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Comparative Analysis Model for The Degree of Health Vulnerability To Air Pollution*

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Abstract

This paper presents a study to evaluate the position of Romania in relation to the other EU countries regarding the degree of human health vulnerability to air pollution. We choose to write this study because human health and environmental health are in an interconnected relationship and it is necessary to evaluate the impact of air pollutants on public health in order to make decisions about the management of the emissions that pollute the air. The paper is based on building synthetic indicators, this is a complex process that involves the selection of different methods, tools, techniques, and variables.

Keywords: environment, air pollution, human health vulnerability

Introduction

Urbanization and industrialization in our time lead to a great challenge, namely air pollution. Air quality degradation has significant effects on the human health.

Air pollution represents the number of pollutants present in an area at a given time, the speed of dispersion of pollutants released into the atmosphere from various sources, and their speed of deposition on surfaces (Yoo, J. M., Lee D. Kim, and others, 2014). The dispersion of pollutants is determined, especially by the atmospheric stability and the wind. The pollutants are classified into two categories: the particles in a gaseous state and the particles in liquid or solid state.

The gaseous pollutants are: nitrogen oxides (NOx), carbon monoxide (CO), sulfur dioxide (SO2), ammonia (NH3), methane (CH4), benzopyrene (BaP), tropospheric ozone O3 obtained by the chemical reactions between NO2 and various volatile organic compounds from the solar radiation (Nathanson, J.A., 2020).

Particulate matter (PM) is a mixture of solid particles and liquid droplets having a wide range of sizes, complex chemical compositions, hygroscopic properties, densities, and shapes varying in time and space depending on the sources and the mechanisms of formation (Seinfeld, John.H., Pandis, Spyros.N. 2016). The diameters of these particles vary from nm to 100µm. PM 10 or PM 2.5 or PM 1 means the particles with a diameter of 10 or 2.5 or 1 µm.

Air pollution is the fourth leading risk of death after hypertension, food risks, and smoking (World Health Organization Air Quality Guideline). The World Health Organization (WHO) reports on six major air pollutants, namely microparticles (PM), carbon monoxide, sulfur oxides, nitrogen oxides, carbon dioxide, and methane.

Short-term exposure to air pollutants can lead to COPD (chronic obstructive pulmonary disease), cough, shortness of breath, asthma, and other respiratory diseases. Long-term effects of air pollution are chronic asthma, pulmonary insufficiency, cardiovascular disease, and even diabetes.

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The cost of air pollution is higher than previously thought because even short-term exposure of children to polluted air has a significant impact on their mental and emotional health. Air pollutants act on the health of children and young people by the biological mechanisms not well understood.

Many diseases also have genetic causes. However, exposure to air pollution can cause an impact on the immune system causing neuroinflammation or the pulmonary inflammatory response and can trigger the release of pro-thrombotic and anti-inflammatory cytokines, setting in motion a systemic inflammatory process (Vadillo-Ortega et al. 2014).

Many children develop aggressive behavior, reduced intelligence, learning difficulties, and hyperactivity due to long-term exposure to pollution (Bellinger D.C, 2008).

Air pollution can also lead to infant mortality, the researchers found that babies with a low birth weight can die in the first year of life, especially girls (deSouza, 2022, Kelishadi, R., Poursafa, P., 2010).

Literature Review

From the literature, there are developed two approaches to reduce the effects of air pollution on human health. The first approach is based on models determining the concentration of pollutants emitted into the atmosphere by using the approximation models (Ma, C.,2010), the scattering models (Goodman, A., Wilkinson, P., Stafford, M., Tonne, C., 2011), the regression models (Su, J. G., Jerrett, M., de Nazelle, A., Wolch, J., 2011), and the interpolation models (Zou, B., Peng, F., Wan, N., Wilson, J. G., Xiong, Y., 2014). The second approach includes models of the impact of air pollution on human health, taking into account the characteristics of the population distribution (Zou, B., Wilson, J. G., et al., 2009).

Most studies (Beckx, C., Int Panis, L., Arentze, et al., 2009) are limited to PM10 and PM2.5 and other atmospheric pollutants and their effects on human health are not taken into account. Recently, there are an interest to study the impact of several combined pollutants on human health.

There are also a large number of novel machine-learning techniques and statistical models that allow us to forecast the concentrations of pollutants in the air. For these models, the data sources are: satellite data, surface observations, meteorological models, and chemical models.

