Determination of Environmental Justice Using the Environmental Quality Index (EQI)

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Abstract.
The environment is one of the factors that affect the health and quality of life of the population. The environmental characteristics here represent health impacts and are relatively well measurable or detectable. The aim of this paper is to analyse the environmental quality index in agglomerations and zones by measurement, SHMU operates the National Air Quality Monitoring Network as the authorized organization for the Air Act. SHMU uses stations that monitor basic pollutants, such as PM10, PM2.5, NO2 and O3. The article showed that above-average values are concentrated in the largest cities, less often also average values of environmental quality. On the contrary, smaller cities are assessed as areas with below-average environmental quality. These parts can be identified as areas with an increased environmental burden and the risk of environmental injustice, and this is how it is necessary to approach the planning of further development. Especially because these are areas that provide economic benefits for the whole city, such as good transport accessibility, services, business activities or jobs, but externalities fall significantly on the population of this area.

Keywords: Environmental Quality Index, Environmental Justice, Regions of Slovakia, European Air Quality Index

JEL classification: *P28, Q56, R58*

1 Introduction

The environment is one of the factors that affect the health and quality of life of the population. Coan and Holman (2008) argue that the main role here is played by the biophysical quality of the environment. The environmental characteristics here represent health impacts and are relatively well measurable or detectable, which can be e.g., values of individual pollutants in the air or noise level. According to many studies by Balestra et al. (2012) show that people increasingly perceive the issue of environmental degradation and depletion of natural resources. The aesthetic value of the environment, which is much more difficult to define, even though it has unquestionably positive effects on the mental health and quality of life of the population, is also gaining more and more attention. People are aware of the benefits of cultural and regulatory ecosystem services, especially appreciating clean air, access to forests or other green spaces, which offer them the satisfaction of basic leisure needs, relaxation, and meeting others (Balestra et al., 2012).

With the ever-increasing proportion of people living in urban areas, there is a growing need to address these needs within urban areas. In a densely populated urban environment, social and economic benefits are concentrated, which are based on the concentration of shops and services, job opportunities, infrastructure, etc. On the other hand, the externalities of human activities also accumulate in the urban environment, which manifest themselves as negative effects on the quality of life and health of the population living in cities. As is the case on a global scale, externalities do not affect all residents equally in the inner urban space. Access to ecosystem services within an inhomogeneous urban environment is also uneven. By Fann et al. (2011) pointed out that this leads to the creation of sub-urban zones with different levels of environmental quality and that it is essential for local authorities to reflect this fact to guarantee the sustainable development of the whole area. To do this, it is necessary to eliminate inequalities not only at the generally accepted level of social, economic, but also environmental. Since market mechanisms cannot well reflect local conditions and the state of the environment in the intra-urban area, several interventions by authorities to ensure environmental justice are applied.

Environmental justice, as defined by the U.S. Environmental Protection Agency (EPA, 1998), "guarantees all people, regardless of race, national origin, or income, to be treated fairly and involved in the development, implementation, enforcement of environmental laws, regulations, and policies." The literature (Middleton et al., 2015; Svarstad and Benjaminsen, 2020) distinguishes three basic approaches to environmental justice:

a) an approach that addresses the implementation of environmental interventions according to who receives or loses environmental benefits or, conversely, who is affected by the environmental burden, so - called. *distributive justice*;
b) an approach where we identify who is involved in decision-making processes and who has an influence on them, the so-called *procedural justice*;
c) an approach where we describe to whom the interests, values and point of view are respected and considered and, conversely, neglected, the so-called *fairness of recognition*.

2 Factors Affecting Environmental Quality

There are several factors that reflect the nature of the environment and can be divided into two main groups. The first group represents environmental benefits that can improve the quality of the surrounding environment and have a positive impact on the quality of life and health of local people. The second group represents the environmental burden, which in turn reduces the quality of the surrounding environment, which results in negative impacts on the quality of life and health of local people.

