



# Application of Environmental Forensics in soil contamination

Methods and a case study

By  
Carlo Monti, Ph.D.  
Exponent International Ltd  
Basel, CH

# Short bio

- Senior managing scientist at Exponent International Ltd, Basel office
- 17 years at Battelle Memorial Institute
- Ph.D. in Ecological Sciences (many years ago!)
- Involved in the major environmental disasters:
  - ILVA, Taranto\*
  - BP Mexico Gulf accident
  - Arkema, France\*
  - Caffaro, Brescia\*
  - Prestige disaster, Galician coastline, Spain
  - Mozzarella cheese dioxin study, Campania, Italy\*
  - Lake Maggiore DDT disaster, North Italy
  - River Mincio Hg and dioxin study, Mantova, Italy\*
  - Venice Lagoon POP studies, Venice, Italy\*
  - ... And many other
- \*indicates a PCDD/F fingerprint study



# Introduction

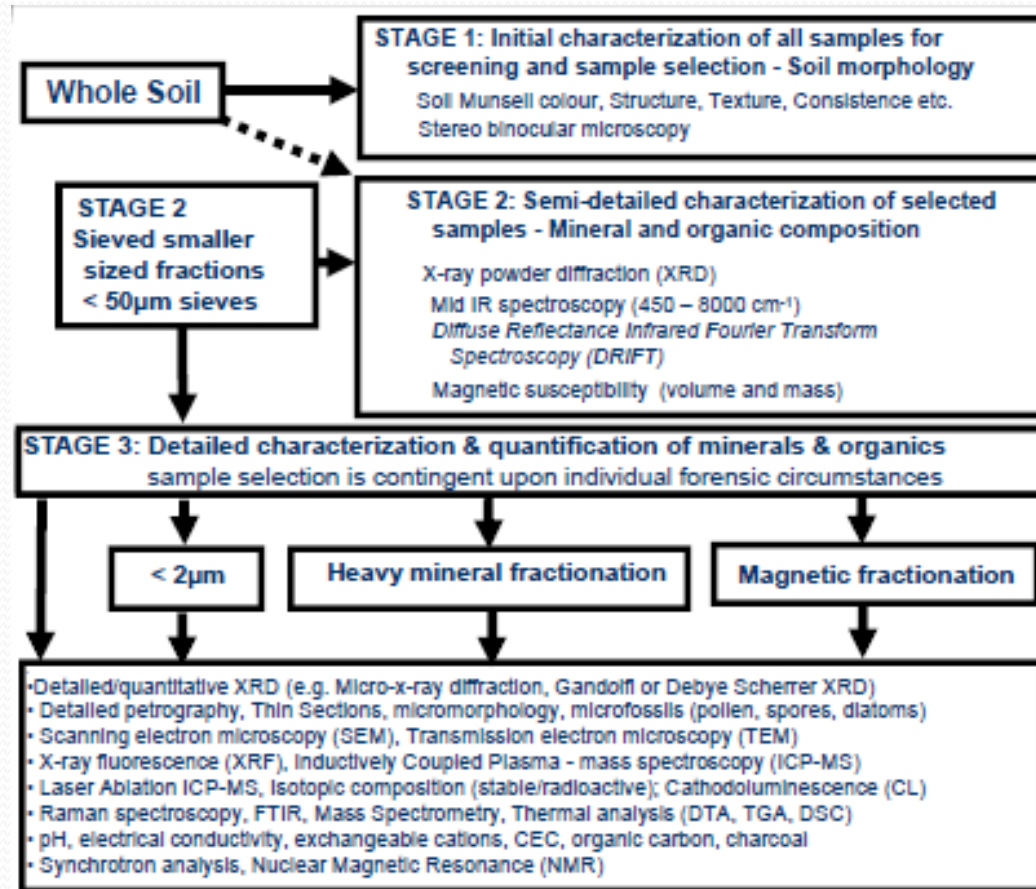
- Scope of the presentation
  - Give a short introduction to soil forensic methods and phylosophy
  - Give an example of their application to a real case
- Contents
  - General analytical methods
  - Statistic
  - A general though about soil science and health
  - Presentation of a real case (Brescia, North Italy, dioxin study)

# Methods

- **Forensic soil science is the science or study of soil that involves the application of soil science. In particular, studies or investigations that involve:**
  - soil morphology,
  - soil mapping (assisted by existing soil maps and spatially held soil data),
  - Mineralogy
  - Chemistry
  - Geophysics
  - biology and molecular biology
- **...to answer forensic legal questions, problems or hypotheses**



# Methods – general scheme



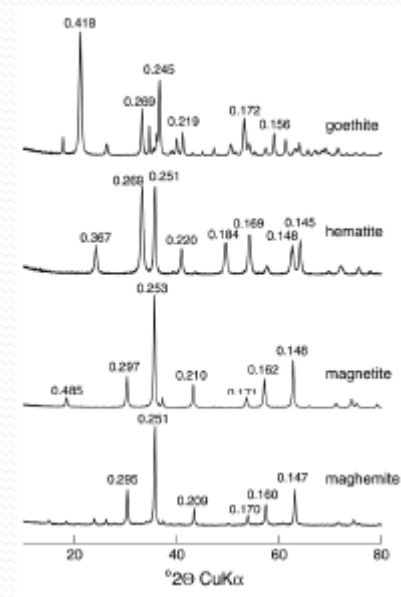
From: Fitzpatrick R.W., and Raven M.D. (2010). Guidelines for Conducting Criminal and Environmental Soil Forensic Investigations: Version 1.1. Centre for Australian Forensic Soil Science. Report No. CAFSS\_076. 26th September 2010. 28pp.

# Methods - geological

- **Colour**
- **Texture**
- **Structure**
- **Consistence**
- **Cristallography**

# Methods - chemical

- X-ray diffraction
- Spectroscopy
- Gas Chromatography
- Double HGMS
- Many other methods
- !!Extremely important:  
enforce a very strong QA/QC  
procedure to be applied to all  
the soil forensic soil steps!!



