Proceedings of the Third International Symposium on Air Quality Management at Urban, Regional and Global Scales. pp. 461-470, 26-30 September 2005, Istanbul – Turkey

THE EVALUATION OF THE AIR QUALITY IMPACT OF AN INCINERATOR BY USING MM5-CMAQ-EMIMO MODELLING SYSTEM: NORTH OF SPAIN CASE STUDY

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ABSTRACT

The use of sophisticated air pollution modeling systems to evaluate the impact of different industrial plant emissions is currently done in extensive way. MM5-CMAQ (PSU/NCAR and EPA, USA) is one of the most applicable air quality modeling systems to evaluate those impacts. In this contribution we present the methodology and results obtained when applying the MM5-CMAQ air quality modeling system for evaluating the potential impact of an incinerator in San Sebastian (Basque Country, Spain). We have used the EMIMO (UPM, Spain) emission model to simulate the emissions from biogenic and anthropogenic sources including traffic and tertiary sector sources. The application also includes the study of the relative impact of a section of an important highway in the surrounding areas of the expected location of the incinerator. The system has been prepared to simulate also Cadmium, Arsenic, Nickel, Lead and Benzo(a)pyrene air quality impacts. The PCDD/F air concentrations have been determined for the 16 toxic dioxins and furans as determined in the bibliography. The criteria pollutants such as CO, NOx, SO2, PM10 and O3 have also been determined according to the different EU Directives which limit the values of such a pollutants for different periods of time.

Key Words: Air Quality, Ozone Concentration, Suspended Particulate Matter, Dioxins and Furans, Incinerator

1. INTRODUCTION

The use of complex numerical air quality modelling systems has increased in the last years for evaluating the impact of different industrial plants and also for air quality simulations over city and regional areas. The main reason to use these sophisticated air quality modelling systems is the increase on computer power availability. Due to the high accuracy of the so-called third generation of air quality modelling systems – which includes complex chemical carbon mechanism, aqueous and aerosol chemistry – the use of these systems is highly recommended particularly for secondary pollutants such as O3 and PAN and for chemically active primary pollutants such as NO and NO2. The complexities involved in the particulate matters transformations recommend the use of these complex numerical models. In this contribution we show the implementation of a modified version of MM5-CMAQ-EMIMO for carrying on an air quality impact analysis for installing an incinerator in the San Sebastián – Donostia (Basque Country (Spain). The study includes also the relative impact of six large industrial plants located in the surrounding area and already existing and finally the relative impact of an important highway located also in the surrounding area.

The modified CMAQ model (EPA USA, 2004) includes Poly-Chlorinated Dibenzo-p-Dioxins and Dibenzo-Furans (dioxins and furans). The model represents their cogeners as divided between gaseous and aerosol forms that exchange mass based on theoretical coefficients for gas to particle portioning. Modelled metals are included in CMAQ as part of the non-reactive aerosol component. Metals modelled are: As, Cd, Ni and Pb. In additional Benzo(a)pyrene (PAH) is also modelled. The model is implemented in a cluster platform in order to be used as a real-time air quality forecasting system by using the ON-OFF approach. The emissions of the projected incinerator in the ON run are incorporated by using the height of the chimney, the prescribed exit gas velocity, diameter of chimney and the limit emission values (worst scenario) prescribed in the Directive/2000/76/CE. The OFF run is done by using EMEP POP and PAH emission inventory. The system is mounted over one mother domain of 400 x 400 km with 9 km spatial resolution and two nesting levels: 100 km model domain with 3 km spatial resolution and 24 km with 1 km spatial resolution. All model domains with 23 vertical layers up to 100 mb and centered over the UTM coordinates prescribed for the projected incinerator. EPER EU industrial emissions (May, 2004) of the surrounding large point industrial sources are used. Results are compared with the target values included in the proposal for a Directive of the European Parlament and of the Council (ENV 194 CODEC 439).

Different other meteorological and dispersion modeling systems exist such as EMEP, RSM, CAMx, etc. (Cleverly et al., 1997; Collins et al., 1997; Derwent, R. and Jenkin M., 1991; Lagner et al., 1998; Roemer et al., 1996; Whitby K.T., 1978; Walcek C., 2000; Schmidt et al. 2001; San José et al. 1994,1996 and 1997) which have similar performance than the one used in this application.

2. THE MM5-CMAQ-EMIMO MODELLING SYSTEM

The MM5 model is a non-hydrostatic mesoscale meteorological model (Pennsylvania State University / National Center for Atmospheric Research) (Dudhia, 1993; Grell et al. 1994) which is widely used around the world for meteorological research and also for operational meteorological use. The MM5 meteorological model is capable to produce 3D wind, temperature, humidity and other important meteorological parameters and variables during simulations of several hours and days. MM5 is a nested-grid primitive-equation model, which uses a terrain following sigma (non-dimensionalized) vertical coordinates. CMAQ model (Community Multiscale Air Quality Modelling System) (Byun et al., 1998) is a Comprehensive Air Quality Model which simulates the chemical transformations and the dispersion of the pollutants in a 3D domain. The input meteorological data is taken from the MM5 meteorological model. CMAQ model is structured in a full modular way. The different configurations should be consistent with those prepared for the meteorological model simulations. Both models, MM5 and CMAQ, are feed with emission data sets which in our case are produced by the EMIMO modeling system (San José et al., 2002). EMIMO is using different global and European data sets which are produced as official data, to estimate the emissions at very high spatial and temporal resolutions (1 km, and 1 hour). EMIMO is currently using EMEP, GEIA and EDGAR global and European datasets (European Topic Center on Air and Climate Change; Gardner et al., 1997; Pacyna et al., 1999; San José et al., 1998, 2004).

