up in a way understandable for the public and the concerns can be spatially located. (A good analogy is the publishing of meteorological data with a state-of-the-art method).

## REFERENCES

- Bruno, F. and Cocchi, D.A., 2002: A unified strategy for building simple air quality indices. *Environmetrics* 13(3), 243-261.
- EPA – Environmental Protection Agency, 40 CFR Part 58 [FRL- 6198-6] RIN 2060-AH92
- Járai-Komlódi, M., 1998: Ragweed in Hungary. In Spieksma, F.Th.M. (ed.) 1998: *Ragweed in Europe. Satellite Symp. Proc. 6<sup>th</sup> Int. Congr. Aerobiol.* Perugia, Italy. Alk – Abello A/S, Horsholm DK. 33-38.
- Makra, L., Juhász, M., Borsos, E. and Béczi, R., 2004: Meteorological variables connected with airborne ragweed pollen in Southern Hungary. *Int. J. Biometeorol.* 49/1, 37-47.
- Makra, L., Juhász, M., Béczi, R. and Borsos, E., 2005: The history and impacts of airborne Ambrosia (Asteraceae) pollen in Hungary. *Grana* 44/1, 57-64.
- Makra, L., Juhász, M., Mika, J., Bartzokas, A., Béczi, R. and Sümeghy, Z., 2006: An objective classification system of air mass types for Szeged, Hungary with special attention to plant pollen levels. *Int. J. Biometeorol.* 50/6, 403-421.
- Makra, L., Juhász, M., Mika, J., Bartzokas, A., Béczi, R. and Sümeghy, Z., 2007: Relationship between the Péczely's large-scale weather types and airborne pollen grain concentrations for Szeged, Hungary. *Grana* 46/1, 43-56.
- Mayer, H., Makra, L., Kalberlah, F., Ahrens, D. and Reuter, U., 2004: Air stress and air quality indices. *Meteorol. Z.* 13, 395-403.
- Mezei, G., Járai-Komlódi, M., Papp, E. and Cserhádi, E., 1992: Late summer pollen and allergen spectrum in children with allergic rhinitis and asthma in Budapest. *Pädiatrie & Pädologie* 27/3, 75.
- Shooter, D. and Brimblecombe, P., 2007: Air quality indexing. *Int. J. Environ. Pollut.* (in press)