The CMAQ system (Community Multiscale Air Quality Modeling System) is a software package that estimates the concentration of ozone and particulate matter in the air and the deposition of these pollutants on the Earth's surface. The forecasts obtained by the CMAQ software are based on satellite weather data.

The CMAQ system gives us numerical air quality models. These models can inform the users both about the chemical composition of the pollutants mixture and about the classes of pollutant compounds and their properties. Unfortunately, many times the models built with the CMAQ favor certain geographical areas (Friberg MD, Kahn RA, et al., 2017), (Tong DQ, Mauzerall DL., 2006).

There are studies of the health associations regarding the daily variation of pollutants and their health outcomes (Bell, M.L., McDermott, A., Zeger, SL., et al. 2004), (Samet J.M., Dominici F, Curriero F.C., et al., 2000), (Zanobetti A, Schwartz, J., 2009) suggesting the prediction models over large geographic areas (Crouse DL, Peters PA, et al., 2015), (Di Q, Wang, Y, 2017), (Jerrett M, Shankardass K, et al., 2008), (Kioumourtzoglou, M.A., Schwartz, JD., 2016), but not on large scale fluctuations.

Following the advantages and the disadvantages of the above-mentioned methods, our paper tries to determine an index of sustainable development of the environment from the point of view of air pollution and a human health vulnerability index to air pollution. We also intend to create a comparative model to establish Romania’s position in the ranking of EU member countries about the two indexes mentioned above.

Determining the index of sustainable development of the environment from the point of view of air pollution

The following variables are chosen to determine the index of sustainable development of the environment from the point of view of air pollution:

X1- carbon dioxide emissions - CO_2 (g/euro current prices);

X2 – methane emissions -CH_4 (g/euro current prices);
X3 - nitrous oxide emissions -N_2O (g/euro current prices);
X4 - emissions of sulfur oxides -SO_2, SO, SO_3 (g/euro current prices);
X5 – ammonia emissions-NH_3 (g/euro current prices);
X6 - emissions of carbon monoxide -CO (g/euro current prices);
X7 – emissions of nitrogen oxides - NO, N_2O_3, N_2O_4, NO_2, N_2O_5 (g/euro current prices);
X8–waste generation (thousands of tons);
X9 – PM 10 - the particles with a diameter of 10 μm (g/euro current prices);
X10 – PM 2.5 - the particles with a diameter of 2.5 μm (g/euro current prices).

The diagnostic variables X1-X10 are variables that prevent the achievement of a good level of environmental protection. The values of the variables are obtained from the Eurostat database. We take into account the year 2020 because for the years 2021 and 2022 there are not enough data for some indicators.

The database contains the values of the variables above mentioned for the EU member countries such as: Romania, Bulgaria, Greece, Italy, Hungary, Spain, Slovakia, Portugal, Belgium, Poland, France, Czech Republic, Croatia, Netherlands, Germany, Slovenia, Lithuania, Ireland, Denmark, Luxembourg, Austria, Latvia, Estonia, Sweden, and Finland.

In the following, we apply the ZUM method (zero unitarization method) (Kukula, K., 2014) to the diagnostic variables. This is a method to normalize the diagnostic variables. Thus, the obtained values of the diagnostic variables are included in the interval [0,1]. The standardized diagnostic variables are presented in Table 1.
The index of sustainable development of the environment from the point of view of air pollution (IDE_{pa}) is obtained by the arithmetic mean of the indicators taken into account.