The MM5 model has been implemented over three nesting domains (one mother level and two nesting levels). Figure 1 shows the three nesting domains centered in the location where the incinerator is planned in San Sebastian (North of Spain).

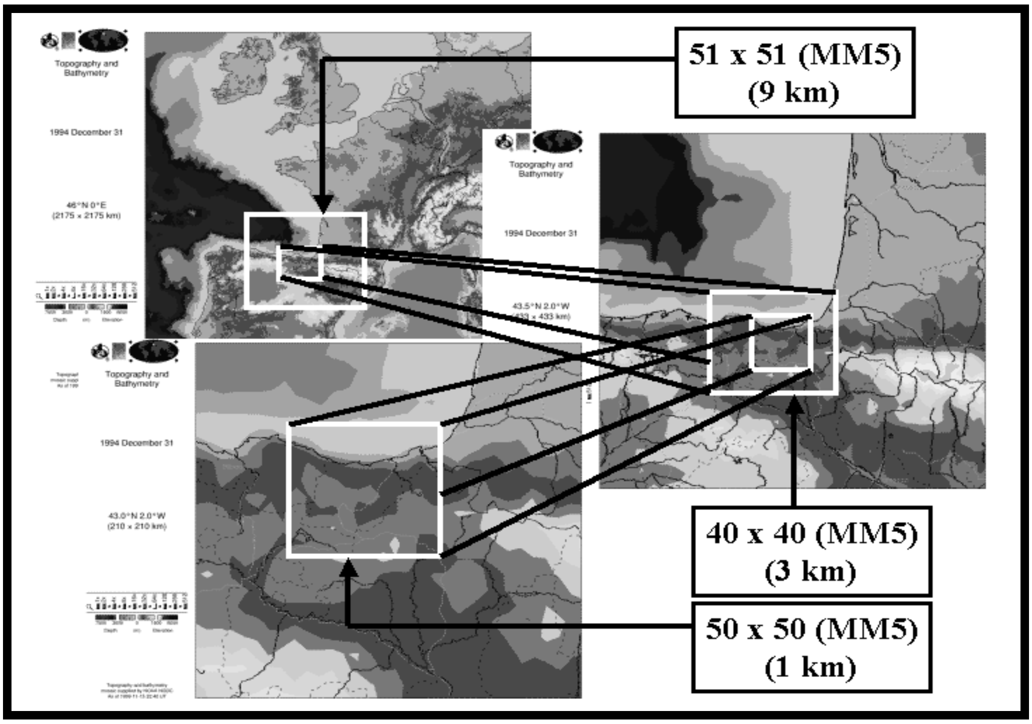

Figure 1. MM5 architecture design over the location in San Sebastián where the incinerator is planned.

The MM5 model is using GSM model (Global Spectral Model) output for initial and boundary conditions. In case of CMAQ, default profiles are used according to CMAQ configuration file. The MM5-CMAQ-EMIMO modeling system has been run for 12 periods of 120 hours each one for the three different model domains along the Nov., 2003 – Oct.,2004 year. Each 120 hour period has been selected for each month. The selection procedure is based on the mobile average over 120 hours for each month by using monitoring data from different air quality monitoring stations. So that, the selected periods corresponds with average pollution periods for the different criteria pollutants. The MM5 model has been run by using the assimilation meteorological data from the Basque Country meteorological network for the selected period of time. The CMAQ model has been implemented exactly into the MM5 model domains. In both models, 23 vertical layers have been used.

CMAQ – EMIMO modeling system has been run simultaneously over the 1440 hours (covering the period Nov., 2003 – Oct., 2004) with two different scenarios: ON and OFF. The OFF scenarios is a full emission scenario including biogenic and antropogenic sources provided by EMIMO. These includes all EPER emission data sets and information provided by different industrial emission sources which are not included in EPER but provided directly by the different companies. The ON scenarios is exactly the same than OFF scenario but including the characteristics and emissions of the projected incinerator. This information includes: a) height of the chimney; b) Diameter of the internal output area in the chimney; c) Temperature at exit of emitted gases; d) Exit velocity of gases; e) Flux of gases emitted for each pollutant. So that, the differences in time and space between both simulations are the expected pollution impact of the projected incinerator over the different model domains for each pollutant. In addition to this, several additional impact studies were performed in order to know the relative importance of such a impact compared with the emissions in the 45 km of the highway surrounding the location of the projected incinerator. Additionally, 6 different large industrial plants located in the 1 km model domain (45 x 45 km) were studied by using the same procedure.

