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Air pollution and cardiovascular disease: state of art and control strategies within “One Health” approach

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Abstract Environmental quality is closely related to human health. In recent years, the growing awareness has led to the definition of an integrated "One Health" approach to protect simultaneously environment, humans and animals. Poor air quality is the most important factor affecting human health and increasing mortality and morbidity. Improving environmental quality is crucial to prevent human health-related risks. Poor air quality is the most important factor affecting human health and increasing mortality risk. The estimates reveal that in 2019 it led 7 million deaths with an alarming percentage of premature ones. Among diseases caused by poor air quality 70% are non-communicable and 60% affect the cardiovascular system. The economic effects are also important: medical expenses increase while the general productivity decreases due to people who cannot work for health-related problems. The situation in the European Union is slowly improving thanks to the joint efforts of the European Commission and the World Health Organization. The most significant health-related risks usually occur in urban areas. This work aims to define the state of the art on environmental policies implemented and identify direct and indirect strategies for control pollutants and reduce health risks. Future perspectives are also presented.

Keywords: Air pollution, One health, Cardiovascular diseases, Health risks, AQHI

1. Introduction

The connection between the environment, humans and animals is increasingly evident. This awareness has led to the birth of the multidisciplinary and integrated approach "One Health" which aims at the joint protection of these components from the effects of climate change(Zinsstag et al., 2018). Many of the gases that cause climate change also have an impact on the environment and human health. Implementing pollution control and reduction actions also mitigates climate change and thus protects human health.

Environmental pollution is the greatest risk factor for human health, comparable only to smoking. Every year, in the world, pollution causes about 9 million premature deaths (about 16% of the total) of which about 7 million is linked to poor atmospheric pollution (Landrigan et al., 2018; Fuller et al., 2022). These numbers underestimate the real ones for two main reasons. The first is linked to the objective difficulties of collecting and processing comprehensive data in many areas, especially in low- and middle-income countries. The second reason is that only effects related to the exposure of the population to particulate matter and ozone are considered, and not other pollutants that certainly adversely affect human health.

According to the analysis of Global Burden Diseases from 1990 to 2019, atmospheric pollution is also one of the major responsible for a high value for the disability-adjusted life years (DALYs) that measure the number of years lost due to illness, disability or premature death (Murray et al., 2020). Global loss of life expectancy (LLE) for air pollution is estimated in 2.9 years but can be significantly reduced through environmental policies to control harmful gaseous emissions(Lelieveld et al., 2020). Air pollution is also a risk factor for the occurrence of many non-communicable diseases (NCDs). These effects can occur on sensitive subjects even when pollution levels are lower than usual. The severity of the health effects associated with exposure to air pollution is inversely related to the frequency of the event. The number of people affected by the most severe events is certainly lower than those affected by the least serious events (Quantification of Health Effects of Exposure to Air Pollution, 2001). Generally short-term exposure is related to respiratory problems such as Chronic Obstructive Pulmonary Disease), cough, shortness of breath, wheezing and asthma. In the long term, polluted air can cause problems in the respiratory tract, cardiovascular system, metabolic system but also mental or perinatal (Manisalidis et al., 2020). Among these, cardiovascular diseases cause the highest deaths and the highest number of DALY in both men and women. (World Health Statistics: Monitoring Health for the SDGs, Sustainable Development Goals.

Geneva: World Health Organization, 2022). Recent studies show that the negative effects of air pollution can be observed at very low concentrations and that there are no observable thresholds below which exposure can be considered safe (Dominici et al., 2019).

This work will define the state of the art on environmental policies implemented at different institutional levels. Direct and indirect strategies for control pollutants and reduce health risks are also identified.

2. Environmental policies and strategies for the air pollution control

According to WHO almost the entire world population (99%) lives breathing bad air (World Health Statistics: Monitoring Health for the SDGs, Sustainable Development Goals. Geneva: World Health Organization, 2022).

