

ABSTRACT

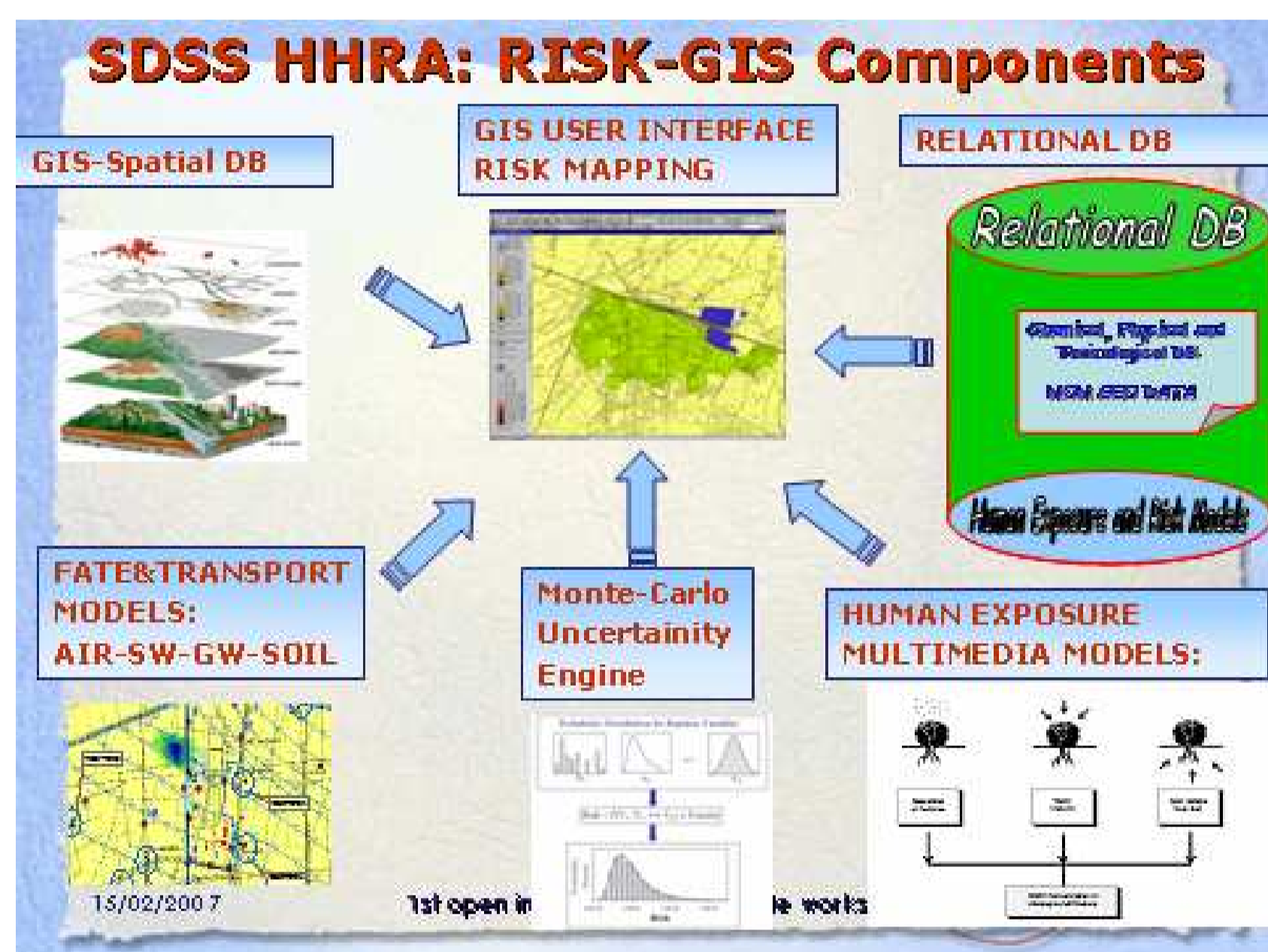
The Assessing and managing of environmental risks connected with industrial and civil activities are matter of great and always increasing complexity and involve problems whose solution cover a wide range of disciplines, from physical sciences and engineering to ecology, economics, sociology and education. As far as the Environmental and Human Health Risk Assessment is concerned, information on environmental and chemicals database, fate and transport models output, site description maps and demographic database have to be integrated. The tools available for processing such information can be identified in maps, databases, spreadsheets, fate and transport models and Geographic Information System.