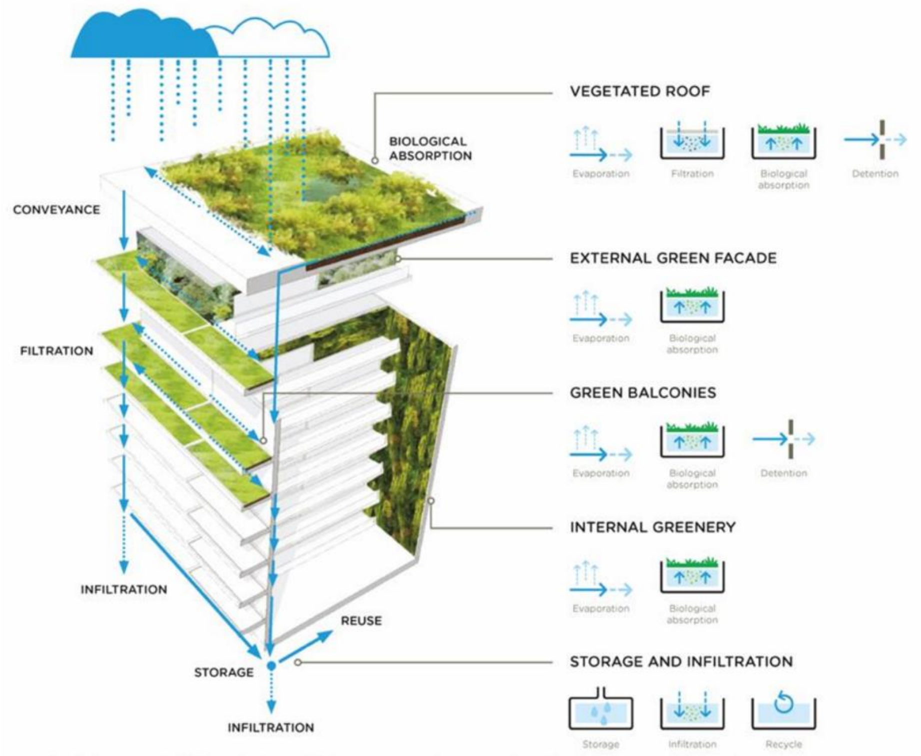

Fig. 1. Building-scale BGI solutions[1]

In the first place from the group of factors of environmental benefits, the factor reflecting the green infrastructure must be mentioned. Greenery includes not only city parks, but also gardens, alleys, green belts, green roofs, riverbanks and more. It has a positive effect on human health, both physical and mental, because it influences stress reduction, relaxation, and overall well-being (Lafortezza et al., 2009; Streimikiene, 2015). In this context, we are talking about the cultural ecosystem services that greenery provides. In addition, greenery provides ecosystem services in a regulatory manner, where it significantly affects the microclimate, the shares of the water regime as well as the shares for air purification, dust capture and noise reduction. Several studies by Maas et al. (2006) and Lakes et al. (2014) explain that one of the main factors that affect the health of the population in urban areas is greenery. A wide range of data is used to identify green infrastructure, and data from remote sensing of the Earth are increasingly

[1] Source: Mehraj U. Din Dar et al. 2021. *RETRACTED: Blue Green infrastructure as a tool for sustainable urban development*. Journal of Cleaner Production 318(3):128474 Available at: https://doi.org/10.1016/j.jclepro.2021.128474

being used. The advantage of this approach is that, unlike most map materials and inventory documents, it can also consider small areas of greenery, grass strips or free-standing trees, regardless of the ownership structure.

Another indicator that demonstrates the environmental benefits is the blue infrastructure, represented mainly by natural water features. Amaral and others (2021) in the studies point to the fact that green and blue infrastructure are combined into one indicator of blue-green infrastructure, because ecosystem water services are largely identical to green, for example in terms of microclimate regulation or increasing aesthetic values of the environment. Of the indicators that represent the environmental burden, indicators of pollution are often used, most often air, sometimes also water pollution. The negative effects of pollutants on human health have long been studied and described. Concentrations of PM10 and PM2.5 dust particles, nitrogen oxides or ground-level ozone are investigated within the negative monitored environmental characteristics (Streimikiene, 2015). Finally, noise, which is associated with negative health effects such as insomnia, hearing loss, depression, anxiety, and concentration disorders, are among the factors that worsen the quality of the environment (Dizdaroglu, 2015).