# Methods - biological

- Microbiology (for example bacteria DNA and RNA studies)
- Bacteria community typization
- Fungi community study
- Algae community study
- Vegetation study
- SEM



# Statistical approaches

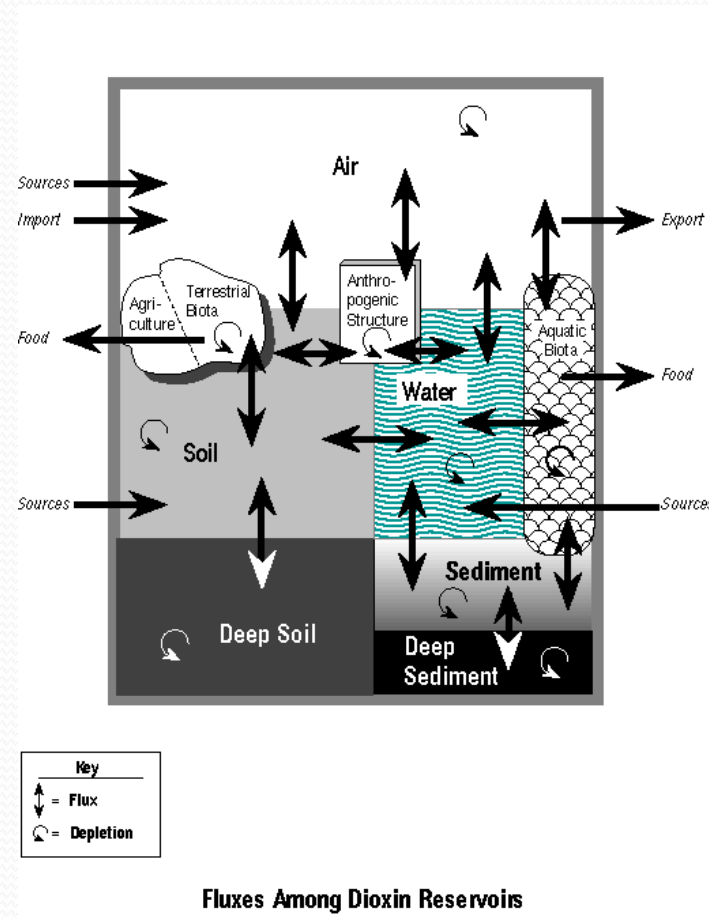
- Normal statistical approach
- Non-parametric tests
- Multivariate methods (PCA, Clusters etc.)
- Peak resolution analysis and other similar approaches
- Six sigma
- Bayesian statistics
- Kriging and other geostatistic
- Data mining

... and other non conventional approaches like visual confrontation!!!!

# Soil and health – the new frontier of the forensic approach

- Many of the western enforced soil laws are risk based
- The concept of the risk type approach is a tool (very conservative) to take decision about different levels of clean up
- Behind the risk concept there is the acceptance that there is a bill to pay to sustain our welfare
- This concept is actually in discussion in many western country due to the fact that, socially, health is considered more important than welfare (we could discuss this point)
- A new epidemiological approach is growing trying to link the environmental quality to the health
- Soils are considered one of the major responsible as they are the reservoir of many contaminants
- Epidemiology may become shortly the new key for defining responsibilities in soil pollution (and in soil forensic)

# Soil and health – the conceptual model



# Soil and health – which models?

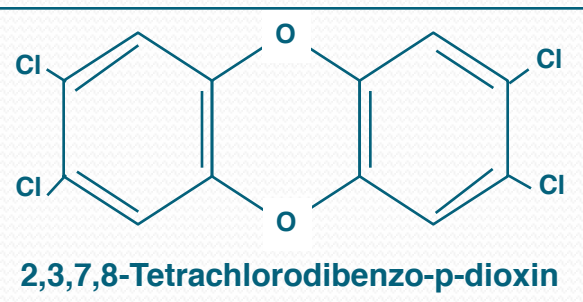
- The models included in an RBCA type approach are not usefull in this new approach
- The soil vs health approach needs more sophisticated models and much more on-site data
- New types of sampling strategies are required together with a new type of risk approach; it has to include many more variables than a RBCA approach.
- It will imply the definition of new targets to confront the data with. They will be based on heath epidemiological data

# The Brescia dioxin case

1. The industrial area of Brescia is one of the oldest industrial areas in Italy and in Europe
2. It has hosted very large and different types of companies in years where the protection of the environment and of the human health were not the most important things. The development of the business and welfare were the most important things
3. Many heavy industries, mostly in the metallurgical and iron end steel area, have been hosted in Brescia industrial area
4. At the beginning of the last century the industrial area were well outside the city; starting from the '60s the city started to surround the industrial area
5. An old agriculture activity has surrounded the industrial area since its establishment and has been carried on until 2000
6. In Italy the first specific environmental law has been enforced in 1974 and was the so called 'Legge Merli' for the protection of freshwaters. Its application has been delayed until 1984. The concentration limit for PCB (as total) was 5 mg/L which is higher than PCB solubility in water

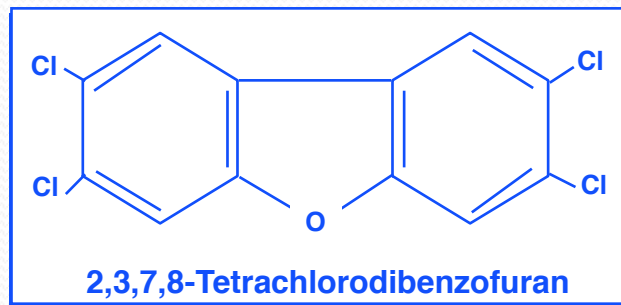


# Dioxin-Like Compounds



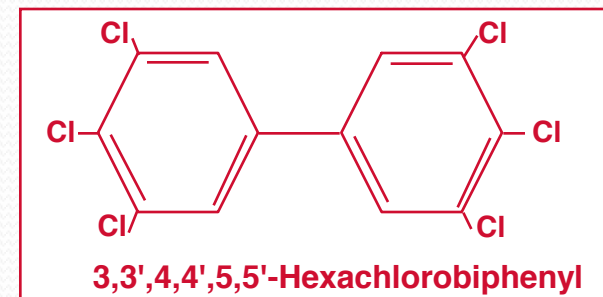
**Dioxins**  
75 congeners  
7 toxic

2,3,7,8-TCDD  
1,2,3,7,8-PeCDD  
1,2,3,4,7,8-HxCDD  
1,2,3,6,7,8-HxCDD  
1,2,3,7,8,9-HxCDD  
1,2,3,4,6,7,8-HpCDD  
1,2,3,4,6,7,8,9-OCDD