Table 1: Standardized diagnostic variables and IDE_{ap} in the year 2020

Country	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	IDE_{ap}
Belgium	0.86	0.93	0.94	0.97	0.92	0.74	0.98	0.95	1.00	0.96	0.93
Bulgaria	0.00	0.00	0.00	0.39	0.61	0.17	0.67	0.91	0.52	0.61	0.39
Czech Republic	0.55	0.54	0.78	0.86	0.65	0.53	0.87	0.97	0.90	0.89	0.76
Denmark	0.79	0.84	0.84	0.00	0.76	0.76	0.00	0.99	0.70	0.43	0.61
Germany	0.85	0.95	0.94	0.96	0.88	0.80	0.93	0.71	0.93	0.89	0.88
Estonia	0.41	0.69	0.66	0.59	0.54	0.00	0.78	0.98	0.56	0.43	0.56
Ireland	0.95	0.67	0.84	1.00	0.62	1.00	1.00	0.99	0.95	1.00	0.90
Greece	0.50	0.48	0.78	0.04	0.61	0.25	0.12	0.97	0.41	0.14	0.43
Spain	0.87	0.77	0.91	0.94	0.57	0.59	0.91	0.00	0.85	0.79	0.72
France	0.97	0.86	0.88	0.98	0.77	0.78	0.98	0.75	0.95	0.96	0.89
Croatia	0.72	0.40	0.69	0.92	0.14	0.64	0.80	1.00	0.43	0.54	0.63
Italy	0.90	0.85	0.97	0.90	0.84	0.90	0.94	0.88	0.95	0.89	0.90
Latvia	0.71	0.52	0.50	0.95	0.31	0.44	0.69	1.00	0.00	0.00	0.51
Lithuania	0.64	0.46	0.38	0.88	0.09	0.72	0.57	1.00	0.72	0.82	0.63
Luxembourg	0.92	1.00	1.00	0.99	1.00	0.87	0.92	0.99	1.00	0.96	0.97
Hungary	0.67	0.47	0.66	0.96	0.31	0.78	0.81	0.99	0.67	0.82	0.71
Netherlands	0.84	0.87	0.94	0.98	0.92	0.85	0.92	0.90	1.00	0.96	0.92
Austria	0.93	0.93	0.97	0.99	0.89	0.75	0.99	0.95	0.97	0.96	0.93
Poland	0.22	0.19	0.56	0.67	0.24	0.31	0.64	0.87	0.56	0.46	0.47
Portugal	0.79	0.62	0.88	0.89	0.72	0.68	0.84	0.99	0.59	0.43	0.74
Romania	0.68	0.02	0.47	0.78	0.00	0.33	0.80	0.85	0.57	0.68	0.52
Slovenia	0.70	0.67	0.88	0.95	0.60	0.13	0.88	1.00	0.85	0.79	0.74
Slovakia	0.64	0.72	0.81	0.92	0.65	0.42	0.90	0.99	0.90	0.93	0.79

Finland	0.84	0.89	0.81	0.94	0.94	0.79	0.87	0.98	0.90	0.93	0.89
Sweden	1.00	1.00	0.94	0.97	0.96	0.86	0.97	0.90	0.95	0.93	0.95

Source: Own calculations

It can be observed Romania has an index of sustainable development of the environment from the point of view of air pollution of 0.52, being positioned above Greece with 0.43, Poland with 0.47, and Latvia with 0.51, Bulgaria being in the last place with 0.39.

Luxembourg is a European country with the best sustainable environmental development with IDE_{ap} = 0.97, followed by Sweden with IDE_{ap} = 0.95.

Determining the human health vulnerability index to air pollution

To calculate the human health vulnerability index to air pollution the following variables are chosen:

X1- Years of life lost due to the disabilities caused by obstructive lung diseases per 100,000 inhabitants attributed to PM2.5;

X2 – Years of life lost due to the disabilities caused by diabetes per 100,000 inhabitants attributed to NO2;

X3 – Years of life lost due to lower respiratory infections caused by air pollution;

X4 - Years of life lost due to lung/bronchi/trachea cancer caused by air pollution;

X5 – Years of life lost due to ischemic heart diseases caused by air pollution;

X6 – Years of life lost due to cerebrovascular accidents caused by air pollution;

X7 – Years of life lost due to chronic obstructive pulmonary diseases caused by air pollution;

X8 – Infant mortality rate;

X9 – Global Health Security Index (GHS).

Between the minimum and maximum values of the variables X3, X4, X5, X6, and X7 there are very large differences and in this case, the values of these variables are logarithmized.

The diagnostic variables X1-X8 are variables that increase the degree of human health vulnerability and the variable X9 has an opposite effect.

Next, we apply the ZUM method, and the standardized diagnostic variables are presented in Table 2.

The human health vulnerability index to air pollution (HVI_{ap}) is obtained by the arithmetic mean of the indicators taken into account.

