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Examination of Air Quality Indexes (AQIs) Role in Urban Air Quality Assessment

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ABSTRACT

Air pollution is a major environmental problem that has a range of negative impacts including human health, damage to ecosystems, food crops and the built environment. Public awareness of air pollution dangers has raised noticeably the need for a concept like air quality index (AQI) as a timely information about the potential changes in air quality. The study area is Veszprém city, one of the oldest urban areas in the East of Hungary, lies approximately 15 km of Balaton Lake. The aim of this work is to highlight the importance of air quality indexes (AQIs) in air quality assessment. Three different long-term AQIs - Long-term Air Quality Index (LAQx), Aggregated Air Quality Index (AAQI), Oak Ridge Air Quality Index (ORAQI) - were calculated and compared, using data between 2007 and 2016. The results proved that air quality in the city is classified from satisfying to good, with a slight variation caused by the meteorological conditions, the demographic growth, and the industrial transition. However, AQI constitutes an effective method to estimate air pollution levels and risks, but more considerations should be taken such as long-term exposure and external parameters that can influence the dispersion of pollutants.

Keywords: Air quality index, air quality assessment, long-term AQI.

1. INTRODUCTION

Scientists maintain that the impact of global warming on the environment is widespread. In the Arctic and Antarctica, warmer temperatures are melting ice, which leads to increase in sea levels and alters the composition of the surrounding sea water. Rising of sea levels has impacts on settlements, agriculture and fishing both commercially and recreationally [1] [2]. However, air pollution is a major environmental problem, strongly related to global warming. It is a by-product of increasing urbanization and industrialization that has a long and evolving history with interesting transitions in line with economic, technological and political changes. It can occur in indoor and in outdoor environments as well [3] [4]. Air pollution can be defined as the emission of harmful substances to the atmosphere. This broad definition therefore encapsulates many pollutants, including: Sulphur dioxide (SO_2), Nitrogen oxides (NO_x), ozone (O_3), particulate matter ($PM_{2.5}$ and PM_{10}), carbon monoxide (CO) and volatile organic compounds (VOCs) [5] [6]. Meanwhile defining ‘’air pollution”, we must consider natural emissions even though they can be very harmful, such as gases and particles from volcanic eruptions, and smoke from forest fires, and anthropogenic emissions as well [7] [8] [9].

Furthermore, air pollution constitutes a problem as old as history itself that can be traced back to when humanity discovered fire. As human populations became settled, demographically grown up and increasingly burned biomass and fossil fuels, the exposure to air pollution and its negative consequences rose significantly [10]. The percentage of populations in developing countries burning solid fuels indoors is ranging from 16% of households in Latin America and the Caribbean and Central and Eastern European regions, to 74% in Southeast Asian and Western Pacific regions and 77% in Africa. In fact, man-made outdoor air pollution became the most important health issue recently. After the industrial revolution, the developed world started to use more energy by the combustion of biomass and fossil fuels in urban areas, leading to significantly high levels of air pollution [11]. Air pollution's impacts are both direct and indirect. The direct impacts include health, damage of materials and ecosystems, and poor visibility (smog) [12] [13]. According to the World Health Organization (WHO), seven million people per year die from air pollution related diseases, including stroke and heart disease, respiratory illness and cancers. Many health-harmful air pollutants also damage the climate such as fine particles of black carbon from diesel and biomass combustion and ground level ozone. Some 4.3 million air pollution-related deaths are due to household air pollution and 3.7 million deaths are due to outdoor air pollution. The most dangerous air pollutant that is related to excess death and disease is $PM_{2.5}$ and in the second place: Ozone that causes significant respiratory illness, including chronic asthma [14] [15].

In 2018, the Institute for Health Metrics and Evaluation (IHME) declared that air pollution is the cause of seven million premature deaths every year (4.3 million from ambient outdoor pollution, and 2.6 million from households) [16]. The indirect impacts include 'acid rain' which results from chemicals being released into the atmosphere [17] [18]. In addition, changes in national and local economy can be a result of air pollution, due to the avoidance of visiting polluted cities [19] [20]. But, the main indirect impact is climate change from the release of Greenhouse gases (GHGs) [21] [22] [23].

Due to its major health risks, particularly, many studies were done in the last ten years to emphasize the importance of air quality index concept in rising the public awareness and deliver concretely the information, but, most of these studies were interested in daily AQIs. [24] [25] [26] [27] [28]

In this paper, we calculated and compared three long-term AQIs, to examine AQI role in air quality evaluation.

2. Materials and Methods

2.1 Study area

Veszprem is one of the oldest urban areas in Hungary at 47°05'34" N and 17°54'49" E with a population of approximately 60,788 inhabitants and an area of 126.93 km^2. It lies approximately 15 km north of the Lake Balaton and 110 km from Budapest. Also, it represents the administrative center of the county of the same name. The weather in Veszprem is very mutable, mainly influenced by three types of climate: the oceanic, the continental and the Mediterranean. The annual average temperature in the city is approximately 10-12 °C. The main sources of air pollution in the city are public transport, private vehicles, public heating and industrial activities.

