





"Un seul métier, L'environnement Atmosphérique"

Health risk assessment related to atmospheric emissions at an industrial zone.

Case study :

An industrial zone in Dunkirk, FRANCE



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Project coordinator

- Data collection
- GIS database management
- Maps production
- Final Report



Emissions

- Industrial Emission Inventory



Health Risk Assessment

- Hazard identification
- High Risk population identification
- Health Risk

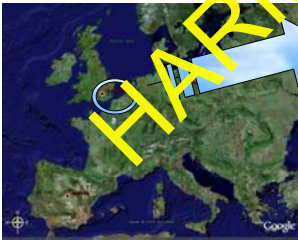
Why a risk assessment on Dunkirk area ?



- **To present a state-of-the-art population exposition study 'limited' to**
 - Air pollution
 - Direct industrial releases
- **To build and make an enhanced tool available to the SPPPI to quantify and follow the trends of health impact due to industry**
 - SPPPI : « Secrétariat Permanent des Prévention des pollutions industrielles » : Consulting and Dialogue structure including local councilors, local environmental organization, non governmental / green association. The SPPPI are driven by the government (DRIR)
- **To validate a methodology to be generalized to other industrial zones of the Region**

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The industrial zone of Dunkirk

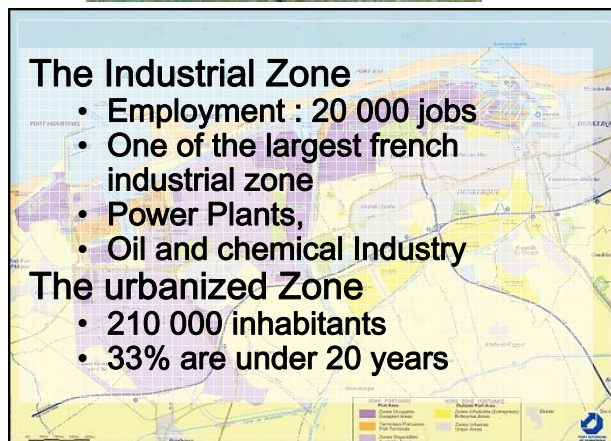


The Industrial Zone

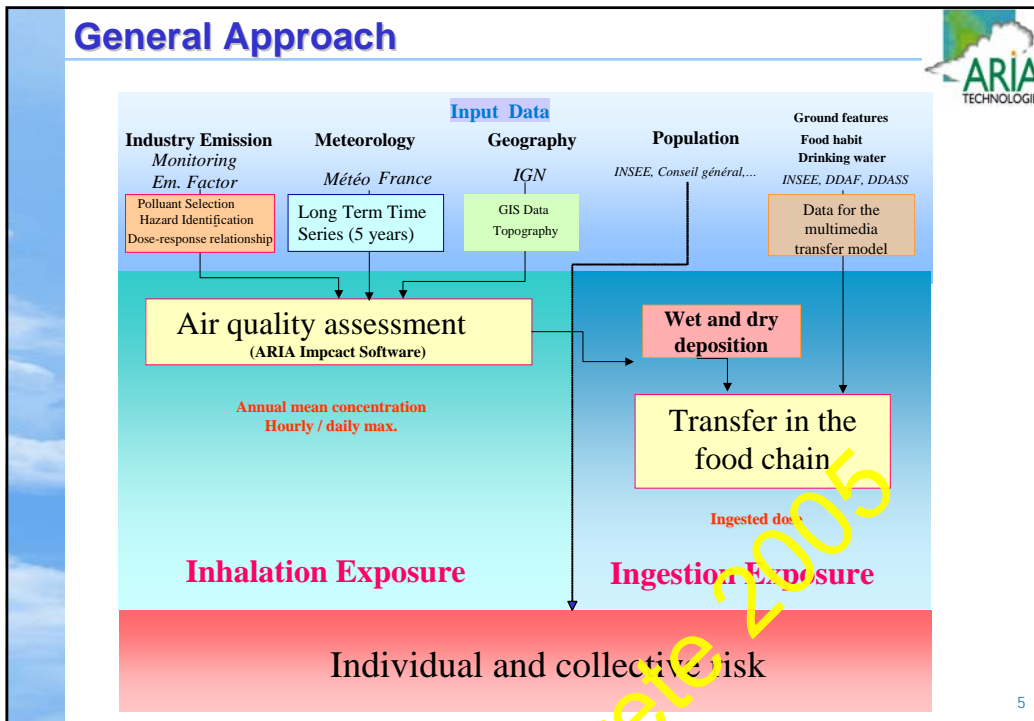
- Employment : 20 000 jobs
- One of the largest french industrial zone
- Power Plants,
- Oil and chemical Industry