Table 2: Standardized diagnostic variables and HVI_{ap} in the year 2020

Country	X1	X2	X3	X4	X5	X6	X7	X8	X9	HVI_{ap}
Belgium	0.56	0.65	0.71	0.66	0.59	0.61	0.69	0.5	0.46	0.60
Bulgaria	0.83	0.79	0.53	0.61	0.78	0.84	0.66	0.95	0.44	0.71
Czech Republic	0.41	0.52	0.69	0.66	0.74	0.65	0.64	0.24	0.72	0.59
Denmark	0.35	0.03	0.53	0.51	0.39	0.47	0.60	0.33	0.26	0.38
Germany	0.72	0.85	0.92	1.00	1.00	0.93	1.00	0.38	0.21	0.78
Estonia	0.03	0.00	0.11	0.05	0.23	0.19	0.00	0.00	0.61	0.14
Ireland	0.13	0.09	0.40	0.34	0.35	0.32	0.43	0.29	0.62	0.33
Greece	0.41	1.00	0.81	0.72	0.67	0.75	0.69	0.50	0.77	0.70
Spain	0.31	0.86	0.83	0.83	0.80	0.82	0.84	0.24	0.40	0.66
France	0.65	0.59	0.91	0.94	0.84	0.88	0.85	0.52	0.36	0.73
Croatia	0.96	0.64	0.46	0.56	0.57	0.61	0.54	0.57	0.88	0.64
Italy	0.88	0.84	0.93	1.00	0.94	1.00	0.99	0.19	0.75	0.84
Latvia	0.41	0.15	0.31	0.31	0.48	0.58	0.19	0.43	0.36	0.36
Lithuania	1.00	0.13	0.33	0.34	0.59	0.55	0.24	0.40	0.45	0.45

Luxembourg	0.34	0.53	0.00	0.00	0.00	0.00	0.09	0.74	0.89	0.29
Hungary	0.89	0.78	0.52	0.74	0.77	0.72	0.72	0.48	0.65	0.70
Netherlands	0.66	0.71	0.68	0.73	0.61	0.65	0.75	0.48	0.25	0.61
Austria	0.65	0.53	0.49	0.57	0.62	0.55	0.61	0.31	0.56	0.54
Poland	0.70	0.51	1.00	1.0	1.0	0.92	0.88	0.52	0.60	0.79
Portugal	0.41	0.74	0.65	0.46	0.51	0.63	0.53	0.29	0.64	0.54
Romania	0.24	0.65	0.82	0.76	0.89	0.96	0.73	1.00	1.00	0.78
Slovenia	0.62	0.49	0.30	0.39	0.35	0.41	0.33	0.12	0.12	0.35
Slovakia	0.59	0.37	0.59	0.55	0.55	0.53	0.43	0.83	0.65	0.57
Finland	0.03	0.08	0.09	0.21	0.40	0.37	0.24	0.12	0.00	0.17
Sweden	0.00	0.01	0.43	0.34	0.50	0.46	0.48	0.12	0.24	0.29

Source: Own calculations

It can be seen Romania is a European country with a high degree of human health vulnerability to air pollution of 0.78, being positioned above Poland with 0.79 and Italy with 0.84.

It should be noted Germany occupies the same position as Romania in terms of the degree of health vulnerability, although it has better environmental protection.

Estonia is the country with the lowest degree of health vulnerability to air pollution, although it does not have the highest degree of environmental protection.

Romania'position in the ranking of EU member countries according to the index of sustainable development of the environment in terms of air pollution and the index of human health vulnerability to air pollution

Next, we tried to make a classification of the twenty-five countries above mentioned, taking into account two indicators, such as the index of sustainable development of the environment from the point of view of air pollution - IDE$_{pa}$ and the index of human health vulnerability to air pollution - HVI$_{ap}$. The data used are presented in Tables 1, 2.

This study uses the K-means clustering technique. The R language was used to solve the algorithm, and the result is displayed in Fig.1.

```
Clustering vector:
       Belgium       Bulgaria Czech Republic        Denmark        Germany
             5              4              3              2              5
       Estonia        Ireland         Greece          Spain         France
             2              1              4              3              5
       Croatia          Italy         Latvia      Lithuania     Luxembourg
             3              5              2              2              1
       Hungary    Netherlands        Austria         Poland       Portugal
             3              5              5              4              3
       Romania       Slovenia       Slovakia        Finland         Sweden
             4              2              3              1              1
```