2.2 Data collection

The data were taken from the Hungarian Air Quality Monitoring Network that provides current and historical air quality monitoring data nationwide. The network consists of two major parts: automatic monitoring stations with continuous measure of wide range of air pollutants in ambient air (such as SO_2, NO_2, NO, NO_x, CO, O_3, Benzene and PM_{10} $PM_{2,5}$…etc.), and manual system with sampling points and consecutive laboratory analysis. The automatic network contains data within one/some hours (historical data back to 2004). Data from manual system are updated at least every quarter year. There are also annual assessment reports for both systems as well as for

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particulate matter (PM_{10}) components. For the calculation of the AQI the automatic network data were used. Daily averages of SO_2, NO_2, NO, NO_x, CO, O_3, Benzene and PM_{10} concentrations were taken from Veszprem station, during the last 10 years (2007-2016). [29]

For the investigation of air quality, it is important to know the parameters that influence ambient air quality. The relevant meteorological parameters are the following: temperature, atmospheric pressure, wind speed and precipitation. The necessary meteorological data were supplied by the Institute of Radiochemistry and Radioecology of Pannonia University. Statistically processed data are in Table 1 (One data is equal to the average of the measured data in one measurement day).

Table 1: Meteorological data of the examined period

	Wind speed [m/s]	Precipitation [mm]	Temperature [°C]
2004	14.78	66.97	11.17
2005	11.14	91	12.72
2006	10.53	61.42	10.25
2007	11.95	62.58	11.29
2008	11.31	66.5	11.04
2009	10.78	69.75	10.83
2010	11.43	110.25	9.54
2011	10.27	43.08	10.51
2012	11.87	44.42	11.05
2013	11.16	83	10.64
2014	9.47	93.58	11.3

2.3 Air quality index concept

The concept of an Air Quality Index (AQI) has been developed and used effectively in many countries for over last four decades [30] [31] [32]. It is defined as an overall scheme that transforms weighted values of individual air pollution related parameters into a single number or set of numbers. However, an AQI was created to translate the complex scientific and medical information into simple and precise knowledge and to communicate with the citizens in the historical, current and predictive sense. [33] As a result, AQI formula can be simplified into the following simple regression model:

$$\mathrm{AQI} = \max\{\mathrm{B_i} * \text{pollutant i}\} \quad (1)$$

Where AQI is the maximum value for the sub-index calculated using the hourly concentration of individual pollutant i (i=1…, 6). And B_i refers to a slope that is constant for pollutant i but differs from one to another pollutant. It is determined by the air quality standards. (Figure 1)

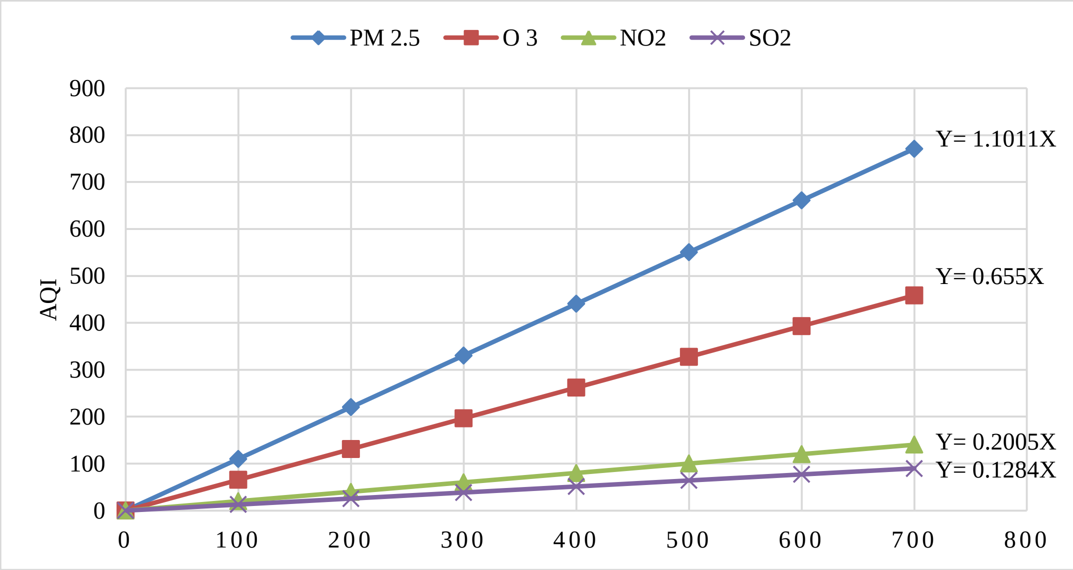

Figure 1: Relationship between hourly concentrations of $PM_{2.5}$, O_3, SO_2, and NO_2 and AQI index values [33]