The urbanized Zone

- 210 000 inhabitants
- 33% are under 20 years



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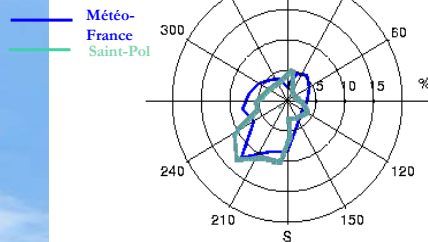
Site

- Domain**
 - 700 km² (50 km x 35 km)
 - Resolution : 250m
- Geographical Data**
 - Topography : IGN
 - Meteorology (6 years hourly) : Météo-France / OPAL'AIR
 - Population : Census of sensitive population

The site is located in the Dunkerque region, as shown in the map. The wind rose diagram (ROSE GENERALE) indicates the prevailing wind directions and frequencies.

ARIA TECHNOLOGIES logo is present in the top right corner.

Meteorology



Source : Météo-France
Source : Saint-Pol (OPAL'AIR)

Representativeness of the met. Time series : Comparison with the meteorological data of the « reference » meteorological station with others available data)

	Saint-Pol	Météo-France
Mean Speed (m/s)	5	6
Calm wind (<1m/s)	<2%	<2%
Prevailing direction	South	south
Mean Speed stable cases (m/s)	3	3
Mean Speed neutral cases (m/s)	7	7

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Industrial Emission



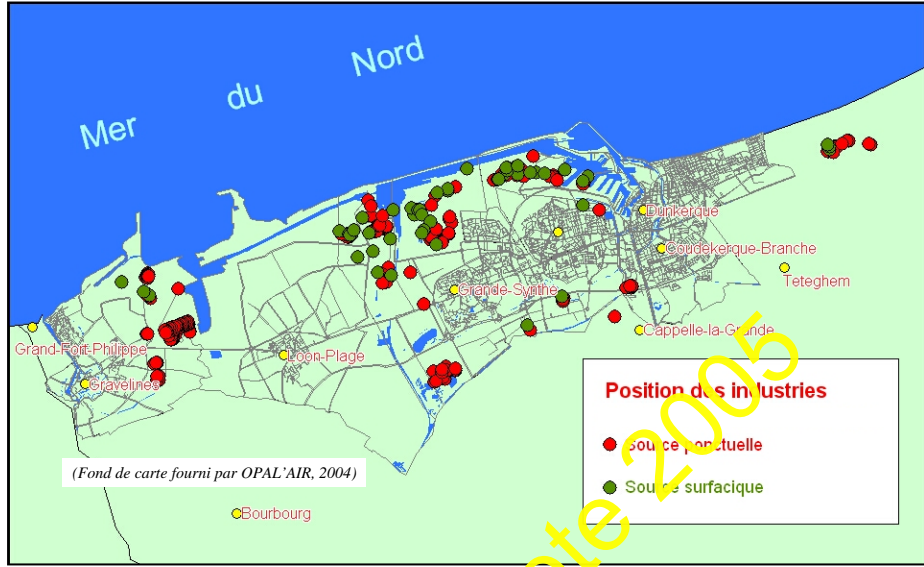
- Methodology.
 - a common questionnaire
 - Site visit
 - Confrontation vs regulatory declaration
- Results
 - 25 sites → 293 significant releases
 - Exact position (LII)
 - Stack Height and diameter
 - Release speed and temperature
 - 16 pollutant species
 - 2002 emission rates

