

# Chemical risks to workers' health in contaminated sites

S. Berardi & E. Bemporad

*Department of Production Plants and Human Settlements,  
Italian Workers' Compensation Authority (INAIL), Italy*

## Abstract

The presence of hazardous chemical agents and carcinogens/mutagens in unsaturated soil and/or groundwater, or their use in clean-up activities, doesn't necessarily entail a risk to human health. It depends on the toxicological characteristics, the concentration of the substance, the transport mechanisms and the exposure media. In Italy, the management of chemical risk to workers' health in contaminated sites is currently not standardized. For this reason, in 2013 a team of experts in the management of contamination sites and of occupational risks, coordinated by INAIL, began to work out a document dealing with the operative instructions to protect the health of workers present for any reason in a contaminated site. This document addresses the main aspects related to the protection of workers exposed to contaminants considering both the toxic and the carcinogenic effects of chemicals. In this paper a particular issue, addressed in the document, is discussed: the proposed methodology to check the presence of chemical and carcinogen/mutagen agents at workplace for the inhalation exposure pathway.

*Keywords: chemical risk, workers' health, soil contamination.*

## 1 Introduction

A contaminated site can be defined as an area, or portion of a territory, in which anthropogenic phenomena have led to such changes in chemical, physical and/or biological properties of the soil, subsoil and groundwater to cause a hazard for the human health and/or for the environment. The presence of contaminated sites is a common problem in all industrialized countries and derives from the presence of human activities, such as factories, mines, landfills. In Italy,



potentially contaminated sites are about 32,000 and more than 4,837 are really contaminated by organic pollutants and/or heavy metals [1].

The presence of hazardous chemical agents and carcinogens/mutagens (collectively referred to as “chemical agents” later in the paper) in unsaturated soil and/or groundwater, or their use in clean-up activities, doesn’t necessarily imply a risk to human health and safety. It depends on the toxicological characteristics, the concentration of the substance, the transport mechanisms and the exposure media. In Italy, the management of chemical risk to workers’ health in contaminated sites is currently not standardized.

For this reason, the Research and Technical-Scientific Sector of the Italian Workers’ Compensation Authority (INAIL) is going to publish an operational guidance titled “The chemical risk to workers in contaminated sites”. In the document hazards are chemical agents and/or carcinogens/mutagens present in the unsaturated and/or groundwater (these chemicals may, or may not, be correlated with work activities on the site); all the workers present for any reason on a contaminated or potentially contaminated site are likely to be exposed; the exposure modes are vapour and soil dust inhalation, dermal contact and ingestion; finally, the damages taken into account are the occupational diseases from health risks and the injuries from safety risks.

This paper reports the principal contents of the guidance and in particular the proposed methodology to check the presence of chemicals and carcinogen/mutagens at workplace for the inhalation exposure pathway and the criteria to determinate the  $CR_{air}$  (the reference concentration for each pollutant in outdoor and indoor air below which workers can be considered as “not actually exposed”), and the strategy for environmental monitoring to make a comparison with the  $CR_{air}$ .

## 2 Description of the procedure

In the guidance, the term “chemical risk management” means the process divided into the following three steps:

**STEP 1: Hazard identification:** Hazard means the intrinsic property of a chemical agent with the potential to cause harm [directive 98/24/EC]. If the workers’ exposure is due to the presence of chemicals in the unsaturated soil and/or groundwater, the hazard identification means to verify their concentration levels in the involved environmental media.

**STEP 2: Risk assessment:** Risk means the likelihood that the potential for harm will be attained under the conditions of use and/or exposure [directive 98/24/EC]. Only after the presence of the chemical agent is verified, the employer shall proceed with the risk (exposure) assessment related to the specific agent, in compliance with the directives 98/24/EC and 2004/37/EC.

**STEP 3: Reduction and control of the risk:** Risk to workers’ health involving chemical agents shall be eliminated or reduced to a minimum (this is just the goal of the remediation activities but workers’ health shall obviously be protected also in the meantime the activities start and during them). Where the results of the assessment reveal a risk to the health of workers, some specific protection, prevention and monitoring measures shall be applied.