**Furans**  
135 congeners  
10 toxic

2,3,7,8-TCDF  
1,2,3,7,8-PeCDF  
2,3,4,7,8-PeCDF  
1,2,3,4,7,8-HxCDF  
1,2,3,6,7,8-HxCDF  
1,2,3,7,8,9-HxCDF  
2,3,4,6,7,8-HxCDF  
1,2,3,4,6,7,8-HpCDF  
1,2,3,4,7,8,9-HpCDF  
1,2,3,4,6,7,8,9-OCDF



**PCBs**  
209 congeners  
12 toxic

3,3',4,4'-TeCB  
3,3',4,4',5-PeCB  
3,3',4,4',5,5'-HxCB



# Dioxin-Like Compounds

- Semivolatile
- Lipophilic
- Hydrophobic
- Persistent
- Bioaccumulating
- Toxics

# Trace Levels --- Highly Toxic

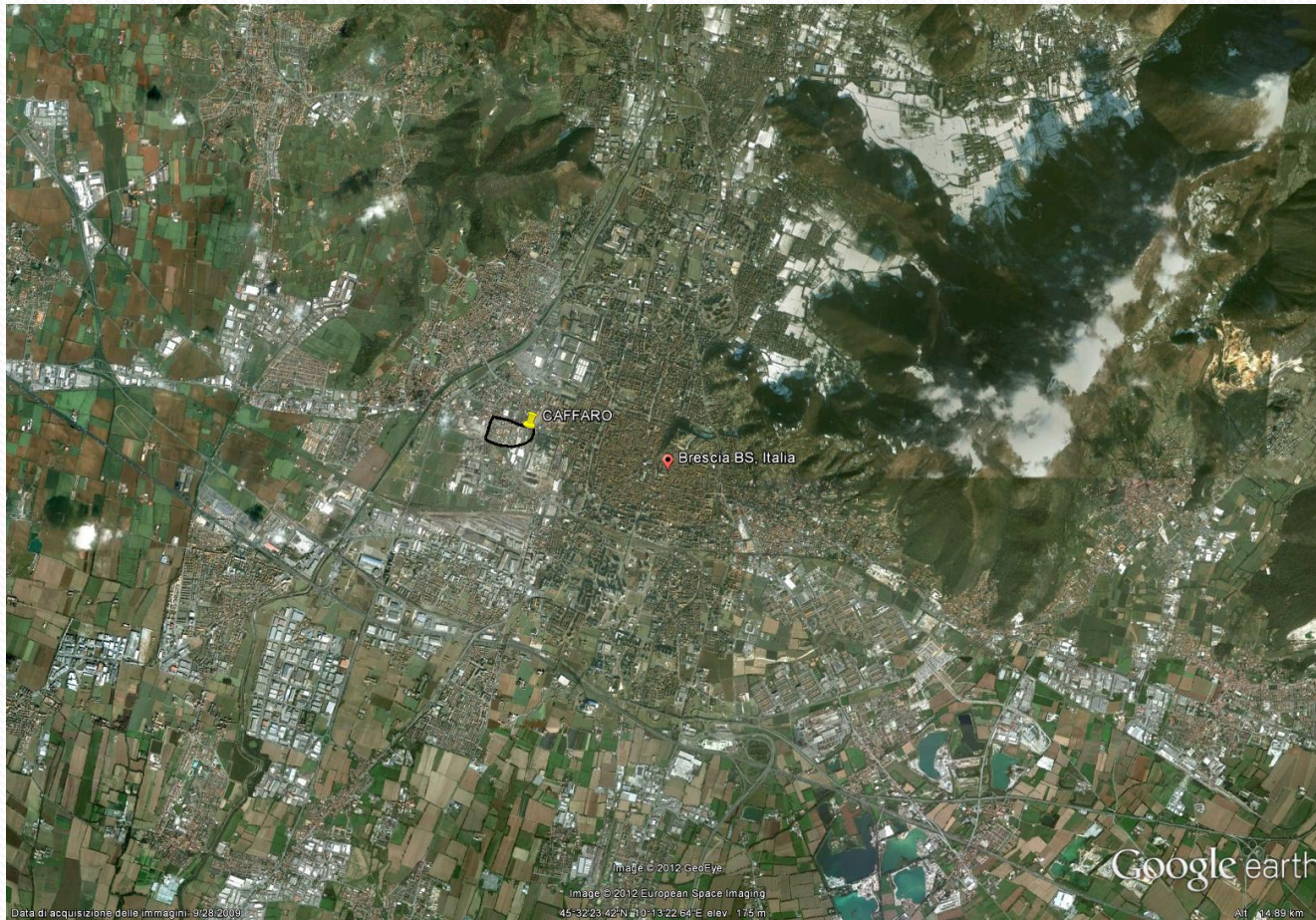
- Soil, Food --- PPT
- Water --- PPQ
- Air --- fg/m<sup>3</sup>
- Human Serum ---PPT
- Intake --- 1pg/kg/d TEQ
- Upper Bound Cancer Risk  $1 \times 10^{-3}$
- Non-Cancer MOE < 10

