HEALTH RISK ASSESSMENT AND ENVIRONMENTAL JUSTICE ANALYSIS USING HHRAP AND BREEZE RISK ANALYST

Human Health Risk Assessment (HHRA) models allow cancer risks as well as acute and long-term non-cancer health risks to be derived from air pollutant concentrations measured by monitors or predicted by dispersion models. While dispersion modeling results will predict where air emissions are going and how concentrated the pollutants are, HHRA modeling will determine whether those concentrations will cause health impacts for those in surrounding areas and if so, where. These health impact predictions are generally much greater in specificity and detail than the conclusions that can be obtained by comparison to standard air pollutant criteria issued by governments and can be a valuable tool in considering the environmental justice (EJ) implications of a given facility. BREEZE® Risk Analyst is a market-leading tool for streamlining and automating HHRA analyses.

Benefits of Risk Assessment Modeling for Environmental Justice Purposes

Risk assessment modeling enables organizations to use modeled health risk results to determine how operations might be impacting socioeconomically disadvantaged areas by integrating modeling results with other EJ-related data, such as demographics of the communities being impacted. Instead of having results that show, "living with X miles of a facility is a risk", risk assessment modeling enables modelers to state that "X neighborhood with X number of low-income residents is at risk", thereby providing a more quantified assessment of risk that can result in organizations making quicker data-driven decisions. Organizations that implement these types of EJ-related risk assessments can benefit by creating a consistent organization-wide approach for conducting the assessments based on an EPA-established methodology.

U.S. EPA Human Health Risk Assessment Protocol (HHRAP)

The U.S. EPA Human Health Risk Assessment Protocol (HHRAP) can be used to assist organizations with determining how operations might be impacting socioeconomically disadvantaged areas and support quick and data-driven decision making. HHRAP was developed by U.S. EPA to provide a means of simulating the risk caused by multi-pathway exposure (direct airborne exposure to pollutants through inhalation and skin contact, as well as indirect exposure such as eating contaminated plants and animals) to a wide variety of hazardous air pollutants. More than 200 pollutants ranging from heavy metals to VOCs are covered by the methodology. HHRAP provides a standardized framework for risk assessments, but with significant flexibility to adapt the "default" configuration to appropriately model unique local circumstances and to account for the pollutant exposures associated with different lifestyles and food sources.

HHRAP Input

Prior to conducting a risk assessment using HHRAP, an air dispersion modeling assessment is completed. This air dispersion modeling assessment calculates the pollutant concentrations from the sources whose health risk impacts are to be evaluated. AERMOD, the U.S. EPA's promulgated near-field air dispersion model, is a prime companion program for HHRAP since airborne concentrations (inhalation exposure) and deposition (multi-pathway exposure) are calculated. While AERMOD is widely used with HHRAP, any dispersion model that meets the following criteria can be used:

- The model can produce gridded output of air pollutant concentrations on both a short term (maximum 1-hour) and long term (annual average) basis.
- If multi-pathway exposure (exposure pathways other than direct inhalation of airborne pollutants, such as ingestion of contaminated soil or food) is to be modeled, the model must also produce gridded output of dry and wet deposition of air pollutants.
- In order to allow efficient completion of HHRAP modelling, the dispersion model should provide output that can be imported into GIS software such as ArcMAP™ or QGIS®.

If dispersion model output is separated into individual gridded output for each emission source, then HHRAP will be able to trace the culpability of final outputs back to individual sources. However, if only the total concentration and deposition output is provided, HHRAP can provide overall risk output considering the combined impact of all sources.

HHRAP Modeling

Modelers can run HHRAP one of two ways: manually or with the aid of an outside program. The HHRAP methodology is provided by the U.S. EPA as a collection of input data and model equations in a PDF format that is applied via hand calculation or automated

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using spreadsheet software. Thus, manually applying HHRAP can be a time-consuming task and is only practical when applying the methodology to a small number of datapoints. A more efficient approach suitable for larger-scale application of HHRAP is to use dedicated modeling software, such as BREEZE Risk Analyst. (Relevant article: Combined Use of AERMOD, ArcGIS™, and Risk Analyst for Human Health Risk Assessment.)

To conduct the modeling assessment, the modeler selects the appropriate input and decides on the exposure profiles to use. U.S. EPA provides six default HHRAP exposure profiles, but the modeler can manually adjust the defaults as needed to reflect a more realistic lifestyle of the residents in the area being modeled. The default adult and child exposure profiles are below:

- A typical resident of an area with limited exposure to locally-grown food sources.
- A farmer with significant direct and dietary exposure to locally-grown food and to contaminated soil.
- A fisher with significant direct and dietary exposure to locally-caught fish from potentially contaminated waters.

The next step is to run the HHRAP equations, either manually or using an automated program like BREEZE Risk Analyst, using dispersion modeling output as input.