The proposed procedure to develop the STEP 1 is outlined in Fig. 1. When a chemical agent contaminates the unsaturated soil and/or groundwater, the legislative decree n.152/2006 requires a comparison between its concentrations measured in the contaminated media and a generic regulatory threshold limit or screening level (CSC). If the CSC is exceeded a risk assessment based on site specific parameters is required to compare the measured concentrations with the result of this assessment or site specific target level (CSR) (STEP 1.1). If the CSR (or the CSC before the site specific assessment) is not exceeded the workers can be considered as “not actually exposed” (the site is not actually contaminated). Otherwise it’s possible to monitor the outdoor or indoor air and compare the analytical data with an air reference concentration ( $CR_{air}$ ) (STEP 1.2). If the  $CR_{air}$  is not exceeded the workers can be considered as “not actually exposed”. Otherwise, to identify the appropriate procedure it is possible to differentiate between three different types of workers:

1. Reclamation operators, i.e. workers involved in the site investigation, inspection, monitoring, sampling and clean-up action.
2. Workers for whom the chemical risk assessment, conducted on the basis of their job before the employer became aware of the soil/groundwater contamination, identified only a slight risk to the safety and health. These workers can be: administrative clerks or technicians, drivers, security guards, teachers, employees in commercial activities or services.
3. Workers for whom the chemical risk assessment, conducted on the basis of their job, before the employer became aware of the soil/groundwater contamination, revealed a (not slight) risk to the safety and health.

To protect workers’ health, the following options are available:

- Option A: Perform actions to make the air concentration less than or equal to  $CR_{air}$  (e.g. applying collective protection measures and/or reducing the daily exposure frequency and/or increasing the air exchange rate).
- Option B (STEP 2): Manage the risk to the health of workers (depending on their tasks) according to the legislative decree n.81/2008 (directive 98/24/EC and 2004/37/EC transposition) duties verifying the compliance with OELs by monitoring workplace atmosphere, considering the suggestions of the National guidance document for worker protection from carcinogens and mutagens [2] where exposure to carcinogens or mutagens occurs.

In general, save particular cases, it is reasonable:

- Manage the risk to the health of the reclamation operators (type 1 workers), by selecting the Option B.
- Manage the risk to the health of the workers previously exposed to only a slight risk to the safety and health (type 2), by selecting the Option A. This is desirable especially where workplaces are similar to life places (such as offices, markets, hospitals, schools or banks).
- To manage the risk to the health of the workers already exposed to a (not slight) risk to the safety and health (type 3), by selecting the Option A or B according to the specificity of the case.

