# Risk analysis for cement and iron&steel factories: from the definition of Best Available Techniques to the environmental compatibility assessment

Giuseppe Genon,[a] Enrico Brizio,[b]

[a]*Department DITAG, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino, Italy. Email: giuseppe.genon@polito.it Tel: 011/5647660*
[b]*Environmental Protection Agency of Piedmont, Via Vecchia di Borgo 11, 12100 Cuneo, Itayl. Email: e.brizio@arpa.piemonte.it Tel: 0171/329266*

In order to establish the environmental acceptability of large technological plants (thermo-electric plants, solid waste incinerators, cement factories, iron and steel plants) it is necessary to evaluate three main aspects, namely emission flux, consequent modification of air quality, transferred dose to population. The first aspect should be evaluated in comparison with the best technologies available for the specific process, the second phase (defined on a local or a regional basis) should be assessed within air quality improvement planning; the third aspect seems in any case the most meaningful and qualifying criterion in order to evaluate the compatibility, as it indicates the real impact on the subject that must be protected. In order to perform the compatibility assessment, it is necessary to identify a pathway leading from emissive flux to imposed dose (corresponding to risk); this approach involves atmospheric dispersion modelling as well as the definition of multimedia transfer mechanisms, from source to receptor.
In the present paper we considered two different plants in Piedmont, NW Italy, an iron&steel production plant and a cement factory, both placed in an alpine zone; the transfer of toxic pollutants through air, fall-out, soil, inhalation, food ingestion has been considered. The sensitivity of results to variations of different parameters has been examined, and it was possible to define the most critical ones, requiring a careful site-specific determination, and the others for which a default estimation seems to be convenient. In conclusion, it is possible to affirm that the multimedia transfer methodology is an effective tool in order to define the environmental compatibility, but its application cannot be carried out without the calibration of many local, site-specific transfer parameters.

## 1. Introduction

Large technological plants emit not only ordinary pollutants (nitrogen oxides, volatile organic carbon, PM), but also specific micro-pollutants, such as dioxins, PCB, PAH, that are usually the crucial point of public concern in the areas where the plants have to be constructed. In order to minimize the negative effects on the environment and chiefly on the exposed population due to these technological plants two verifications should be performed: the first necessary condition is the technological adequacy, that is the application of BAT (best available techniques) and the compliance with law emission limits. After this assessment, it is necessary to take into account the real impact imposed by the technological plant on receiving environment; more deeply, it is necessary to define the pollutant dose imposed to exposed population through all the impact pathway and to compare it to suitable criteria. A positive result for the described second phase can lead to the definition of the definite environmental compatibility that seems to be required in order to avoid suspects about the plant; besides, a positive evidence substantially establish a significant and final approach, that is useful in order to confirm the structural adequacy hypothesis.

A so structured approach could be mandatory when dealing with dioxin emissions; these substances creates large alarm and public concern (this way limiting structure acceptance) because of their high toxicity; the emission of this pollutant chiefly involves concentrated origins and it can be quite easily identified as far as generating source are concerned; consequently, the described approach can be applied to real dioxin sources, and more in the compatibility assessment can be carried out.

The described approach that can be referred to as environmental sanitary risk assessment, is frequently performed by using a modellistic approach, described in details by literature, as can be observed for example in Schuhmacher et al. (2004). In order to avoid a useless formal application, it is necessary that the different calculation steps are considered with the required critical analysis; on the contrary, the obtained result can be considered as a brilliant methodology exemplification, but it doesn’t have any meaning from the substantial point of view.

The present paper is devoted to the explanation and analysis of the applicative problems for the calculation methodology, by taking into account literature results, but also some observations that have been obtained during the application of the risk analysis procedure for two technological plants placed in NW Italy (L. Riceputi, 2007, G. Scibilia, 2007); based on this analysis some perspective indication will be obtained.

## 2. Calculation procedures within risk analysis

The assessment of the exposition to toxic, potentially carcinogenic pollutants, is usually performed by taking into account the following steps:

- emissive conditions analysis, and emitted flux definition;
- identification of exposition ways;
- estimation of media concentrations for exposition through different ways, by taking into account transport mechanisms or equilibrium phenomena;
- assessment of the pollutant assumption through the considered exposition ways.