HHRAP Output

HHRAP output includes cancer risk and non-cancer risk categories. Cancer risk is expressed as the incremental likelihood that an exposed person will develop cancer (e.g., a risk of 1x10-5 indicates that a person living in that location for the specified exposure period has a 1 in 100,000 chance of developing cancer because of their exposure, over and above their baseline cancer risk). For the cancer risk, there is no "lower bound". Any exposure, no matter how small, equates to some increase in cancer risk. The cancer risk is calculated separately for each pollutant, and a total cancer risk is obtained by summing the individual pollutant cancer risks. The non-cancer risk is quantified via a "Hazard Index" (HI) for each pollutant. If multiple modeled pollutants impact the same organ or system, then the HIs for each of those pollutants are added together to give a total HI for that organ or system. The HI is defined by U.S. EPA as a conservative threshold: an HI smaller than 1 indicates that the pollutant(s) are unlikely to cause adverse non-cancer health impacts over a lifetime of exposure, while an HI greater than 1 indicates that the possibility of serious non-cancer health impacts may exist, and further study is needed to quantify or reduce the risk. When displaying the cancer risk and non-cancer risk output, the program includes pollutant-specific details, the total risks (i.e., the sum of individual pollutant risks), and output at each receptor.

BREEZE Risk Analyst for Environmental Justice Analyses

If the purpose of the modeling is to demonstrate compliance with health risk standards, then comparing the cancer risk value and HI to the applicable standard may be sufficient. However, many modeling purposes, such as assessment of the environmental justice impacts of a facility, may benefit from integration of the model results with other data. Due to the geospatial nature of HHRAP model results and the risks they signify, this kind of analysis is best performed using GIS software such as ArcMap or QGIS, which allow easy integration of health risk data with population and socioeconomic/demographic data.

BREEZE Risk Analyst, an add-in for Esri™ ArcGIS, is a highly flexible and expandable GIS-based analysis platform for conducting multi-pathway human health risk assessments and contains a HHRAP module, which can directly read in AERMOD and other dispersion model output, and which automates all of the HHRAP calculations. The HHRAP module includes the following risk modeling capabilities:

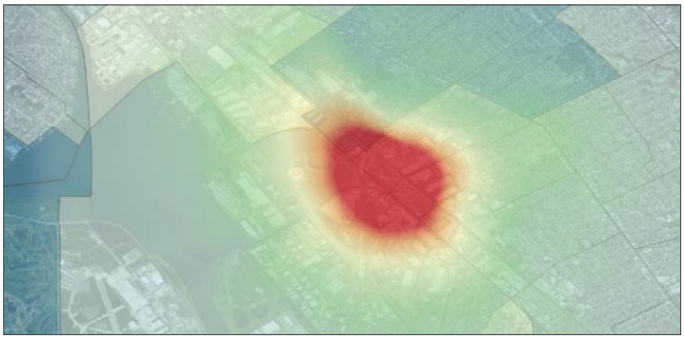
- **Environmental Media** - air, water, soil, and sediment
- **Risk Characterization** - acute exposure, cancer risk, and noncancer hazard
- **Exposure Pathways** - inhalation, eggs, soil, milk, produce (above and below ground), fish, beef, drinking water, pork, dermal, and chicken
- **Exposure Scenarios** - resident adult and child, fisher adult and child, farmer adult and child, nursing infant, or user defined (e.g., on-site worker)

Risk Analyst seamlessly combines all the necessary tools, databases, GIS functionality, and fate and transport and exposure modeling equations into an affordable and easy to use software application. The GIS add-in inherits the full functionality available in ArcGIS allowing users to take full advantage of ArcGIS' powerful capabilities including visualizing, managing, creating, and analyzing geospatial data. Fundamental to risk modeling, users can understand the geographic context of the data, visualize relationships, and identify patterns in ways not possible without geospatial awareness.

In addition to being used to conduct human health risk assessments worldwide, BREEZE Risk Analyst has been used for EJ-related assessments. (A technical paper that includes an example of this can be provided upon request.) EJ initiatives are focused on implementing a more systematic approach to reducing environmental and health disparities for minority, low-income and tribal populations and improving the air, water, and land in these communities. These EJ initiatives have been pursued for decades, however, recent legislative developments, changes in agency procedures, public participation, plus investor and external stakeholder actions are requiring regulators and the regulated community to apply significantly increased attention to potential EJ exposure and assure their actions are not causing disparate adverse environmental, health, or safety impacts on vulnerable communities.

Using BREEZE Risk Analyst to conduct human health risk assessments and subsequent EJ-related assessments streamlines and simplifies the process and provides output in formats that allow organizations to quickly analyze the results and take any appropriate actions. Using dispersion modeling output as input (e.g., from BREEZE AERMOD), modelers can easily setup and run HHRAP through BREEZE Risk Analyst and then analyze the output that is provided in a basic table format and a GIS shapefile format. The

image below shows a HHRAP example that was conducted using BREEZE Risk Analyst, after which the results were exported to the QGIS software program in shapefile format. In this image, you'll see that the area in which the criteria was exceeded was overlaid with population data, showing that more than 30,000 people live in potentially affected areas.



Overlay of cancer risk data on census data to determine the potentially affected population

For a demonstration of Risk Analyst or for more information, contact the BREEZE team at +1 972.661.8881 or breeze@trinityconsultants.com. You can also visit the product page at trinityconsultants.com/software/products/risk-analyst. Similarly, for more information about our EJ-related services, please click here.

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