RISK-GIS is the implementation on ARCVIEW® GIS of a Human Health Decision Support System useful to support an expert user interested in assessing and managing such risk typologies for a territory characterized by the presence of several industrial sources, which, daily or accidentally, emit dangerous pollutants able to impact on different environmental media.

The produced software draws the contours of individual and total risk on a map of the territory examined, by means of a Geographical Information System whose capabilities rise from an integrated architecture specifically designed to estimate potential human health risk resulting from many industrial sources.

A case study concerning a working industrial site shows in which way the designed tool can help local planning authorities and policy makers in managing risks and planning remedial and reduction actions.

RISK-GIS STRUCTURE



THE RISK ASSESSMENT PROCEDURE IN EHHRA-GIS

Exposure Quantification - INTAKE

The Quantification of Human Exposure Dose (INTAKE) require:

- COC Concentration in the environmental exposure media

$$C(x, y, z)_{exposure} = f(TF, C(x, y, z)_{environmenta})$$

- Exposure Rate (Inhalation, Ingestion, Dermal Contact)
- Body Weight
- Exposure Frequency and Duration
- Averaging Time (AT Life Time for Cancer Risk)

$$I_{i,j}(x, y, z) = \sum_k \frac{C_{i,km} \cdot CR_{j,k} \cdot EF_{j,k} \cdot ED_{j,k}}{BW_j \cdot AT_{j,k}}$$

Human Receptor Characterization

Cancer Risk Assessment

$$Individual\ CancerRisk_j(x, y, z) = \sum_i LADD_{i,j} \cdot CSF_i$$

DEF: Incremental Probability that a human receptor will develop cancer, based on a unique set of exposure, model, and toxicity assumptions

Toxic Hazard Quotient

$$HQ_j(x, y, z, t) = \sum_i \frac{ADD_{i,j}}{RfD_i}$$

- Multiple COC / receptor j
- Different exposure pathways k

The procedures adopted in EHHRA-GIS system for estimating the COC concentration in various exposure media calculate the concentration of chemical in an exposure medium from the chemical concentration in the environmental compartment, with an inter-media transfer factor:

$$C(x, y, z, t)_{exposure} = TF \cdot C(x, y, z, t)_{environmenta}$$

TF = Inter media transfer factor from an environmental compartment to an exposure medium (chemical-specific partition coefficient).

The following bioaccumulation models are implemented in the system:

- bioaccumulation in vegetables
- bioaccumulation in food of animal origin
- bioaccumulation and bioconcentration in aquatic organisms.

Fate and Transport Models provide the concentration of chemicals of concern in the environmental compartments: air, surface soil, root-zone soil, surface water and groundwater. The system graphical user interface allows the interaction with the different stages of the simulation taking advantage of Gis spatial analysis tools.

Currently the following models are integrated in the system:

- ISC3-GIS** (short-term and long-term version) and **AERMOD-GIS** for the atmospheric dispersion of pollutants
- CALINE-GIS** for the atmospheric dispersion of pollutants emitted by vehicles on roadways
- SOIL-GIS** for the transport of pollutants in soil and in groundwater
- FOOD-CHAIN MODEL** for the bioaccumulation in the food chain.

CASE STUDY

Geographic area characterized by the presence of industrial, urban and agricultural areas.

SOURCES :

- one atmospheric point source within an incineration plant
- surface soil in the industrial area contaminated by leaks of benzene from chemical or manufacturing plants
- groundwater contaminated by arsenic

To map the contamination of surface soil and groundwater, spatial interpolation of sampled point data of concentration was performed, in order to evaluate a spatial distribution of concentrations (Fig.1).