According to Central Pollution Control Board (CPCB) research [34], two steps are involved in formulating an AQI: formation of sub-index (for each pollutant) and aggregation of sub-indices to get an overall AQI. The formation of sub-indices (I_1, I_2...., I_n) for n pollutant variables (X_1, X_2...., X_n) is carried out using sub-index functions that are based on air quality standards and health effects. Mathematically;

$$I_i = f(X_i),$$
$$i=1, 2... n. \quad (2)$$

Where, each sub-index represents a relationship between pollutant concentrations and health effect. Meanwhile, the general equation for the sub-index (I_i) for a given pollutant concentration (C_p); as based on 'linear segmented principle' is calculated as:

$$I_i = [\{(I_{HI} - I_{LO})/ (B_{HI} - B_{LO})\} * (C_p - B_{LO})] + I_{LO} \quad (3)$$

Where,

B_{HI}= Breakpoint concentration greater or equal to given concentration.

B_{LO}= Breakpoint concentration smaller or equal to given concentration.

I_{HI} =AQI value corresponding to B_{HI}

I_{LO} = AQI value corresponding to B_{LO}

I_p = Pollutant concentration (in µg/m^3)

Plus, the aggregation function is usually a summation or multiplication operation or simply a maximum operator. (Equation 4)

$$I = F(I_1, I_2, \ldots, I_n) \quad (4)$$

There are two types of AQI: Short term and Long-term indexes. The long-term indexes are evaluating changes in air quality over a period of years for purpose to assess the effectiveness of environmental policies improvement. The short-term indexes are used by local air pollution control agencies to investigate the daily air quality. In this work, the focus was on the long term assessment of air quality indexes.

2.3.1 Oak Ridge Air Quality Index (ORAQI)

Oak Ridge National Laboratory published the ORAQI in 1971. This aggregation was a non-linear function [35]. Thus, it was designed for use with all major pollutants recognized: SO_2, NO_2 and PM. This index includes a coefficient C, where C depends to the number of pollutants: it equals to 39.02 when n = 3, and 23.4 when n = 5. [36]

$$ORAQI = (C * \sum_{i=1}^{3} \left(\frac{C_i}{EPAS_i}\right))^{0,967} \qquad (5)$$

Where; C_i is the concentration of pollutant i and $EPAS_i$ is the EPA standard for pollutant i. The concentration of the pollutants was based on the annual mean as measured by the EPA National Air Sampling Network (NASN). The EPA standards used in the calculation were the EPA secondary standards normalized to a 24-h average basis: 0.10 ppm for SO_2, 0.20 ppm for NO_2, and 150–160 µg/m^3 for particulates [36].

2.3.2 LAQ_x - long term index

LAQ_x has been developed to evaluate the long-term integral air quality related to well-being and health of people. It was applied to analyze the evolution of air pollution from 1985 to 2005 at different urban and rural sites in Germany. This index is grouped into six classes according to the German school grade system, i.e. LAQ_x class 1 indicates a very good air quality, while very poor air quality is described by LAQ_x class 6 [37]. LAQ_x was described by Mayer [38] as well as Mayer and Kalberlah [39] in details. As they are like those for DAQ_x, it is sufficient to explain only characteristics of LAQ_x to understand the results. Due to the long-term impacts of some pollutants on human health, LAQ_x considers annual mean values of benzene, NO_2, PM_{10}, SO_2 and the annual number n of days with DAQ_x* ≥4.5, which corresponds to an exceeding of EU standards in the single air pollutants forming DAQ_x [40] A linear interpolation between single LAQ_x classes is required. Therefore, LAQ_x values for each substance i were introduced, abbreviated by LAQ_x_i and calculated according to the EPA index AQI [40] by the formula below,

$$LAQx_i = \left[\left(\frac{LAQx_{iup} - LAQx_{ilow}}{C_{up} - C_{low}}\right) * (C_{inst} - C_{low})\right] + LAQx_{ilow} \qquad (6)$$

Where C_{inst} is the annual mean value of the air pollutant i and the annual number of days with DAQ_x* ≥ 4.5, C_{up} and C_{low} are the upper and lower thresholds of the concentration ranges for the air pollutant i and DAQ_x* ranges (Table 2), respectively, as well as LAQ_{x_iup} and LAQ_{x_ilow} are the LAQ_{x_i} values corresponding to C_{up} and C_{low}. The maximum LAQ_{x_i} value, which can be assigned a specific LAQ_{x_i} class, determines LAQ_{x_ifs}, which is the LAQ_x value of the index-forming substance (Figure 2).

