Impact on the health and environment of particles emissions proceeding from ceramic plants

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In general, the particles emissions to the atmosphere are one of the main environmental problems of the ceramic manufacture industries. These emissions take place mainly in the firing and drying stages (the last one considered not significant).

The project "Minimization of pollutants emissions in small and medium companies of Castilla y León and impact on the health and the environment carried out in Spain", involves the integration of the dispersion modelling of pollutants emissions with two tools of environmental management: Life Cycle Assessment (LCA) and Impact Pathway Analysis (IPA), for the achievement of the emissions minimization and the reduction/elimination of its damage to the health and the environment.

This paper is focused on the comparative analysis of the particles emissions to the atmosphere proceeding from two different kinds of ceramic plants that use different energy sources, petroleum coke and natural gas. This study has been carried out using an atmospheric dispersion model, ADMS 3.3, and two tools of environmental management, LCA and IPA.

The selected fuel used in the kiln and/or drying place during the process of firing, and it is yield from energy and from an environmental point of view, significantly influences in the atmospheric emissions generated and in the characteristics of the final product.

1. Ceramic plants

This study has been carried out in two ceramic plants, one of them located in Corrales del Vino, Zamora (Spain) (plant A) and the other in Crespos, Ávila (Spain) (plant B).

Plant A: is a ceramic plant using natural gas as energy source. Ceramic products, bricks, etc are made in this plant situated in Zamora (Spain). The potentially polluting points that are submitted to control are six: cogeneration engine, two dryers, predryer, kiln and boiler.
Normally, the cogeneration engine works approximately at 200 ºC. The kiln works at 900ºC.

The operation time of the emissions points during the whole year is the following: boiler, 720 h/year, kiln, predryer and two dryers, 7.920 h/year and cogeneration engine, 7.200 h/year.
Plant B: is a ceramic plant using petroleum coke as energy source. Ceramic products, bricks, etc are made too in this plant situated in Ávila (Spain). This ceramic plant only has one emission point, the kiln. The fuel feeding the kiln is petroleum coke (derived from the carbon). The kiln works in a range from 880 ºC to 900 ºC.
The operation of the emission point during the whole year is 6.720 h/year. The production is estimated in 50.000-60.000 units/day of bricks.

The total emissions of the ceramics plants understudy were monitored several times during two months. The main air pollutants: SO_2, NO_2, CO, CO_2 and particles, were analysed but this paper is only focused on the study of the particles emissions to the atmosphere.
This study of micro-pollutants emission has been carried out by means of an atmospheric dispersion model, developed by the commercial software ADMS 3.3, an environmental impact model and an environmental cost model.

2. ADMS 3.3, LCA and IPA

The ADMS 3.3 software tool has been used in this work to model the atmospheric dispersion of pollutant emissiion of ceramic plants.
This software links to other software packages, such as Surfer, a contour plotting package for easy and effective display of results, and Arc View and MapInfo GIS (Geographical Information System) software, for displaying of results and easy data entry.
The model is applicable up to 60 km downwind of the source and provides useful information for distances up to 100 km.

LCA studies environmental aspects and potential impacts through the product’s life cycle (from cradle to grave), from raw material acquisition to production, use, and final disposal.
IPA is a tool to assess the environmental fate and exposure of emissions to air. It allows to evaluate the damages to human health and ecosystems in physical impact parameters and in monetary terms.
The software SimaPro and RiskPoll have been used in this work to evaluate the damages produced by the emission of the particles on the environment and the human health.
SimaPro is a software to collect, analyse and monitor the environmental performance of products and services. It is a tool to model and assess complex life cycles in a systematic and transparent way, following the ISO 14040 series recommendations.
RiskPoll is a set of “simplified” risk assessment tools for quantifying impacts to public health following routine airborne emissions.

3. Procedure

The model described above allowed obtaining the concentration maps of emissions in the atmosphere of the area studied.
With the information about emissions of particles, the space coordinates, where each of the plants are, and according to the meteorological conditions (National Institute of Meteorology, INM, Spain) the data were treated with ADMS 3.3 that is to say, the modelling of emissions was proceeded.

Next, the damages produced by the emission of the particles on the environment and the human health are studied using the tools LCA and IPA.