Environmental policies for air quality control provide for the establishment of national source control laws to build a framework for cooperation at regional level. Many countries have also decided to implement economic sanctions or incentives to combat pollution (Ren et al., 2023). At all stages, the process should be fully participatory in order to raise public awareness about environmental issues and how they impact public health (Mirabelli et al., 2020).

Measures to control pollutant sources must be defined by taking into account many aspects, including their complexity and the specific characteristics of the sector from which they come, such as construction, transport or industry. In the European Union, the control of pollutant sources is pursued through the implementation of directives that specify both the rules governing emissions and the technologies to be used. In the United States since 1970 air quality has been regulated by the "The Clean Air Act" which has recently been incorporated into the "United States Code" in Title 42 concerning "Public Health and Welfare". In this legislative act are presented all the limits to be respected, also for the common "criteria pollutants" (particulate, ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, and lead) defined by the Environmental Protection Agency (EPA) (U.S. Congress, 2018) . In Canada, the regulatory instrument for controlling pollutant emissions into the atmosphere is the Canadian Environmental Protection Act 1999 (Basu & Lanphear, 2019). In China in 2016 the Air Pollution Prevention and Control Action Plan was adopted. It's the only legislative instrument at national level for the prevention and control of air pollution (Feng & Liao, 2016). In India, one of the countries with the highest levels of air pollution in the world, in 2019 the National Clean Air Programme was emitted to set particulate matter reduction targets of 20-30% for 2024, compared to 2017 values (Ganguly et al., 2020). Based on national legislative acts, local or regional governments implement source monitoring and control plans to achieve the objectives set.

National legislative instruments consider that air pollution is a transboundary issue because airborne dust that can travel long distances. The dust from Sahara Desert contributes in high percentages to PM_{10} air pollution in the southern European area and the Middle East, with peaks that reach 60% in the most extreme events (Hoffmann et al., 2021). In this context, actions of individual nations are ineffective. They have to be part of a regional joint framework based on binding agreements and legally defined pollution control and monitoring mechanisms (Ren et al., 2023). The implementation of regional cooperation models is never easy because of major differences in cultures, interests, practices and environmental laws between different communities. Even after the formal signature of the regional agreements, defining and implementing shared processes and actions is a time-consuming process that requires widespread commitment *(Jiao et al., 2021)*. Although awareness of the issue nowadays is high, many efforts to simplify and optimize all process components are still required.

3. Focus on Europe: legislative framework for air pollution

In the United Nations (UN), WHO and the European Commission (EC) in recent years have implemented numerous environmental actions and programs to protect public health.

In 2015, with the 2030 Agenda, the UN General Assembly defined the 17 Sustainable Development Goals (SDGs) and 169 targets to be reached by 2030. Although many of the targets implicitly speak of sustainable development and improvement of environmental quality, only the 3.9 target links pollution to its negative effects on health because it proposes to "By 2030, substantially reduce the number of deaths and diseases from hazardous chemicals and air, water and soil contamination"(UN General Assembly, 2015).

In 2021 the European Commission developed the plan 'Towards Zero Pollution for Air, Water and Soil'. The first target for 2030 is to reduce by 55% the effects on health and in particular premature deaths related to air pollution, reflecting the strong importance of the issue (European Commission, 2021).

The WHO in 2021 defined the new global guidelines for air quality (AGQ 2021). They have no regulatory value but are a support to institutions around the world for the definition of policies to be implemented for the control and reduction of air pollution. The values in AGQ 2021 were determined after a comprehensive study of the results obtained by authoritative bodies (Committee on the Medical Effects of Air Pollutants of United Kingdom, Health Canada, and United States EPA). The recommended values in the AGQ 2021 are more restrictive than those in WHO Guidelines of 2005. In particular, the annual average of fine particulate matter ($PM_{2.5}$) is reduced from 10 to 5 $\mu g/m^3$, inhalable particulate matter (PM_{10}) from 20 to 15 $\mu g/m^3$, nitrogen dioxide (NO_2) from 40 to 10 $\mu g/m^3$, and the daily limit for carbon monoxide (CO) of 4 $\mu g/m^3$ is suggested. Only the recommended value for sulphur dioxide (SO_2) calculated with an average time has increased from 20 to 40 mg/m^3 following more in-depth studies not yet available in the literature in 2005 (WHO Global Air Quality Guidelines, 2021).