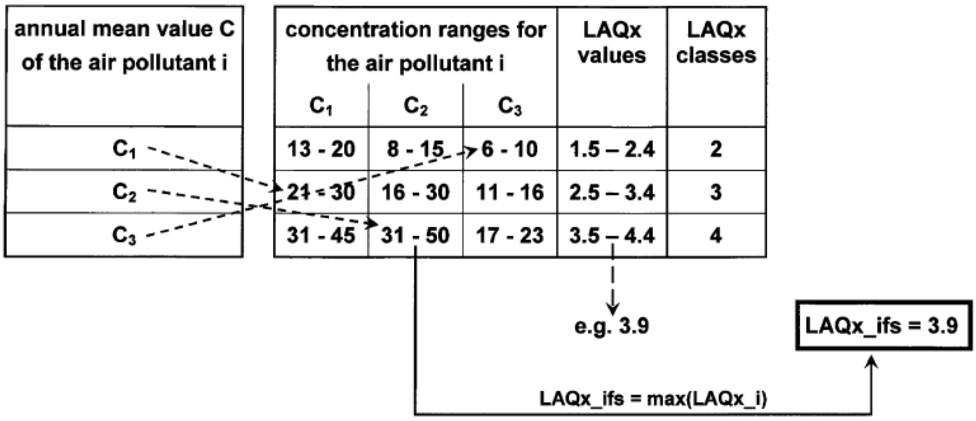

Figure 2: Scheme to determine LAQ_{x_ifs} [37]

Table 2: Assignment of ranges of air pollutant specific concentrations (benzene, NO_2, PM_{10}, and SO_2: annual mean values) and annual number n of days with DAQx* ≥ 4.5 to LAQ_x values and LAQ_x classes inclusive of classification names. [37]

Benzene ($\mu g/m^3$)	NO_2 ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	DAQx* (n)	LAQx value	LAQx class	Classification
0.0–0.2	0–12	0–7	0–5	0–2	0.0–1.4	1	Very good
0,3-1	13-20	8–15	6–10	3–5	1.5–2.4	2	Good
1.1–2.0	21–30	16–30	11–20	6–15	2.5–3.4	3	Satisfying
2.1–5.0	31–40	31–40	21–120	16–30	3.5–4.4	4	Sufficient
5.1–25.0	41–200	41–50	121–350	31–40	4.5–5.4	5	Poor
>25.0	>200	>50	>350	>40	>= 5,5	6	Very poor

Thereby, LAQ_x is calculated by:

$$LAQx = LAQx\_ifs + \sum_{i=1}^{N}\left[\frac{1}{3}(LAQx_i - 0.75 * LAQx\_ifs)\right] \quad (7)$$

Where, N is the number of modifying substances (at most 3).

2.3.3 Aggregated Air Quality Index (AAQI)

This index was used in Turkey first time, to evaluate long-term exposure to air pollutants. It offers decision-makers condensed environmental information for performance monitoring, policy progress evaluation and decision-making. The index aggregates concentrations of three air pollutants: Sulphur dioxide, nitrogen dioxide, and particulate matter. Therefore, the first step is the normalization of variables that they can be comparable.

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"Distance to Reference Value Normalization" method is applied since this approach is widely used in environmental applications [41]. The general equation to calculate the aggregated value of individual indicator i (S_i) is given as follows:

$$S_i = C_i / C_{tv} \quad (8)$$

Where C_i (µg/m^3) is the raw value of individual indicator i and C_{tv} (µg/m^3) is the EU long-term limit value for the pollutant i. The weights of the environmental indicators (SO_2, NO_2 and PM_{10}) must be specified before the aggregation in order to build a single index. The general formula of normalized index, is given as follows :

$$I_s = \sum_{i=1}^{N} w_i * S_i \quad (9)$$

Where I_S represents the aggregated index for the station S, N is the number of indicators to be aggregated, S_i is the normalized values of the indicators for indicator i and w_i is the weight of indicator i. According to [41], w_1,w_2,w_3 were assigned to 1/3 weight, since equal weights were adopted for the three environmental indicators.

3 Results and Discussion

3.1 Long-term Air Quality Index (LAQ_x)

LAQ_x method is including four air pollutants not like the other two indexes, which gives it more feasibility to assess the contribution of these parameters in air pollution. LAQ_x is grouped into six classes according to the German school grade system: LAQ_x class 1 indicates a very good air quality, while very poor air quality is described by LAQ_x class 6.

