CHEMICAL AND BIOLOGICAL AIR POLLUTANTS, AS PARAMETERS OF COMPLEX AIR QUALITY INDICES

TEKLA EÖTVÖS – LÁSZLÓ MAKRA

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

Abstract
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 characterized 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 efficacy of these indices to the civil society we aim to introduce geographic information system (GIS) methods into publishing air quality information.

Keywords: chemical air pollutants; biological air pollutants; air quality index; GIS

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 the nature because it is always polluted by various components.

The pollutants can be classified in several ways according to their origin (natural or anthropogenic, or chemical or biological), residence time (persistent, changing or considerably changing), formation mechanism (primary and secondary pollutants), phase (solid, liquid, gaseous), and the effect on human health (toxic, carcinogenic, allergic). Concentration of these pollutants has increased in the atmosphere with the development of technology, industry, transportation and the large-scale spread of cultivation of industrial crops. Therefore monitoring of air quality became very important due to the harmful effects on the biosphere thus on human health. Measurements are being performed at monitoring stations placed in cities, which stations are run by environmental or public health authorities. Concentration of sulphur-dioxide, nitrogen-oxides, PM_{10}, ozone and carbon-monoxide are the most often measured components. In addition – owing to the increasing frequency of allergic illnesses – monitoring of pollen and measurement of its concentration became increasingly important. Level of air pollution was attempted to describe 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 effect of chemical and biological pollutants and, secondly, to use GIS methods in order to increase the efficacy of the air quality analysis.

2. Methods

2.1. Chemical and biological air 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 followings: 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 element 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 European Union concerning Clean Air Protection.

We can define air pollution as follows: gases, solid particles and aerosols that change 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_2S, SO_2, HCl, NO_x, CO, CO_2, CH_4, NH_3, 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-gases, dioxin, benzene, etc.) and soot and ash.

Though the above mentioned components are well known pollutants, the 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_2, NO_x, O_3, dust (PM_{10}, soot, ash), and of the biological pollutants the pollen of ragweed.

2.2. Chemical air pollutants: CO, O_3, SO_2, NO_x, dust (PM_{10}, soot, ash)

Most of the indices consider these five pollutants, at the same time they are the most frequently measured pollutants, too.

Carbon-monoxide is extremely poisonous for people and animals. Breathing it in, it attaches to haemoglobin and squeeze out oxygen. Haemoglobin becomes carbon-monoxide haemoglobin, which cause 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 cardiac infarct 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_2 is adsorbed to mucous membrane, acidic reaction of which has irritant effect. Entering the bloodstream, haemoglobin becomes sulfo-haemoglobin; hereby it hinders to take oxygen. Clean air restores the healthy state. 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 adult suffering from asthma are the most endangered.

Nitrogen-oxides irritate mucous membrane, cause coughing, nausea, headache, dizziness at acute poisoning. These symptoms go off in a few hours then some hours later pneumonia, pneumonoedema may develop. In fresh air acute poisoning does not occur. Nitrogen-dioxide has twofold impact mechanism. Attached to mucous membrane, it forms nitrous or nitric acid, which damages the tissues locally. If it enters the bloodstream, haemoglobin is oxidized to methehemoglobin, 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 during short exposed time. 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 ephitelium of the respiratory tracts; while dust particles smaller, than 10 μm (PM_{10}) can enter to lungs. Chemical composition, physical properties, concentration of the dust determines the effect on the respiratory system. Breathing dusty air aggravates the state of people with asthma; reduces resistance ability against infections and toxic materials. Dust particles can adsorb viruses, bacteria, fungus, toxic materials and, hence, help them to enter the organs. Those, suffering from respiratory or cardio-vascular diseases as well as elderly people are the most endangered.

2.3. Biological air pollutants: ragweed pollen

Ambrosia is one of the most common and mostly studied weed in Hungary. It is supposed to come from the south part of North-America and by the second half of the 19th century four American species has already become acclimatized in Europe. These are short (or common) ragweed (*Ambrosia artemisifolia* = *Ambrosia elatior*), giant ragweed (*Ambrosia trifida*), perennial ragweed (*Ambrosia psilostachya*) and Silver ragweed (*Ambrosia tenuifolia*). *Ambrosia elatior* is the mostly spread species of them. In Europe, ragweed pollen pollution of the Carpathian Basin is the highest, sometimes with two orders of magnitudes higher pollution 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 existed in Southern Transdanubia, since then it has spread apart in the whole country. Local climate promotes its quick expansion. Thus, the blooming and pollen emission is significant. Pollen can survive in soil for long time – even some decades. The main blooming period is between July and October, but in August is the most intensive.
Ambrosia is dangerous not only for people sensitized to allergy but it can cause severe damage in the agriculture as well. It occurs in large quantities along roads,

railway embankments, uncultivated fields, it squeezes out the planted plants (for example alfalfa), it is hard to eradicate because it does not have natural competitor, since it is a new species in the country.

Allergy is an abnormal reaction against materials, which can be found in the environment and is normally harmless to human health. 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-thirds of them have pollen-sensitivity, and at least 60 % of this pollen-sensitivity 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 registrated 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: The human body reacting against the allergen, produces specific antibodies; namely, protein molecules. These are IgE (immunglobulin E) molecules. These antibodies attach to special cells. These can be found in the respiratory organs and intestines, where allergens can enter easily. Many chemical compounds are forming; one of them is histamine, which is important in developing of an allergic reaction. Breathing in chemical compounds can cause nose and eye itching, in more serious cases asthmatic asphyxia, or utricaria, 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.

2.4. Introduction to air quality indices

First trials to formulate air quality state in relation to pollutant levels appeared in 1960s.

It usually meant that concentration intervals were defined for some pollutants, and these intervals had a detailed description. In this paper 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[1] value	O_3		PM_{10}		CO	SO_2
	8 hours	1 hour	$PM_{2.5}$, 24 hours (ppm)	PM_{10}, 24 hours (ppm)	8 hours (ppm)	24 hours (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

[1]PSI values: Proposed by Environmental Protection Agency 40 CFR Part 58[FRL- 6198-6] RIN 2060-AH92

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 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 – 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 strength of their effects to 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 on the data. There is no any 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 it is not characteristic. Even simple air quality indices need skills in mathematical statistics (Bruno – Cocchi, 2002).

Table 2. Air Quality Index (AQI), EPA

Air quality guide			
Air quality	**AQI**	**Caution – Ozone**	**Caution – very small particles ($PM_{2.5}$)**
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.	

3. Results

3.1. 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 mucous membrane may intensify the effects of chemical pollutants. When creating of complex indices, at least time and spatial averaging is needed to perform, respectively. Objection can be raised against time-averaging of compounds that have no long term effects (for instance CO), thus time averaged data may not indicate severe short term exposures.

3.2. 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 multiplicator 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 understandable for the public and the concerns can be spatially located. (A good analogy is publishing of meteorological data with a state-of-the-art method).

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