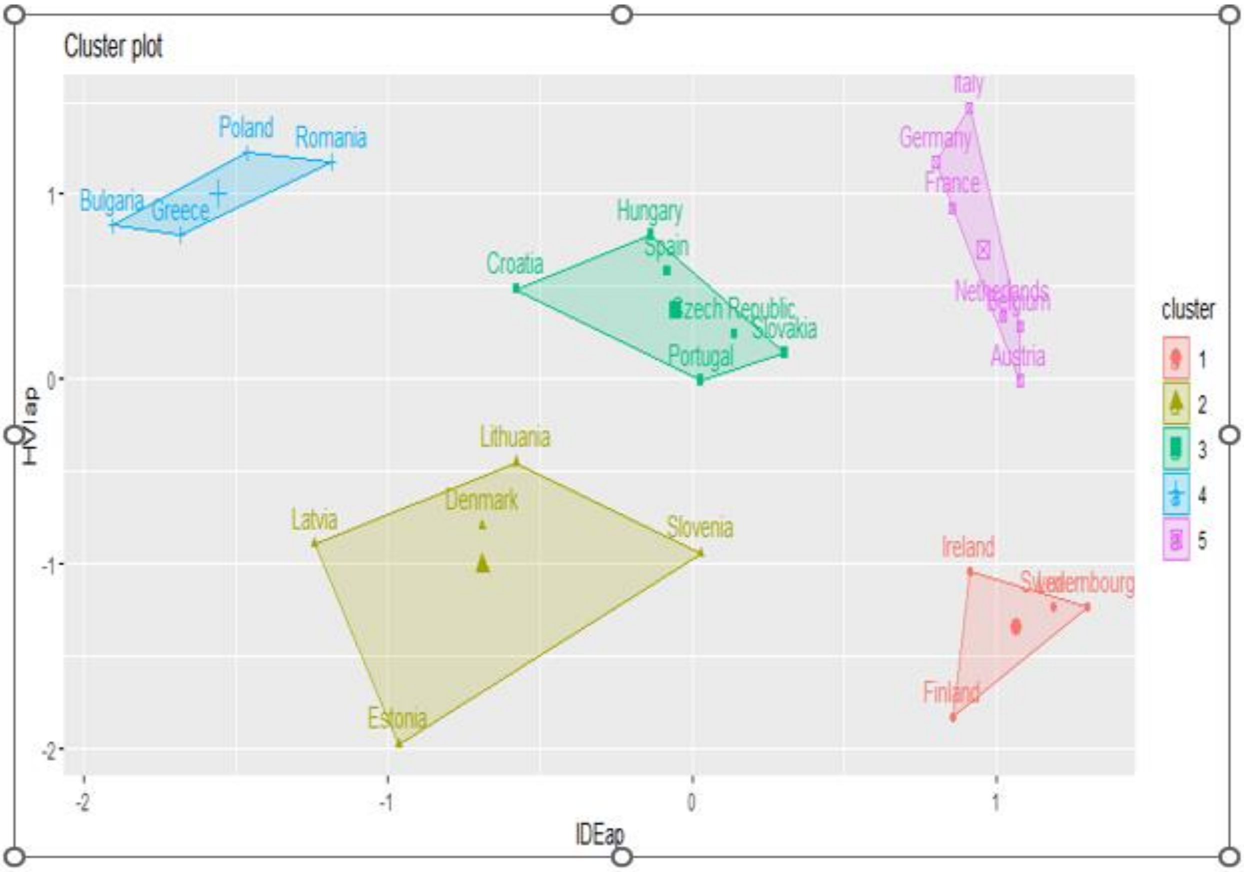

Fig.1 Classification of countries according to the index of sustainable development of the environment in terms of air pollution and the index of human health vulnerability to air pollution
Source: Own sources

Following the use of the K-means method, the twenty-five countries were classified into five groups.

Fig. 1 shows us that Romania is part of the group with a very high degree of vulnerability of the population's health to air pollution and with a very low degree of environmental development. Poland, Greece, and Bulgaria are also part of this group.

Ireland, Sweden, Luxembourg, and Finland form the group of countries with very good environmental protection and very low health vulnerability to pollution.

Germany, France, Italy, Austria, Belgium, and the Netherlands form the group of countries with a very high degree of health vulnerability and with very good environmental protection.

Lithuania, Latvia, Estonia, Slovenia, and Denmark form a cluster characterized by relatively good environmental development and very good health of the population in relation to air pollution.

Hungary, Spain, the Czech Republic, Slovakia, Croatia, and Portugal are countries with a high degree of environmental development and with an average degree of human health vulnerability to air pollution.