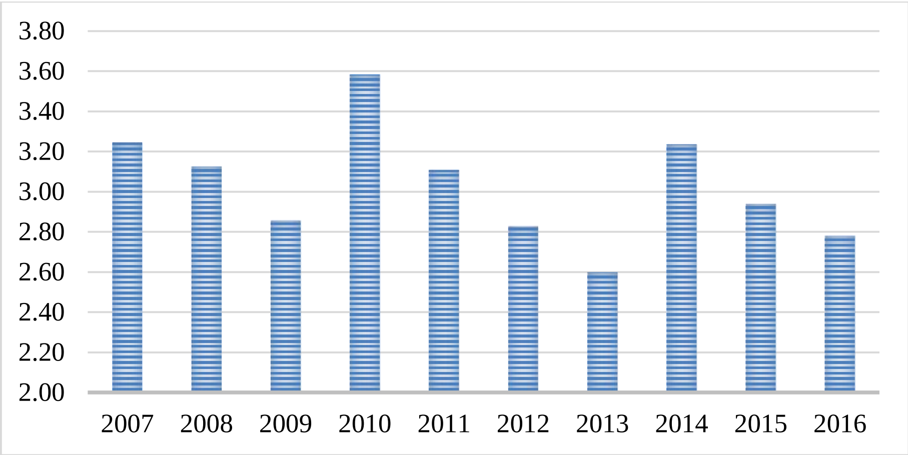

Figure 3 : LAQ_x variation between 2007 and 2016

Based on the graph (Figure 3) LAQ_x was in a potential decrease from 3.25 in 2007 to 2.78 in 2016, with a slight variation. The maximum was 3.58 in 2010 while the minimum was 2.6 in 2013. The integral long-term air quality evaluated by LAQ_x has changed for the best from 2007 to 2016. In Veszprem, air quality was classified as satisfying in the last ten years. The lower values of LAQ_x indicate a better air quality, while the higher ones reflect the reverse. The decreasing tendency of LAQ_x values was certainly modified by the overall meteorological conditions. LAQ_x values were raised in years with a remarkable portion of consecutive extremely hot summer days. The modifying effect became apparent notably in 2010 and 2014, which had extreme heat waves in Europe.

3.2 Oak Ridge Air Quality Index (ORAQI)

Oak Ridge Air Quality Index (ORAQI) was designed to be used with all major air pollutants verified by EPA. It can be used to assess daily or annual air quality changes including three or five parameters. Due to the lack of data, we used just three parameters: SO_2, NO_2 and PM_{10}. The value close to 10, describes the condition of naturally occurring unpolluted air. A value of 100 is the equivalent of all pollutant concentrations reaching the established standards.

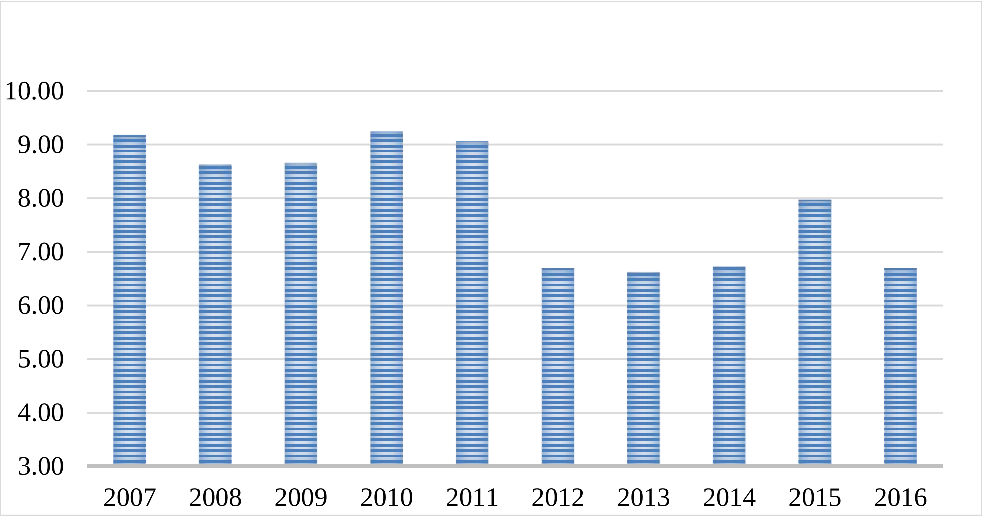

Figure 4: ORAQI variation between 2007 and 2016

It can be noticed (Figure 4) that the ORAQI decreased from 9.17 in 2007 to 6.7 in 2016, with a moderate fluctuation in 2010 and 2011. The maximum value was 9.26 in 2010, while the minimum was registered in 2013 (6.63). Despite the slight variation in ORAQI values, air quality in Veszprem city is still classified as good. The potential decrease from 9,06 to 6,7 between 2011 and 2012 is related to the important decrease in PM_{10} yearly concentration. In fact, the annual long-term air quality evaluated by ORAQI has changed for the best in the last ten years. However, ORAQI was created to give an overview about air pollution in urban areas and to evaluate the efficiency of environmental policies. But, it is only emphasizing the effect of three pollutants, while the contribution of other parameters is ignored and that could be a disadvantage comparing to other revised indexes.

3.3 Aggregated Air Quality Index (AAQI)

Table 3: Categories of AAQI [41]

Index	Value Air Quality
>1	The EU standards are exceeded by one pollutant or more
1	The EU standards are fulfilled on average
<1	The situation is better than the norms on average

AAQI represents the city general air quality conditions in a year. It is based on annual average mean of pollutants concentrations compared to annual limit values. Table 3 summarizes the three categories of air quality evaluated by AAQI.

