Photocatalytic materials in Belgium: from laboratory to on site applications

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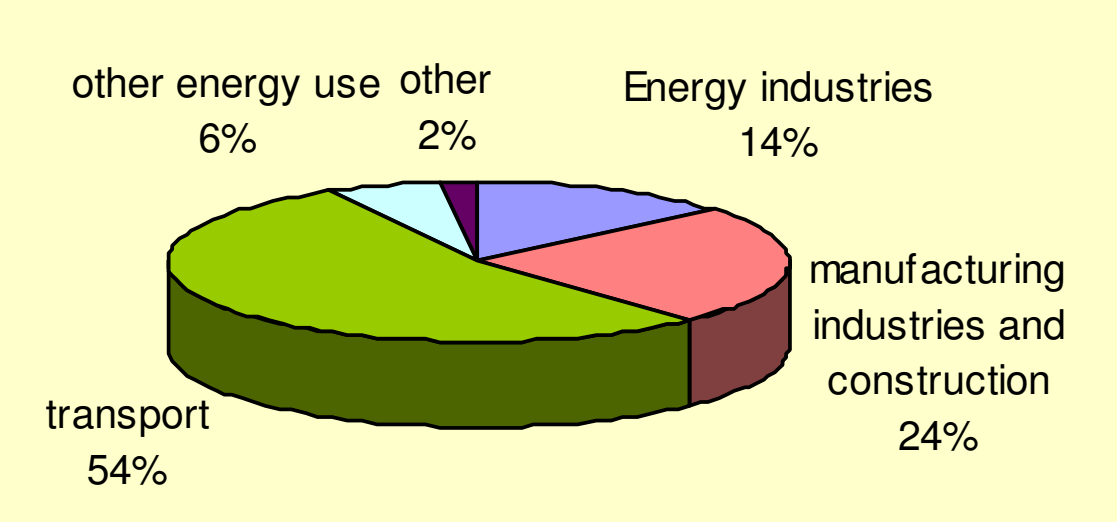
Why using photocatalytic materials in road construction?



- Traffic: emission of NO_x, VOC,…
- Smog formation
- As close to source as possible

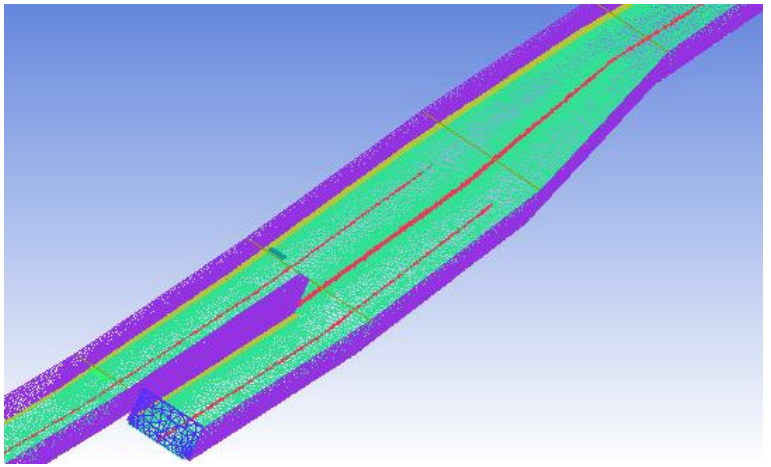
Ozon formation in presence of NO_2 and VOC:

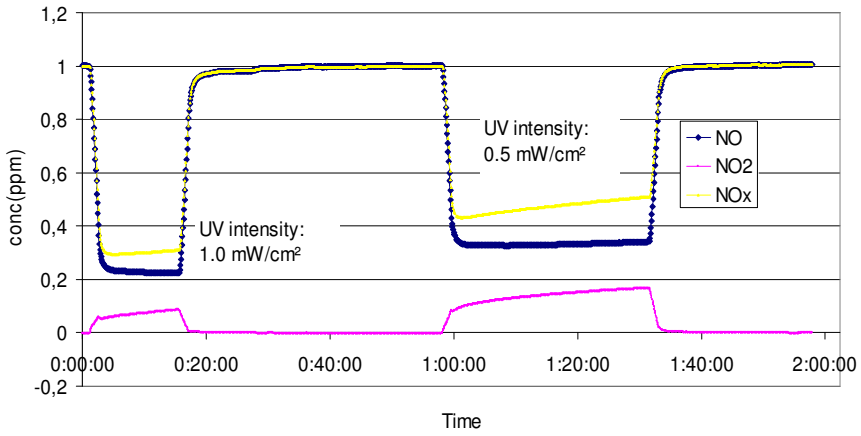
$$NO_2 + O_2 + hu \rightarrow O_3 + NO$$

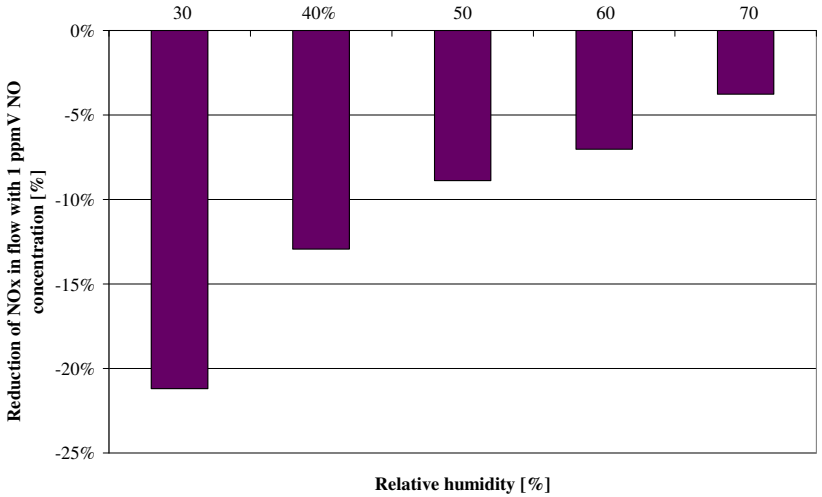
in presence of VOC → ~~$NO + O_3 \rightarrow NO_2 + O_2$~~ **$NO \rightarrow NO_2$**

High photocatalytic efficiency

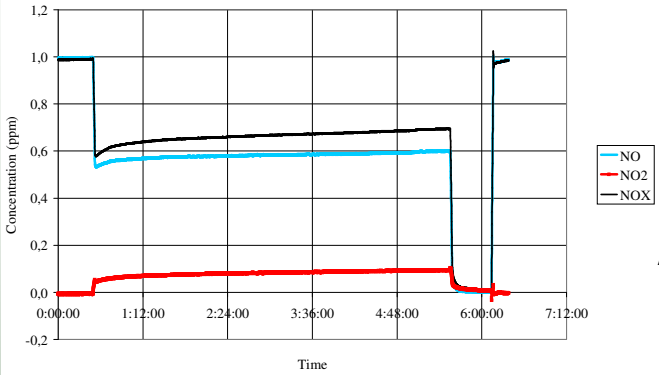
- High contact time
  - Air flow
  - Turbulence
  - Contact surface
- High light intensity (UV-light)
- Low relative humidity
- Optimal TiO_2- content at surface (efficiency – durability)

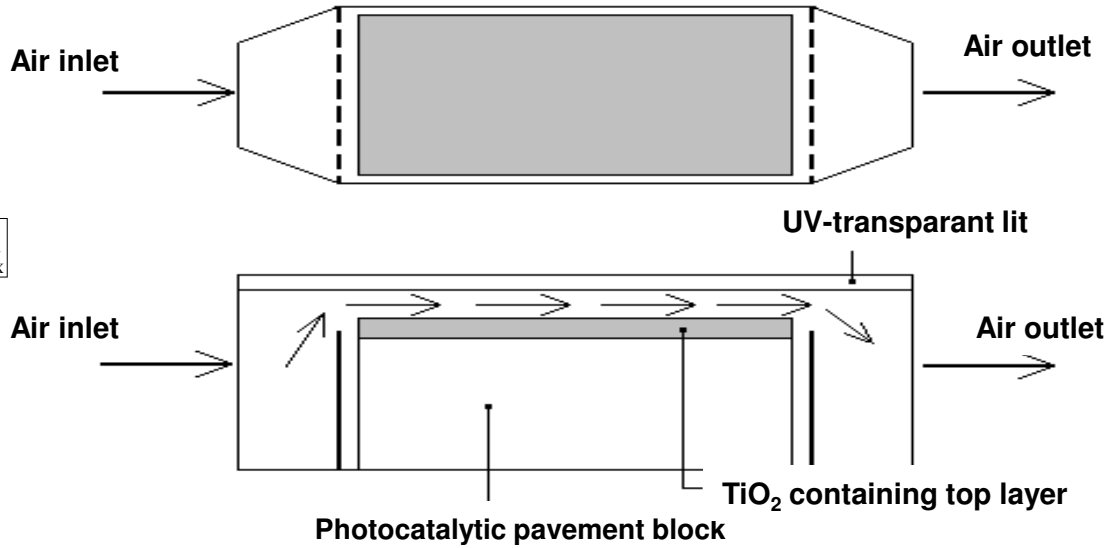






Measurement according to ISO-22197-1 (NO_x)





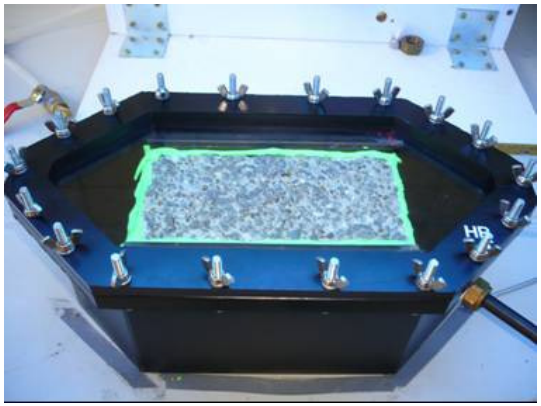
T: 23°C

R.H.: 50%

Air flow: 3l/min

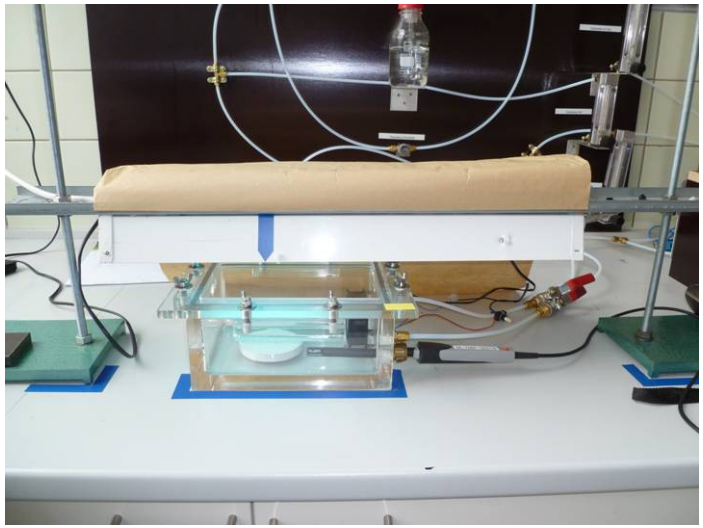
NO-conc.: 1 ppmV

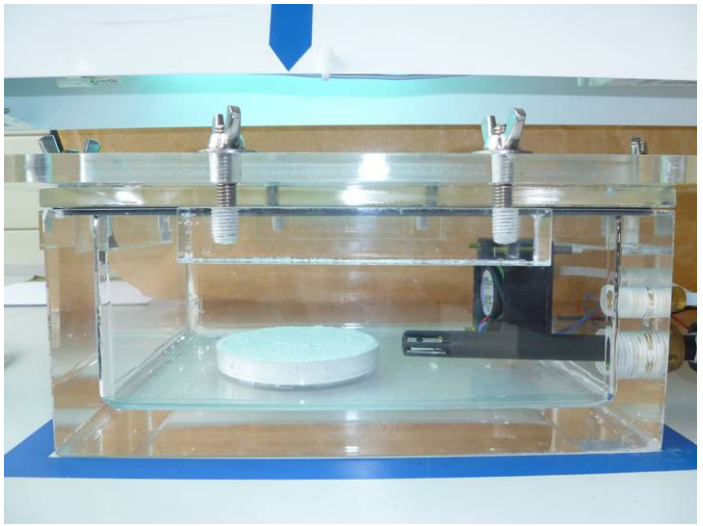
Light intensity: 10 W/m²



Pre-treatment: rinsing with distilled water and drying overnight at laboratory conditions