Company	Activity
AIR LIQUIDE	Gas Production
AJINOMOTO	Chemistry industry
ALUMINIUM Dunkerque	Metallurgy
ASCOMETAL	Metallurgy
ASTRA-ZENECA	Pharmaceutical Ind.
BASF	Phytosanitary Ind.
BORAX	Petrochemistry
BUS VALERA	Metallurgy
COMILOG	Metallurgy
DALKIA	Energy
DAUDRUY	Oil factory
DPC	Hydrocarbure Storage
EDF	Production d'énergie
GTS (Sollac)	Metallurgy
LAFARGE	Cement factory
LESIEUR	Oil factory
POLIMERI	Craquage d'hydrocarbures
RDME	Metallurgy
REXAM	Metal boxes ind.
RINGO	Déshydratation de chicorée
RUBIS	Dépôt d'hydrocarbures
SOLLAC AtI Arcelor	Metallurgy
SOLLAC Mardyc	Metallurgy
SRD Raff	Refinerie
TOTAL	Refinerie

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Industrial Emission

Emission sources and local air quality network : OPAL'AIR



Hazard identification



- Existence of a Health Risk
 - Risk of cancer
 - Risk for specific organs or system (liver, nervous central system, etc...)
 - Risk for reproduction
- Existence of Health Risk linked to permanent exposure
- Existence of dose-response relationships

Species	Risk with threshold		Risk without threshold	
	inhalation	ingestion	inhalation	ingestion
1,3-butadiene	x		x	
arsenic		x		x
benzene	x		x	
benzo(a)pyrene			x	x
cadmium	x	x	x	
chromium VI	x		x	
chromium III		x		
dioxines		x		x
Sulfur dioxyde	x			
manganese	x			
mercury		x		
methylmercury		x		
nickel	x	x	x	
Nitrogen dioxyde	x			
Lead	x	x		
toluene	x			
xylenes	x			

Hazard identification



- **Respirating system** : 1,3-butadiene, cadmium, chromium, SO₂, nickel, NO₂ and xylenes
- **Brain and Nervous Central system** : arsenic (non-organic), manganese, mercury, lead, toluene and xylenes
- **Renal system** : cadmium, mercury and lead
- **Cardiovascular system** : 1,3-butadiene, arsenic (non-organic), benzene, nickel, lead and xylenes
- **Hepatic system** : xylenes
- **Skin system** : arsenic (non-organic), chromium III
- **Bone and digestive system** : lead, chromium
- **Cancer** : 1,3-butadiene, arsenic (non-organic), benzene, benzo(a)pyrene, cadmium, chromium VI, nickel and dioxines

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EVALUATION OF HUMAN EXPOSURE



• Inhalation :

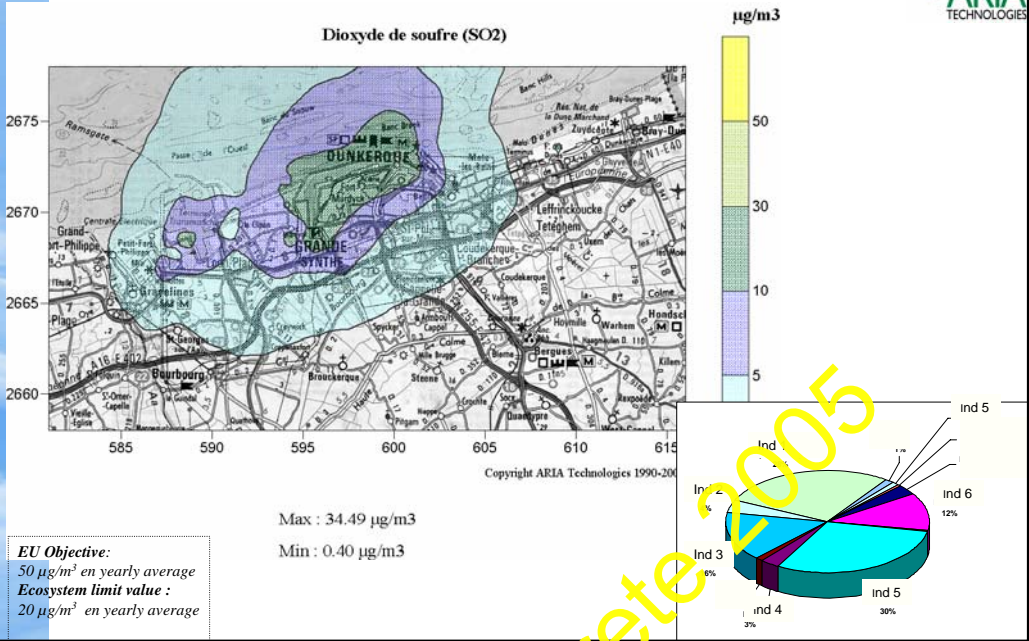
- ➡ **Yearly Average pollutant concentration in each cell**
(ARIA Impact Software)
- ➡ **Percentile 98 and more for cell concentration**
(ARIA Impact Software)