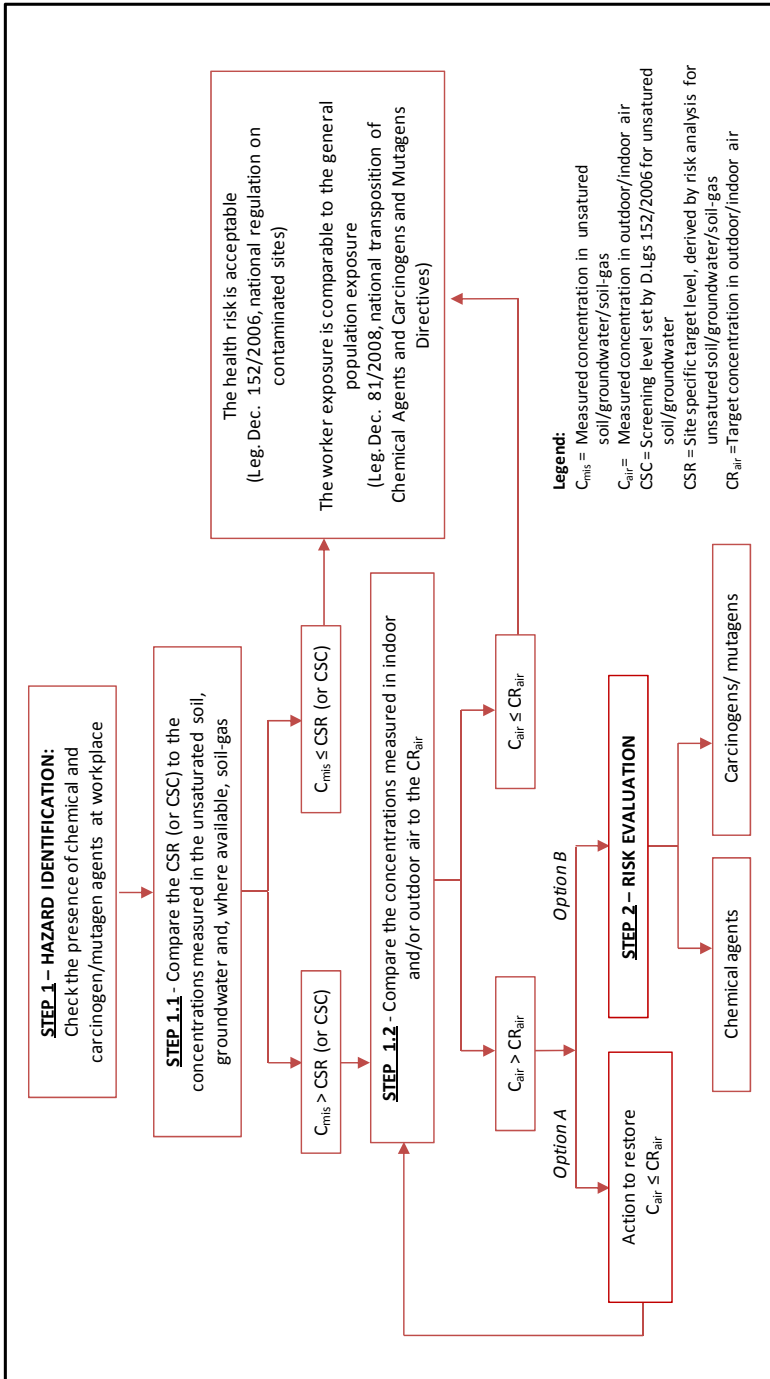


Figure 1: Procedure flow sheet for hazard identification.

In the phase of “hazard identification” it isn’t necessary to distinguish between chemical agents and carcinogens/mutagens, because the  $CR_{air}$  can be reasonably considered as a reference level for the general population.

### 3 Reference values for chemical agent concentrations in air ( $CR_{air}$ )

Reference values must be defined for concentrations of chemicals agents in air to compare with the actual values measured by environmental monitoring or estimated by quantitative models. The  $CR_{air}$  defined in the Operational Guide provides a basis for protecting workers’ health to be adversely affected by inhalation of hazardous or carcinogen vapor and suspended particles. Below the  $CR_{air}$  the risk to the safety and health of workers is certainly slight or, for carcinogens or mutagens, the workers are “not exposed”. To satisfy this requirement the total concentration of each soil (or groundwater) pollutant in air shall not be greater than its  $CR_{air}$ . The total concentration in air is equal to the sum of the concentration in the vapor phase and, where applicable, in the thoracic fraction ( $PM_{10}$ ) of the suspended particles measured during the monitoring campaigns. The  $CR_{air}$  is valid for both indoor and outdoor air because the site of exposure does not directly affect the exposure–response relationship [3].

The criteria to determine  $CR_{air}$  (Fig. 2), provide the following steps:

**Step 1:** The  $CR_{air}$  coincides with the background level, when available. Background level shall be measured where the pollution level is not dominated by a single source (industry, traffic or residential heating), but is influenced by the integrated contribution from all sources upwind of the station. The position of the background measurement stations shall be locally assessed depending on the site context (rural, urban, industrial area), according to the criteria laid down by the directive 2008/50/EC on ambient air quality and cleaner air for Europe. Air quality data collected by the monitoring network managed by public or private entities and compliant with regulatory requirements are published by the National Institute for the Environmental Protection and Research [4]. Where the presence of the chemical agent is related to local sources other than polluted soil or groundwater (e.g. traffic, strongly anthropic areas) and a background level is not available, its determination should be case-specific according to criteria agreed with the Competent Authority. Finally, where the background level is lower than the calculated  $CR_{air}$  (step 3) the adoption of this latter value for  $CR_{air}$  is anyway conservative.

**Step 2:**  $CR_{air}$  coincides with national or international limit/target/guideline value, when available. The Legislative Decree n. 155/2010, national transposition of the directive 2008/50/EC, in order to protect human health, among the soil pollutant listed by the Legislative Decree n. 152/2006 regulates benzene, some heavy metals, particularly arsenic, cadmium, lead, nickel and also benzo[a]pyrene in the  $PM_{10}$  fraction of suspended particulate matter. For other pollutants, it is possible to refer to WHO Air quality guidelines. The

pollutants of concern for soil addressed by the Air quality guidelines for Europe [3] and by the guidelines for indoor air quality [5] are mercury, chromium (VI), manganese, vanadium, styrene, toluene, 1,2-dichloroethane, dichloromethane, trichloroethylene, tetrachloroethylene, vinyl chloride, polychlorinated dibenzodioxins and dibenzofurans (PCDD/Fs) and polychlorinated biphenyls (PCB). WHO guideline values for 1,2-dichloroethane, dichloromethane and tetrachloroethylene are at present based on noncarcinogenic effects while they are all classified as carcinogens both by the UE (cat. 1B or 2) and the IARC (Group 2A or 2B). Then in specific cases the opportunity to take into account the carcinogenic effects of these pollutants should be assessed. In these cases the next steps (2 or 3) are appropriate.