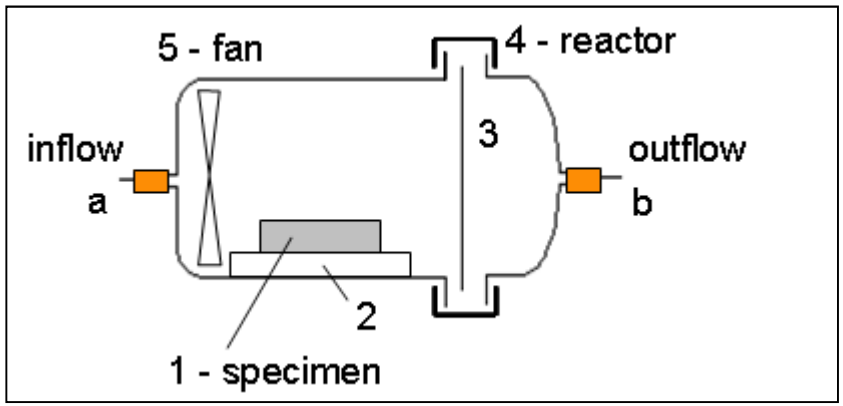
CSTR-test method CEN/TC36/WG2





Test parameters Round Robin (April-June 2011):

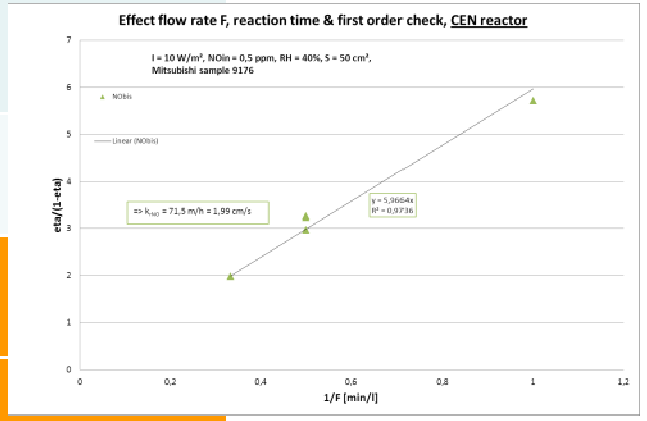
Parameter	Unit of measurement	Nominal Value	Allowed variation
Average irradiance	W/m^2	**20**	5%
Input concentration of NO_2	ppmv	**<0.010**	-
Input concentration of NO	ppmv	**0.50**	10%
Temperature inside the reactor	°C	**25**	±5°C
Humidity of the gases at 25°C	%	**40%**	±5%
Flow	$L\ min^{-1}$	**2.0**	20%
Net volume of the Reactor	L	**3.0**	20%



Average results: CEN versus ISO, same conditions!

- CEN: C0*F/S*η/(1-η) ⇔ ISO: C0*F/S*ln[1/(1-η)]
- Test conditions: RH = 40%, F = 2l/min, NOin = 0,5ppm, I = 10W/m², 

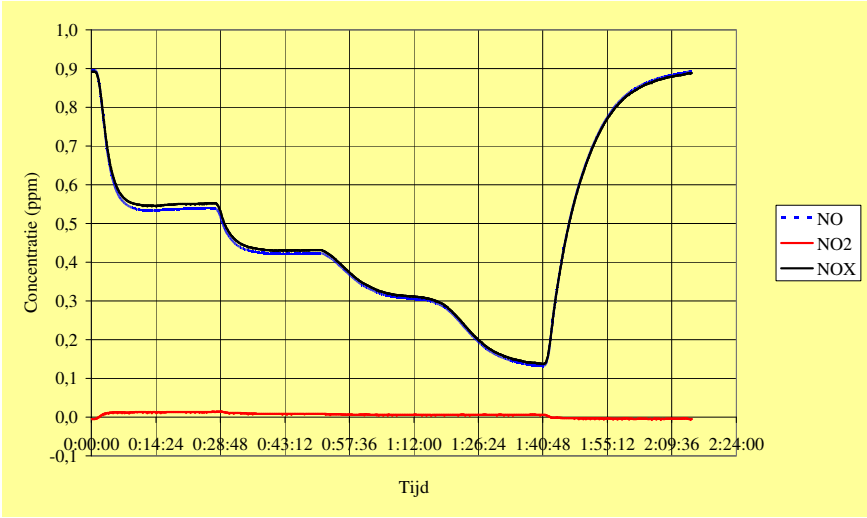
Sample: 9176/1,2,3	ISO (2l/min)	CEN (2l/min)	CEN (1-2-3 l/min)
Conversion NO [%]	66,2±3,3	75,9±1,0	-
Conversion NO_x [%]	64,7±3,3	72,9±1,6	-
Rate NO [mg/h.m²]	16,5±1,8	45,6±2,5	44,3±3,1
Rate constant NO [m/h] = rate/Cin	*27,0±2,9*	74,6±4,1	*72,5±5,1*

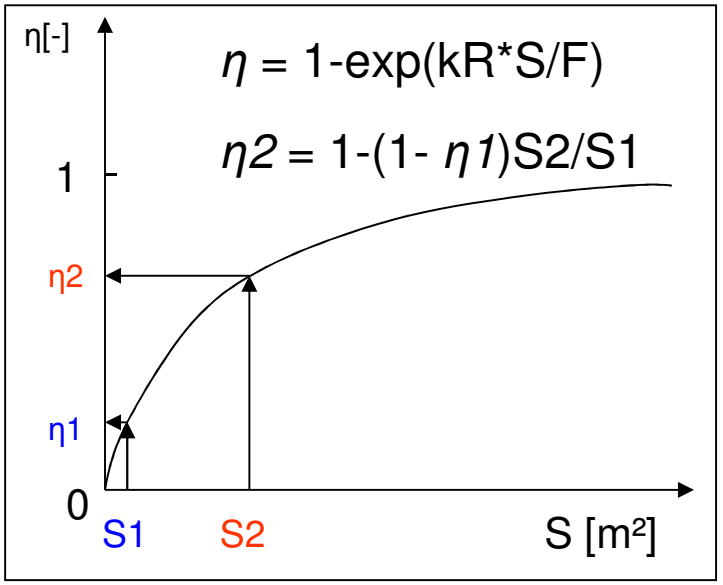


Factor 2,7 difference!

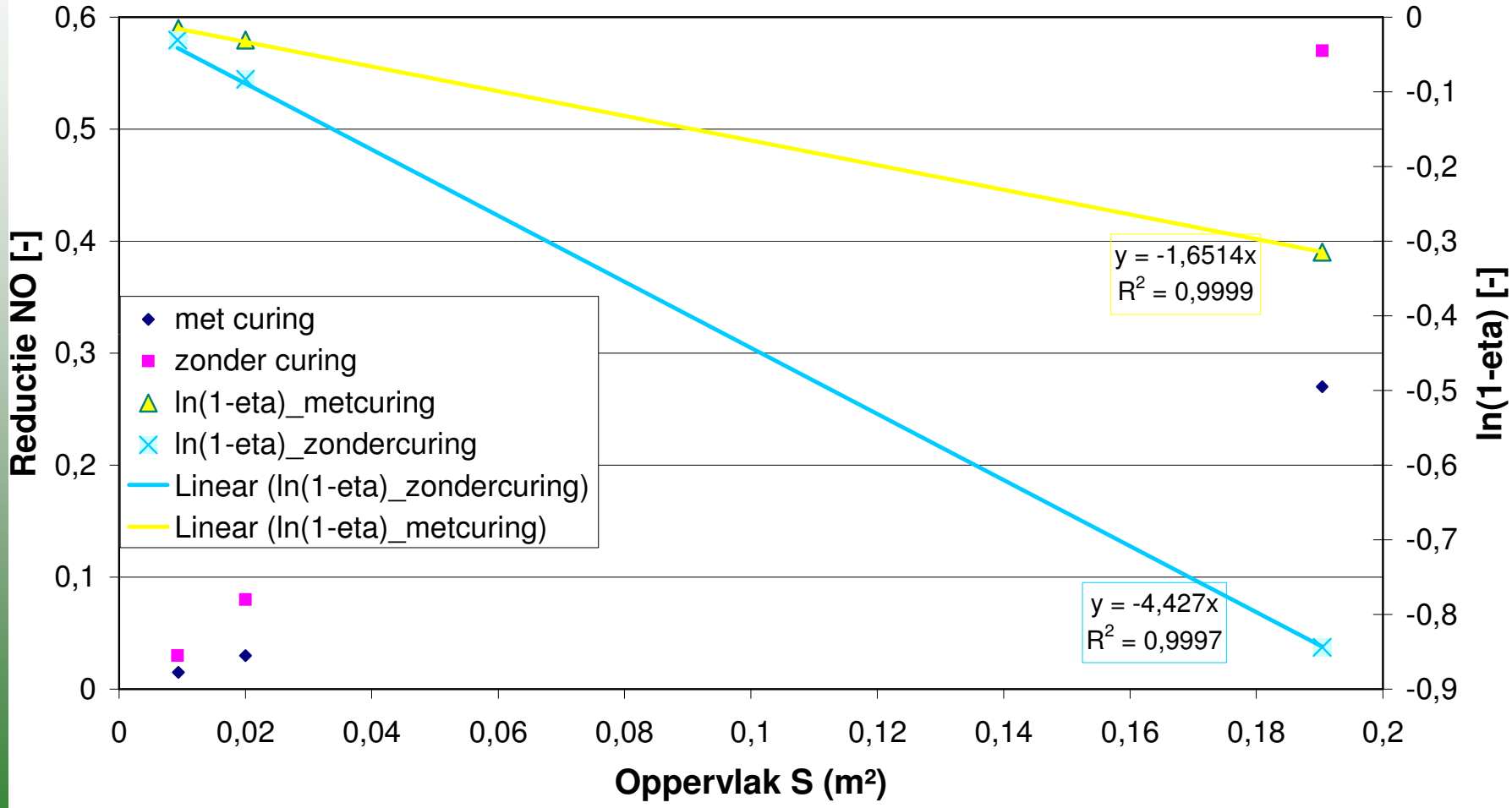
=> European standard is needed!

Effect of surface in laboratory with ISO => NO extrapolation possible to 'on site' application!