The problem of health effects related to air pollution is so felt that AGQ 2021 have been signed by over 100 medical, public health, scientific societies and patient representative organisations through a joint statute carried out by the European Respiratory Society and the International Society for Environmental Epidemiology (Hoffmann et al., 2021). In Europe, AGQ 2021 will be transposed with a new Air Quality Directive to replace and update the contents of Directives 2008/50/EC and 2004/107/EC. The European Commission presented the proposal at the end of 2022.

4. Measuring air pollution levels: from AQI to AQHI

To measure air quality levels and record changes over time, monitoring actions are necessary. Many countries in the world use indices to evaluate and quantify air pollution. With Air Quality Index (AQI) is a dimensionless index that measures the level of defined pollutants in the atmosphere in a given time interval.

There are several variants in the world for AQI, mostly based on the US EPA model. The authorities, through the definition of the AQI, are able to inform citizens promptly and to recommend behaviours that help reduce the health risks arising from exposure to pollution (Du et al., 2020). AQI in the United States is calculated by considering 5 pollutants: particulate matter (PM_{10} and $PM_{2.5}$), carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and ozone (O_3). The index can assume a numerical value between 0 and 500. This interval is divided into 6 progressive classes, each of which represents a level of atmospheric quality and increasingly stringent recommendations for citizens (U.S. Environmental Protection Agency, 2018).

The calculation of AQI is based on the identification of the pollutant with the highest concentration compared to the defined legislative standards. For this reason it fails to take into account the additive effects of pollutants that act together and cause more significant health effects (Cao et al., 2021). In addition, AQI doesn't describe the risk of mortality and morbidity from non-threshold exposure (Stieb et al., 2008).

To cope to these limits, the Air Quality Health Index (AQHI) has been defined. This index was first developed and applied by the Healthy Environments and Consumer Safety Branch of Canada to considers the effects on human health resulting from exposure to air pollution (Stieb et al., 2008). AQHI has a value from 1 to 10 but in case of very high air pollution the level is reported as 10+. Higher numbers are associated with higher health risks and therefore more restrictive behaviour to protect humans. According to this model, behavioural advice is different for vulnerable individuals defined as "at risk" and all others. The calculation of AQHI is based on the measurement of ozone, nitrogen dioxide and particulate matter levels PM_{10} and $PM_{2.5}$ (Environment and Climate Change Canada, 2007).

AQI and AQHI are both reliable for predicting national daily mortality risk. AQHI is a more flexible index because it allows to consider different pollutants in relation to the territory to be analyzed but also a specific population target to make the estimate more detailed (Du et al., 2020).

5. Future perspective

Worldwide, many programs exist for reducing the concentration of pollutants in the air for the protection of public health. Control policies based on innovative methodologies using technologically advanced tools must be developed. Air quality control models must be dynamic to give instant indications of pollution levels. At the same time, methodologies should aim to assess health effects to provide real-time guidance on the best behaviour to adopt to protect humans. Once effective models have been defined, it will be necessary to focus on the groups most vulnerable to air pollution because they are those on which the effects can be very significant even for low exposure levels. The Canadian model with the AQHI index could be optimized and applied by other Countries in the world where the AQI index is still used.