As a starting point, it is necessary to completely define the emitting source, as concerns flow rate, pollutant concentration, solid phase – gas phase partition, temperature.

Afterwards, the first considered transfer mechanism consists in the atmospheric dispersion; in order to obtain a correct implementation of this procedure step, a careful determination of atmospheric dynamics is required, together with definition of the system orography; in this case, it is important to choose the most convenient dispersive model between many literature indications. Based on the atmospheric conditions, it is possible to forecast wet and dry deposition mechanisms, responsible for pollutant’s soil concentration; anyway, it should be taken into account also the removal phenomena that can occur directly into the soil (J. Nouwen et al., 2001). The wet and dry deposition phenomena are also responsible for transfer mechanisms from air to the exterior vegetation tissues (M. Schuhmacher et al, 2006); on the contrary as far as the soil retained pollutant is considered, it can impact on the sub-soil external vegetation structures, through a root concentration factor (M. Meneses et al, 2002). The following step involves transfer from soil and vegetation to the fat part of meat, milk and eggs; this phenomenon is described on the basis of a bio-concentration factor starting from grass and feed; in a similar manner a bio-concentration factor is defined for soil, to consider its accidental ingestion; for all these fractions it is necessary to take into account a diet fraction, arising from the quantity of the ingested pollutant vector. Similar considerations can be done for the chicken meat and eggs concentrations (Harrad and Smith, 1997), and also in this case it is possible to identify a concentration phenomenon from the feed matrix to the fat receptor tissue.

The last point involves the definition of scenarios for human exposure; it is necessary to define the diet fraction received by receptors starting from food that are originated from the considered territory, and this intake must be added to inhalation and to involuntary soil ingestions. The last exposure mechanism to be considered is the dermal contact pathway, depending on the contact frequency.

The transfer factor so indicated will be discussed in the following chapters.

## 3. Definition of emission and atmospheric dispersion model

As far as atmospheric modelling is concerned, one can easily obtain data such as flow-rate, pollutant concentration, geometric features of emission point, temperature. A fundamental aspect to be considered here is that the general definition "dioxins" contains many congeners are contained, with different volatilities; moreover the solid phase – gas phase equilibrium that is assumed at the moment of emission is then modified in atmosphere depending on temperature and dust concentration of the plume. As a matter of fact, by following a lagrangian approach, the dust concentration of the plume decreases and in general it can be observed also a temperature decrease. As a first hypothesis, it is possible to assume that the system presents an evolution toward an irreversible equilibrium between gaseous and particulate phase; this equilibrium reaches a maximum value corresponding to a critical temperature, and subsequently the established condition is no more modified in atmosphere; as a consequence, the two fractions follow different fates, the first one bound to homogeneous atmosphere mixing phenomena, the second to motion regimes of particles. Figure 1 indicates the partition evolution for 2,3,7,8 TCDD as a function of the ambient temperature: it is possible to observe that the critical partition is deeply influenced by local and time-varying conditions. Based on atmospheric dispersion models, taking also into account the settling phenomenon for the solid phase fraction, it is possible to obtain air concentrations plots, as well as wet and dry depositions; Figure 2 reports air concentration maps at the ground level for a plant placed in Piedmont in a valley area; there one can notice the important effect of topography on concentration outputs.