Effect of surface – NO extrapolation to 'on site' application



Choice of application method of photocatalytic material

Application of TiO_2

Mixed in the mass of the concrete

- TiO_2 added to the cement:

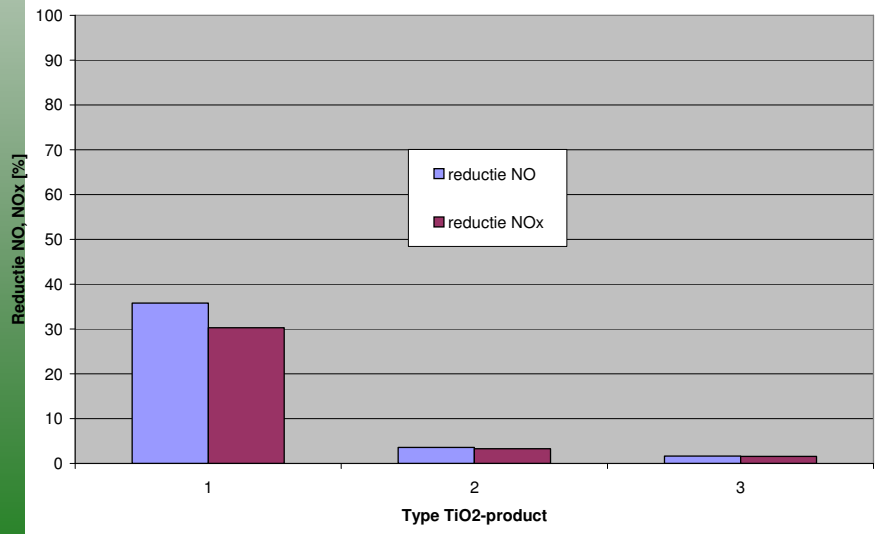
+ durability

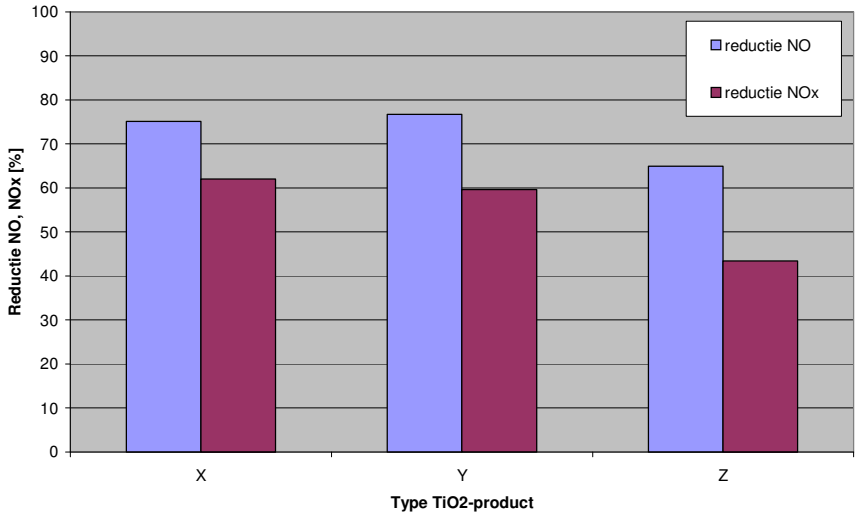
- cost (higher concentration, double layered concrete)
- only TiO_2 at the surface is active

Dispersion or coatings at the surface

+ direct contact with light and polutants
+ applicable on new and existing roads
+ cost: no double layer

- durability: adherence to the surface
- compatible with curing compound





Recent applications

Horizontal applications:

- Photocatalytic pavement blocks (Antwerp, Bergamo, Japan, Vlaardingen)
- Hot mix asphalt and cementitious mortar (Italy and France)
- Thin concrete overlay (Vanves, Paris)
- Double layered concrete (Belgium, Duwijck and Lier)

Vertical applications:

- Noise reducing barriers (The Netherlands (IPL project), France, Italy, Germany)
- Coatings on buildings (London)
- Tunnels – with or without adapted lighting (UK, Italy, Sweden, Brussels, Leopold II tunnel, The Netherlands, Germany)

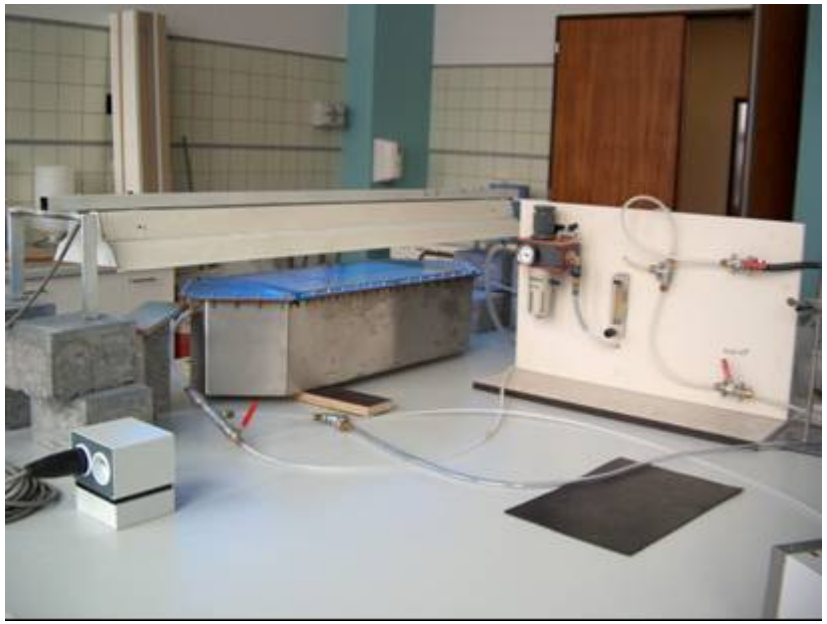
Modelling of environment to translate laboratory results into real situations

- NR2C-project: modelling of tunnel and of high-way
- IPL-project: noise barriers in neighbourhood of highway
- Photopaq project

Sideways on the "Leien" - Antwerp

- 10.000 m² photocatalytic pavement blocks as pilot project on the parking lanes of a main axe in Antwerp is constructed in 2004-2005
- 2*4.5m on a total width of 60 m!

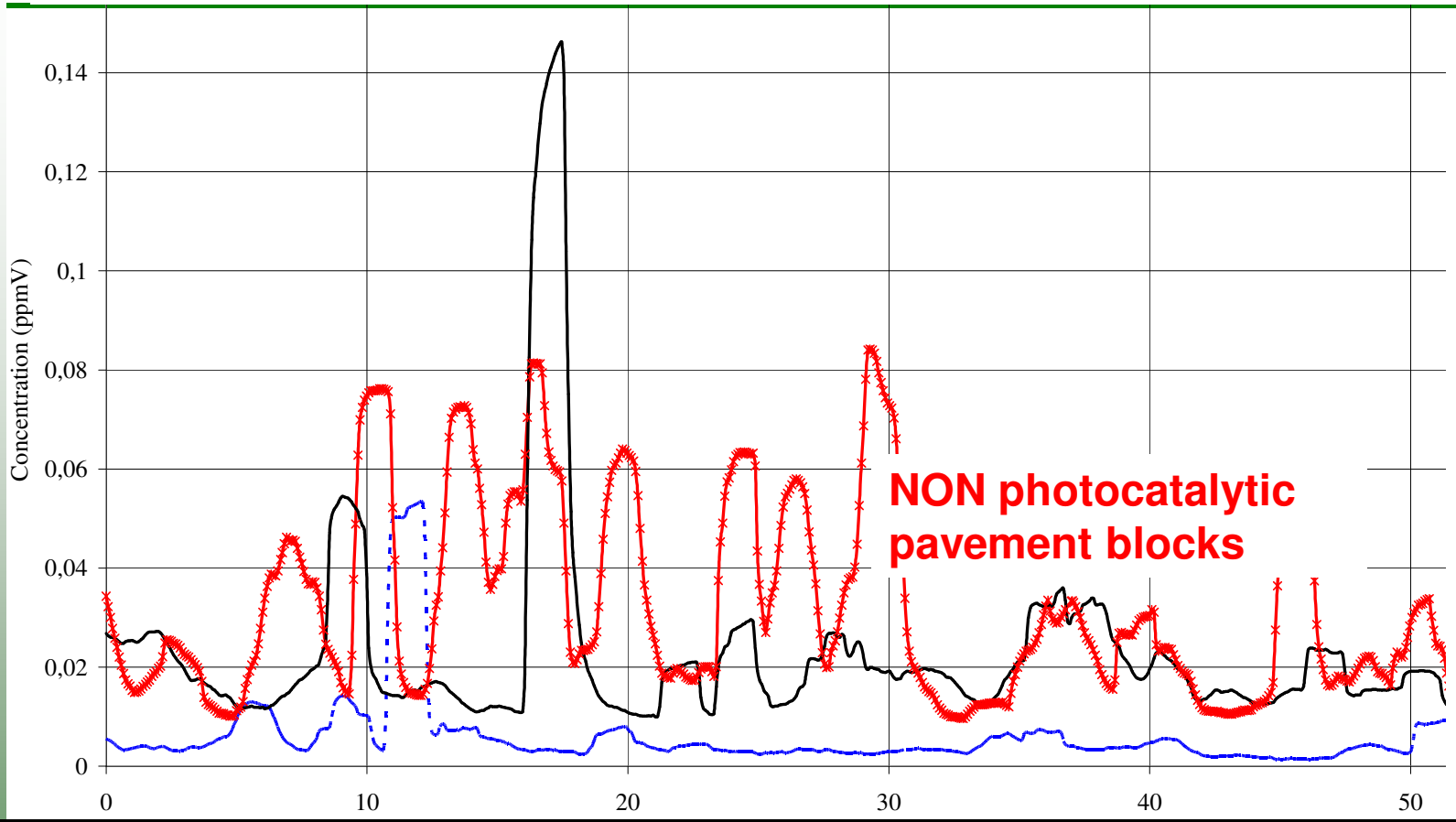
Photocatalytic materials



In the laboratory:
on 2 pavement blocks

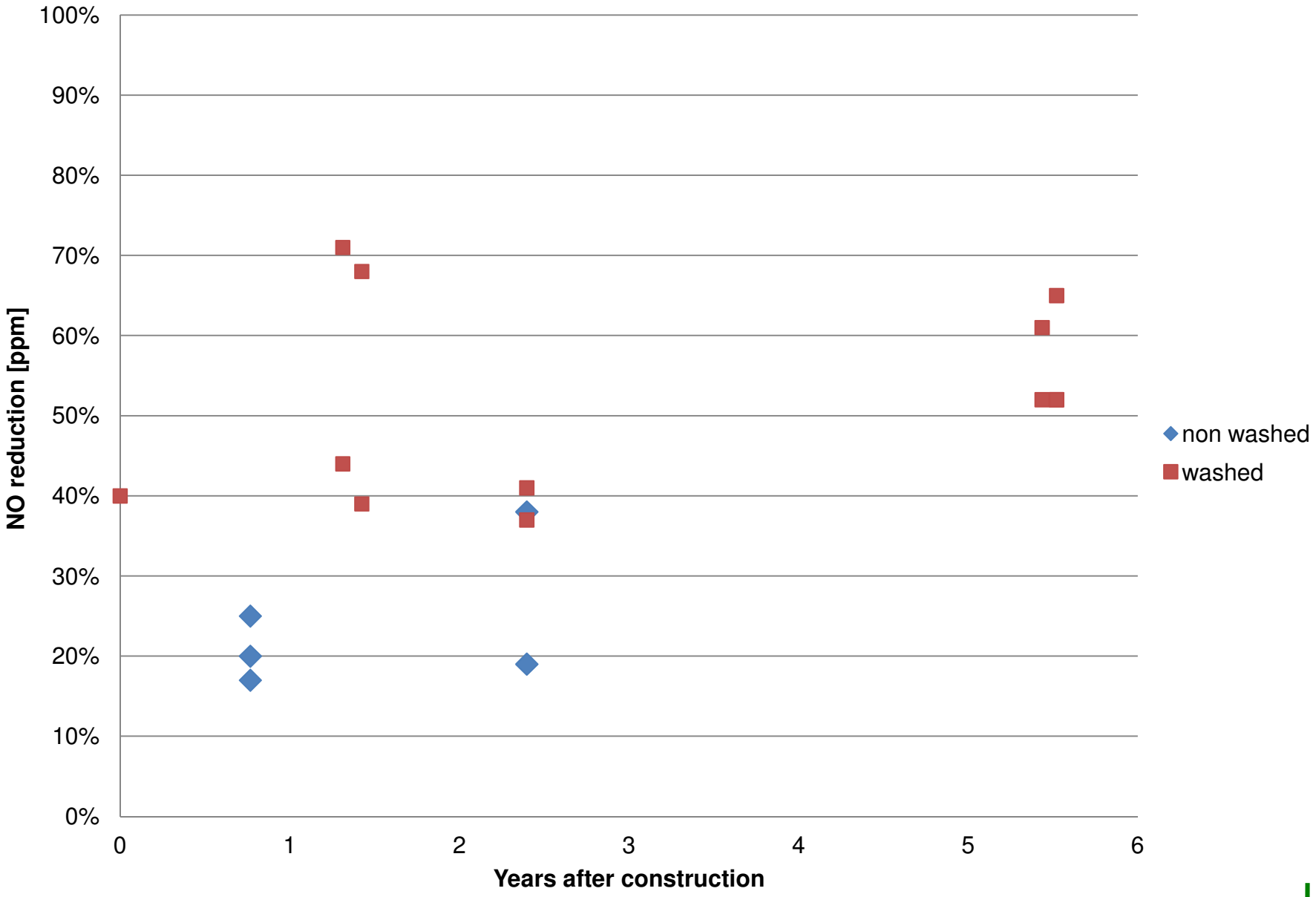
In the field:
air inlet at 5 cm
above the photocatalytic
pavement blocks