References

Basu, N., & Lanphear, B. P. (2019). The challenge of pollution and health in Canada. Canadian Journal of Public Health, 110(2), 159–164. https://doi.org/10.17269/s41997-019-00175-7

Cao, R., Wang, Y., Huang, J., Zeng, Q., Pan, X., Li, G., & He, T. (2021). The construction of the air quality health index (AQHI) and a validity comparison based on three different methods. Environmental Research, 197, 110987. https://doi.org/10.1016/j.envres.2021.110987

Dominici, F., Schwartz, J., Di, Q., Braun, D., Choirat, C., & Zanobetti, A. (2019). Assessing Adverse Health Effects of Long-Term Exposure to Low Levels of Ambient Air Pollution: Phase 1. Research Reports: Health Effects Institute, 2019, 200.

Du, X., Chen, R., Meng, X., Liu, C., Niu, Y., Wang, W., Li, S., Kan, H., & Zhou, M. (2020). The establishment of National Air Quality Health Index in China. Environment International, 138, 105594. https://doi.org/10.1016/j.envint.2020.105594

Environment and Climate Change Canada. (2007, September 10). About the Air Quality Health Index. https://www.canada.ca/en/environment-climate-change/services/air-quality-health-index/about.html

European Commission. (2021). Communication from the commission to the european parliament, the council, the european economic and social committee and the committee of the regions Pathway to a Healthy Planet for All EU Action Plan: 'Towards Zero Pollution for Air, Water and Soil'.

Feng, L., & Liao, W. (2016). Legislation, plans, and policies for prevention and control of air pollution in China: Achievements, challenges, and improvements. Journal of

Cleaner Production, 112, 1549–1558. https://doi.org/10.1016/j.jclepro.2015.08.013

Fuller, R., Landrigan, P. J., Balakrishnan, K., Bathan, G., Bose-O'Reilly, S., Brauer, M., Caravanos, J., Chiles, T., Cohen, A., Corra, L., Cropper, M., Ferraro, G., Hanna, J., Hanrahan, D., Hu, H., Hunter, D., Janata, G., Kupka, R., Lanphear, B., … Yan, C. (2022). Pollution and health: A progress update. The Lancet Planetary Health, 6(6), e535–e547. https://doi.org/10.1016/S2542-5196(22)00090-0

Ganguly, T., Selvaraj, K. L., & Guttikunda, S. K. (2020). National Clean Air Programme (NCAP) for Indian cities: Review and outlook of clean air action plans. Atmospheric Environment: X, 8, 100096. https://doi.org/10.1016/j.aeaoa.2020.100096

Hoffmann, B., Boogaard, H., de Nazelle, A., Andersen, Z. J., Abramson, M., Brauer, M., Brunekreef, B., Forastiere, F., Huang, W., Kan, H., Kaufman, J. D., Katsouyanni, K., Krzyzanowski, M., Kuenzli, N., Laden, F., Nieuwenhuijsen, M., Mustapha, A., Powell, P., Rice, M., … Thurston, G. (2021). WHO Air Quality Guidelines 2021–Aiming for Healthier Air for all: A Joint Statement by Medical, Public Health, Scientific Societies and Patient Representative Organisations. International Journal of Public Health, 0. https://doi.org/10.3389/ijph.2021.1604465

Jiao, Y., Su, M., Ji, C., Yang, S., & Zhang, P. (2021). How to design fully cooperative policies to abate transboundary air pollution between two highly asymmetric regions: An abnormal incrementalism analysis. Journal of Cleaner Production, 278, 124042. https://doi.org/10.1016/j.jclepro.2020.124042

Landrigan, P. J., Fuller, R., Acosta, N. J. R., Adeyi, O., Arnold, R., Basu, N. (Nil), Baldé, A. B., Bertollini, R., Bose-O'Reilly, S., Boufford, J. I., Breysse, P. N., Chiles, T., Mahidol, C., Coll-Seck, A. M., Cropper, M. L., Fobil, J., Fuster, V., Greenstone, M., Haines, A., … Zhong, M. (2018). The Lancet Commission on pollution and health. The Lancet, 391(10119), 462–512. https://doi.org/10.1016/S0140-6736(17)32345-0