**Step 3:** The  $CR_{air}$  is calculated applying the risk assessment procedure in backward mode that is setting the acceptable level for the human health risk and selecting the most conservative value between the ones calculated for carcinogenic and noncarcinogenic effects:

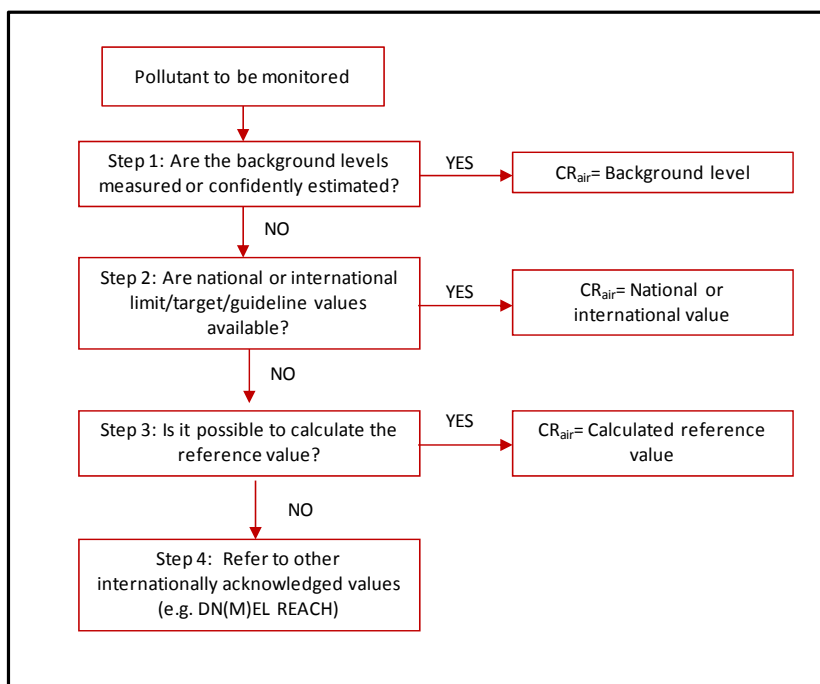


Figure 2: Procedure to define the  $CR_{air}$ .

$$CR_{air} \left[ \frac{\mu g}{m^3} \right] = \frac{TR}{EM \cdot SF_{inhal}} \times 10^3 \quad \text{carcinogenic effects} \quad (1)$$

$$CR_{air} \left[ \frac{\mu g}{m^3} \right] = \frac{THQ \cdot RfD_{inhal}}{EM} \times 10^3 \quad \text{noncarcinogenic effects} \quad (2)$$

where:

- TR is the acceptable value for the individual risk from carcinogenic substances;
- SF<sub>inhal</sub> is the inhalation Slope Factor value for the pollutant of concern;
- THQ is the acceptable value for the individual non carcinogenic risk (Target Hazard Quotient);
- RfD<sub>inhal</sub> is the inhalation Reference Dose value for the contaminant of concern;
- EM is the effective Exposure Rate defined as the quantity of inhaled air per body weight unit, estimated by the following expression [6]:

$$EM \left[ \frac{m^3}{Kg \times day} \right] = \frac{B_{air} \times EF_d \times EF \times ED}{BW \times AT \times 365 \frac{days}{year}} \quad (3)$$

The Legislative Decree n.152/2006 sets acceptable values for the individual carcinogenic risk (TR=10<sup>-6</sup>), the cumulative carcinogenic risk (TR<sub>CUM</sub>=10<sup>-5</sup>) and the individual and cumulative risk for noncarcinogens (THQ=THQ<sub>CUM</sub>=1). Table 1 contains the definition and default values of the parameters to be used for EM and then CR<sub>air</sub> calculations [6]. The site-specificity of the exposure factors to derive contextualized target values is anyhow recommended.

Table 1: Default exposure factors for CR<sub>air</sub> calculation.

Exposure Factor (EF)		Symbol	Unit	Industrial/ commercial Adult
Body weight		BW	Kg	70
Average exposure time to carcinogens		AT <sub>c</sub>	years	70
Average exposure time to noncarcinogens		AT <sub>n</sub>	years	ED
Exposure duration		ED	years	25
Exposure frequency		EF	days/year	250
Daily exposure frequency		EF <sub>d</sub>	hours/day	8
Outdoor/indoor inhalation rate by activity level	Sedentary/ Passive	B <sub>air</sub> (B <sub>o</sub> /B <sub>i</sub> )	m <sup>3</sup> /hour	0.90
	Moderate Intensity			1.50
	High intensity			2.50

When the calculated value results lower than the Limit of Quantitation (LOQ) of the selected analytical method, the CR<sub>air</sub> should coincide with the



same LOQ. The Operational Guidance contains a list of some available analytical methods with their LOQs.