Measuring in the field - no conclusive results



	Time	Traffic	R.H.	Temperature	UV-Light intensity
1	10:32–11:32	1332	33 %	25°C	12 W/m²
2	11:41-12:41	1494	30 %	27°C	17 W/m²
3	14:10-15:10	1620	25 %	32°C	25 W/m²

Measurement in laboratory - effect of rain



Conclusions from the project in Antwerp

- Durability of the efficiency is present: reduction of NO_x after 6 years on site did not decrease (as tested in the lab)
- Durability of the pavement blocks is comparable to that of classic pavement blocks (freeze-thaw resistance)
- Washing of the surface is needed in order to regain the original efficiency, this can be done by the rain

- Measurements on site are very complex – no conclusive results are obtained: a lot of parameters such as wind, temperature, traffic, sun light intensity are influencing the reduction rate

ECO2PROFIT – INTERREG project

double layered concrete with recycled concrete aggregates in base layer and photocatalytic concrete in top layer on industrial zone “Den Hoek” in Wijnegem and in “Duwijck” in Lier, Belgium

met de steun van:

Europese Unie
Europees Fonds voor Regionale Ontwikkeling

Onderstaande partners nemen deel aan het Interreg project eco2profit

Vlaanderen Nederland
Europa investeert in uw regio

POM Limburg
POM Vlaams-Brabant
POM Provinciale Ontwikkelingsmaatschappij Oost-Vlaanderen
OCW
LIOF
RMD
INTERLEUVEN
PARK management

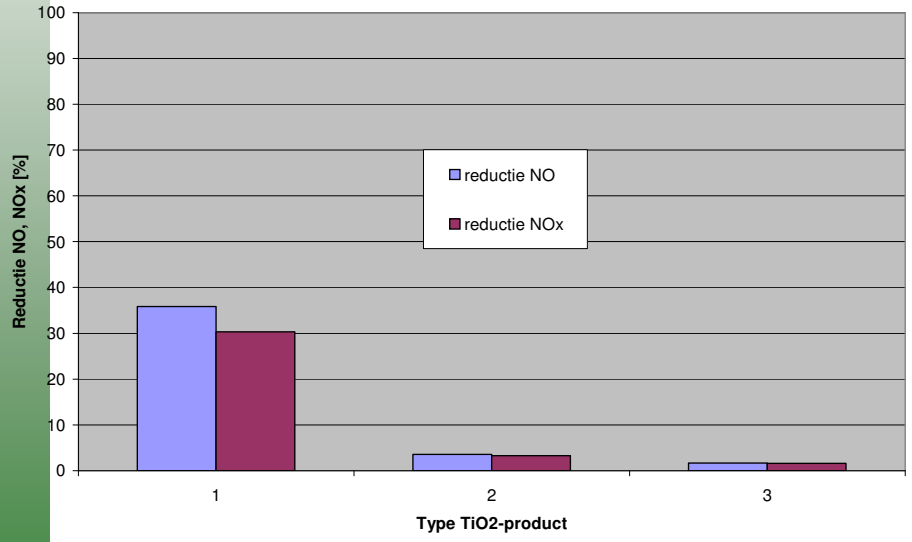
Laboratory research

- Optimal type of photocatalytic material
- Concrete composition (aggregate 0/6,3 mm – air entrainer (3-4% air in fresh concrete)
- Influence of curing compound
- Influence of surface treatment (exposed aggregate concrete, brushed concrete)
- Recycled concrete aggregates as coarse aggregate (> 6,3 mm) in bottom layer

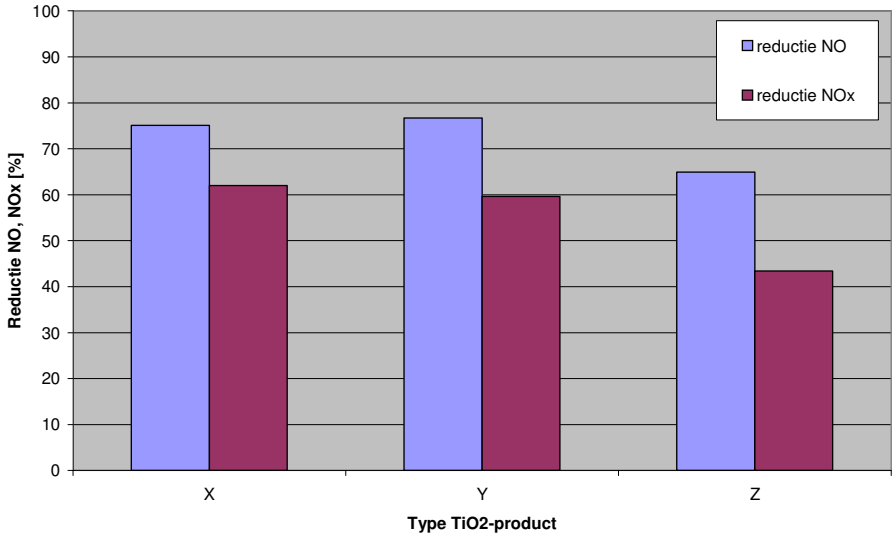
Conclusions from the laboratory research

- Not all TiO_2 is photocatalytic!
- Dispersion has higher efficiency but lower durability (adherence to surface)

In the mass

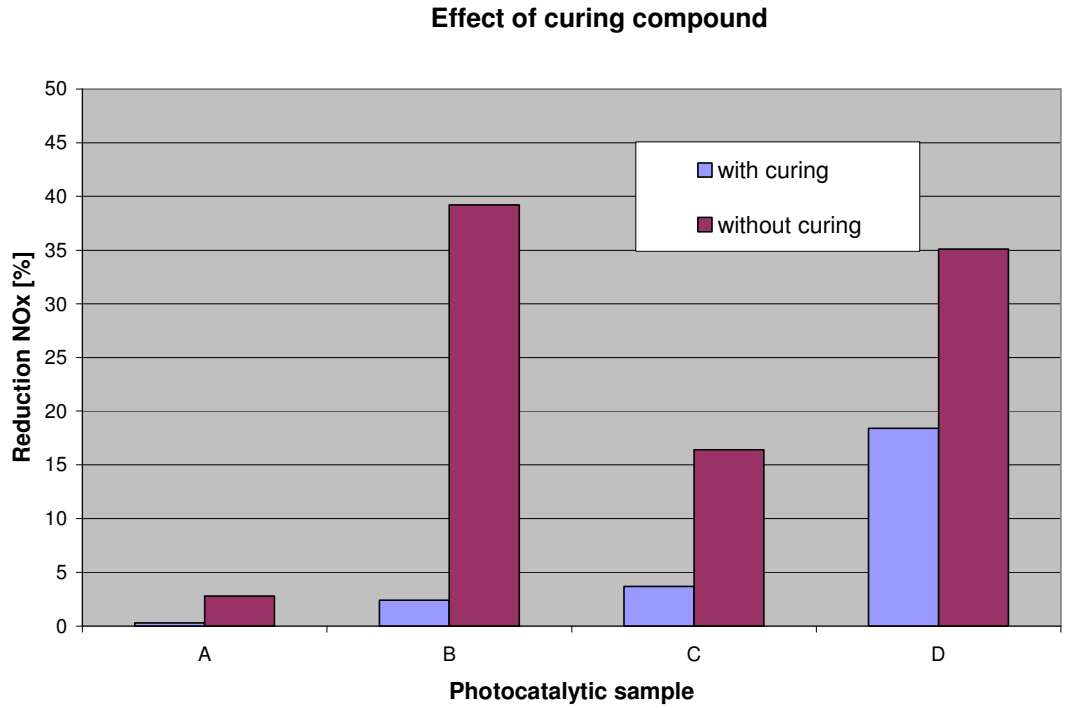


Dispersion



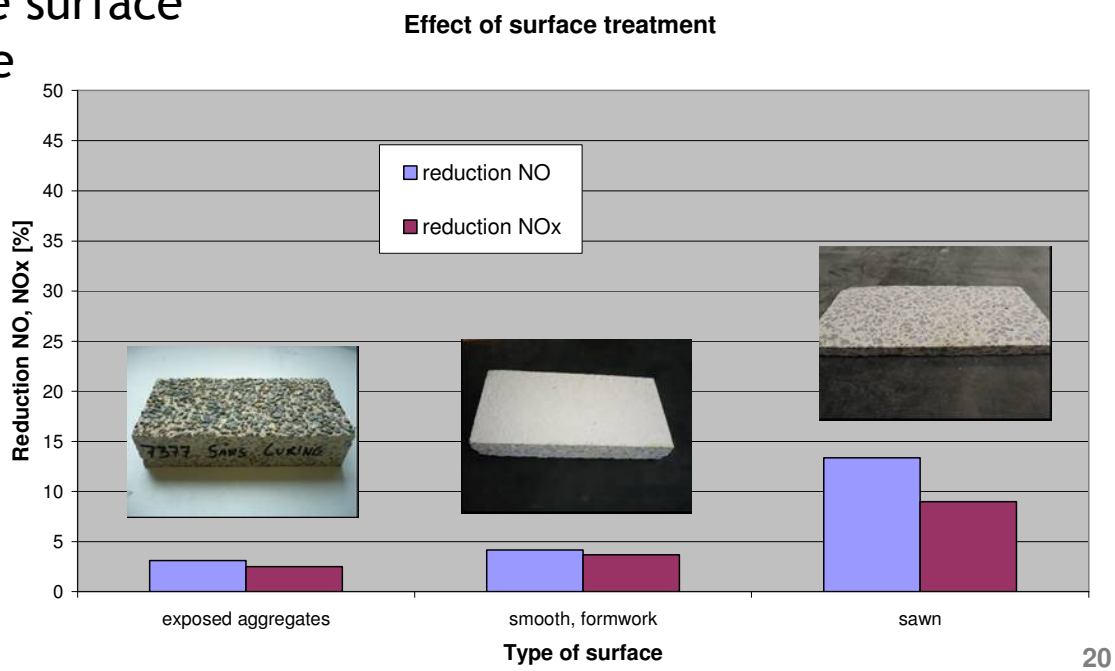
Conclusions from the laboratory research

- Not all TiO_2 is photocatalytic!
- Optimalisation of concrete composition: dispersion has higher efficiency but lower durability (adherence to surface)
- Effect of curing conditions: influence of curing compound



Conclusions from the laboratory research

- Not all TiO_2 is photocatalytic!
- Optimalisation of concrete composition: dispersion has higher efficiency but lower durability (adherence to surface)
- Effect of curing conditions: influence of curing compound
- Effect of surface treatment
  - Active component at the surface
  - Roughness of the surface