4. Modelling. Inputs and outputs

Some of the input data used in the modelling are shown:

<u>The ceramic plant with natural gas as energy source:</u>
Height of the stack = 9,20 m
Inner diameter of the stack = 1,71 m
Vertical velocity of release at exit point = 13,1 m/s
<u>The ceramic plant with petroleum coke as energy source:</u>
Height of the stack = 11 m
Inner diameter of the stack = 1m
Vertical velocity of release at exit point = 8 m/s

The average pollutant emission rate in two months for each ceramics plants is shown in the table 1:

Table 1: Particle emission rate (g/s)

Ceramic plant	Particles (Month 1)	Particles (Month 2)
Plant A	0,068	0,069
Plant B	0,242	0,330

In the case of plant A, month 1: June and month 2: July (2007)
In the case of plant B, month 1: April and month 2: June (2007)

The concentration results are viewed as a contour plot over a map in which the ceramic plants under study were marked. The dispersion of the particles under study was modelled.
The maps included in the next sections show the areas affected by the emissions and the magnitude of the overall impact.

4.1 Modelling of the plant A

The dispersion of particles from the plant that use gas natural as energy source during the month of July is represented in the figure 1. The particles emission rate is 0,069 g/s. There is not a tendency of the dispersion plume towards an specific direction because the meteorological conditions were very variables during that month. The dispersion is extended as maximum approximately 800 m. The maximum concentration reached is 0,6 μg/m^3.

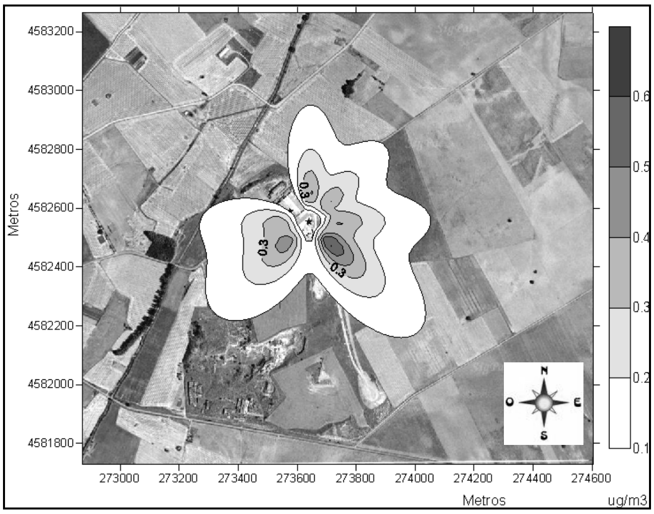


Figure 1: Dispersion of particles given off from the kiln of the plant A during the month of July

4.2 Modelling of the plant B

The dispersion of particles from the plant that use petroleum coke as energy source during the month of April is represented in the figure 2. The particles emission rate is 0,242 g/s. The dispersion is extended as maximum, approximately, 300m. The maximum concentration is 8 μg/m^3.

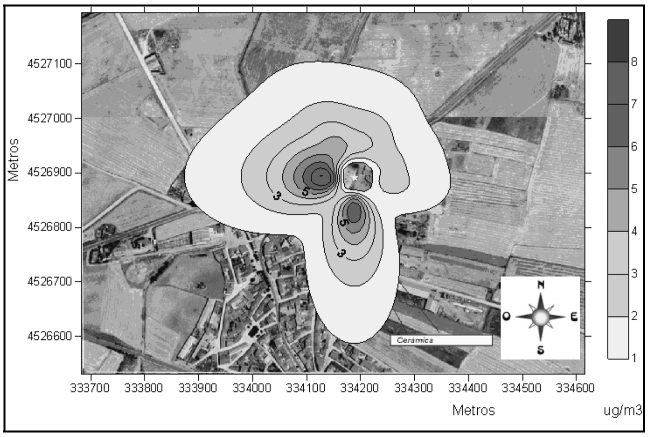


Figure 2: Dispersion of particles given off from the kiln of the plant B during the month of April

5. Impact on the health an environment. Inputs and outputs

Environmental evaluation:

Operation time of the kiln, plant A = 7.920 h/year

Operation time of the kiln, plant B = 6.720 h/year

In evaluation of environmental risks, and under the perspective of the precaution principle is usual to study the "worst-case" scenario. Therefore, in this study, it is proposed the analysis of two scenarios.

Scenario 1 (E_{max}): The emissions corresponding to the upper limit of the confidence interval of the highest measurement.