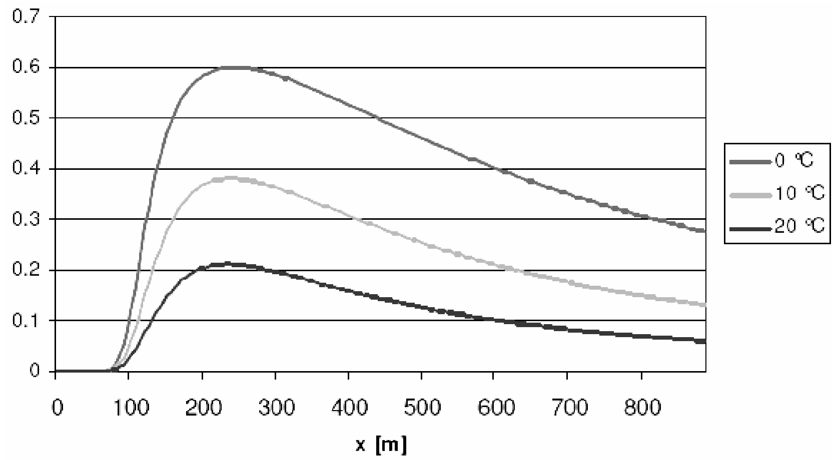


Figure 1: Dioxin fraction on particles as a function of distance from stack and ambient temperature

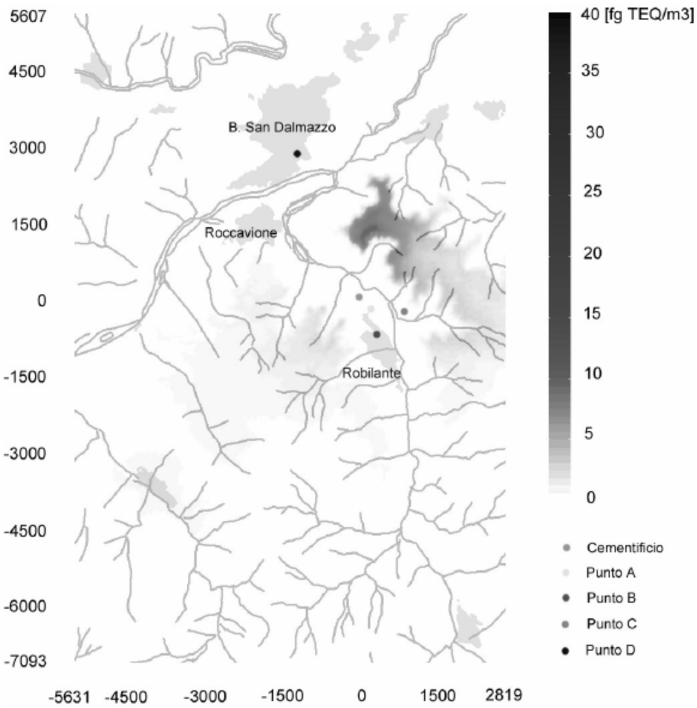


Figure 2: Calculated air concentration of dioxins close to a cement factory

Figure 3 reports an example of soil deposition (wet and dry) that is strongly determined by local precipitations and dust granulometry. The air concentration and soil deposition maps can be compared to experimental data that in some cases are at disposal in order to validate and calibrate the procedure. For example, one could compare the distribution of different congeners and their gas-solid partitions respectively at the emission and for ground level concentration, or in settled materials; the level of agreement between the determined profiles can lead to a confirmation of a possible influence of specific sources with respect to background situations.