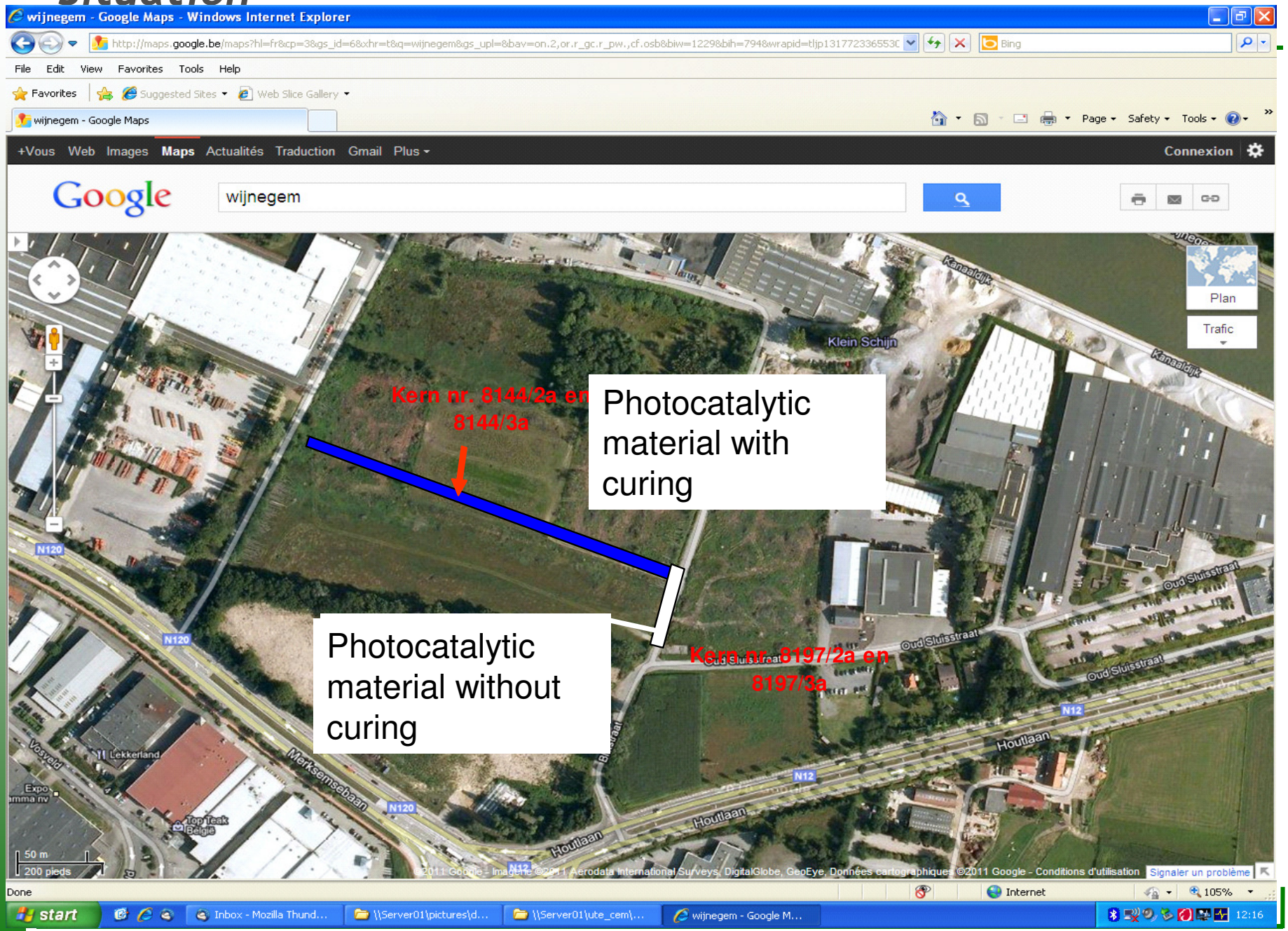


Double layered concrete

- Wet-in-wet application – excellent adhesion

- Recycled aggregates in base layer
- TiO_2 in top layer – white color

Situation


wijnegem - Google Maps - Windows Internet Explorer
wijnegem
Kern nr. 8144/2a en 8144/3a
Photocatalytic material with curing
Photocatalytic material without curing
Kern nr. 8197/2a en 8197/3a
Klein Schijn
Kanaaldijk
Oud Sluisstraat
Houtlaan
Merksemsebaan
N120
N12
Lekkerland
Plan
Trafic
50 m
200 pieds

Measurement of influence of different parameters with 'on site' test

NOin = 1000 ppbV

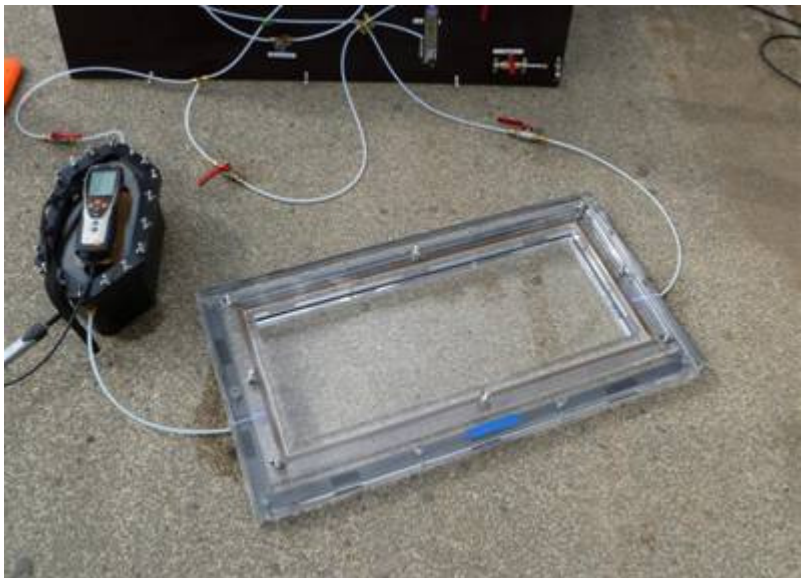
RH = 50%

Flow = 3 l/min

Surface = 70 x 30 cm² (10 x labo!)

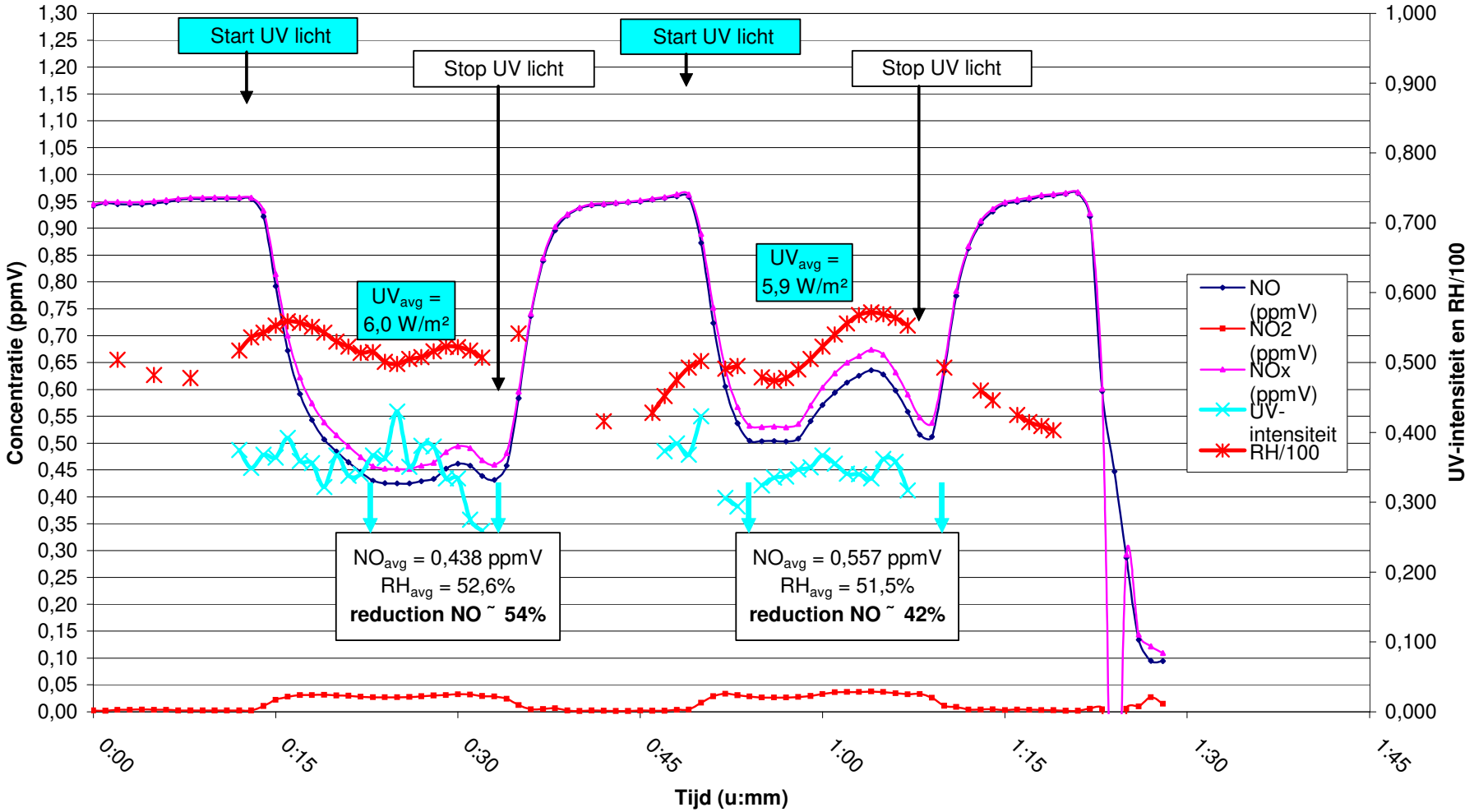
Sun light (I[W/m²] varies!)

! Parameter study "on site", not real effect on air quality!



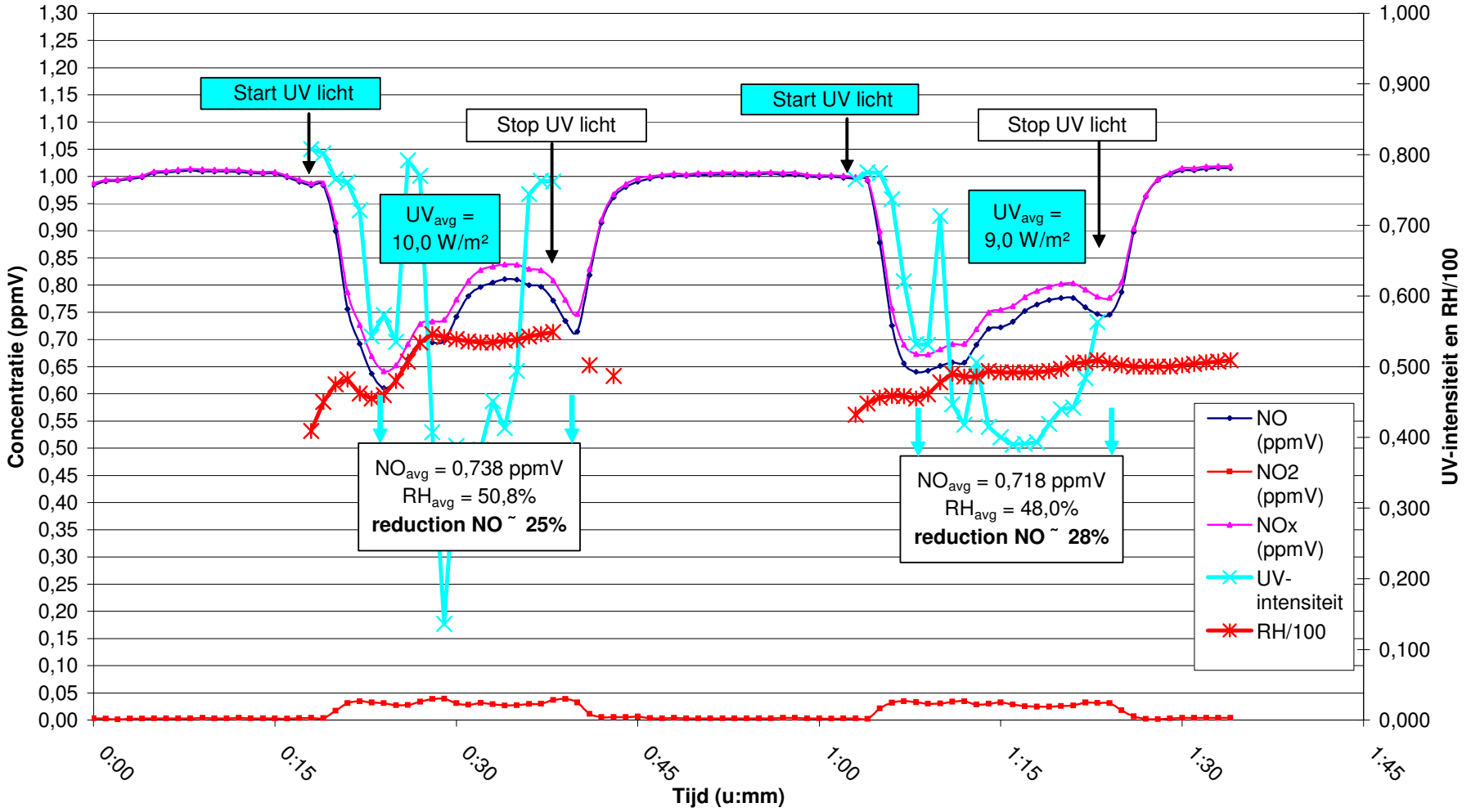
Point 1: photocatalytic material without curing