3 Methods and Methodology

Composite indicator methods were used to compile the index. This was preceded by the processing of several data layers of the area of interest in the environment of SHMU (*Slovak hydrometeorological institute*) stations, which was also used in the visualization of the results. The methodology of compiling the index is described in more detail later in this chapter.

3.1 Air Quality Index - Monitoring Area of Interest

The area of interest to which the methodology has been applied is the territory of the Slovak Republic, where SHMU uses stations that monitor basic pollutants, such as PM10, PM2.5, NO2 and O3. To air quality assessment, the territory of the Slovak Republic was divided into agglomerations and zones. For sulphur dioxide, nitrogen dioxide, nitrogen oxides, particulate matter PM10 and PM2.5 fractions, carbon monoxide, polycyclic aromatic hydrocarbons, and benzene there are 2 agglomerations and 8 zones, for lead, arsenic, cadmium, nickel, mercury, and ozone it is 1 agglomeration and 1 zone. Within agglomeration 1, the territory of the capital of the Slovak Republic, Bratislava, is monitored, and agglomeration 2 covers the territory of the city of Košice and the municipalities of Bočiar, Haniska, Sokoľany and Veľká Ida. 8 zones represent the territory of 8 regions: Bratislavský, Trnavský, Nitriansky, Trenčiansky, Banskobystrický, Žilinský, Košický and Prešovský.

To provide the basis for the assessment of air quality in agglomerations and zones by measurement, SHMU operates the National Air Quality Monitoring Network (NMSKO) as the authorized organization for the Air Act. In 2020, 40 monitoring stations were included in the network with a different measurement program, which depends on the type and location of the MS. The number of MS considers the requirements of Decree no. 244/2016 Coll. on air quality as amended by Decree no. 296/2017 Coll. to determine the minimum number of sampling points for the continuous measurement of concentrations of individual pollutants in ambient air. In 2020, out of the total number of 40 NMSKO monitoring stations, 4 stations (Chopok, Topoľníky, Stará Lesná and Starina) were in the European EMEP network and the Chopok station was in the global GAW (*Global Atmosphere Watch*) WMO network.

Fig. 2. NMSKO network of monitoring stations in 2020[2]

Individual agglomerations and zones are very diverse both in terms of area and population. They are similarly heterogeneous in terms of the nature of the landscape and its use and functional arrangement. There are parts with a clear urban character, high density of buildings and industrial areas, as well as parts with a rather rural character with arable land to areas with a relatively high proportion of forests.

3.2 Environmental Quality Index Indicators

The index was compiled using eight sub-indicators, four belong to the group of environmental benefits and the other four then represent the environmental burden. The structure of the environmental quality index is shown in Fig. 3. Data sources and data sets obtained from NMSKO monitoring stations were searched for these indicators. These were very diverse data, and it was necessary to process them to capture the evaluated properties of the areas of interest, i.e., the monitored zones and agglomerations. On the environmental benefits side, groups of factors were used to compile the index, considering both green and blue infrastructure.

[2] Source: Slovak hydrometeorological institute (SHMU). Ministry of Environment of the Slovak Republic. Monitoring network. Available: https://www.shmu.sk/sk/?page=224

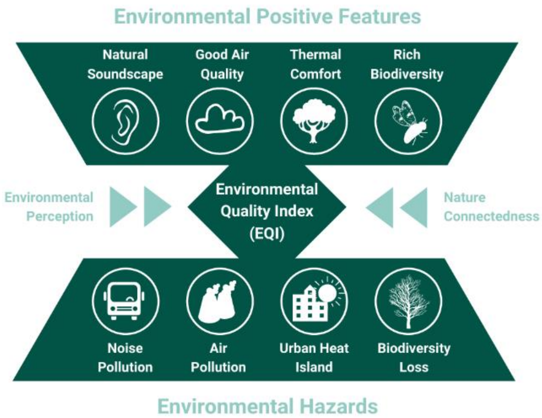

Fig. 3. Approach and Environmental Quality Indicator Theoretical Framework[3]

3.3 European Air Quality Index

Air quality assessment is based on measuring the concentrations of several pollutants in the air. Air quality is often expressed by an index. The air quality index converts pollutant concentrations expressed in µg / m3 into a multi - level word scale (e.g., air quality - good, satisfactory, acceptable, bad, and very bad) or into a numerical scale (e.g., 1-10 or 0-500, etc.).