Conclusions

Air pollution is the main environmental risk factor for human health, exposure to air pollution can be both inside and outside households. The pollutants emitted into the atmosphere cause many diseases and, thus, increase human health expenses and decrease work efficiency. Also, air pollution affects, in particular, women's fertility, and the health of pregnant women and children.

The present paper studies the impact of air pollutants on public health in the EU member countries taking into account a variety of pollutants such as: carbon dioxide, methane, nitrous oxide, sulfur oxides, ammonia, carbon monoxide, nitrogen oxides - NO, N_2O_3, N_2O_4, NO_2, N_2O_5, waste generation, PM 10 and PM 2.5.

In this paper, we built a classification of the EU countries according to the index of sustainable development of the environment in terms of air pollution and the index of human health vulnerability to air pollution.

This study shows us the degree of human health vulnerability mostly depends on the sustainable development of the environment in terms of air pollution.

From the data obtained and the international statistics, it can be seen the leaders with the best environmental protection to air pollution and with the lowest risk of diseases due to pollution are: Finland, Sweden, Luxembourg, and Ireland. In these countries, public transport or bicycles are used more, and ecological materials are used for the construction of houses. They also use hydro energy, geothermal energy, wind energy, and biofuels. All these countries can be examples for Romania. Thus, many of the energy and administrative strategies used by them can be implemented because there are sufficient natural and human resources in Romania.

Estonia is the country with the lowest degree of health vulnerability to air pollution, at the opposite pole is Italy with the highest degree of health vulnerability to air pollution.

The results of this analysis performed using the multivariate comparative analysis method may differ if a different set of diagnostic variables is adopted or if a different time interval is chosen.

The purpose of this paper is to increase the level of awareness of the Romanian population regarding the improvement of the quality of the environment and individual behavior. The purpose of this paper is to increase the level of awareness of the Romanian population regarding the improvement of the quality of the environment and individual behavior.

It is also necessary for the Authorities to be aware that they must provide the population an efficient public transport and better waste management.

References

- Babiarz, A.P., Misztal, A., Kowalska, M. (2019), An impact of macroeconomic stabilization on the sustainable development of manufacturing enterprises: the case of Central and Eastern European Countries, *Environment, Development and Sustainability,* vol 23, pg. 8669-8698
- Beckx, C., Int Panis, L., Arentze, T., Janssens, D., Torfs, R., Broekx, S., Wets, G. (2009). A dynamic activity-based population modeling approach to evaluate exposure to air pollution: Methods and application to a Dutch urban area. *Environmental Impact Assessment Review*, 29 (3), 179–185. doi: https://doi.org/10.1016/j.eiar.2008.10.001
- Bell ML, McDermott A, Zeger SL, Samet JM, (2004) Dominici F. Ozone and short-term mortality in 95 US urban communities, 1987-2000. *JAMA*.;292(19):2372–8. https://doi.org/10.1001/jama.292.19.2372
- Bellinger, DC. (2008) Very low lead exposures and children's neurodevelopment. *Curr Opin Pediatr*. 20:172–7. 10.1097/MOP.0b013e3282f4f97b
- Crouse DL, Peters PA, Hystad P, Brook JR, van Donkelaar A, Martin RV, et al. (2015) Ambient PM2.5, O3, and NO2 exposures and associations with mortality over 16 years of follow-up in the Canadian census health and Environment cohort (CANCHEC). *Environ Health Perspect.*;123(11):1180–6. https://doi.org/10.1289/ehp.1409276
- deSouza, P. N. *et al.* (2022) *Sci. Total. Environ.* **815**, 152755 Doi: 10.1016/j.scitotenv.2021.152755
- Di Q, Wang Y, Zanobetti A, Wang Y, Koutrakis P, Choirat C, et al. (2017) Air pollution and mortality in the Medicare population. *N Engl J Med*.;376(26):2513–22. https://doi.org/10.1056/NEJMoa1702747
- en.wikipedia.org/wiki/Environmental_Vulnerability_Index
- Friberg MD, Kahn RA, Holmes HA, Chang HH, Sarnat SE, Tolbert PE, et al. (2017) Daily ambient air pollution metrics for five cities: evaluation of data fusion-based estimates and uncertainties. *Atmos Environ*.;158:36– 50. https://doi.org/10.1016/j.atmosenv.2017.03.022
- Goodman, A., Wilkinson, P., Stafford, M., Tonne, C. (2011). Characterizing socio-economic inequalities in exposure to air pollution: A comparison of socio-economic markers and scales of measurement. Health & Place, 17 (3), 767–774. doi: https:// doi.org/10.1016/j.healthplace
- https://sustainabledevelopment.un.org/post2015/transformingourworld
- https://unfccc.int/sites/default/files/resource/parisagreement_publication.pdf
- https://unhabitat.org/sites/default/files/2019/05/nua-english.pdf
- https://unhabitat.org/World%20Cities%20Report%2020
- https://worldpopulationreview.com/country-rankings/healthiest-countries
- https://www.arcadis.com/campaigns/citizencentriccities/index.html