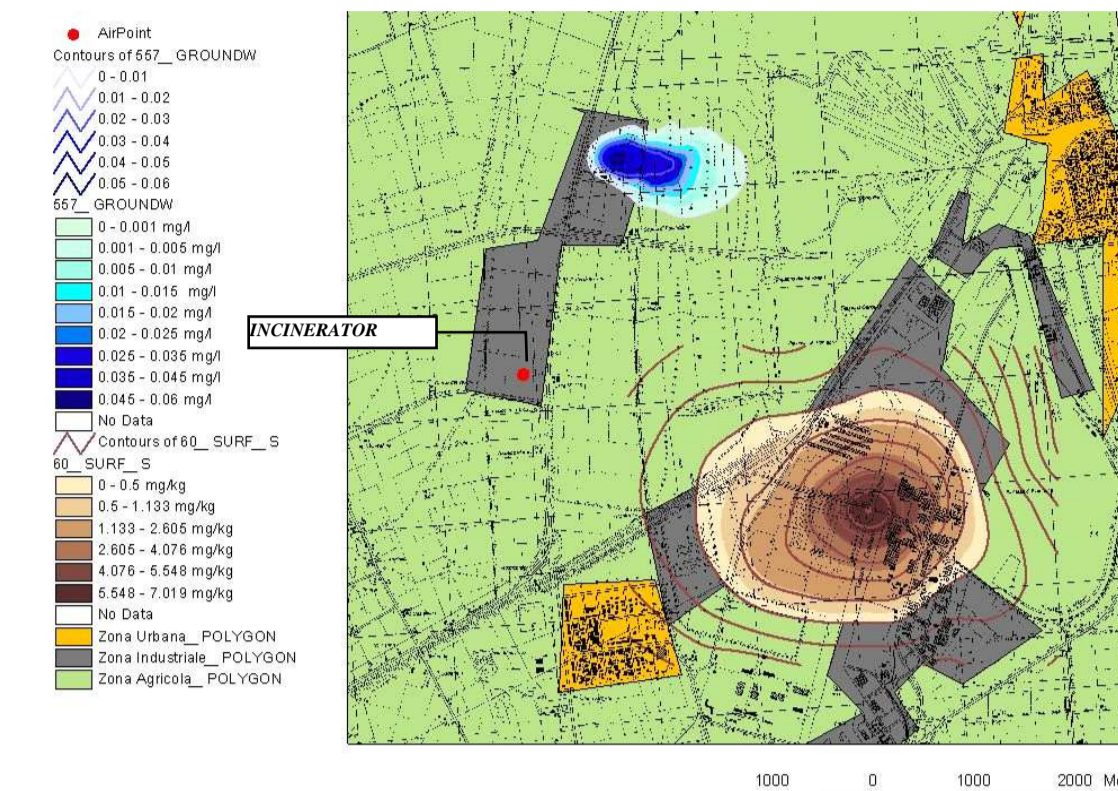


Fig.1: Map of concentration of Benzene in soil (mg/Kg) and Arsenic in groundwater (mg/l)