As there is currently no uniform calculation methodology, there are several air quality indices (AQI), for example:

- **European Air Quality Index** (The European Environment Agency, EEA)
- Daily Air Quality Index (UK - Committee on Medical Effects of Air Pollutants, COMEAP)
- Real-time air quality index (global air pollution according to The United States Environmental Protection Agency, EPA)
- Air Quality Health Index (Canada)
- Air Pollution Index (Malaysia)
- Pollutant Standards Index (Singapore)

European Air Quality Index

It is based on measurements of the concentrations of five basic pollutants at a given station in individual European countries (a total of more than 2,000 stations). These concentrations are then converted to an air quality index according to the Tab. 1:

[3] Source: Using the right environmental indicators: Tracking progress, raising awareness, and supporting analysis. UNSTATS Publication. Available: http://dx.doi.org/10.6027/TN2012-535

Table 1. European Air Quality Index[4]

Pollutant	Index level (based on pollutant concentrations in µg/m3)				
	Good	Fair	Moderate	Poor	Very poor
Particles less than 2.5 µm ($PM_{2.5}$)	0-10	10-20	20-25	25-50	50-800
Particles less than 10 µm (PM_{10})	0-20	20-35	35-50	50-100	100-1200
Nitrogen dioxide (NO_2)	0-40	40-100	100-200	200-400	400-1000
Ozone (O_3)	0-80	80-120	120-180	180-240	240-600
Sulphur dioxide (SO_2)	0-100	100-200	200-350	350-500	500-1250

The index level (*European AQI*) expresses a 5-scale scale (air quality - good, satisfactory, acceptable, bad, very bad) and corresponds to the worst value (level) of all measured pollutants at a given station, where:

- Transport stations - monitor fewer pollutants, only those that measure NO2 and PM (PM2.5 or PM10) at the same time are taken from them.
- Other stations - the calculation of the index includes those that simultaneously measure at least three pollutants NO2, O3 and PM.
- Index for PM10 and PM2.5 is calculated from concentrations based on 24-hour moving averages (this is the average of consecutive 24-hour values).
- Current index captures the situation six hours ago; The site also provides the ability to view its values seven to 48 hours ago.
- *European AQI* was launched in November 2017.

4 Research Results

Based on the above methodology, an environmental quality index was calculated for each agglomeration and zone. With its help it is possible to compare individual zones with each other and it is also possible to visualize in the form of map output. This makes it possible to identify wider links and relationships throughout the city and to identify potential problem areas that may increase the potential for inequality. The values of the indices of individual parts are summarized in Tab. 2.

[4] Source: European Environment Agency. *Air Quality Index*. GIS Map Application. Published 18 Nov 2021. Available: https://www.eea.europa.eu/themes/air/air-quality-index

Table 2. Values of the Air Quality Index on 29.06.2022, 15:00[5]