- https://www.imd.org/smart-city-observatory/home/
- https://www.who.int/data/gho/data/indicators
- Jerrett M, Shankardass K, Berhane K, Gauderman WJ, Künzli N, Avol E, et al. (2008) Traffic-related air pollution and asthma onset in children: a prospective cohort study with individual exposure measurement. *Environ Health Perspect*.;116(10):1433–8. https://doi.org/10.1289/ehp.10968
- Kelishadi, R., Poursafa, P.(2010), Air pollution and non-respiratory health hazards for children, *Archives of Medical Science*, vol.6, Issue 4, pg.483-495
- Kioumourtzoglou M-A, Schwartz JD, Weisskopf MG, Melly SJ, Wang Y, Dominici F, et al. (2016), Long-term PM2.5 exposure and neurological hospital admissions in the northeastern United States. *Environ Health Perspect*.;124(1):23–9. https://doi.org/10.1289/ehp.1408973
- Kukula K (2014), Zero Unitarisation Method as a Tool in Ranking Research, *Economic Science for Rural Development*, No.36, pg.95-100
- Kukuła, K.; Bogocz, D., (2014), Zero Unitarization Method and Its Application in Ranking Research in Agriculture. *Econ. Reg. Stud*., no 7, pg. 5–13
- Ma, C. (2010). Who bears the environmental burden in China – An analysis of the distribution of industrial pollution sources? Ecological Economics, 69 (9), 1869–1876. doi: https://doi.org/10.1016/j.ecolecon.2010.05.005
- Manisalidis I., Stavropoulou E., Stavropoulou A., Bezirtzoglou E (2020)., Environmental and Health Impacts of Air Pollution: A review, *Frontier in Public Health*, vol.8
- Nathanson, J.A., (2020), Air pollution – ozone, https://www.britannica.com/science/air-pollution
- Samet JM, Dominici F, Curriero FC, Coursac I, Zeger SL. (2000), Fine particulate air pollution and mortality in 20 US cities, 1987–1994. *N Engl J Med.*;343(24):1742–9. https://doi.org/10.1056/NEJM200012143432401
- Seinfeld, John.H., Pandis, Spyros.N. (2016), Atmospheric Chemistry and Physics. From Air Pollution to Climate Change, Ed. Wiley, pg.537-562
- Su, J. G., Jerrett, M., de Nazelle, A., Wolch, J. (2011). Does exposure to air pollution in urban parks have socioeconomic, racial, or ethnic gradients? Environmental Research, 111 (3), 319–328. doi: https://doi.org/10.1016/j.envres.2011.01.002
- Tong DQ, Mauzerall DL.(2006) Spatial variability of summertime tropospheric ozone over the continental United States: implications of an evaluation of the CMAQ model. *Atmos Environ*.;40(17):3041–56. https://doi.org/ 10.1016/j.atmosenv.2005.11.058
- Vadillo-Ortega, F, Osornio-Vargas A, Buxton MA, et al (2014) Air pollution, inflammation, and preterm birth: a potential mechanistic link. Med Hypotheses 82(2):219–224
- Zanobetti A, Schwartz J. (2009), The effect of fine and coarse particulate air pollution on mortality: a national analysis. *Environ Health Perspect*.;117(6):898–903. https://doi.org/10.1289/ehp.0800108
- Zou, B., Peng, F., Wan, N., Wilson, J. G., Xiong, Y. (2014). Sulfur dioxide exposure and environmental justice: a multi-scale and source-specific perspective. Atmospheric Pollution Research, 5 (3), 491–499. doi: https://doi.org/10.5094/apr.2014.058
- Zou, B., Wilson, J. G., Zhan, F. B., Zeng, Y. (2009). Air pollution exposure assessment methods utilized in epidemiological studies. Journal of Environmental Monitoring, 11 (3), 475. doi: https://doi.org/10.1039/b813889c