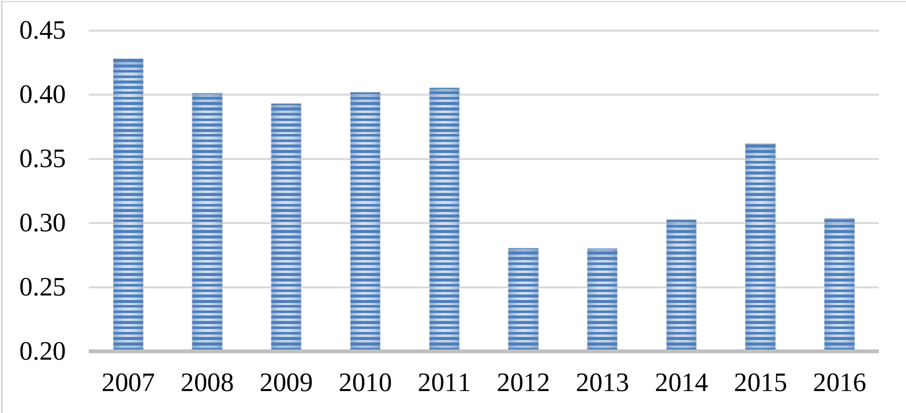

Figure 5: AAQI variation between 2007 and 2016 in Veszprém

The situation in Veszprem is better than the norms on average because the values didn't exceed 1. The long-term air quality assessment evaluated by the aggregated air quality index shows, that air pollution has a decreasing tendency and it is not representing any risk. AAQI decreased from 0,43 in 2007 to 0,3 in 2016. The minimum was 0,28 in 2012 and 2013, while, the maximum was 0,43. The index results provide a general review about the air pollution levels and the priority level to implement or to improve the environmental policy. However, the air quality in Veszprem is good and the efforts should be focused on maintaining the clean air by minimizing the new emission sources that could have environmental impacts. AAQI concept provides a relative measure of the annual average air quality in relation to the European limit values, since the target was selected as the EU annual air quality standards. It was created to consider the long-term exposure to air pollution based on distance to the target set by the EU annual norms. Despite its ability to identify the overall air quality, it is limited in three air pollutants (SO_2, NO_2, and PM_{10}), which can mislead the decision makers during the implementation of environmental policies.

3.4 Comparison of Different Air Quality Indices

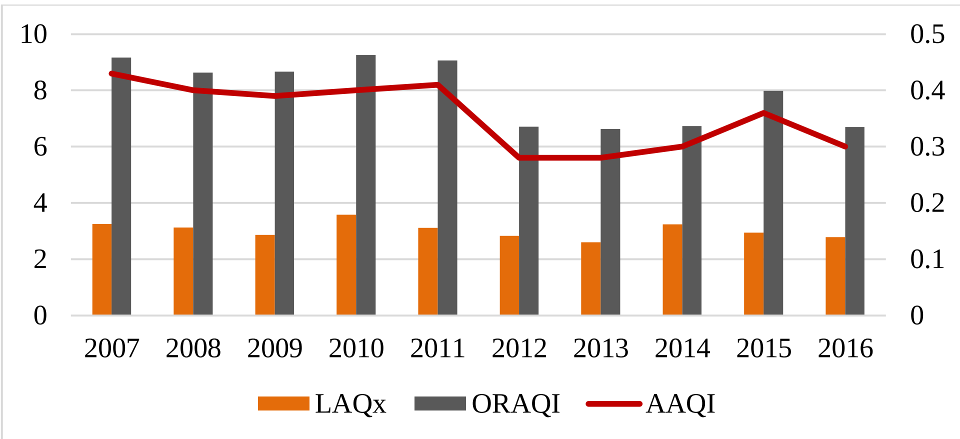

Figure 6: Comparison of air quality index values

AAQI and ORAQI include only SO_2, NO_2 and $PM_{10,}$ whereas LAQ_x includes Benzene too. Air quality index values were in decrease from 2007 to 2016 with a slight variation in 2010 for all indices. In 2011, AAQI increased which can be explained by the raise of PM_{10} concentration to attend 26.51 µg/m^3. However, AAQI and ORAQI have the same rhythm of variation due to the pollutants type and number used to evaluate air quality. The non-conformity in values is simply explained by the parameters and constants used in their equations. Due to the consideration of four pollutants, LAQ_x is more feasible in air quality evaluation. But, Benzene concentrations in Veszprém are so low and ranged between 1.23 µg/m^3 and 0.91 µg/m^3 which can't show clearly the difference in this case. Despite the different expression of the studied AQIs, air quality in Veszprém was classified from satisfying to good which confirms clearly the role of this concept in measuring air pollution levels.

The studied AQIs can be used effectively to evaluate environmental policies and to give an overview about air quality, but they don't reflect precisely air pollution levels due to the exclusion of some dangerous pollutants like lead and VOCs, that might have health risks in longer exposure periods, and meteorological parameters which probably influence air pollutants dispersion from the source.