# The Brescia dioxin case





# The Brescia dioxin case





# The Brescia dioxin case

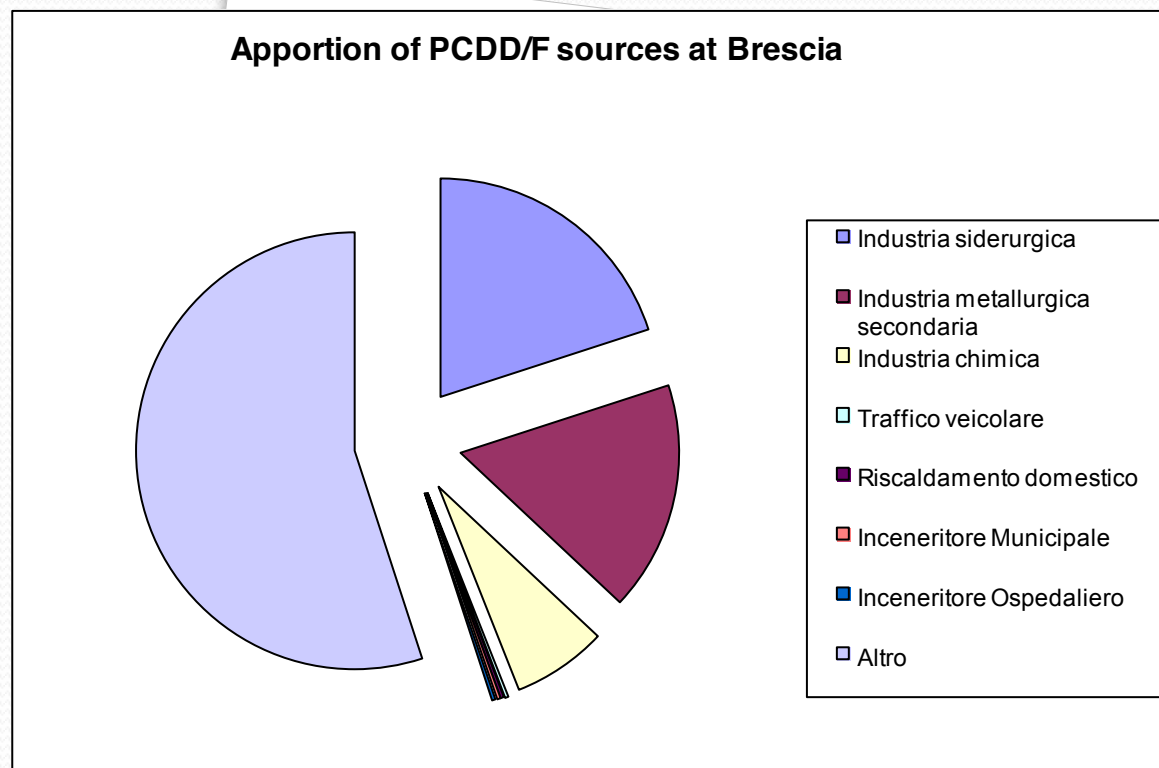


# The Brescia dioxin case

- The chemical plant begun its activity at the beginning of the last century (1906)
- The main productions have been different types of organic chlorinated compounds included:
  - Chlorobenzenes
  - DDT
  - PCB
- Beside the production of PCB, the company has managed for years an activity of recovering the PCB oil from transformers.
- The company has managed since the '30s a chloroalkaly plant; the technology employed was the mercury cell. The plant has been dismissed in the '90s.



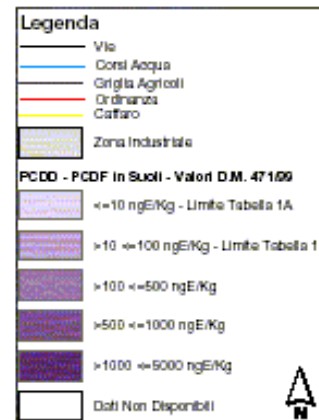
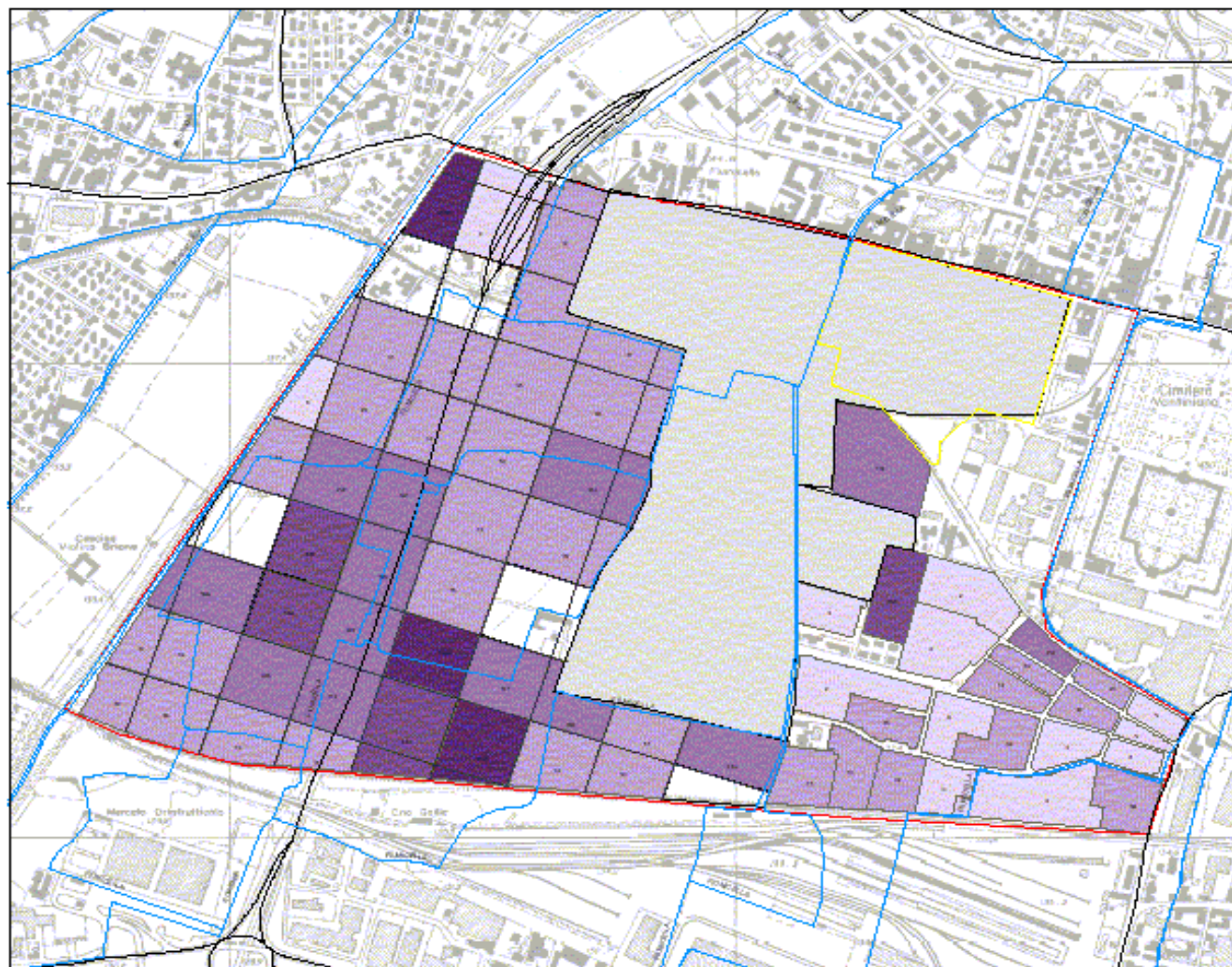
## The Brescia dioxin case