Lelieveld, J., Pozzer, A., Pöschl, U., Fnais, M., Haines, A., & Münzel, T. (2020). Loss of life expectancy from air pollution compared to other risk factors: A worldwide perspective. Cardiovascular Research, 116(11), 1910–1917. https://doi.org/10.1093/cvr/cvaa025

Manisalidis, I., Stavropoulou, E., Stavropoulos, A., & Bezirtzoglou, E. (2020). Environmental and Health Impacts of Air Pollution: A Review. Frontiers in Public Health, 8, 14. https://doi.org/10.3389/fpubh.2020.00014

Mirabelli, M. C., Ebelt, S., & Damon, S. A. (2020). Air Quality Index and air quality awareness among adults in the United States. Environmental Research, 183, 109185. https://doi.org/10.1016/j.envres.2020.109185

Murray, C. J. L., Aravkin, A. Y., Zheng, P., Abbafati, C., Abbas, K. M., Abbasi-Kangevari, M., Abd-Allah, F., Abdelalim, A., Abdollahi, M., Abdollahpour, I., Abegaz, K. H., Abolhassani, H., Aboyans, V., Abreu, L. G., Abrigo, M. R. M., Abualhasan, A., Abu-Raddad, L. J., Abushouk, A. I., Adabi, M., … Lim, S. S. (2020). Global burden of 87 risk factors in 204 countries and territories, 1990–2019: A systematic analysis for the Global Burden of Disease Study 2019. The Lancet, 396(10258), 1223–1249. https://doi.org/10.1016/S0140-6736(20)30752-2

Ren, C., Yu, C. W., & Cao, S.-J. (2023). Development of urban air environmental control policies and measures. Indoor and Built Environment, 32(2), 299–304. https://doi.org/10.1177/1420326X221120380

Stieb, D. M., Burnett, R. T., Smith-Doiron, M., Brion, O., Shin, H. H., & Economou, V. (2008). A New Multipollutant, No-Threshold Air Quality Health Index Based on Short-Term Associations Observed in Daily Time-Series Analyses. Journal of the Air & Waste Management Association, 58(3), 435–450. https://doi.org/10.3155/1047-3289.58.3.435

UN General Assembly. (2015). Transforming our world: The 2030 Agenda for Sustainable Development. https://wedocs.unep.org/xmlui/handle/20.500.11822/9814

U.S. Congress. (2018). 42 U.S.C. CH.85: Air Pollution Preventon and Control.

U.S. Environmental Protection Agency. (2018). Technical Assistance Document for the Reporting of Daily Air Quality – the Air Quality Index (AQI).

WHO global air quality guidelines. Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Geneva: World Health Organization. Licence: CC BY-NC-SA 3.0 IGO. (2021). World Health Organization. https://apps.who.int/iris/handle/10665/345329

World Health Organization. Regional Office for Europe. Quantification of health effects of exposure to air pollution: Report on a WHO working group, Bilthoven, Netherlands 20-22 November 2000. Copenhagen: WHO Regional Office for Europe. (2001). https://apps.who.int/iris/handle/10665/108463

World health statistics: Monitoring health for the SDGs, sustainable development goals. Geneva: World Health Organization; 2022. Licence: CC BY-NC-SA 3.0 IGO. (2022).

Zinsstag, J., Crump, L., Schelling, E., Hattendorf, J., Maidane, Y. O., Ali, K. O., Muhummed, A., Umer, A. A., Aliyi, F., Nooh, F., Abdikadir, M. I., Ali, S. M., Hartinger, S., Mäusezahl, D., de White, M. B. G., Cordon-Rosales, C., Castillo, D. A., McCracken, J., Abakar, F., … Cissé, G. (2018). Climate change and One Health. FEMS Microbiology Letters, 365(11). https://doi.org/10.1093/femsle/fny085