Stanica	IKO	PM_{10}	$PM_{2.5}$	NO_2	O_3	SO_2
Bratislava, Kamenné nám.	17	17	1			
Bratislava, Trnavské Mýto	25	16	24	25		
Bratislava, Jeséniova	54	19	20	5	54	1
Bratislava, Mamateyova	52	20	23	4	52	4
Bratislava, Púchovská	17	15	17	13		4
Rovinka, mobilná AMS	22	22		3		5
Pezinok, Obrancov mieru	52	17	18	4	52	
Senec, Boldocká	52	16	27	9	52	
Nitra, Janíkovce	51	15	14	2	51	
Nitra, Štúrova	23	22	23			2
Komárno, Vnútorná okružná	15	14	15	6		
Plášťovce	51	26	35	2	51	
Topoľníky, Aszód, EMEP	50	14		2	50	1
Senica, Hviezdoslavova	32	25	32			5
Trnava, Kollárova	32	23	27	32		
Sereď, Vinárska	18	13	18	3		
Trenčín, Hasičská	33	29	26	33		4
Púchov, 1. mája	32	25	32			10
Bystričany, Rozvodňa SSE	24	21	24			18
Handlová, Morovianska cesta	28	21	28			6
Prievidza, Malonecpalská	47	25	38	17	47	10
Žarnovica, Dolná	29	20	29	10		
Žiar nad Hronom, Jilemnického	35	29	35			
Zvolen, J. Alexyho	29	20	29			
Banská Bystrica, Štefánikovo nábrežie	38	36	38	34		
Banská Bystrica, Zelená	30	23	30	2		
Lučenec, Gemerská cesta	47	23	34	11	47	
Hnúšťa, Hlavná	22	21	22			
Jelšava, Jesenského	50	16	28	2	50	
Žilina, Obežná	46	27	36	11	46	
Oščadnica	49	24	39	2	49	2
Martin, Jesenského	44	33	44	14		
Ružomberok, Riadok	42	33	42	10	42	14
Chopok, EMEP	48			2	48	
Liptovský Mikuláš, Školská	41	24	41	4		4
Košice, Ďumbierska	58				58	
Košice, Amurská	35	23	35			
Košice, Štefánikova	37	28	37	15		8
Kojšovská hoľa	48	15		3	48	
Veľká Ida, Letná	30	16	30			
Strážske, Mierová	28	19	28			
Trebišov, T. G. Masaryka	48	22	35	7	48	
Krompachy, SNP	35	26	35	17		1
Poprad, Železničná	35	23	35	7		
Stará Lesná, AÚ SAV, EMEP	45	19	23	2	45	
Gánovce, Meteo. st	46	21		3	46	
Prešov, Arm. gen. L. Svobodu	41	28	41	38		
Humenné, Nám. slobody	47	28	41	5	47	
Starina, Vodná nádrž, EMEP	41			2	41	
Kolonické sedlo	30	22	30			
Vranov nad Top., M. R. Štefánika	31	24	31			3
Bardejov, Pod Vinbargom	46	33	40	6	46	

Note: Good air quality - green colour *("Enjoy your usual outdoor activities")*
Deteriorated air quality - orange colour ("*Old and sick people, pregnant women and young children: Consider limiting strenuous outdoor activities, especially if you experience health symptoms."* and *"Entire population: In case of symptoms such as eye irritation or cough, consider limiting strenuous outdoor activities."*)
Poor air quality - red colour ("*Old and sick people, pregnant women and young children: Avoid strenuous outdoor activities."* and *"Entire population: Limit strenuous outdoor activities."*)

Due to the effective assessment of air quality, the territory of Slovakia is divided into zones and agglomerations. In individual zones, the concentrations of pollutants are not the same in all parts of the zone. Usually there are areas with significant sources of emissions and deteriorating air quality, but also relatively clean areas without sources. After a gradual analysis of all monitored regions, we could evaluate the situation.

4.1 Evaluation of Air Quality in the Monitored Slovak Regions

The AQI in the **Bratislava** region reaches **53**, which can be assessed as **poor**.

Table 3. Air quality in the zone: Bratislava region, 29.06.2022, 18:00[6]

Area:	The population:	Population density:	Sensitive groups:
1 685,40 km2	236 076 persons	140,07 persons / km2	Age: 0-14:19,68 % 65+: 14,81 %

[5] Source: Slovak hydrometeorological institute (SHMU). Ministry of Environment of the Slovak Republic. SHMU Station. Available: https://www.shmu.sk/sk/?page=1&id=oko_iko

The AQI in the **Trnava** region reaches **31**, which can be assessed as **good**.

Table 4. Air quality in the zone: Trnava region, 29.06.2022, 18:00[6]

Area:	The population:	Population density:	Sensitive groups:
4 146,30 km2	565 324 persons	136,34 persons / km2	Age: 0-14:14,68 % 65+: 17,75 %

The AQI in the **Trenčín** region reaches **33**, which can be assessed as **good**.