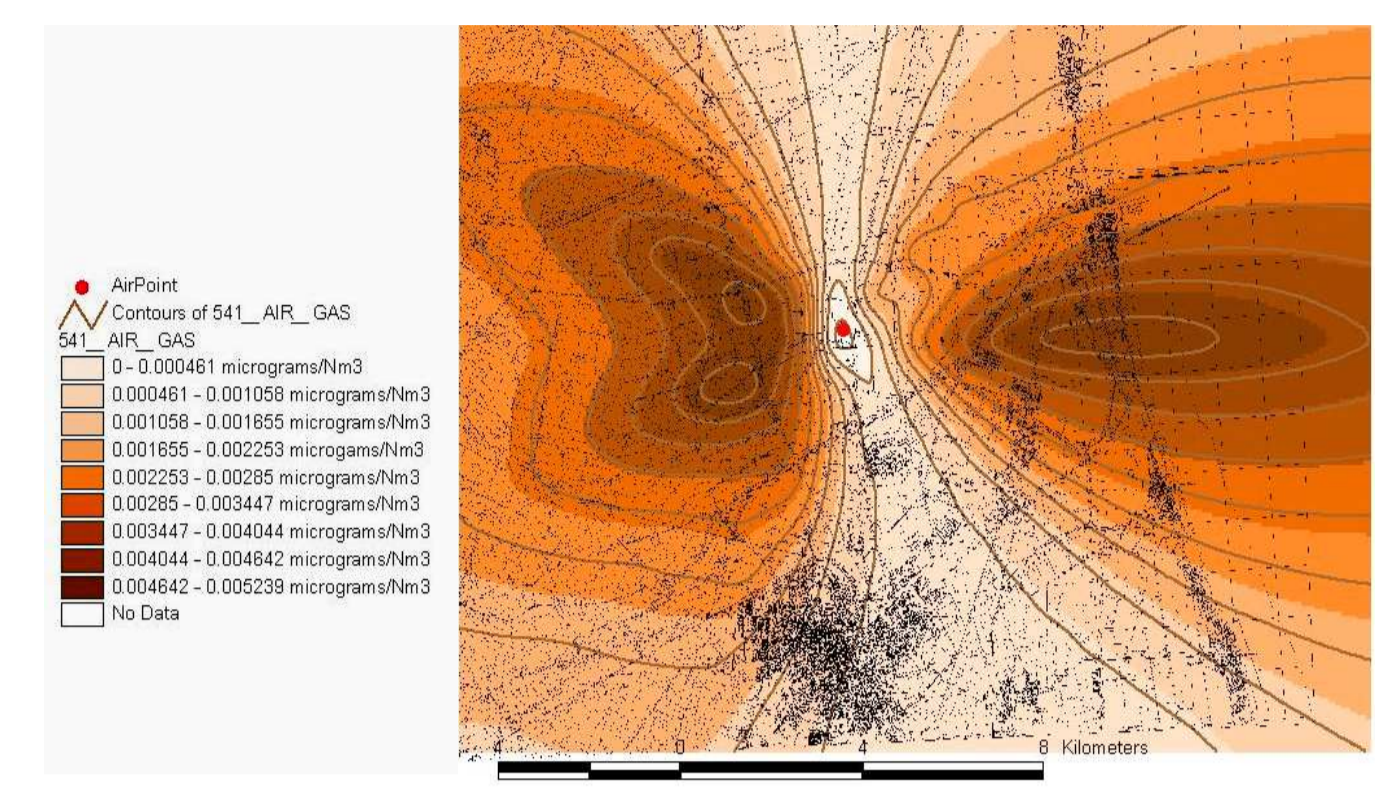


Fig.2: ISCLT3 simulation – distribution of concentration of CO in air in µg/Nm³

To estimate the atmospheric dispersion of pollutants and the dry deposition on the soil, due to the emissions of the incinerator, the EPA mathematic model ISCLT3 (Industrial Source Complex Long Term), integrated in the system, had employed (Fig.2).

The **Chemicals of Concern** emitted by the stack of the incinerator: Carbon Monoxide, Hydrogen Chloride, Hydrogen Fluoride, Sulfur Dioxide, Nitrogen Dioxide, Cadmium, Mercury, Dioxins and Furans.

Human receptors identification:

- adult workers in the industrial areas
- adults resident in the urban areas
- children resident in the agricultural areas.

Finally it is carried out the calculation of **Intake** (Fig.3) and the quantification of **Cancer Risk** (Fig.4) and **Hazard Quotient** for the population localized in the study area.