Measerement of NOx on the 17th of August 2011 at the surface without curing compound



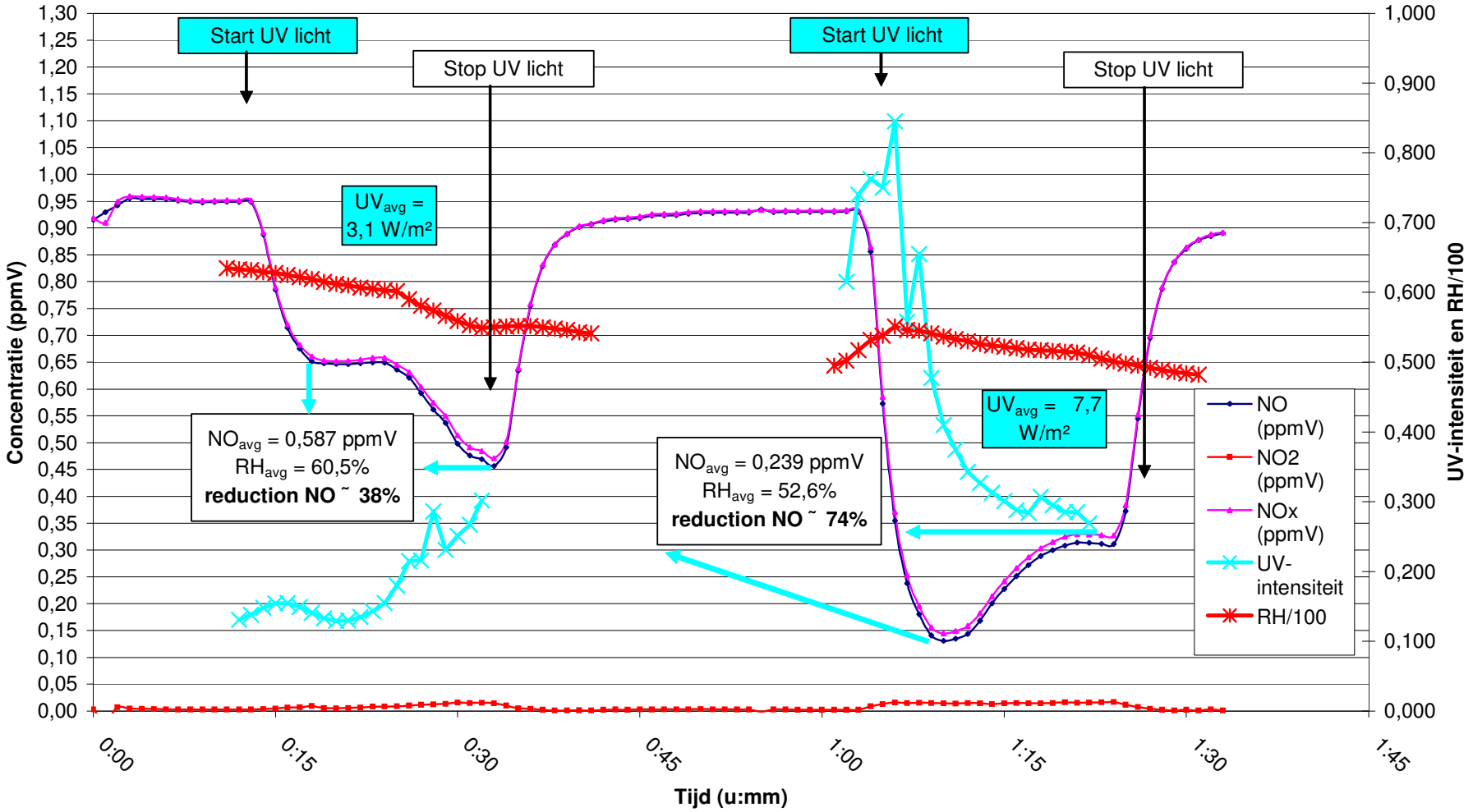
Point 2: photocatalytic material with curing

Measerement of NOx on the 17th of August 2011 at the surface with curing compound

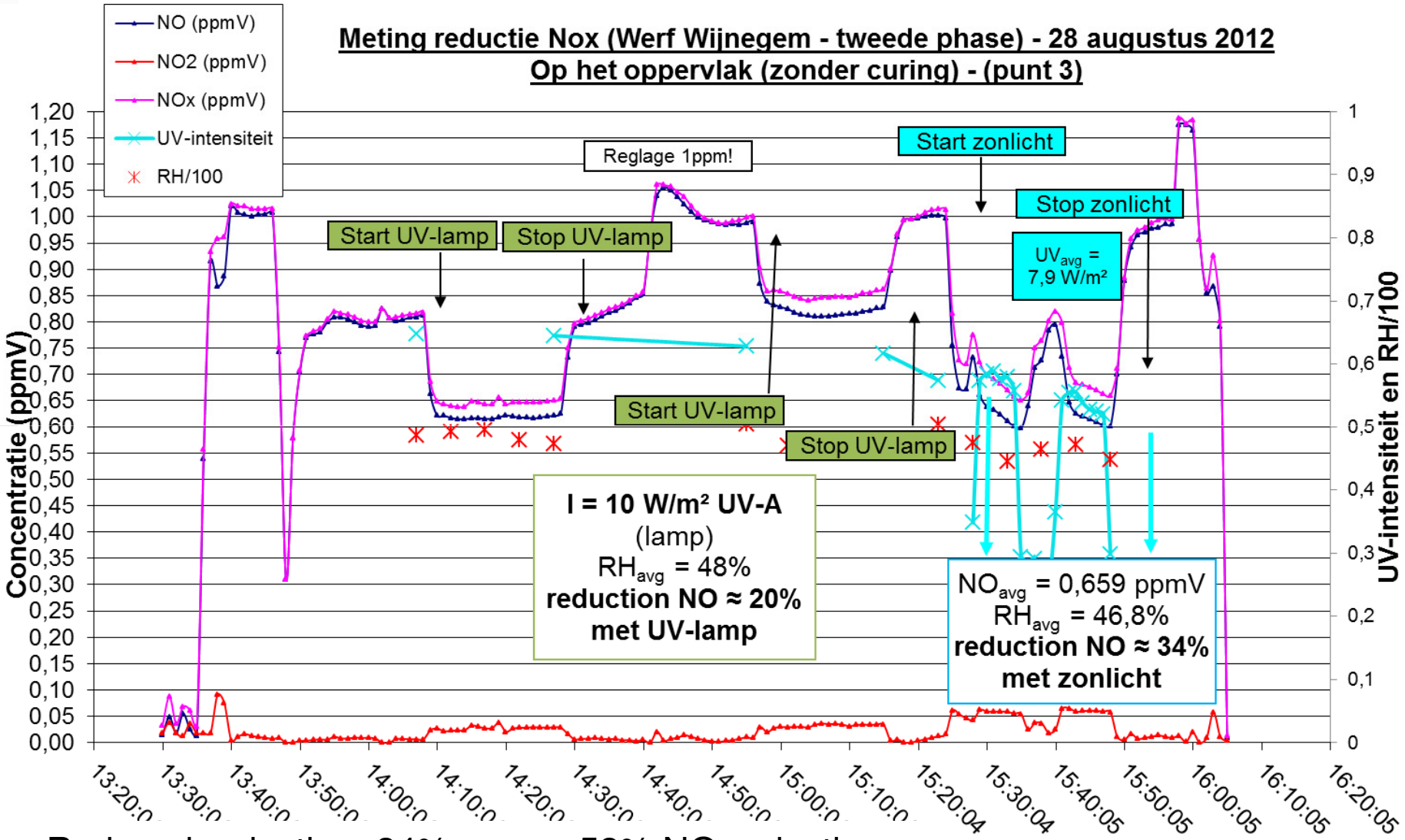


Point 3: photocatalytic material without curing

Measerement of NOx on the 18h of August 2011 at the surface without curing compound

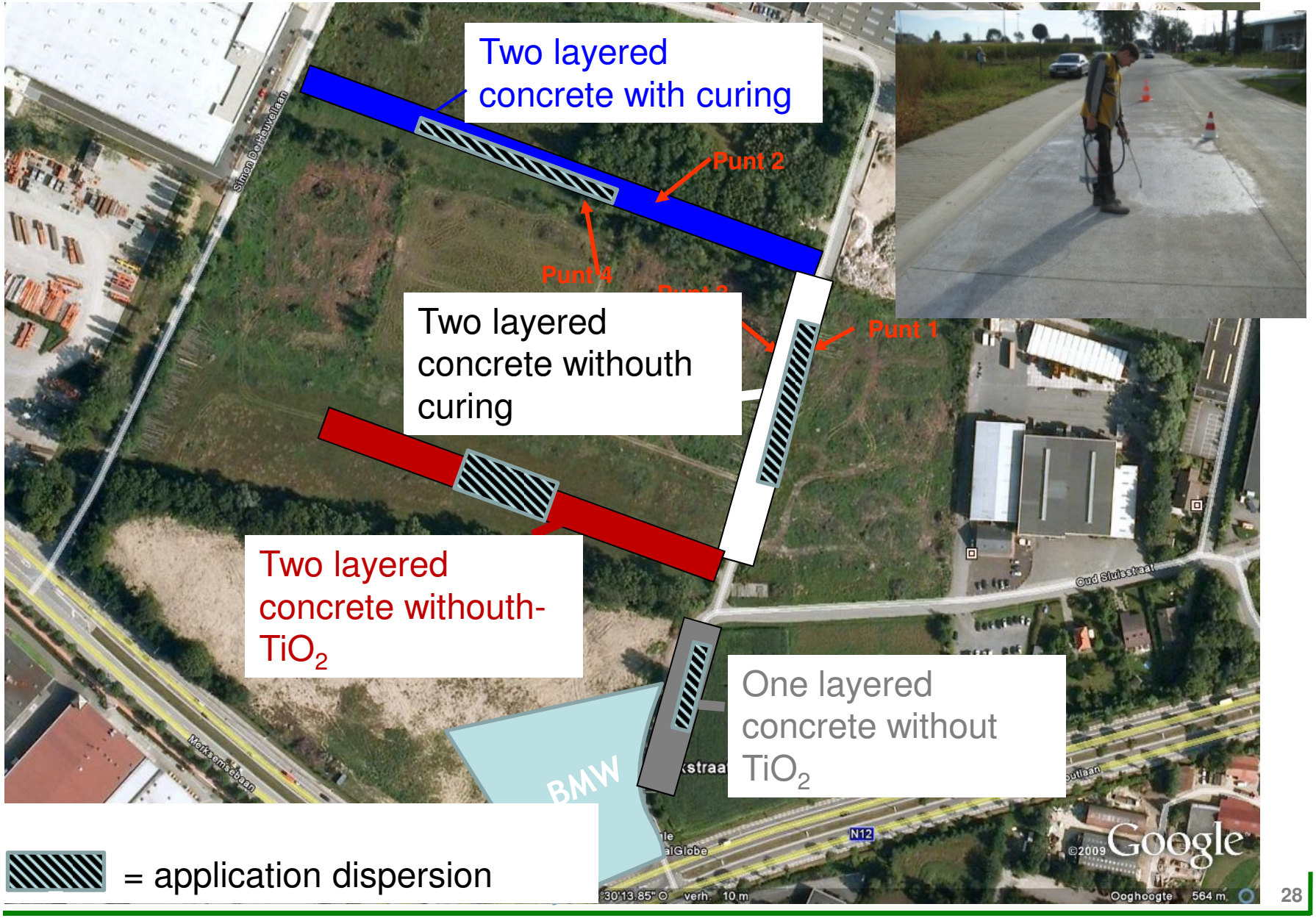


Measurement after 17 months in service



Reduced reduction: 34% versus 52% NO-reduction – durability? Pollution of the surface?