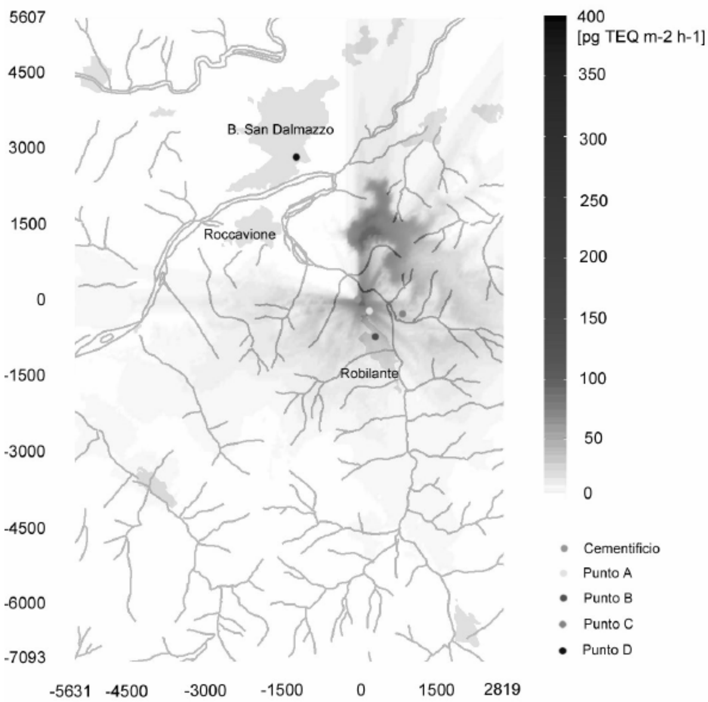


Figure 3: Calculated wet and dry deposition of dioxins close to a cement factory

## 4. Soil, vegetation, food concentrations

The soil concentration depends on dioxin deposition phenomena and different removal phenomena; the mixing height of soil is a parameter of great interest, based on its destination; in fact it is possible to observe variations from a few centimetres for natural soils to 20-30 cm for cultivated soils, influencing the final concentration of the media.

Another important aspect involves the dioxin decay phenomena in soil, depending on both physico-chemical and biological kinetic aspects; some default data can be found within literature, but their reliability should be established by experimental assessments.

The partition between soil and root concentration for different plants is usually described by equilibrium condition instead of an evolution as a dynamic enrichment; for the equilibrium coefficient very large variations can be observed, for different plants also the order of magnitude can change, leading to substantial differences on plant concentration.

The dioxins can be transferred also to plant tissues that grow externally from the soil, due to particles' sedimentation (taking into account also the washing mechanism deriving from meteorological phenomena) and the foliar adsorption (bio-transfer). Also in this case it is possible to find literature values for the abovementioned transfer coefficients, but it is possible to recognise large variation possibilities from one case to another (also the magnitude order can vary). As far as different foods (cow meat, milk,

chicken meat, eggs) are concerned, bio-concentration factors have been defined, starting from soil, grass, feeding materials, but also in this case very different values for different applications can be observed.
As a conclusion, in order to define the concentration ranges in the last media two main critical aspect have been observed, even though the transfer mechanisms are clearly individuated:

1) in some cases the indicated models are pseudo–equilibrium models, that are characterised by a bio-concentration factor, and based on this factor a static relationship between the two environments is established; in comparison, it is possible to take into account different feeding and removal mechanisms through different environments; the two hypothesis are probably schematic representations of the same more complex phenomenon, where the second representations take into account the transitory phase, the first ones the asymptotic value;
2) de-fault values for the above-mentioned considered mechanisms can be suggested, together with variation intervals, but without verification it is impossible to establish if they correspond to the considered case.

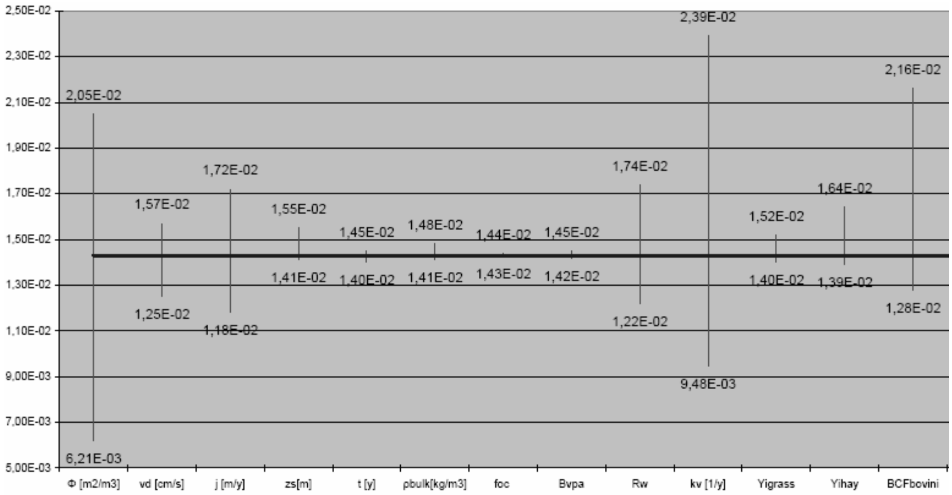

Figure 4: Influence of different parameters on the statistical distribution of daily intake

