AirQ+: carcinogenic pollutants and risk analysis
AirQ+: carcinogenic pollutants and risk analysis

AirQ+

December 2020
Abstract

AirQ+ is a software tool for quantifying the health burden and impact of air pollution developed by the WHO Regional Office for Europe. AirQ+ includes methodologies to assess the impacts of short- and long-term exposure to ambient air pollution. The main methodologies use evidence generated by epidemiological cohort studies showing a relationship between average long-term air pollution concentration levels and the mortality risks in exposed populations. Assessing the impact of air pollution is suggested when evaluating the consequences of policies and interventions or of hypothetical scenarios. AirQ+ should always be used with the support of an epidemiologist or air pollution impact assessment expert. To facilitate users in their analyses, AirQ+ comes with manuals that require increasing levels of expertise. This manual describes how AirQ+ can be used to estimate the risk of cancer due to lifetime exposure to a carcinogenic air pollutant. AirQ+ can calculate risk based on unit risk originated by occupational studies or toxicological data. Users with data on the concentrations of specific substances in the air but without data on classical air pollutants can use AirQ+ to quantify the risk of developing cancer using unit risk values. The AirQ+ software uses default unit risk values for arsenic, benzene, benzo[a]pyrene, chromium, nickel and vinyl chloride.

Keywords

AIR POLLUTANTS
BENZ0(A)PYRENE
CARCINOGENIC AIR POLLUTANTS
AIR POLLUTION – exposure
UNIT RISK

© World Health Organization 2020

Some rights reserved. This work is available under the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 IGO licence (CC BY-NC-SA 3.0 IGO; https://creativecommons.org/licenses/by-nc-sa/3.0/igo).

Under the terms of this licence, you may copy, redistribute and adapt the work for non-commercial purposes, provided the work is appropriately cited, as indicated below. In any use of this work, there should be no suggestion that WHO endorses any specific organization, products or services. The use of the WHO logo is not permitted. If you adapt the work, then you must license your work under the same or equivalent Creative Commons licence. If you create a translation of this work, you should add the following disclaimer along with the suggested citation: “This translation was not created by the World Health Organization (WHO). WHO is not responsible for the content or accuracy of this translation. The original English edition shall be the binding and authentic edition: AirQ+: carcinogenic pollutants and risk analysis. Copenhagen: WHO Regional Office for Europe, 2020.”

Any mediation relating to disputes arising under the licence shall be conducted in accordance with the mediation rules of the World Intellectual Property Organization. (http://www.wipo.int/amc/en/mediation/rules/)


Cataloguing-in-Publication (CIP) data. CIP data are available at http://apps.who.int/iris.

Sales, rights and licensing. To purchase WHO publications, see http://apps.who.int/bookorders. To submit requests for commercial use and queries on rights and licensing, see http://www.who.int/about/licensing.

Third-party materials. If you wish to reuse material from this work that is attributed to a third party, such as tables, figures or images, it is your responsibility to determine whether permission is needed for that reuse and to obtain permission from the copyright holder. The risk of claims resulting from infringement of any third-party-owned component in the work rests solely with the user.

General disclaimers. The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of WHO concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted and dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

The mention of specific companies or of certain manufacturers’ products does not imply that they are endorsed or recommended by WHO in preference to others of a similar nature that are not mentioned. Errors and omissions excepted, the names of proprietary products are distinguished by initial capital letters.

All reasonable precautions have been taken by WHO to verify the information contained in this publication. However, the published material is being distributed without warranty of any kind, either expressed or implied. The responsibility for the interpretation and use of the material lies with the reader. In no event shall WHO be liable for damages arising from its use.
# Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acknowledgments</td>
<td>iv</td>
</tr>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Inhalation risk assessment of BaP</td>
<td>2</td>
</tr>
<tr>
<td>Background</td>
<td>2</td>
</tr>
<tr>
<td>WHO default unit risk methodology</td>
<td>2</td>
</tr>
<tr>
<td>Example calculation using unit risk</td>
<td>3</td>
</tr>
<tr>
<td>Caveat</td>
<td>3</td>
</tr>
<tr>
<td>References</td>
<td>4</td>
</tr>
</tbody>
</table>
Acknowledgments

The authors of this publication are: Pierpaolo Mudu (European Centre for Environment and Health, WHO Regional Office for Europe) and Michal Krzyzanowski (Kings College London, United Kingdom of Great Britain and Northern Ireland).