Application of dispersion on the concrete



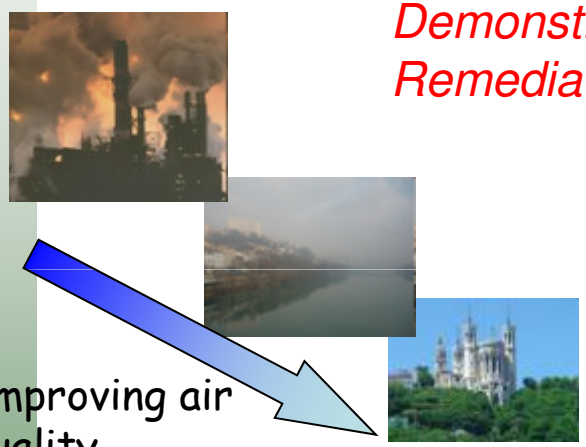
Conclusions from the ECO2PROFIT project

- Durable concrete is put in place
- Air purification efficiency is reduced by curing compound
- Efficiency decreases over time due to loss of purifying capacity or due to deposition of solids on the surface (industrial area)

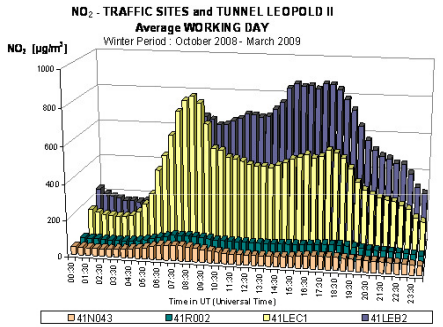
Photocatalytic materials in tunnel in Brussels

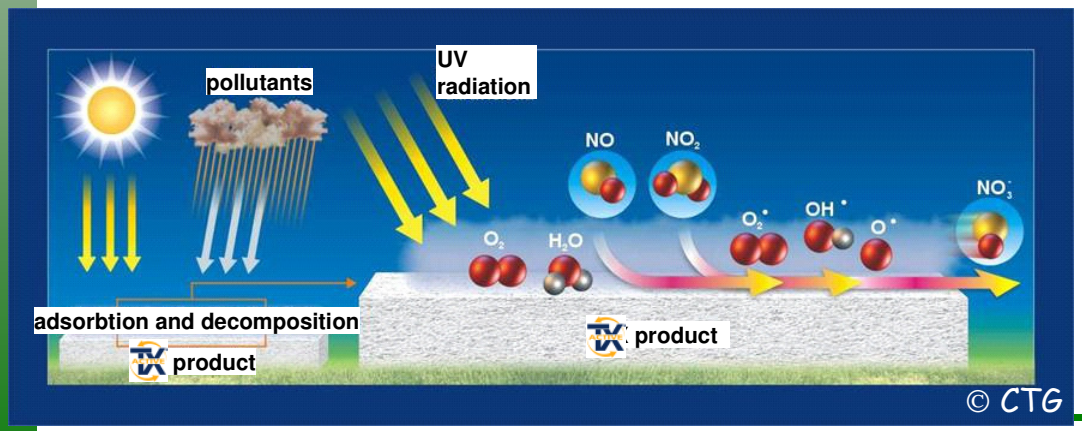
- LIFE+ project PHOTOPAQ: application of photocatalytic materials on the walls and roof of the Leopold II tunnel in Brussel with additional UV-light installed

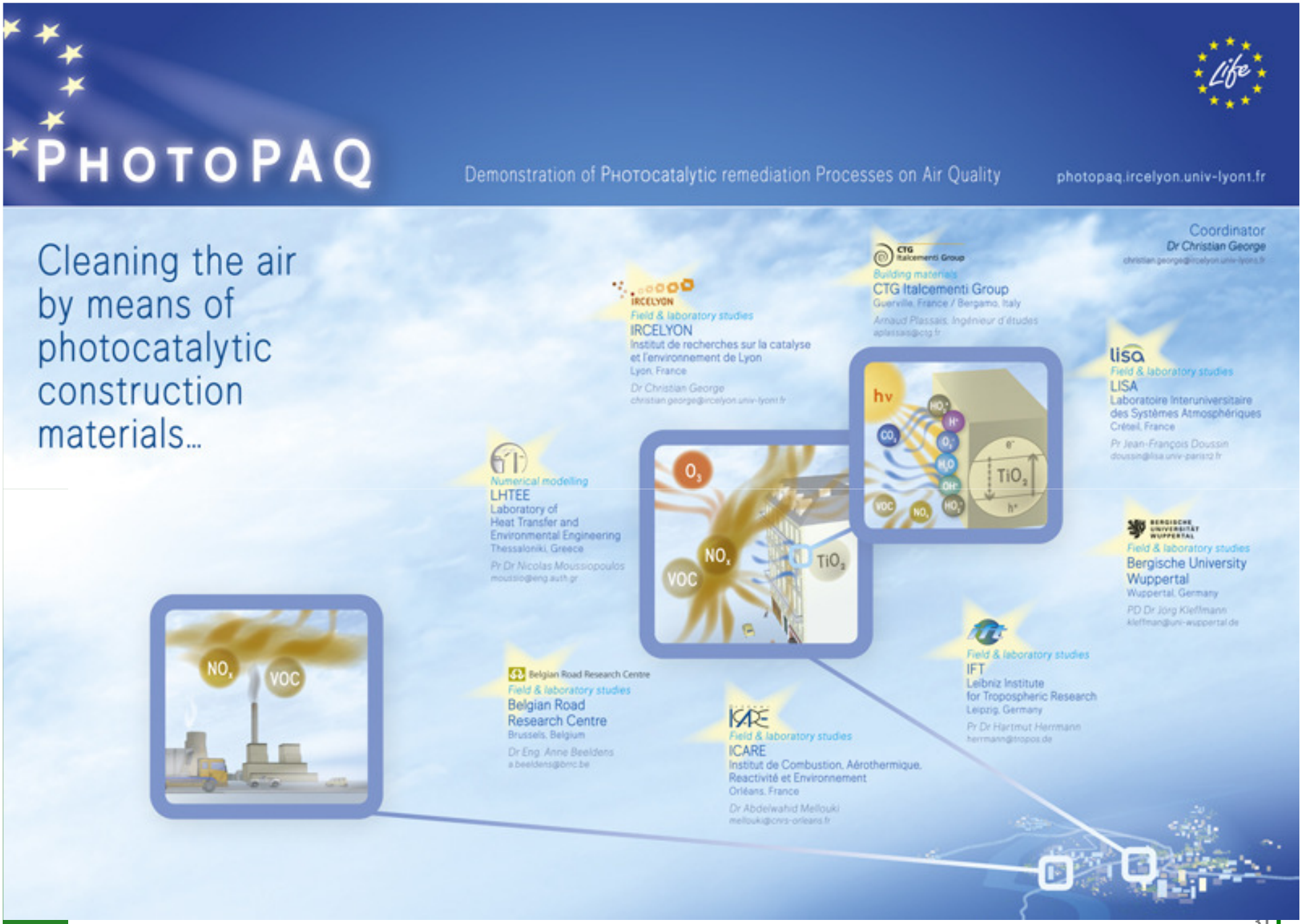
*Demonstration of **Photo**catalytic Remediation **P**rocesses on **A**ir **Q**uality*



Improving air quality






PHOTOPAQ
Demonstration of PHOTOcatalytic remediation Processes on Air Quality
photopaq.ircelyon.univ-lyon1.fr
Cleaning the air by means of photocatalytic construction materials...
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O3
NOx
VOC
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Objectifs of the project

- demonstrate the usefulness of photocatalytic materials for air pollution reduction
- providing recommendation to the European authorities on the practical application for air treatment
- designing better environmental indicators and methods to assess the impact of this new technology in European cities

Aims to give answer to following questions:

- What conditions are needed for highest efficiency?
- Where is the place for maximum depollution?
- What differences are there in different areas across Europe?

What are the challenges for the application of TiO_2 in tunnels?

- No UV-light, very limited visible light => extra UV-lights!
- High concentration of pollutants => risk of covering of the surface; risk of no activation due to covering of the surface before installation of the lamps
- No rain in the tunnel => cleaning with water is necessary

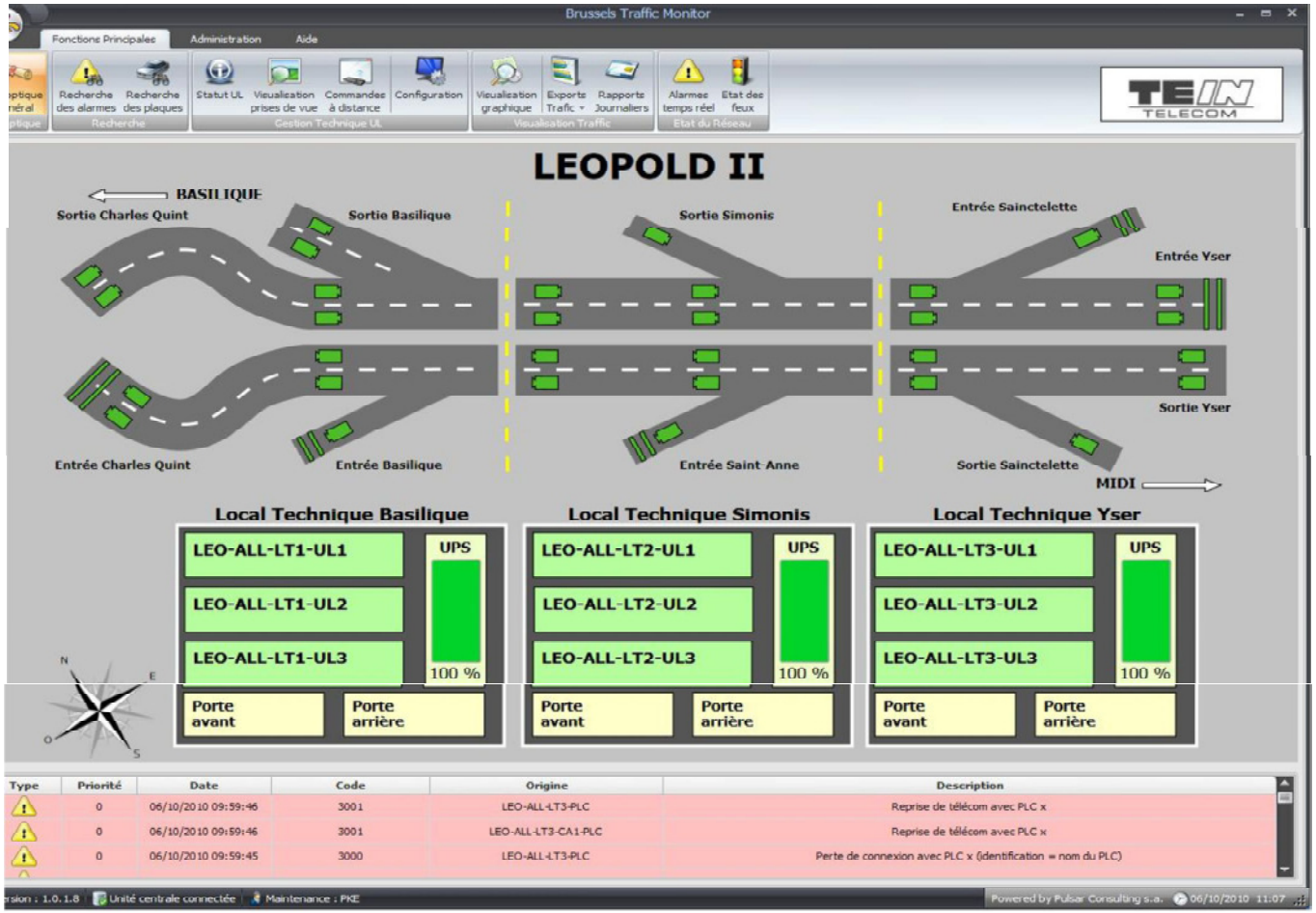
But

- Possibility to install extra lighting
- Large surface available (walls and roof)
- Cars will cause turbulence
- Outlet of the tunnels!
- Better for the environment; reduction in ventilation, cleaner air for the surrounding area