# The Brescia dioxin case

- The scopes of our job were:
  - Identify the responsibility of the company as related to the PCDD/F soil pollution outside the plant
  - Identify other possible responsibilities
  - Identify if the responsible of the PCDD/F found in the sediment of the agriculture canals
  - Perform a RBCA Level III risk assessment on the soils at the plant
- The data
  - The PCDD/F concentration data included:
    - Soils inside and outside the plant
    - Sediments of the canals
    - Air dust
    - Vegetables
    - Human blood and human breast milk
    - In 2005 about 500 samples analyzed
- The statistical approach
  - We used a multivariate statistical approach to analyze the data

# Mappatura PCDD - PCDF in Suoli Ordinanza

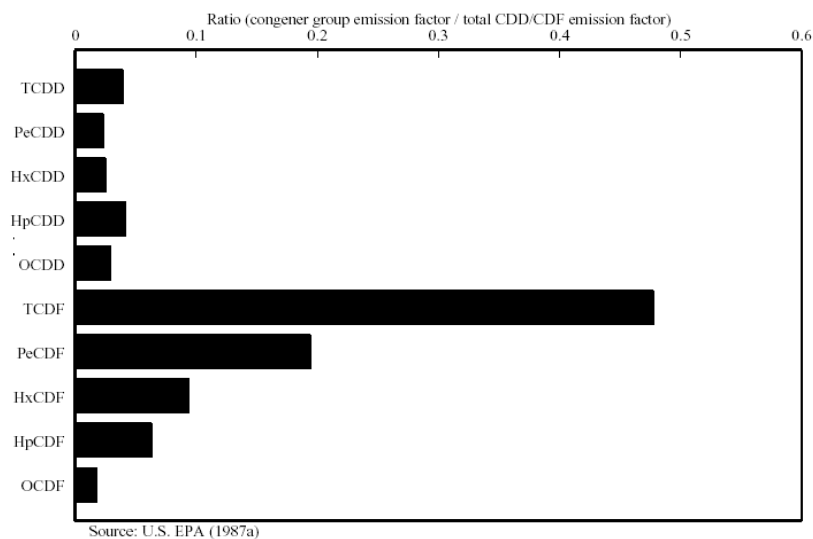


05			
04			
03			
02			
01			
Prima Emissione			
DATA	19/10/02	COMUNE	Lussignea
PCDD		CAPO	Capretti
Mappatura PCDD - PCDF Suoli Ordinanza			

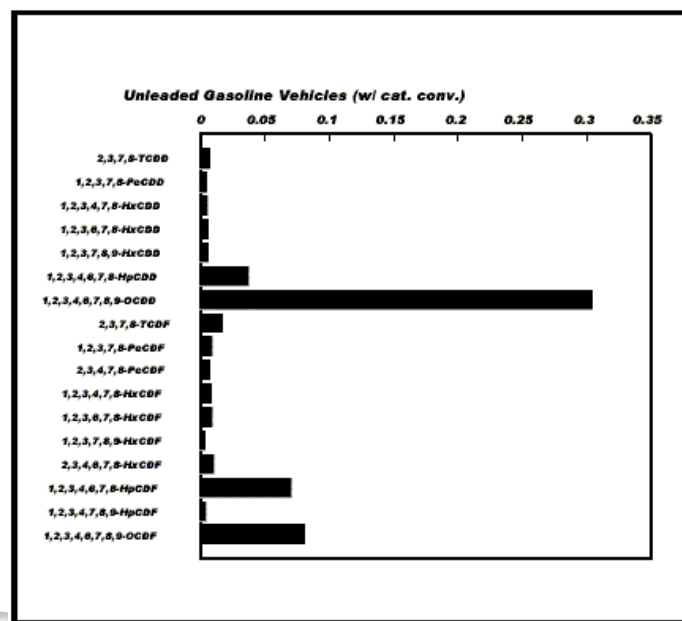
# The Brescia dioxin case

- The fingerprint
  - The fingerprint is characteristic of each activity that produce dioxins
  - There are many typical fingerprints published by different authorities
  - In the normal world the actual fingerprint is determined by the overlap of different sources
  - The apportion is normally done by confrontation
  - The fingerprint is defined without the transformation of the congeners in I-TEQ