The WHO Regional Office for Europe gratefully acknowledges Cécile Kairo (Santé publique France) for suggestions to improve the text. Thanks also to Magali Corso (Santé publique France), Dorota Jarosinska (WHO European Centre for Environment and Health, WHO Regional Office for Europe), Ingu Kim (WHO European Centre for Environment and Health, WHO Regional Office for Europe), Alain Le Tertre (Santé publique France) and Sylvia Medina (Santé publique France) for their comments on an earlier version. The AirQ+ project was partially financed by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.
AirQ+ allows calculations of the risks due to exposure to carcinogenic air pollutants based either on concentration-risk functions generated by epidemiological studies of general populations or on unit risk based on occupational studies or toxicological data. The difference between the two approaches is substantial (Röösli et al., 2003).


For regulatory purposes, risk assessments often address seemingly unanswerable questions, such as determining the exposure which results in a one-in-a-million added risk of disease, or the number of deaths in the US population caused by a specific agent or avoidable through regulatory actions.

While the dose-response relationship is of prime interest in risk assessment, epidemiologic studies more typically address the exposure-response relationship.

The AirQ+ software uses default unit risk values for arsenic, benzene, benzo[a]pyrene (BaP), chromium (VI), nickel and vinyl chloride based on the Air Quality Guidelines for Europe (WHO Regional Office for Europe, 2000) (Table 1); the International Agency for Research on Cancer (IARC) classifies these substances as carcinogenic for humans (IARC Group 1). However, users can input different unit risk values, for example from the French Agency for Food, Environmental and Occupational Health and Safety (ANSES) or the US National Library of Medicine website (NLM, 2019). Unit risk shows the risk of cancer associated with lifetime exposure to a unit concentration (1 µg/m³ or 1 ng/m³) of a substance.

Table 1. Unit risk values for carcinogenic pollutants

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Unit risk</th>
<th>Site of tumour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>1.5 \times 10^{-3} (per 1 µg/m³)</td>
<td>Lung</td>
</tr>
<tr>
<td>Benzene</td>
<td>6 \times 10^{-6} (per 1 µg/m³)</td>
<td>Blood (leukaemia)</td>
</tr>
<tr>
<td>BaP</td>
<td>8.7 \times 10^{-3} (per 1 ng/m³)</td>
<td>Lung</td>
</tr>
<tr>
<td>Chromium (VI)</td>
<td>4 \times 10^{-2} (per 1 µg/m³)</td>
<td>Lung</td>
</tr>
<tr>
<td>Nickel</td>
<td>3.8 \times 10^{-4} (per 1 µg/m³)</td>
<td>Lung</td>
</tr>
<tr>
<td>Vinyl chloride</td>
<td>1 \times 10^{-6} (per 1 µg/m³)</td>
<td>Liver and other sites</td>
</tr>
<tr>
<td>Other</td>
<td>Specified by the user</td>
<td></td>
</tr>
</tbody>
</table>

Source: WHO Regional Office for Europe (2000).

The next section shows an example risk assessment of BaP.

---
1 For details on key terms, please refer to the AirQ+ Glossary, which is accessible on the main welcome window.
2 For a comparison of results and a discussion of epidemiology-based methods with estimates for the same population based on unit risk factors, see Röösli et al. (2003).
3 Please see INERIS (2009) for ANSES risk values.
Inhalation risk assessment of BaP

Background

“Polycyclic aromatic hydrocarbons (PAHs), which are generated from the incomplete combustion of organic (carbonaceous) material, are ubiquitous contaminants in ambient air” according to Dybing et al. (2013:75). BaP is selected as the indicator for PAHs because its toxicity is best characterized out of all the carcinogenic PAH compounds. According to the Air Quality Guidelines for Europe (WHO Regional Office for Europe, 2000: p. 94), BaP alone will probably underestimate the carcinogenic potential of airborne PAH mixtures, since co-occurring substances are also carcinogenic. Nevertheless, the well-studied common constituent of PAH mixtures, BaP, was chosen as an indicator, although the limitation and uncertainties in such an approach were recognized.