4. Conclusion

The examination of three long-term AQIs constitutes a relevant method to prove their important role in air quality assessment. These AQIs: Long-term Air Quality Index (LAQx), Aggregated Air Quality Index (AAQI), and Oak Ridge Air Quality Index (ORAQI) - were calculated and compared, using data between 2007 and 2016. The results proved that air quality in Veszprem is classified from satisfying to good during the last ten years. Despite the limitation of the examined AQIs in three or four pollutants and without considering external parameters that can influence air quality, this concept can be considered as a useful tool to support the government, especially in the preventive health care system, to raise public awareness about environmental issues and to evaluate environmental policies efficiency in long-term.

Much progress is still to be done in the revised AQIs, mainly through more careful considerations of combined multiple pollutants impact, low level exposure and with more timely transfer of information to the public.

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References

[1] Moore Frances, Climate Change and Air Pollution: Exploring the Synergies and Potential for Mitigation in Industrializing Countries, Sustainability. 2009; 1: 43-54

[2] National Research Council. Climate Stabilization Targets: Emissions, Concentrations, and Impacts over Decades to Millennia. Washington, DC: The National Academies Press, 2011: p. 18-25. Available from: https://doi.org/10.17226/12877

[3] Jacob, Daniel J. and Darrell A. Winner. Effect of Climate Change on Air Quality, Atmospheric Environment. 2009; 43(1): 51–63. doi: 10.1016/j.atmosenv.2008.09.051

[4] Lu Li-Shun, Lin Bo-Huei, Wong Tin-Chi. Interactive Qualifying Project: Air Pollution in Asia, 2005-2006: p.9-10

[5] Bai Lu, Wang Jianzhou, Ma Xuejiao and Lu Haiyan. Air Pollution Forecasts: An Overview. Int J Environ Res Public Health; 2018. doi: 10.3390/ijerph15040780

[6] Choudhary Mahendra, Garg Vaibhav, Causes, Consequences and Control of Air Pollution. In: All India Seminar on Methodologies for Air Pollution Control, At Malviya National Institute of Technology. August 2013; Rajasthan, India. p.1-4.

[7] Daly Aaron and Zannetti Paolo, An Introduction to Air Pollution – Definitions, Classifications, and History. Chapter 1 of Ambient Air Pollution (P. Zannetti, D. Al-Ajmi, and S. Al-Rashied, Editors). Published by The Arab School for Science and Technology (ASST) (http://www.arabschool.org.sy) and The EnviroComp Institute (http://www.envirocomp.org/). 2007: p. 2-3

[8] Lagzi István, Mészáros Róbert, Gelybó Györgyi, and Leelőssy Ádám, Atmospheric Chemistry. Eötvös Loránd University. 2013: p.14-17

[9] Pénard-Morand C, Annesi-Maesano I, Air pollution: from sources of emissions to health effects. European Respiratory Society 2004; 1(2): p.110-111. Available from: https://doi.org/10.1183/18106838.0102.108

[10] Nagdeve Dewaram A, Population Growth and Environmental Degradation in India. Population Association of America_ Annual Meeting Program; Session 100: Environmental Consequences of Population Growth/Decline. March 2007; New York; p1.

[11] Hutton Guy, Air Pollution Global Damage Costs of Air Pollution from 1900 to 2050 [dissertation]. Copenhagen: Copenhagen Consensus Center; 2011; p. 4-5

[12] Phinney Lisa, Environmental Impacts of Air Pollution Air Pollution. Air Quality Sciences; Meteorological Service of Canada. 2004. Available from: https://novascotia.ca/nse/air/docs/Phinney-EnvironmentalImpacts.pdf

[13] European environment agency, Air pollutants and global effects, 2018 [cited 30 October 2018]. Available from: https://www.eea.europa.eu/

[14] WHO, Ambient and Household Air Pollution and Health Update 2014, 2014. [cited 03 May 2018]. Available from: http://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health.

[15] WHO, Air Pollution, Climate and Health. [cited 20 November 2018]. Available from: http://www.who.int/sustainable-development/AirPollution_Climate_Health_Factsheet.

[16] IHME, Over seven billion people face unsafe air: State of Global Air 2018, 2018. [cited 10 October 2018] Available from: http://www.healthdata.org/

[17] Kucera V and Fitz S, Direct and indirect air pollution effects on materials including cultural monuments. Water, Air, and Soil Pollution; 1995: 85 (1): p.153–165. https://doi.org/10.1007/BF00483697

[18] Sivaramanan Sivakumaran, Acid Rain; Causes, Effects and Control Strategies. Central Environmental Authority (Sri Lanka); 2016. p1-2.

[19] Lanzi Elisa et al, OECD report. The Economic Consequences of Outdoor Air Pollution, Editions OCDE, Paris; 2016; p.1-39. https://doi.org/10.1787/9789264257474-en.