Tunnel Léopold II : intensive measuring campaign

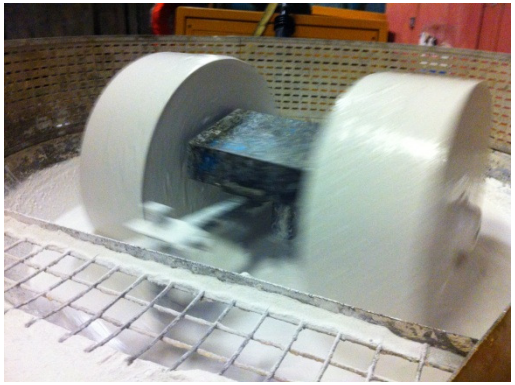
ian Road
Research Centre

Tunnel Léopold II : intensive measuring campaign



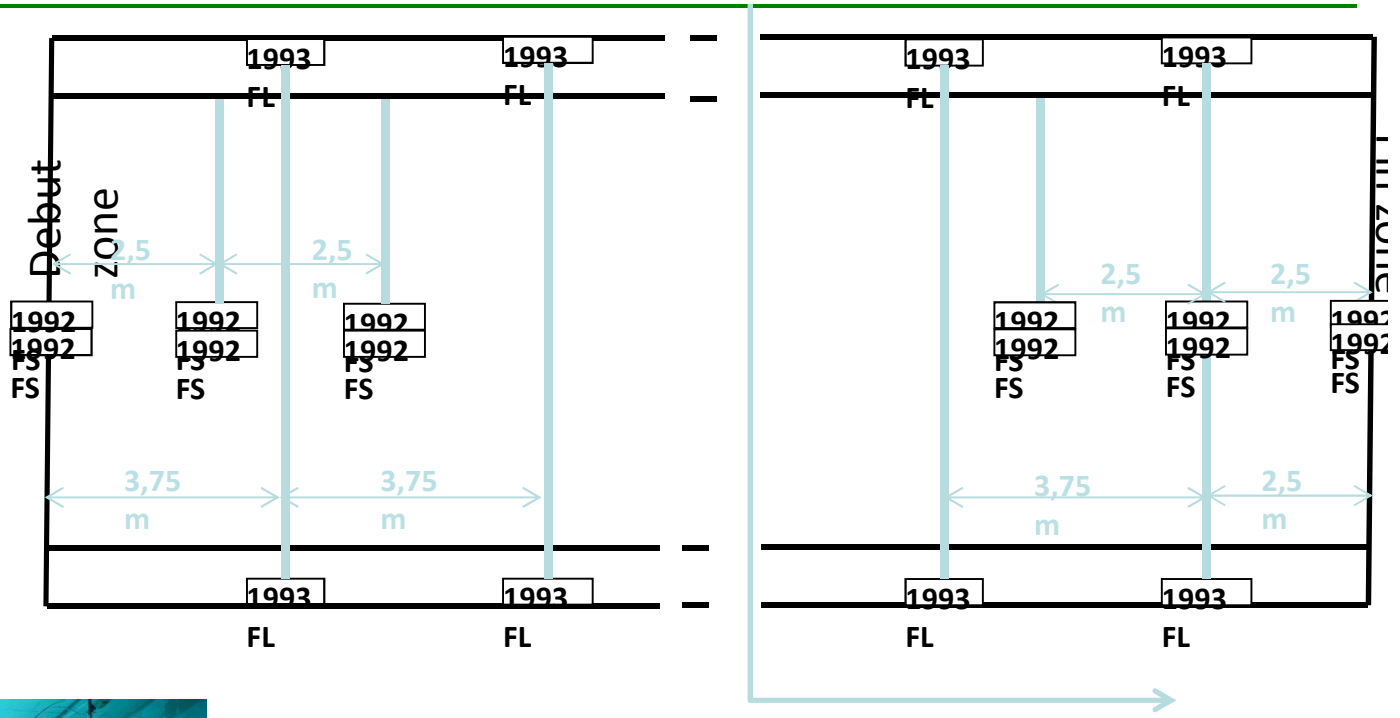
Tunnel Léopold II : field campaign

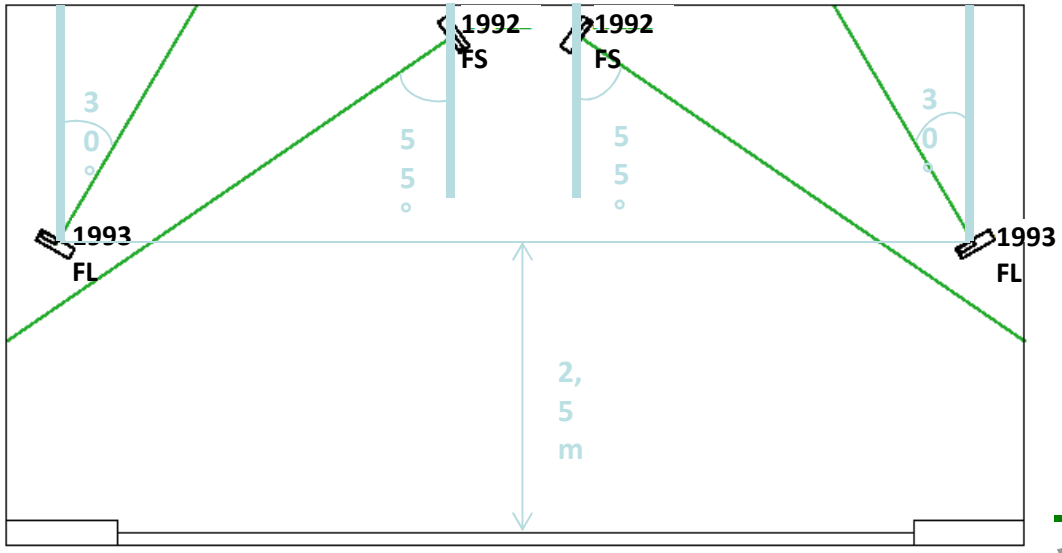
Execution phase II: application of product and lighting



- Cleaning of the walls and ceiling
- Mixing and spraying of the product
- Installation of UV light – transition zone
- Activation period

Installation of lamps – aim: 4 W/m²





Measuring points

„Front“
shifted up traffic of the corner

„main“
1-2 m next to port 4018

sampling inlets

1 m

2 m

photocatalytic active area
extended to ~160 m

1 m

Measuring equipment: front site and main site

Tunnel Léopold II : intensive measuring campaign

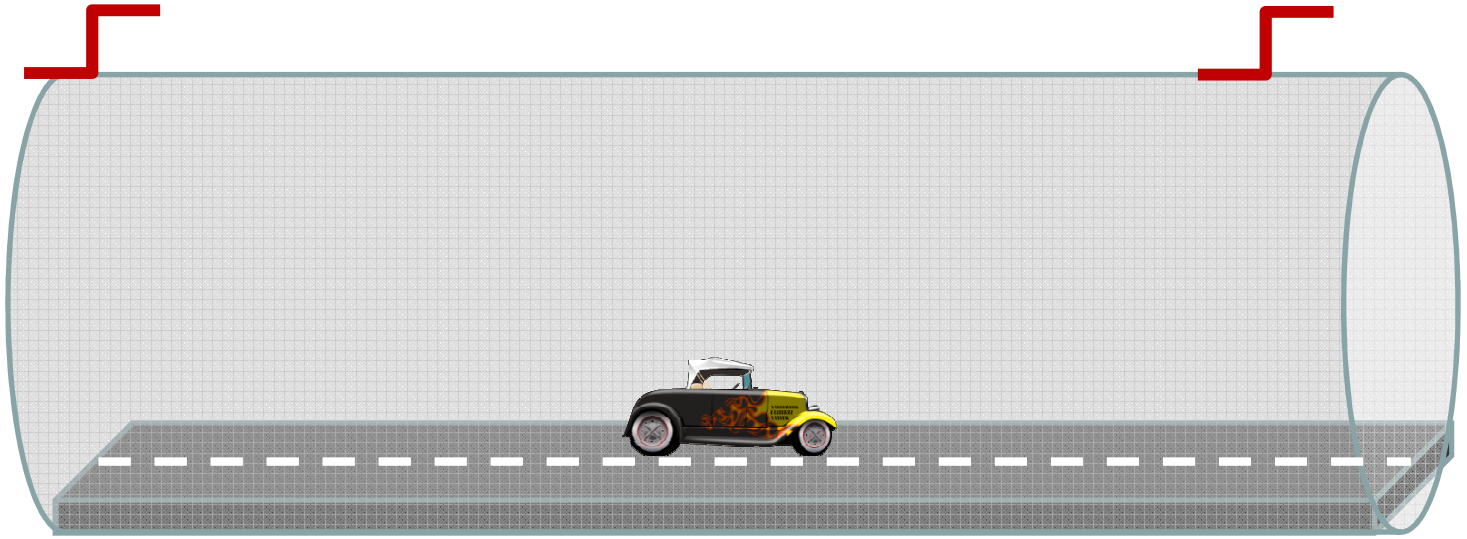
A full characterization of the air quality (35 equipments)

Ozone
NOx / NOy
(Many) VOCs
CO / CO2
Particles (size + composition)

Temperature
Wind speed
Relative humidity
Traffic
Ventilation

Front Station

Main Station



Treated section

Measuring campaign

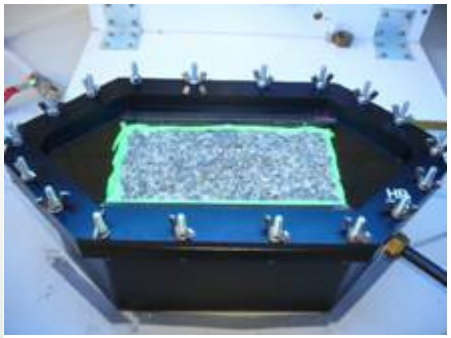
- Same equipement on front and main site
- Intercallibration of the equipment
- Measurements with light on/off over different periods of the day
- Interpretation: determination of noise level – wind direction changes over night…
- No conclusive results from first calculations: Too poluted? Too short activation period? Too low light intensity?

Second test campaign in Bergamo

- Street canyon
- Treatment of vertical walls
- Parallel canyon street

Conclusion

- Laboratory versus in situ: efficiency of products is increasing in laboratory, knowledge on optimal parameters is better, results in situ are expected and needed
- Type of the photocatalytic material: European standard is necessary
- Durability of the photocatalytic material: important parameter for sustainable applications
- Evaluation of in situ testing: activation time, contact time, light intensity,representative measurements,…



Thank you for your kind attention