## The Brescia dioxin case - fingerprints

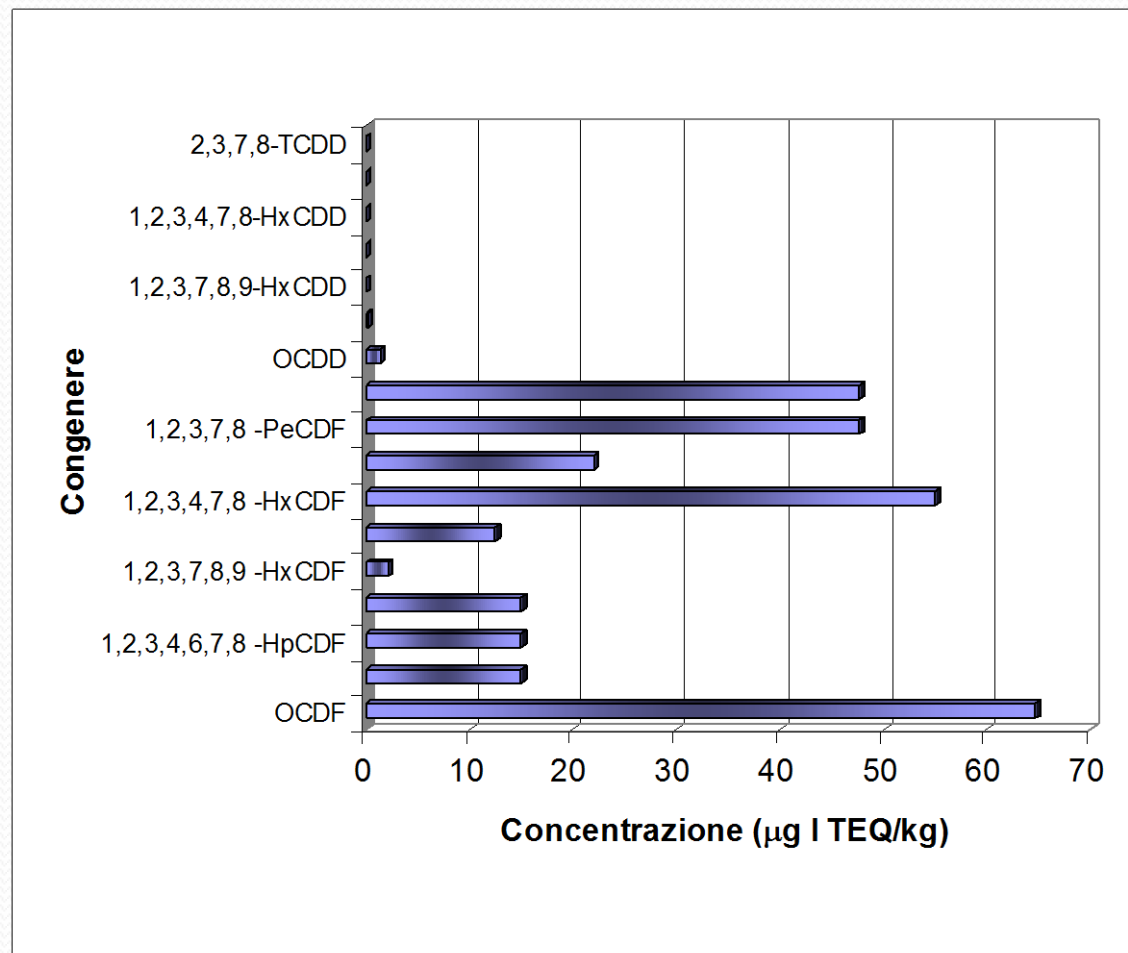


Iron and steel sintering plant



Diesel truck

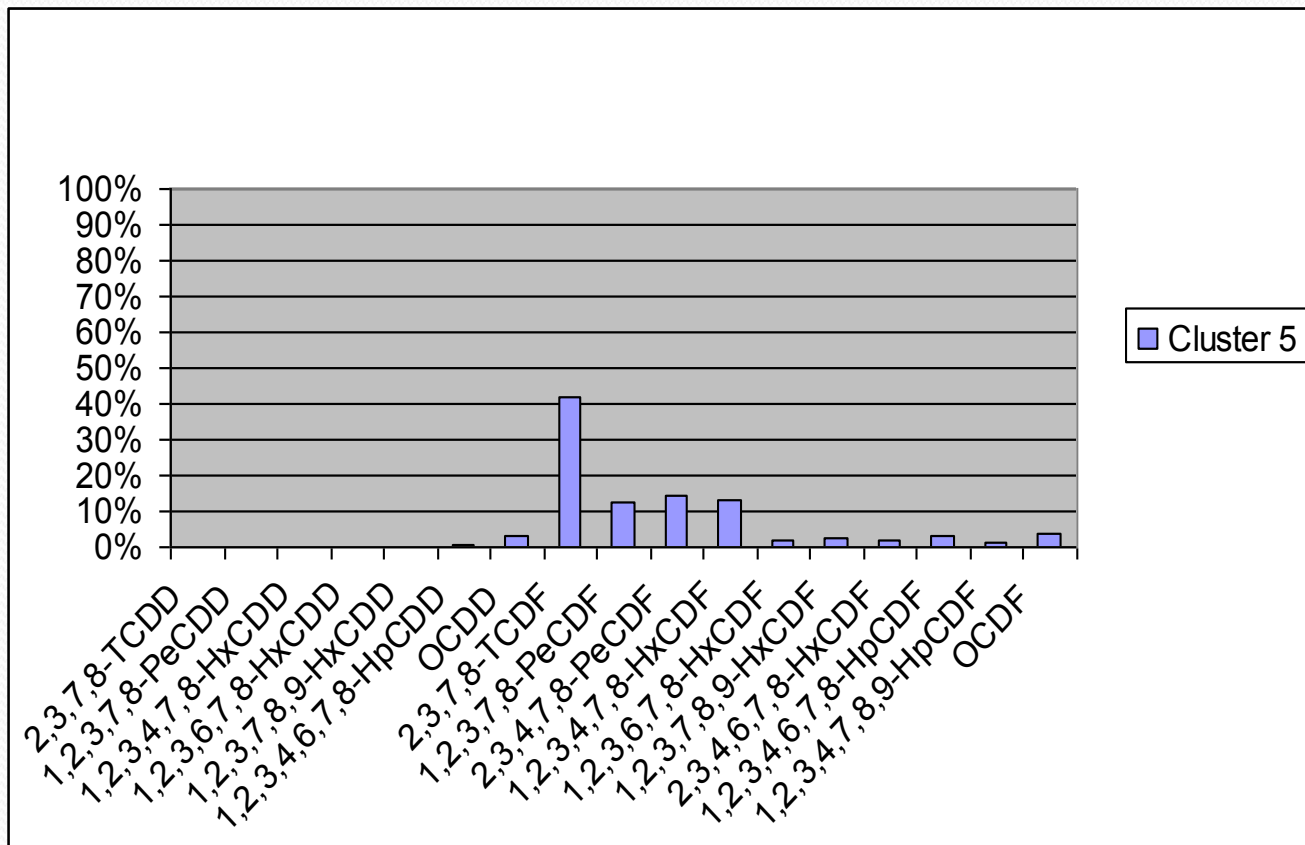
## The Brescia dioxin case



PCB production fingerprint

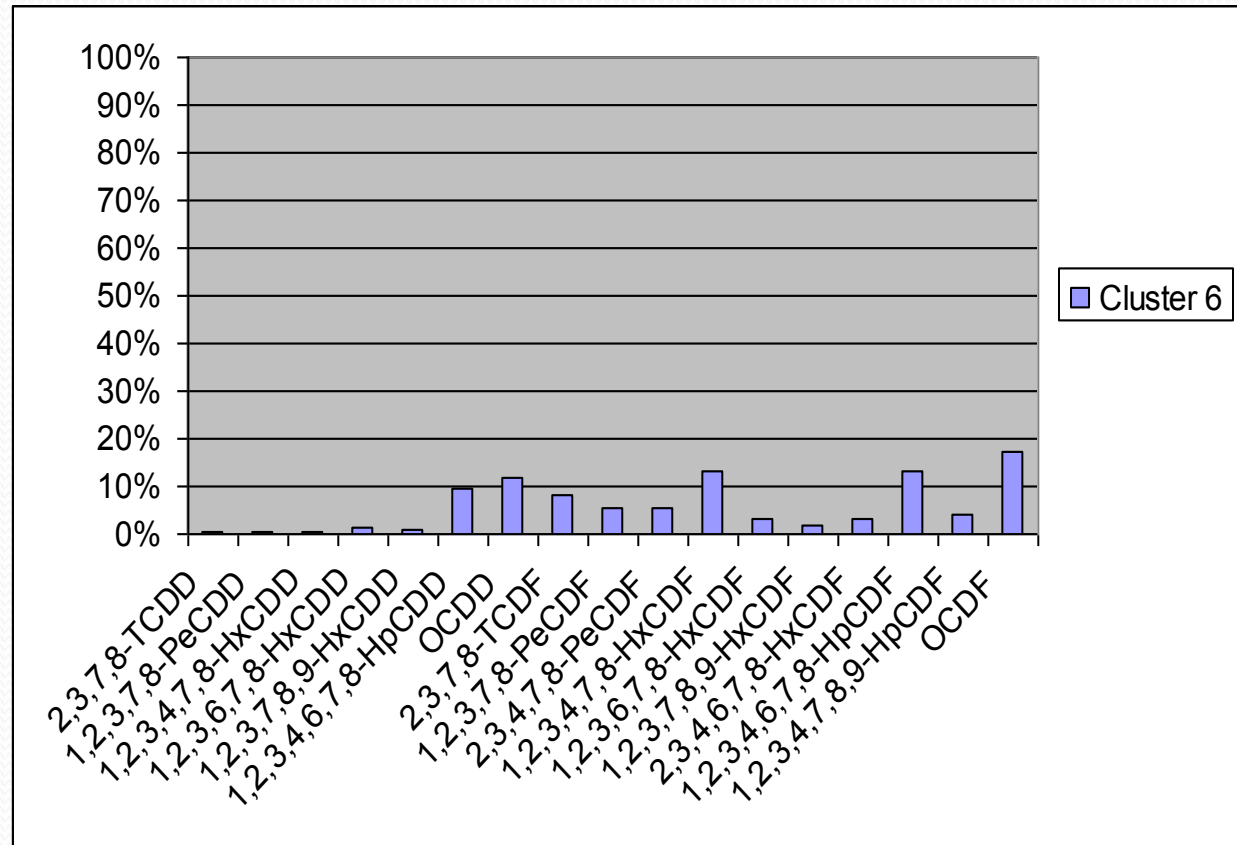


## The Brescia dioxin case



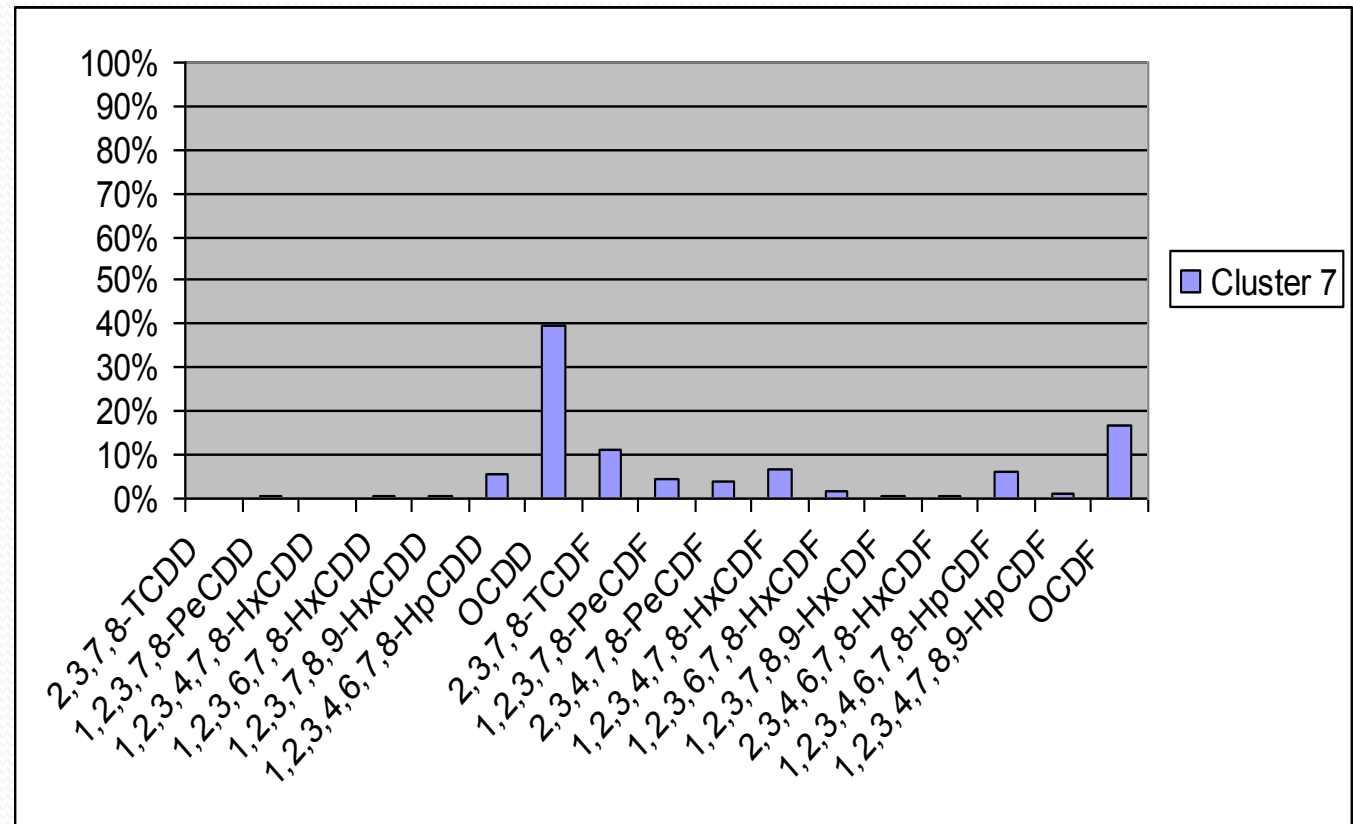
Cluster 5: 8 external points, 4 internal points