• Ingestion :

- ➡ **Yearly dry and wet Deposition computations**
(ARIA Impact Software)
- ➡ **Multi-media Transfer**
(Modified version of CALTOX 2.3)

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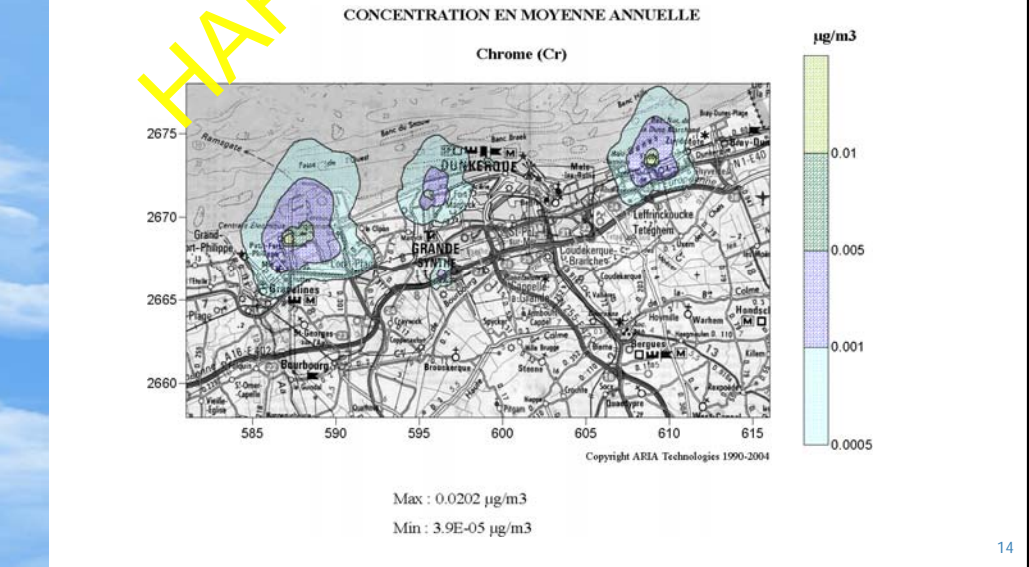
Atmospheric dispersion and deposition