[20] Cheung Catherine and Law R, The Impact of Air Quality on Tourism: The Case of Hong Kong. Pacific tourism review; 2001, v. 5, no. 1/2. p. 69-74.

[21] House Jo, Brovkin V, Betts R, Constanza B, Assunc M¸ Dias S, Holland B, Le Quere C, Phat N K, Riebesell U, Scholes M. Climate and Air Quality. Ecosystems and Human Well-being: Current State and Trends. p.378-379. Available from: https://www.millenniumassessment.org/documents/document.282.aspx.pdf

[22] Ramanathan V, Feng Y. Air pollution, greenhouse gases and climate change: Global and regional perspectives. Atmospheric Environment. 2009; 43: p.37-50.

[23] Institute of advanced sustainability studies, Links between Greenhouse Gases, Climate Change and Air Quality [cited 13 November 2018] Available from: https://www.iass-potsdam.de/

[24] Lemeš Samir, Air Quality Index (AQI) – Comparative Study and Assessment of an Appropriate Model for B&H. In: 12th Scientific/Research Symposium with International Participation "Metallic and Nonmetallic Materials" MNM; April.2018; Vlašić, Bosnia and Herzegovina.

[25] Li Youping, Tang Ya, Fan Zhongyu, Zhou Hong, Yang Zhengzheng, Assessment and comparison of three different air quality indices in China. Environmental Engineering Research; 2018; 23(1): p.21-27. https://doi.org/10.4491/eer.2017.006

[26] Makra László, Eötvös Tekla, Assessment of Air Pollution with Air Quality Indices in Szeged, Southern Hungary. Epidemiology: 2009; Vol.20 (6); p S97. doi:10.1097/01ede.0000363003.91836.eb

[27] Patel Jaykumar, Salvi Hirva, Patel Neha, Ambient Air Quality Assessment Using Air Quality Index of Delhi. In: ICRISET2017: International Conference on Research and Innovations in Science, Engineering and Technology. Selected Papers in Civil Engineering, July 2017: vol 1, p.124--131.

[28] Bishoi Biswanath, Prakash Amit, Jain V.K. A Comparative Study of Air Quality Index Based on Factor Analysis and US-EPA Methods for an Urban Environment. Aerosol and Air Quality Research; 2009: 9(1):1-17.

[29] The Hungarian Air Quality Monitoring Network. Available from: http://levegominoseg.hu

[30] Mandal TK, Gorai AK. Air Quality Indices: A Literature Review. J Environ Sci Eng. 2014: 56(3):357-62.

[31] Liu Chung-Ming, Effect of PM2.5 on AQI in Taiwan. Environmental Modelling and Software; 2002; 17(1):29-37. doi: 10.1016/S1364-8152(01)00050-0

[32] Dongsheng Z et al, The driving factors of air quality index in China. Journal of Cleaner Production

2018; 197 (1): 1342-1351. Available from: https://doi.org/10.1016/j.jclepro.2018.06.108

[33] Chen Hong, Copes Ray. Review of Air Quality Index and Air Quality Health Index. Epidemiology: 2012; 23 (5S). doi: 10.1097/01.ede.0000417302.49629.63

[34] Central Pollution Control Board/ Government of India, 2018 [cited 04 October 2018] Available from: http://cpcb.nic.in/National-Air-Quality-Index/.

[35] Thom G C and Ott W R, Air pollution indices: A compendium and assessment of indices in the United States and Canada. Technical report of the Council on Environmental Quality, Washington, D.C. (USA); Environmental Protection Agency, Washington, D.C. (USA); NP-20903; 1975: p 17-18

[36] EPA, Guideline for reporting of daily air quality—Air Quality Index (AQI). Environmental Protection Agency, EPA-454/R-99-010, Office of Air Quality Planning and Standards, Research Triangle Park, N1999.

[37] Mayer H, Kalberlah F, Two impact related air quality indices as tools to assess the daily and long-term air pollution. International Journal of Environment and Pollution; 2009: 32,232–243. doi: 10.1504/IJEP.2009.021814

[38] Mayer H, Indices for the human–bio meteorological assessment of the climate’s thermal and air pollution component. Gefahrstoffe-Reinhaltung der Luft 66, 2006: 165–174 (in German).

[39] Mayer H, Makra L, Kalberlah F, Ahrens D, Reuter U, Air stress and air quality indices. MeteorologischeZeitschrift 13, 2004: 395–403.

[40] Mayer H, Holst J, Schindler D, Ahrens D, Evolution of the air pollution in SW Germany evaluated by the long-term air quality index LAQx. Atmospheric Environment; 2008: 42:5071-5078. doi: 10.1016/j.atmosenv.2008.02.020

[41] Büke Tayfun, Köne Aylin Çigdem, Assessing Air Quality in Turkey: A Proposed, Air Quality Index. Sustainability; 2016: vol. 8 (73). doi: 10.3390/su8010073