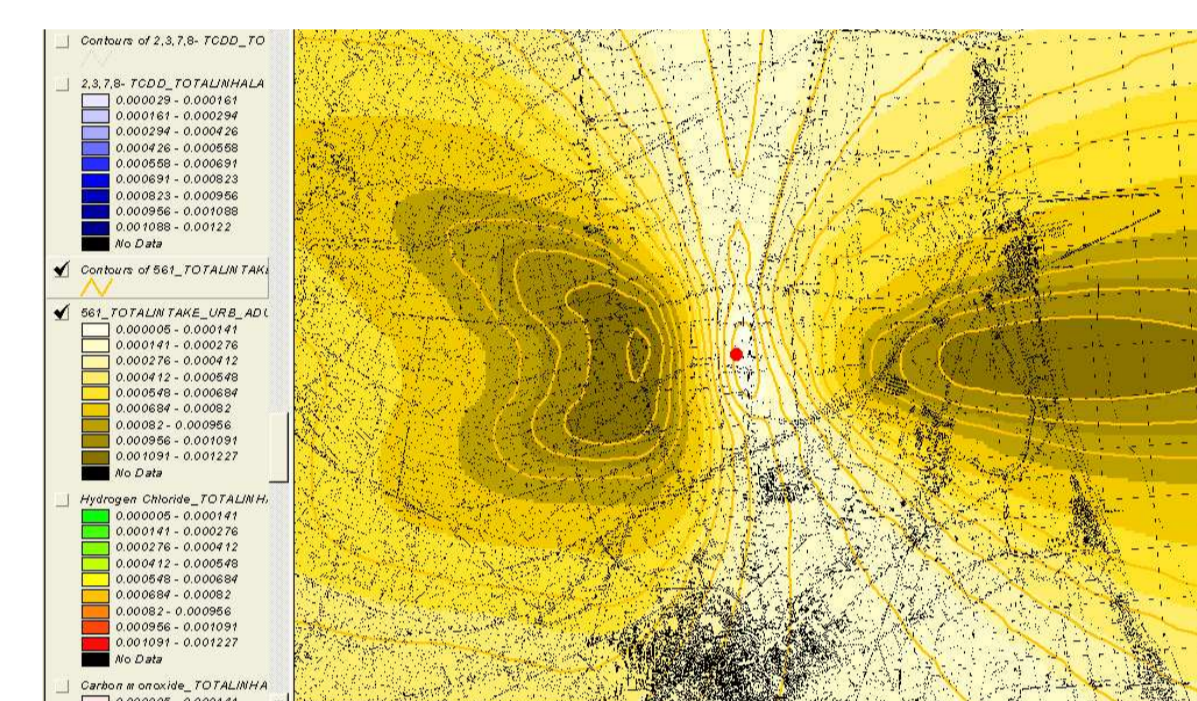


Fig.3: Total intake of cadmium mg/kg-d(· 10⁻³) for urban adult receptors

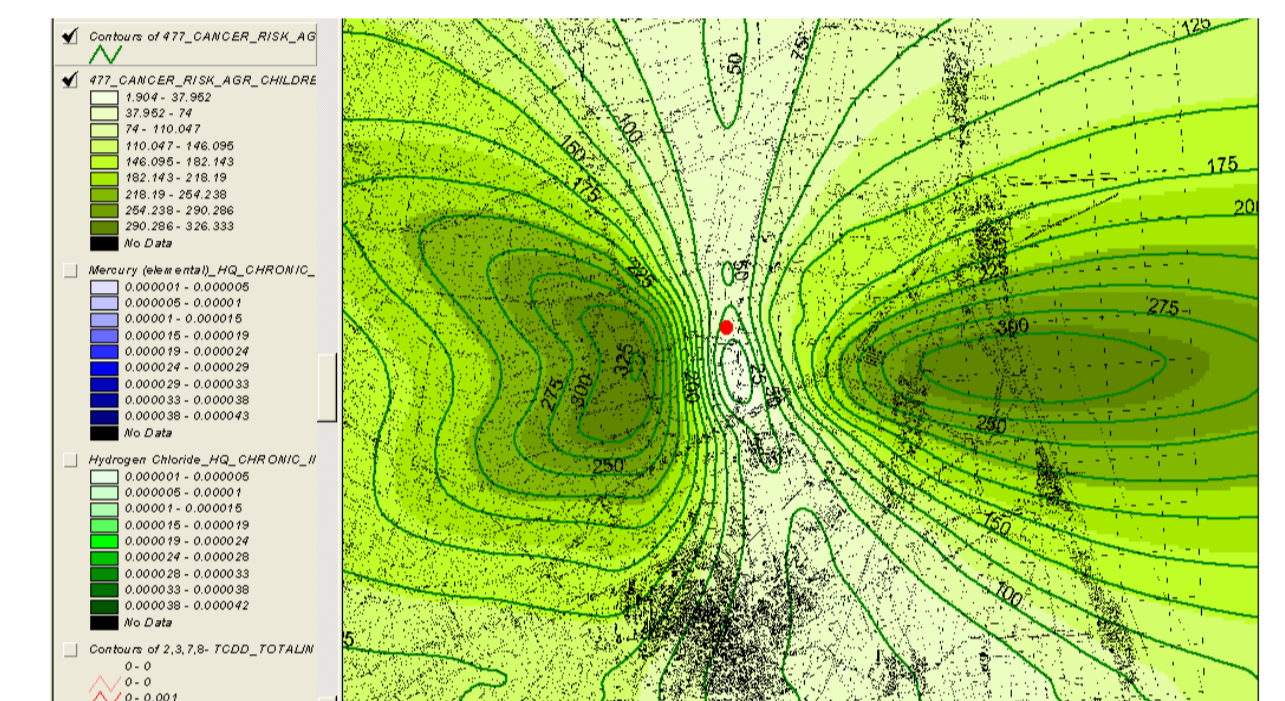