In major European urban areas, annual mean concentrations of BaP are in the range 1–10 ng/m³ (European Environment Agency, 2018). Concentrations of BaP from remote and rural sites are estimated between 0.02 and 1.6 ng/m³ and in city centres are generally below 3 ng/m³ (European Commission, 2001). The European Union Directive 2008/50/EC establishes an annual limit of 1.0 ng/m³ for BaP.

WHO default unit risk methodology

This calculation uses the default unit risk value for BaP from the Air Quality Guidelines for Europe (WHO Regional Office for Europe, 2000: p. 95).

Based on epidemiological data from studies in coke-oven workers, a unit risk for BaP as indicator air constituent for PAHs is estimated to be $8.7 \times 10^{-5}$ per ng/m³. The corresponding concentrations of BaP producing excess lifetime cancer risks of 1/10 000, 1/100 000 and 1/1 000 000 are 1.2, 0.12 and 0.012 ng/m³, respectively.

Using the default unit risk of $8.7 \times 10^{-5}$ per ng/m³, AirQ+ calculates lifetime lung cancer risk (R) for a population exposed over its lifetime to BaP at concentration C (in ng/m³) as:

$$R = C \times (8.7/100 \ 000)$$

If the population consists of P people exposed to a concentration C during a lifetime, the additional number of lung cancer cases attributed to PAHs would be $R \times P$ in this population.
Example calculation using unit risk

For a population of 10 123 400 exposed to a BaP concentration of 2 ng/m³ the additional lifetime risk of lung cancer would be 1761 cases, which corresponds to 0.25 cases per 100 000 (Fig. 1). The user needs to input the contaminant concentration and the exposed population, and may choose to change the default unit risk.

Fig. 1. Example calculation of additional lifetime cancer cases due to BaP exposure

Caveat

This module of AirQ+ can estimate the risk of cancer due to lifetime exposure to carcinogenic air pollutants. When considering PAHs in the air, several assumptions are made. The composition of PAH mixtures in the environment varies significantly depending on the location considered, time/season of measurements and local land use, for example for industrial or transport activities. Another assumption is that the effects of all PAHs are supposed to be the same as for BaP.

The conversion between unit risks and relative risks is possible using conversion factors and some examples are available in the scientific literature.

Users should consider that the exclusive use of BaP as an indicator might not always be appropriate and could probably underestimate risk. Also other components of ambient air pollution cause lung cancer and all mortality estimates and cause-specific calculations based on particulate matter with a diameter of 2.5 µm or less (PM$_{2.5}$) would include the effects of BaP exposure.
References


The WHO Regional Office for Europe

The World Health Organization (WHO) is a specialized agency of the United Nations created in 1948 with the primary responsibility for international health matters and public health. The WHO Regional Office for Europe is one of six regional offices throughout the world, each with its own programme geared to the particular health conditions of the countries it serves.

Member States

Albania  Andorra  Armenia  Austria  Azerbaijan  Belarus  Belgium  Bosnia and Herzegovina  Bulgaria  Croatia  Cyprus  Czechia  Denmark  Estonia  Finland  France  Georgia  Germany  Greece  Hungary  Iceland  Ireland  Israel  Italy  Kazakhstan  Kyrgyzstan  Latvia  Lithuania  Luxembourg  Malta  Monaco  Montenegro  Netherlands  North Macedonia  Norway  Poland  Portugal  Republic of Moldova  Romania  Russian Federation  San Marino  Serbia  Slovakia  Slovenia  Spain  Sweden  Switzerland  Tajikistan  Turkey  Turkmenistan  Ukraine  United Kingdom  Uzbekistan

WHO/EURO:2020-1561-41312-56214

WHO European Centre for Environment and Health
Platz der Vereinten Nationen 1, D-53113 Bonn, Germany
Tel: +49 228 815 0400
E-mail: euroceh@who.int
Website: http://www.euro.who.int/ecehbonn