## The Brescia dioxin case



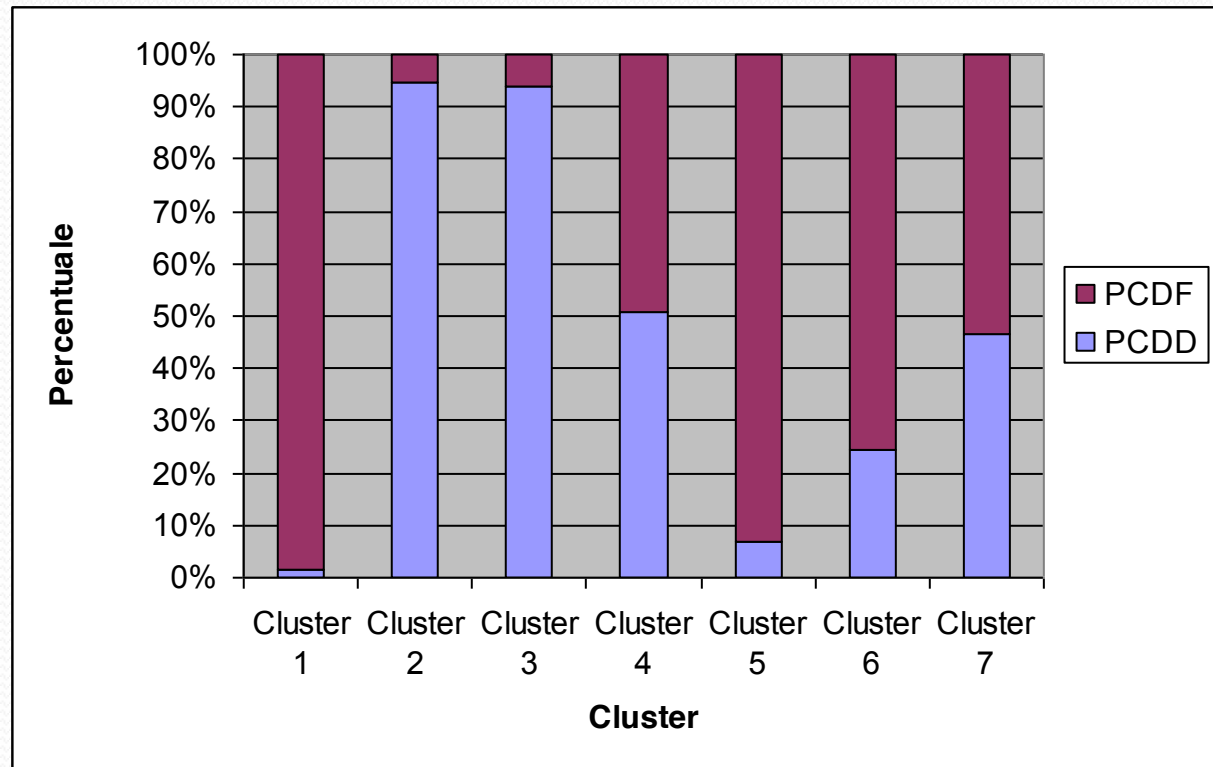
Cluster 6: 9 internal, 17 external

## The Brescia dioxin case



Cluster 7: 5 internal, 63 external

## The Brescia dioxin case



Ratio PCDD /PCDF of the seven clusters

# The Brescia dioxin case

- The responsibilities of the pollution have been identified
  - Qualitatively by using the fingerprint analysis
  - Quantitatively by the estimation of the PCDD/F amount released for each industrial and civil activity
- The clean up of the site and of the surrounding areas is still pending

The end



Thank you for your patience!  
Any question?

Carlo Monti  
Senior Managing Scientist  
Exponent International Ltd  
Aeschenvorstadt 57  
4051 Basel, CH  
cmonti@exponent.com