Fig.4: Total Cancer Risk due to dioxins (· 10⁻⁹) for children receptors

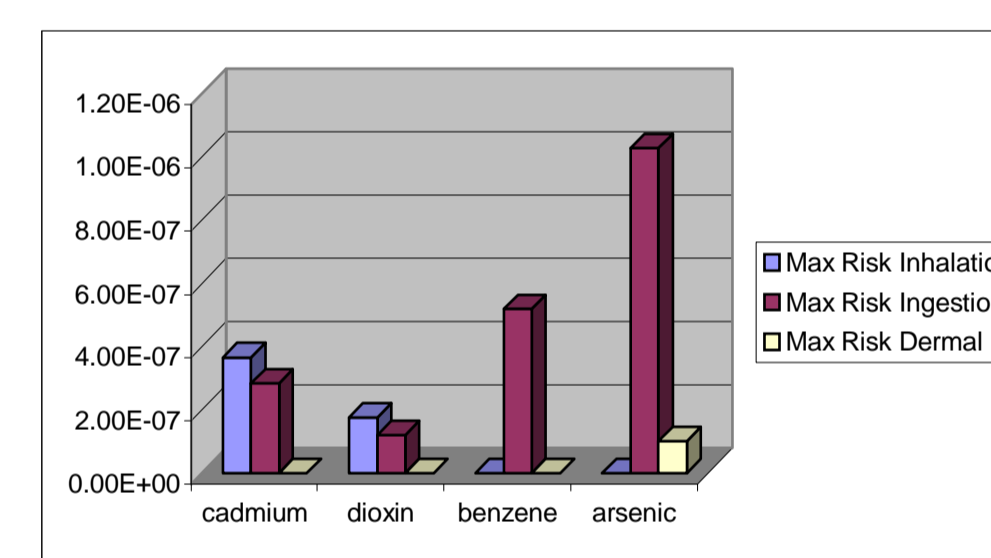
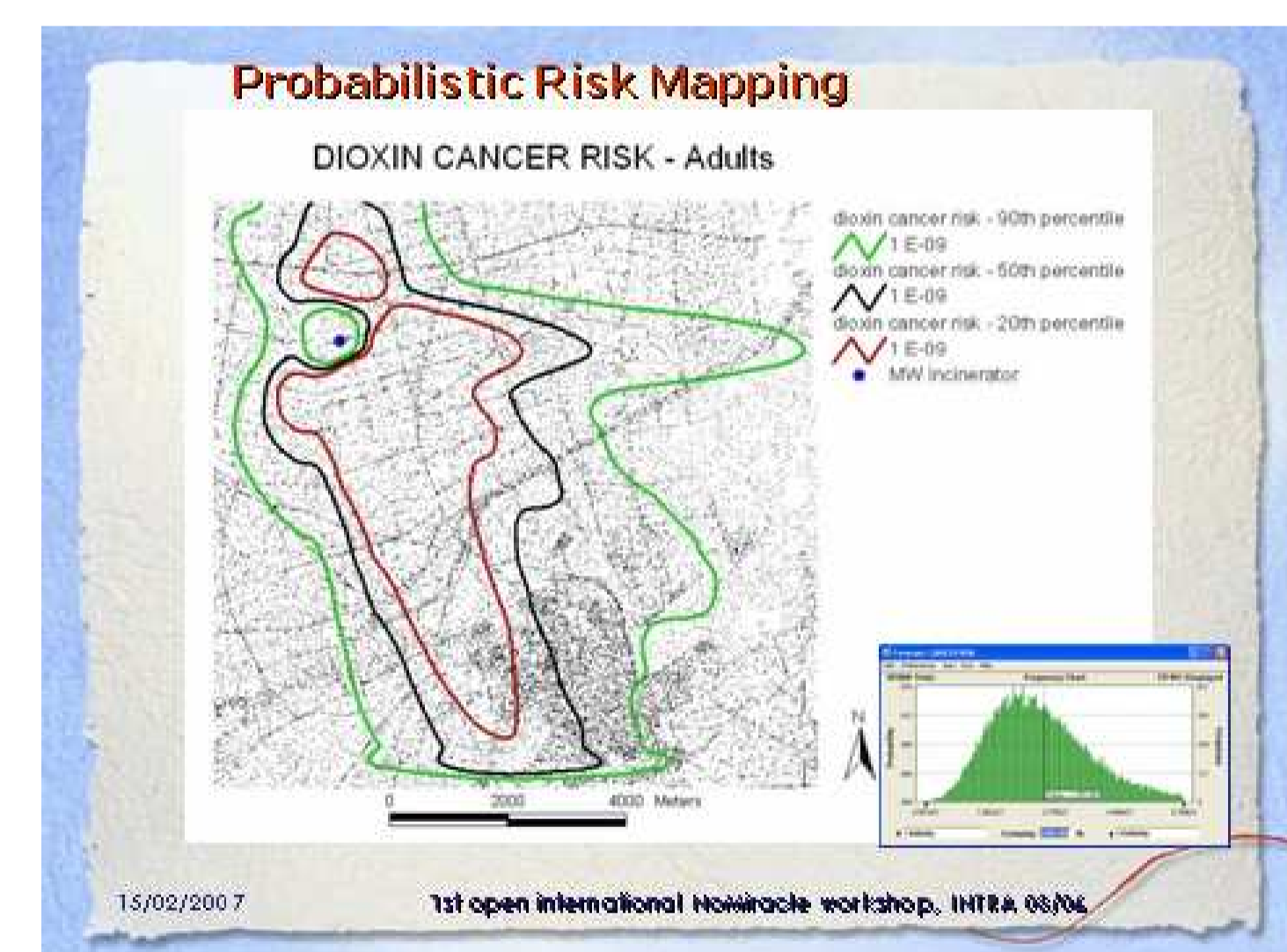