Figure 4 reports the influence of different parameters on the statistical distribution of daily intake (this parameter will be defined in the next paragraph). It is possible to observe that the parameters that mostly influence the daily intake are (decreasing order of importance): ambient temperature, specific particles area, soil removal kinetic constant, cow bio-concentration factor, yearly average rain intensity, dry deposition velocity, retention of wet deposition on plants. For some parameters that are strongly dependent on the local conditions the strict dependence requires a site-specific calibration; on the contrary for others, that are more difficult to be experimentally determined in account of the considered transfer mechanism, it is evident the need for a deeper investigation, by using directed experimentations.

## 5. Exposition ways and dose determination

The dose to receiving population can be calculated as the (lifetime) average daily intake (mg/day per kg of body weight) on the basis of the described media concentration (soil, water, air, animal, vegetables). The exposure pathways are:

- inhalation: based on daily breathing rate (usually a well known parameter), air concentration, that has previously been discussed, and time percentage that is spent in the indicated location; the last parameter, strongly influent on the final result, can present highly varying values in connection with different life styles of the exposed population; for this reason it is a very critical point of discussion;
- soil ingestion and dermal contact: data concerning, soil dermal contact and ingestion rates, and also information about absorption factors, are usually at disposal; but also in this case the life style, the performed activities, the contact frequency and time length can be extremely different, and so they can have a strong influence on the final result;
- food ingestion: in this case we have good information about body absorption factors; on the contrary it is very difficult to estimate the frequency factor, corresponding to the percentage of contaminated food, compared to the total quantity of ingested food; because of the great importance of this mechanism, it is possible to use conservative values, by considering high percentages of "food autarchy", but the soundness of this hypothesis, and the limits of it, must be deeply discussed.

The calculated dose leads to risk definition by using the well-known dose-response correlations, both for carcinogenic and toxic substances; this last part of calculation seems in any case to be solely a mathematical exercise, taking into account that all the elements that have been collected in the previous dose definition. By using a Monte-Carlo simulation analyses on the different rates that are included in the exposure pathway, it is possible to build a probabilistic risk distribution, but the confidence that can be assigned to the risk values is a strict function of the actual estimation of the true values for the different transfer steps that are considered in the calculation procedure.

## 6. Conclusions

The environmental risk evaluation procedure that has been presented seems to be a correct approach in order to rationally define the environmental compatibility of a proposed technological structure: moreover many application examples can be found in pertaining literature, besides to a clear model explanation and description.

Nevertheless, there are large fields of low knowledge, and therefore an automatic system application seems to be a mystifying procedure; in particular, two main problems can be observed: first of all the transfer mechanisms through the natural compartments (air, soil) and the eco-system (vegetation, animals) should be partially defined, as they are strongly site specific; on the other hand, the dose involving exposed population is strongly dependent on its habits, life styles and expositions frequency rates. Based on this reasoning, even though this part of calculation seems to be more linear in comparison to the previous multiphase transfer aspects, it is even more deeply influenced by statistic variations, referring to sociological, and also nutritional aspects.

In order to give an higher reliability to the application of the described procedure, we think that three points should be deepened:

- experimental comparison of measured and calculated values for air concentrations, wet and dry depositions, soil concentrations; this assessment aims at calibrating the dispersion mechanism within the specific environment;
- experimental studies (Welsch-Pausch and McLachlan, 1998) of the model aspects and the parameters influencing multimedia transfer in the different eco-system components, in order to arrive to a better defined and more quantitative description of phenomenon; the analysis should be carried out on a entirely local scale, but in some cases the results can be extrapolated and used to other local situations;
- statistical evaluation of the exposed population habits, including food ingestion, exposition times to different pollution conditions, contact circumstances with different polluted media.

As a conclusion, the individuated procedure seems to be interesting and useful, but by sure very difficult; it requires information deriving from interdisciplinary analyses; in order to obtain a rationally based compatibility assessment, while avoiding formal solution, there aren't any other possibilities.

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