Scenario 2 (E_{min}): The emissions corresponding to the arithmetic average of the realised measurements.

Table 2: Annual emissions (t/year)

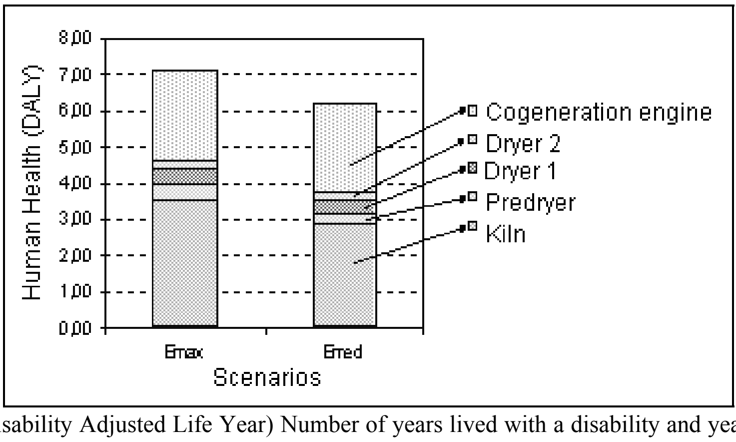
Ceramic plant	E_{max}	E_{med}
Plant A	1,99	1,97
Plant B	10,57	6,93

5.1 Impact of the plant A

The environmental damage, to the human health and to the ecosystem quality produced by the kiln is showed in the figures 3 and 4.

The annual value of the damage to the human health for the scenario of maximum emission is estimated in 7,12 DALY, versus 6,24 DALY for the average scenario.

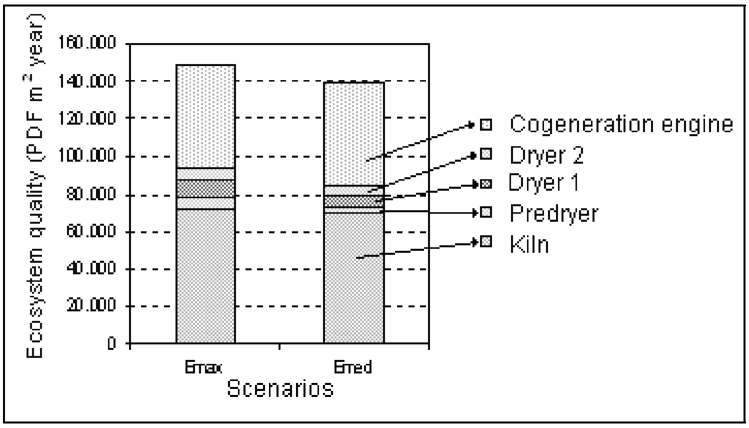
The kiln is the main responsible of the damages to the human health, ~50%.



DALY (Disability Adjusted Life Year) Number of years lived with a disability and years lost due to premature mortality.

Figure 3: Distribution of the damages to the human health for emissions points

The annual value of the damage to the ecosystem quality is estimated in 148.303 PDF·m^2·year, for the scenario of maximum emission, versus 139.336 PDF·m^2·year, for the average scenario.
As it happened in the category of damages to the human health, the kiln is the main responsible of the damages to the ecosystem quality, ~48%.



PDF·m^2·year (PDF, Potentially Disappeared Fraction) Percentage of species disappeared in a certain area during 1 year

Figure 4: Distribution of the damages to the ecosystem quality by emission points

The kiln is the main responsible of the environmental costs, ~47%. The particles emissions have an environmental cost of the ~13% (figure 5).

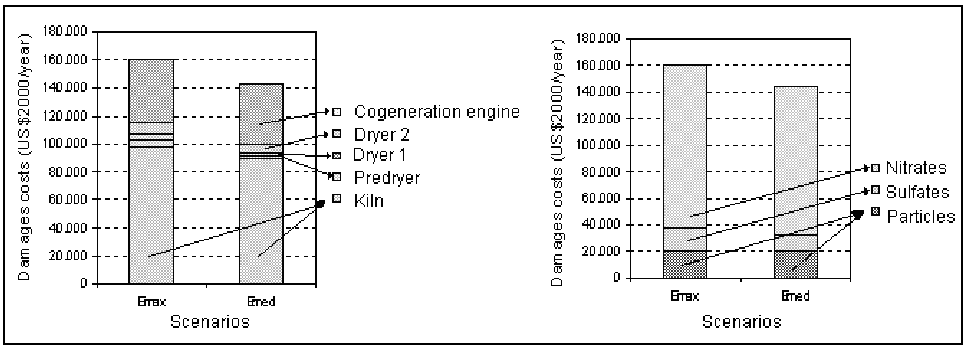


Figure 5: Distribution of the environmental costs by emission points and by emitted pollutants

5.2 Impact of the plant B

The damage to the human health of the kiln and the contribution of the particles to the environmental costs are showed in the figure 6.