Fig. 5: Maximum Cancer Risk for adults receptors working in the industrial district.

Examining results in the light of acceptable lifetime cancer risk defined by USEPA, 10⁻⁴ – 10⁻⁶, the maximum human health risk calculated for the different typologies of receptors living in the case study area has to be considered acceptable for all analyzed COCs.



CONCLUSIONS

The complexity of Environmental and Human Health Risk Assessment and the large amount of different data to be handled in their management call for the development of systems that can perform analyses of differing natures. This study underlines the importance of integrating different tools and shows as a package can be built that reassembles these tools.

RISK-GIS, provides a valuable tool for evaluating and managing health risk. It assists risk managers in evaluating risk data, judging the effectiveness of remedial options and selecting the one which will minimize health risk, in supporting public acceptability of remediation plan. The tool output contribute to the site characterization and subsequent development; the results of the risk assessment displayed on georeferenced maps can be used to help determine whether additional response action is necessary at the site, modify preliminary remediation goals, help support selection of the 'no-action' remedial alternative, where appropriate and document the magnitude of risk at a site, and the primary causes of that risk.

REFERENCES

- National Academy of Sciences (NAS) "Risk Assessment in the Federal Government: Managing the process" – National Academy Press. Washington, D.C. 1983
- USEPA "Risk Assessment Guidance for Superfund: Volume I. Human Health Evaluation Manual (Part A)" - OERR. Washington, D.C. 1989
- USEPA "Solid waste and Emergency Response. Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities", Volume I, II, III - 1998
- USEPA "Exposure Factors Handbook" – Office of Research and Development – NCEA 1997
- University of California Davis "CalTOX, A Multimedia Total Exposure Model For Hazardous-Waste Sites" Part I: Executive Summary Lawrence Livermore National Laboratory 1994
- USEPA "Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities", 1998.
- USEPA "Integrated risk information system" – Database on the toxicology information network, 1996.
- USEPA "User's Guide for the industrial source complex (ISC3) dispersion models for use in the multimedia, multipathway and multireceptor risk assessment (3MRA) for HWIR 99" – Office of solid waste, 1999.
- S. Bagli, G. Spadoni "Ehhra-gis: environmental and human health risk assessment using Gis" – Proc. of ESREL 2000, SRA-EUROPE annual conference, Edinburgh (UK) 2000, II: 1415-1420.
- S. Bagli, G. Spadoni, "Ehhra-gis: un sistema informativo geografico per valutare il rischio per la salute umana", Ingegneria Ambientale, - 31, 9, 2002.