**Step 4:** When the background level cannot be measured or confidently estimated and neither the  $CR_{air}$  is calculable as the pollutant is not carcinogenic by inhalation and an inhalation RfD (for noncarcinogenic effects) is not available, other internationally acknowledged values could be used. For example the Derived No (Minimum) Effect Level DN(M)EL estimated for the specific target, long term, systemic (or local when more precautionary) effects, by entities subjected to REACH can be considered [7].

## 4 Air monitoring

The environmental investigation is aimed at the comparison with the defined  $CR_{air}$ . An overall strategy shall be developed to allow the collection of samples being representative of the actual exposure of the workers by both spatial and temporal points of view.

For indoor air the monitoring strategy can be developed referring to the National Institute of Health indications [8]. For outdoor air references are available in the directive 2008/50/EC considering the exposure to pollutants derives from soil or groundwater contamination. Some indications, particularly referring to industrial sites, are reported below.

**Sampling techniques.** Indoor/outdoor air according to specific technical EN standards can be monitored by:

- Personal sampling: the equipment is placed on the employee and samples air in the breathing zone;
- Static sampling: the equipment is placed in a fixed location in the area of concern.

In the cases of our concern the following indications refer to environmental sampling.

**Spatial distribution of sample points.** The number of sampling points is strongly related to the extension of the contamination source. For outdoor air at least one sample per homogeneously polluted area should be planned. In general a point is representative of an area surface of no more than 2500 m<sup>2</sup> (50 m x 50 m) [6]. Where the site is contaminated by hydrocarbons, for which notable concentration gradients are expected, a lower distance (e.g. 10-20 m) is advisable. To define homogeneously polluted areas is possible to refer to the criteria for site area division laid down in the national guidelines for the application of human-health risk assessment [6]. Limiting the search to within 30 metres of the site boundary, except where a preferential pathway (e.g., utility corridor) exists that connects the site to contaminated media further than 30 metres away, is recommended [9]. Where the homogeneously polluted area is large (>5 ha) sampling locations shall be selected by reasoned criteria guaranteeing the entire area to be represented. The sampling devices shall be located where the exposure (detected contamination and workers presence) is



maximum. For indoor air, buildings within 100 feet (30 m) laterally of subsurface vapor sources (or 100 feet vertically of underlying vapor sources) should be considered “near” for purposes of a preliminary analysis, under the assumption that preferential vapor migration pathways are absent [10]. At least one sampling device shall be placed away from the influence of local emissions. To characterize indoor air a sample per each room is not generally needed and a representative room on the ground floor or basement if present, where the exposure is maximum, can be identified.

**Sample and monitoring duration.** Each sample shall go on for a time equal to the daily exposure frequency ( $EF_d$  in Tab. 1) associated to the selected  $CR_{air}$  value. Generally sample duration shall comply with EN 689/1997 standard indications for the determination of shift values, except for specific conditions to be case-by-case assessed. The measurements to determine the environmental concentration should go on for 5-14 days [8]. Measurement campaigns should be at least one during summer and one during winter to appraise seasonal variations related to meteorological conditions and/or cycles of activity. On the basis of the initial measurement results the monitoring plan should be updated. The duration shall be associated to the selected  $CR_{air}$  value, representative of all the possible exposure conditions and particularly of the worst ones.

## 5 Conclusions

This paper illustrates some features of an operational guidance to be published by the Italian Workers’ Compensation Authority (INAIL) to assist the employer or the supervisory authority in the management of the chemical risk to workers in contaminated sites, not still standardized.

A way to identify the presence of a risk to the workers’ health by inhalation of hazardous chemical agents and/or carcinogens/mutagens from contaminated soil or groundwater is provided, to decide if the risk assessment related to these chemical agents, in compliance with the directives 98/24/EC and 2004/37/EC, is necessary. An overall procedure to manage the risk is outlined differentiating three types of workers according to their activities and tasks. The opportunity to differentiate the way to proceed in function of the eventual overlapping of environmental and other occupational exposure has been so far generally neglected in the current practice. The paper focuses then on the criteria to define the reference values for hazardous or carcinogen vapor and suspended particles in indoor and outdoor air ( $CR_{air}$ ) to allow the comparison with the actual measured or estimated values. Where air measurements are carried out monitoring strategies are finally outlined. A plain tool to check the presence of chemical and carcinogen/mutagen agents at work for the inhalation exposure pathway, harmonising the environmental and occupational regulations, is so made available.

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