Atmospheric dispersion and deposition



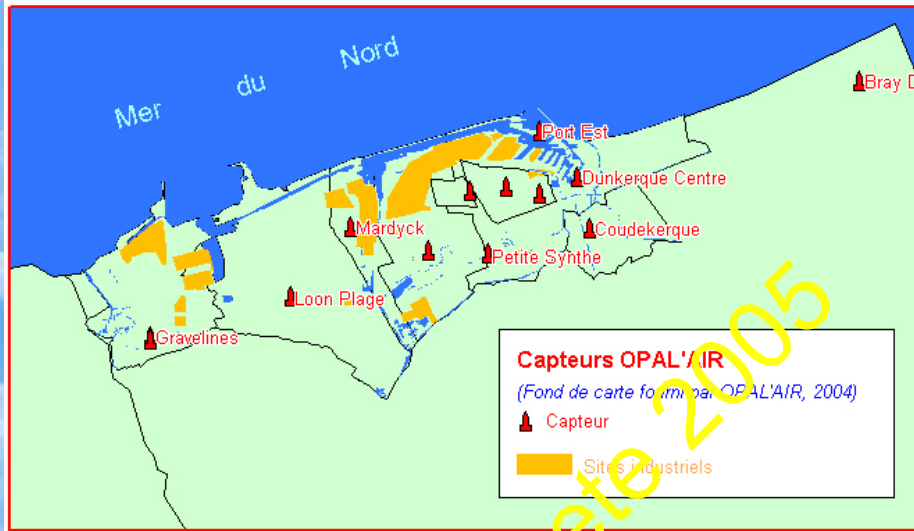
Chromium : more around main sources



Atmospheric dispersion and deposition



Check the Coherence between results and the air quality monitoring network data



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Atmospheric dispersion and deposition



Coherence with air quality monitoring data

Station	SO ₂		
	Measurement	Computation	Ratio Computation / Measurement
Dunkerque Centre	6,7	5,7	0,9
Port Est	11	15,2	1,4
Fort Mardyck	14,9	11,6	0,8
Saint Pol Cheminots	9,4	11	1,2
Coudekerque	7,4	3,7	0,5
Petite Synthe	6,4	4,7	0,7
Grande Synthe	8,8	9,5	1,1
Mardyck	6,5	10	1,5
Loon Plage	6,5	4,5	0,7

- SO₂ is a good industrial tracer
- Total Bias < 5%

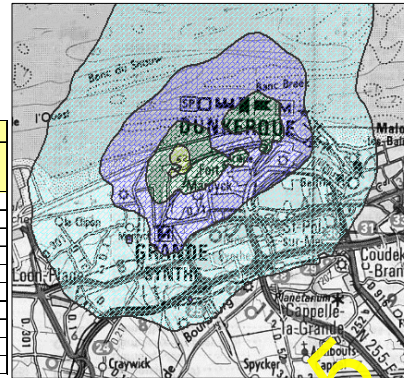
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Atmospheric dispersion and deposition



NOx

Station	NOx (µg/m³)		
	Measurement	Computation	Ratio Computation/Measurement
Dunkerque Centre	49,9	4,19	0,084
Port Est	-	-	-
Fort Mardyck	39,9	10,2	0,256
Saint Pol Cheminots	-	-	-
Coudekerque	-	-	-
Petite Synthe	53,8	4,22	0,078
Grande Synthe	-	-	-
Mardyck	-	-	-
Loon Plage	-	-	-
Gravelines	33,4	1,22	0,037



- **Important gap with measurement → Industry is not prevailing**
 - SO₂ and NO_x maxima are not measured at the same station
 - The ratio is coherent with the total emission ratio (ie traffic and residential)
- **Industry represents less than 10% of NOx measured by OPAL'AIR (25% at Fort Mardyck)**

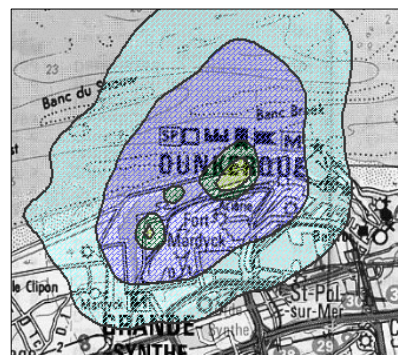
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Atmospheric dispersion and deposition



Particles (PM10)

Station	PM 10 (µg/m³)		
	Measurement	computation	Ratio Computation/Measurement
Dunkerque Centre	24	1,6	0,07
Port Est	-	-	-
Fort Mardyck	27	4,9	0,18
Saint Pol	23	2,3	0,10
Coudekerque	-	-	-
Petite Synthe	22	1,4	0,07
Grande Synthe	24	2,3	0,10
Mardyck	-	-	-
Loon Plage	-	-	-
Gravelines	24	0,3	0,01



- **Homogeneous results on all sensors → background prevailing**
- **PM emission quantification is difficult and mainly limited to process emissions**