Table 5. Air quality in the zone: Trenčín region, 29.06.2022, 18:00[6]

Area:	The population:	Population density:	Sensitive groups:
4 501,81 km2	582 567 persons	129,41 persons / km2	Age: 0-14:14,02 % 65+: 18,88 %

The AQI in the **Nitra** region reaches **50**, which can be assessed as **poor**.

Table 6. Air quality in the zone: Nitra region, 29.06.2022, 18:00[6]

Area:	The population:	Population density:	Sensitive groups:
6 343,73 km2	671 508 persons	105,85 persons / km2	Age: 0-14:13,83 % 65+: 18,75 %

The AQI in the **Žilina** region reaches **45**, which can be assessed as **moderate**.

Table 7. Air quality in the zone: Žilina region, 29.06.2022, 18:00[6]

Area:	The population:	Population density:	Sensitive groups:
6 808,53 km2	691 136 persons	101,51 persons / km2	Age: 0-14: 15,87 % 65+: 16,26 %

The AQI in the **Banská Bystrica** region is **40**, which can be assessed as **moderate**.

Table 8. Air quality in the zone: Banská Bystrica region, 29.06.2022, 18:00[6]

Area:	The population:	Population density:	Sensitive groups:
9 453,99 km2	643 102 persons	68,02 persons / km2	Age: 0-14:14,69 % 65+: 18,03 %

The AQI in the **Prešov** region is **41**, which can be assessed as **moderate**.

Table 9. Air quality in the zone: Prešov region, 29.06.2022, 18:00[6]

Area:	The population:	Population density:	Sensitive groups:
8 972,76 km2	827 028 persons	92,17 persons / km2	Age: 0-14:18,02 % 65+: 14,81 %

The AQI in the **Košice** region is **35**, which can be assessed as **moderate**.

Table 10. Air quality in the zone: Košice region, 29.06.2022, 18:00[6]

Area:	The population:	Population density:	Sensitive groups:
6 457,94 km2	556 832 persons	86,22 persons / km2	Age: 0-14:18,23 % 65+: 14,71 %

Based on the environmental quality index set in the monitored regions of Slovakia, we can observe that above-average values are concentrated in the largest cities, less often also average values of environmental quality. On the contrary, smaller cities are assessed as areas with below-average environmental quality. These parts can be identified as areas with an increased environmental burden and the risk of environmental injustice, and this is how it is necessary to approach the planning of further development. Especially because these are areas that provide economic benefits for the whole city, such as good transport accessibility, services, business activities or jobs, but externalities fall significantly on the population of this area.

When planning targeted interventions by the responsible authorities, it is also necessary to monitor in such risky areas the share of the population group that is more susceptible to environmental aspects, especially low-population groups, people with lower education and the long-term unemployed. The prioritization of measures should be measured to show the synergy of the negative impacts of the environmental burden together with the economic and social burden (Fann et al., 2011).

5 Conclusion

The air quality index is primarily a tool for communicating air quality information to the public. At the same time, it also makes it possible to comprehensively assess air pollution with several pollutants. In both cases, the key factor is the choice of pollutants to be included in the index calculation. In Slovakia, current information on air pollution at individual measuring stations is published in real time and information on long-term trends in air quality in the annual assessment reports of the SHMU. We also have data on air quality throughout Slovakia in the form of a web map service.

Based on values of average annual concentrations NO2, SO2 and PM10, the average annual air quality index was calculated according to the methodology of Kotlík (1997). The map expression of the air quality index shows the improvement of air quality after 2006 practically in the whole territory of Slovakia. The most endangered localities with polluted air, endangering sensitive persons, include the area of Horná Nitra, the surroundings of the U. S. Steel Košice plant and the capital of the Slovak Republic, Bratislava. The disadvantage of the selected index is the highlighting the impact of SO2 and the neglect of annual exceedances daily PM10 limit values in some areas, so another task will be to obtain the necessary input data and to calculate the European YACAQI index, which better reflects the real state of air pollution.

Long-term air quality indices can be used primarily as a source of information to support decision-making processes in politics and public administration. From this point of view, it would be beneficial to link the values of the air quality index with demographic data.

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