The annual value of the damage to the human health for the scenario of maximum emission is estimated in 4,90 DALY, versus 3,57 DALY for the average scenario.

The particles are one of the main responsible of the damages to the human health and contributes to the environmental costs in a ~28%.

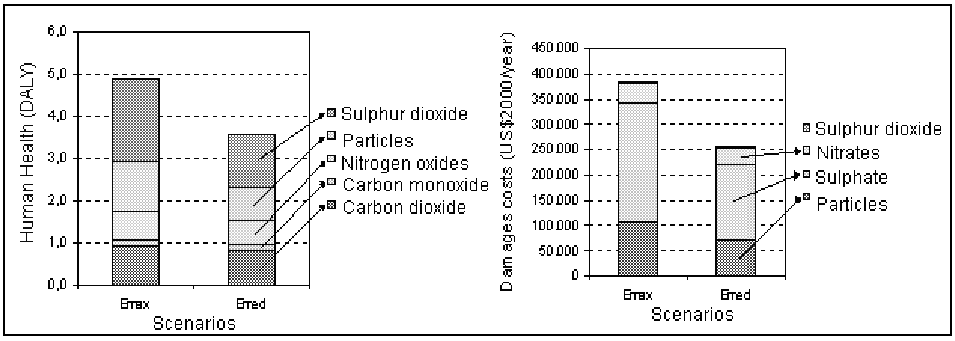


Figure 6: Contribution of the particles to the damages to the human health and to the environmental costs

6. Conclusions

In the case of the ceramic industry with natural gas as energy source (plant A), the particles emissions are lower (1, 97 t/year) than in the case of the facility with petroleum coke as energy source (plant B), (6, 93 t/year).

The particles dispersion from the plant A is higher or covers a wider surface than the dispersion from the plant B, because of unfavourable meteorological conditions; however the concentrations in the dispersion plume are higher for the plant B than for plant A, because of the type of energy source used.

In spite of that the kiln is the main responsible of the environmental damage, to the human health and to the ecosystem quality, the impact of the particles is not specifically much significant (~5%) in the plant A.

Observing the scenario of maximum emission (E_{max}) in the plant B, it is necessary to emphasize that the contribution of the particles to the damage to the human health is 1,16 DALY or 119.626 € (year 2007).

The particles emissions contribution to the environmental costs is 15% more in the case of the ceramic industry with petroleum coke as energy source.

The advantages of using natural gas (plant A) are the following: the emissions are smaller than with the rest of fuels, the LCV (Lower Calorific Value) is higher, etc. And the disadvantages are: high cost, does not count on the necessary infrastructure, etc.

Regarding the advantages of using petroleum coke (plant B), these are the following: low cost, availability, etc. And the disadvantages are: particles emissions in the transport and storage, higher emissions than when using natural gas as energy source, high content in sulphur (however the emissions are catalyses during the process), etc.

8. Acknowledgements

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7. References

ADMS, 2004. Users guide ADMS 3.3 Software, CERC, Cambridge, UK.

Muñoz I., Domenech X., Malato S., 2006, Life cycle assessment as a tool for green chemistry: application to different advanced oxidation processes for wastewater treatment. Ministerio de Educación y Ciencia, Ciemat, España.

Sonnemann G., Castells F., Schuhmacher M., 2004, Integrated Life-cycle and risk assessment for industrial processes. Advanced Methods in Resource and Waste Management. Lewis Publishers, Boca Raton, Florida.

Spadaro J.V., 2004, RISKPOLL. Manual and reference documentation. Impact assessment tools to estimate the health and environmental risk from exposure to routine atmospheric emissions.

CAR/PL, Centro de Actividad para la Produccion Limpia (Center of Regional Activity for the Clean Production), 2006, Prevención de la contaminación en el sector cerámico estructural (Prevention of the pollution in the ceramic structural sector).