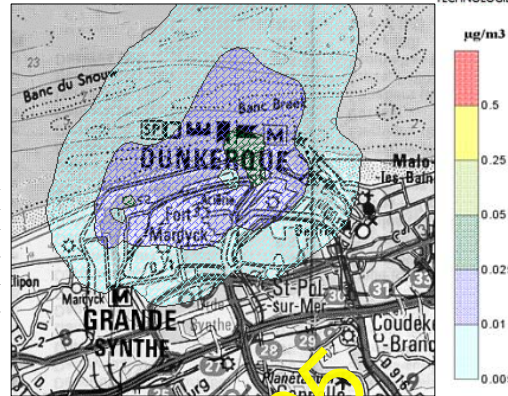
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Atmospheric dispersion and deposition



Heavy Metal

Port-Est Station	meas.	comp.	Ratio Comp./ Mes.
Arsenic (ng/m ³)	1	1	1
Cadmium (ng/m ³)	0,37	0,4	1,14
Lead (ng/m ³)	29	10	0,35



- OK for Arsenic et Cadmium
- Ratio > 3 for lead on this station
- Note : Hourly max. (58 ng/m³) are coherent with measurements

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Atmospheric dispersion and deposition



Results on maximum (1/2)

Pollutant	C _{max} computed (µg/m ³)	Deposition rate (µg.m ⁻² .s ⁻¹)	EU Objective
NOx	30,7	-	40
SO2	31	-	50
HF	1,9	-	-
Lead	0,04	2,9.10 ⁻⁴	0,25
Arsenic	-	1,2.10 ⁻⁴	-
Chromium	0,01	4,2.10 ⁻⁵	-
Nickel	0,008	1,4.10 ⁻⁴	-
Manganese	0,3	-	-

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Atmospheric dispersion and deposition



Results on maximum (1/2)

Pollutant	C _{max} computed (en µg/m ³)	Deposition computed (µg.m ⁻² .s ⁻¹)	EU Objective
mercury	0,005	4,0.10 ⁻⁵	-
cadmium	0,008	9,8.10 ⁻⁵	-
benzene	11,2	-	2
xylenes	0,5	-	-
toluene	0,03	-	-
1-3-butadiene	0,08	-	-
benzo(a)pyrene	0,0001	-	-
dioxines et furanes	1,5.10 ⁻⁷	-	-

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Risk assesment → Risk with threshold



Individual risk = ratio of concentration or dose /
Toxicological Reference value

$$IR = CI \text{ (ou DJE) } / VTR$$



IR < 1



Low probability to have
a toxic effect even on
sensitive population

IR > 1



Toxicological effect
could be expected

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Risk assesment → Risk without threshold



**Excess of Individual risk
(no threshold)**

$$\text{ERI} = \text{ERU} \times \text{CI (ou DJE)}$$



$\text{ERI} < 10^{-5}$



'Acceptable' risk

$\text{ERI} > 10^{-5}$



'Non acceptable' risk

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VTR Sources



Where can we find the toxicological reference value?

	Hazard identification	VTR	Cancerogenesis
OMS	x	x	x
ATSDR	x	x	x
EPA	x	x	x
OEHHA	x	x	
Health Canada	x	x	
RIVM	x	x	
HSDB	x		
INERIS	x		
INRS	x		
UE			x

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Risk assesment



Cardiovascular system

Pollutant	Exposition path	maximum risk index
1,3-butadiène	inhalation	$4,2 \cdot 10^{-2}$
arsenic (non-organic)	ingestion	$4,3 \cdot 10^{-2}$
benzene	inhalation	0,4
nickel	ingestion	$4,2 \cdot 10^{-4}$
plomb	inhalation	$7,3 \cdot 10^{-2}$
xylènes	inhalation	$5,2 \cdot 10^{-3}$
TOTAL		0,6

Renal system

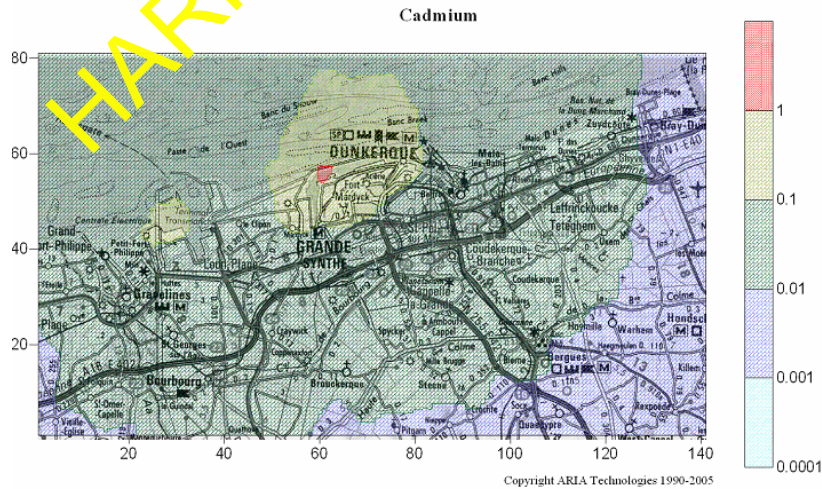
Pollutant	Exposition path	Maximum Risk Index
cadmium	inhalation	1,6
	ingestion	$5,9 \cdot 10^{-2}$
mercury	ingestion	$3,0 \cdot 10^{-3}$
lead	ingestion	$2,0 \cdot 10^{-2}$
TOTAL		1,7

Respiratory system

Pollutant	Exposition path	Maximum Risk Index
1,3-butadiene	inhalation	$4,2 \cdot 10^{-2}$
cadmium	inhalation	1,6
chromium	inhalation	$5,3 \cdot 10^{-2}$
SO2	inhalation	0,6
nickel	inhalation	$8,0 \cdot 10^{-2}$
NOx	inhalation	0,8
xylènes	inhalation	$5,2 \cdot 10^{-3}$
TOTAL		3,2

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Cadmium Respiratory and renal System (inhalation)



IR > 1 → No residential area



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Estimation des risques



Nervous System

Pollutant	Exposition path	Maximum Risk Index
arsenic	ingestion	$4,3 \cdot 10^{-2}$
manganese	inhalation	7,7
mercury	ingestion	$3,0 \cdot 10^{-3}$
lead	inhalation	$7,3 \cdot 10^{-2}$
toluene	inhalation	$9,4 \cdot 10^{-5}$
xylènes	inhalation	$5,2 \cdot 10^{-3}$
Total		7,8

Hepatic System

Pollutant	Exposition path	Maximum Risk Index
xylènes	inhalation	$5,2 \cdot 10^{-3}$

Digestif System

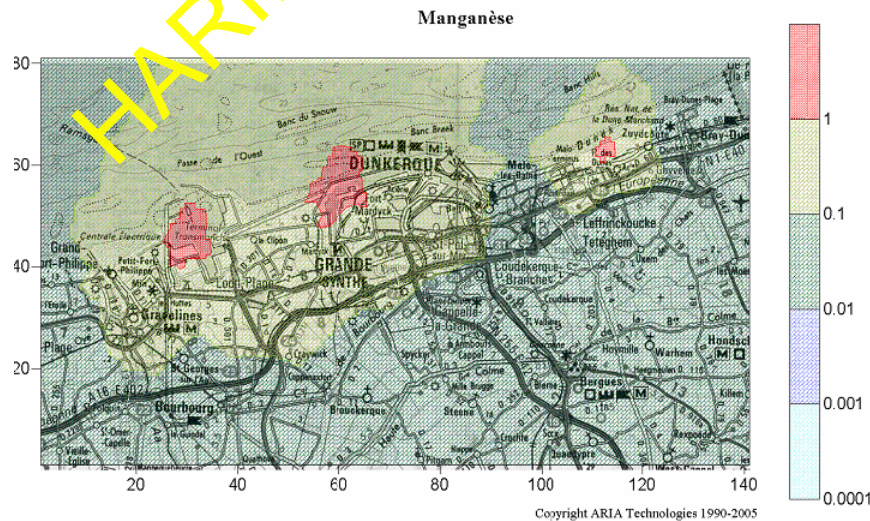
Pollutant	Exposition path	Maximum Risk Index
Lead	ingestion	$2,0 \cdot 10^{-2}$

Skin

Pollutant	Exposition path	Maximum Risk Index
arsenic	ingestion	$4,3 \cdot 10^{-2}$
chromium	ingestion	$4,0 \cdot 10^{-6}$
TOTAL		$4,3 \cdot 10^{-2}$

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Manganese : Map IR>1 (inhalation)



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Risk assesment



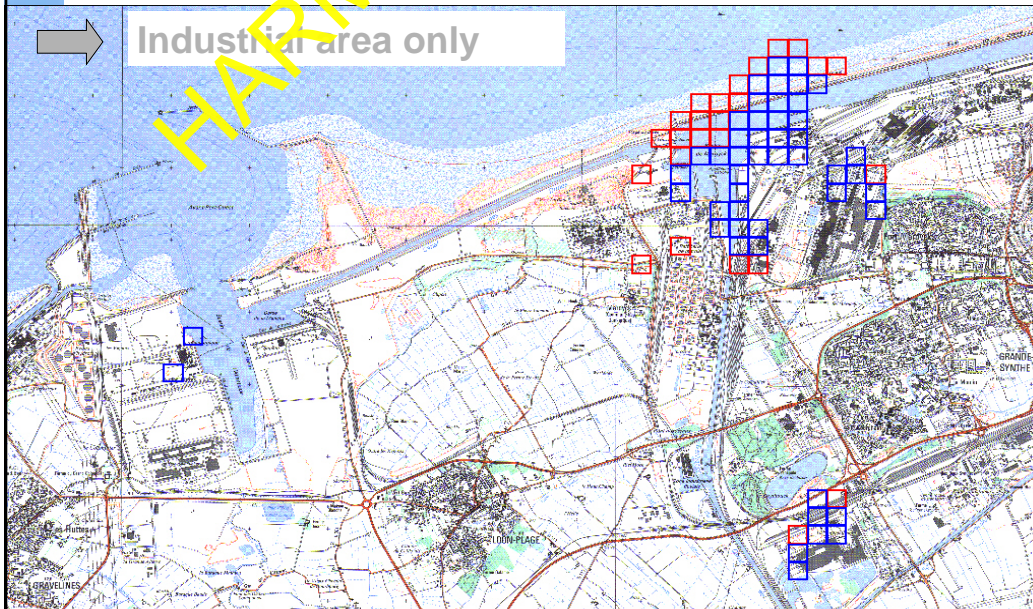
Cancer Risk

Pollutant	Exposition path	ERI maximum
1,3-butadiene	inhalation	$1,1 \cdot 10^{-6}$
arsenic inorganique	ingestion	$8,3 \cdot 10^{-6}$
benzene	inhalation	$1,1 \cdot 10^{-5} - 3,7 \cdot 10^{-5}$
benzo(a)pyrene	inhalation	$4,2 \cdot 10^{-8}$
	ingestion	$7,0 \cdot 10^{-8}$
cadmium	inhalation	$1,4 \cdot 10^{-5}$
chromium VI	inhalation	$1,9 \cdot 10^{-4}$
nickel	inhalation	$1,3 \cdot 10^{-6}$
TOTAL		$2,3 \cdot 10^{-4} - 2,5 \cdot 10^{-4}$

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Risk assesment

Cancer risk ERI > 10^{-5}



Risk assesment (summary)



Risk with threshold (IR>1)
(worrying situation)

Chromium



Residential area
reached

→ To be refined :
all chrome is
assimilated here
chromium VI

Dioxines et
furanes
cadmium
manganese



Industrial zone
only

Risk with threshold (ERI > 10-5)
non acceptable



Benzene
Cadmium



Industrial zone only

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Conclusion



(1) Dunkirk

- To be completed with all the other sources (traffic and residential)
- PM risk assesment to be completed

(2) SPPPI :

- Satisfied with these results.
- Same work on « Pas de Calais » in progress

(3) Harmo conference

- Need of **long term** experiment data in the Model Validation Kit
- Need of **deposition** experiment data in the Model Validation Kit

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