In order to establish the relative impact of the A8 Highway in the surrounding areas, a detailed traffic emission inventory was performed based on the accounting detailed data sets provided by the Basque Country Government.

The chemical mechanism used in CMAQ model was the CBM-IV with aqueous and aerosol chemistry (Gery et al. 1989; Stockwell et al. 1977). We have added the different metals (non-reactive species) to the chemical FORTRAN code and also we have implemented the dioxins and furans mechanism provided by Hutzell W.T. (2002). The PCDD/F chemical mechanism incorporates 10 different furans and 6 dioxins as shown in Table 1.

Table 1. Toxic Dioxins and Furans analyzed in the present experiment and the correspondent Toxic Equivalent Factor.

	Name	Toxic Equivalent Factor
2,3,7,8	TCDD	1
1,2,3,7,8	PeCDD	0,5
1,2,3,4,7,8	HxCDD	0,1
1,2,3,6,7,7	HxCCD	0,1
1,2,3,7,8,9	HxCDD	0,1
1,2,3,4,6,7,8	HpCDD	0,01
2,3,7,8	TCDF	0,1
2,3,4,7,8	PeCDF	0,5
1,2,3,7,8	PeCDF	0,05
1,2,3,4,7,8	HxCDF	0,1
1,2,3,6,7,8	HxCDF	0,1
1,2,3,7,8,9	HxCDF	0,1
2,3,4,6,7,8	HxCDF	0,1
1,2,3,4,6,7,8	HpCDF	0,01
1,2,3,4,7,8,9	HpCDF	0,01
	OTCD	0,001

The MM5-CMAQ-EMIMO modeling system has been calibrated by comparing the model results with the observations taken in the different monitoring stations (18) located at the Basque Country and provided by the Basque Government. Figure 2 and 3 show the comparison between observations at Mondragón and Azpeitia monitoring stations for O3 and PM10 with the simulated data obtained by the MM5-CMAQ-EMIMO modeling system.

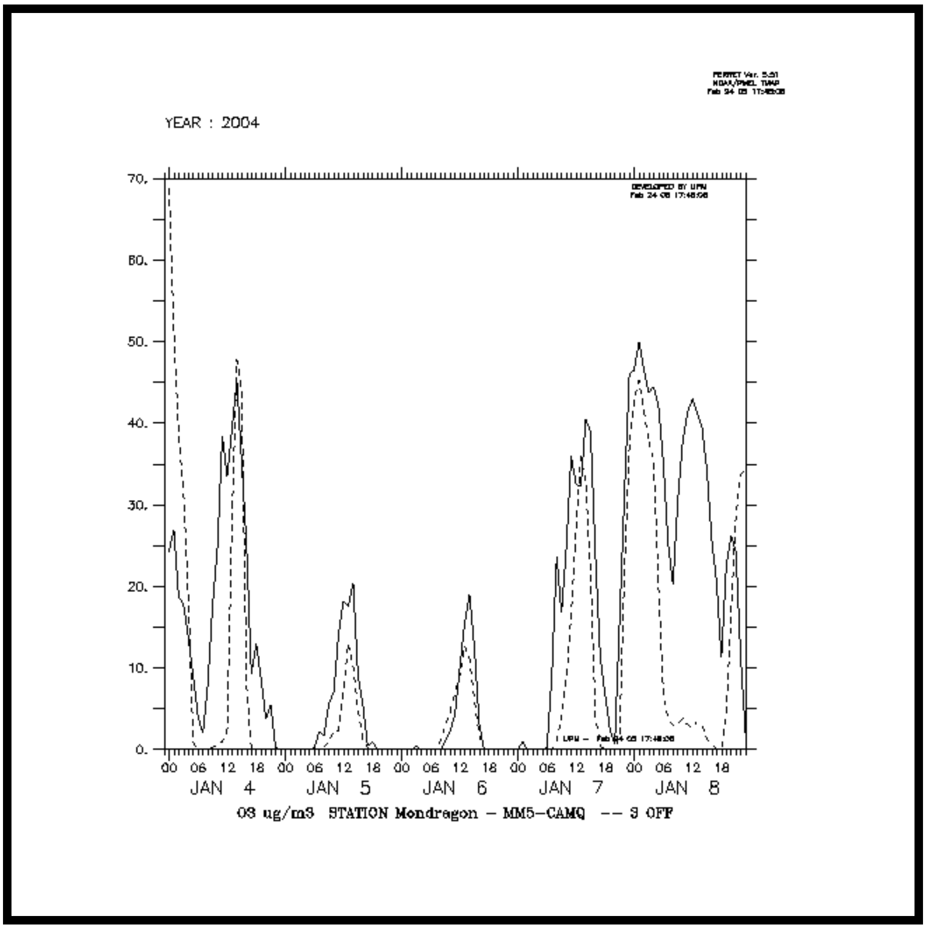

Figure 2. Comparison between O3 observations and simulated data as produced by MM5-CMAQ-EMIMO modelling system for Jan, 4-8, 2004 at Mondragón monitoring station in the 3 km spatial resolution model domain

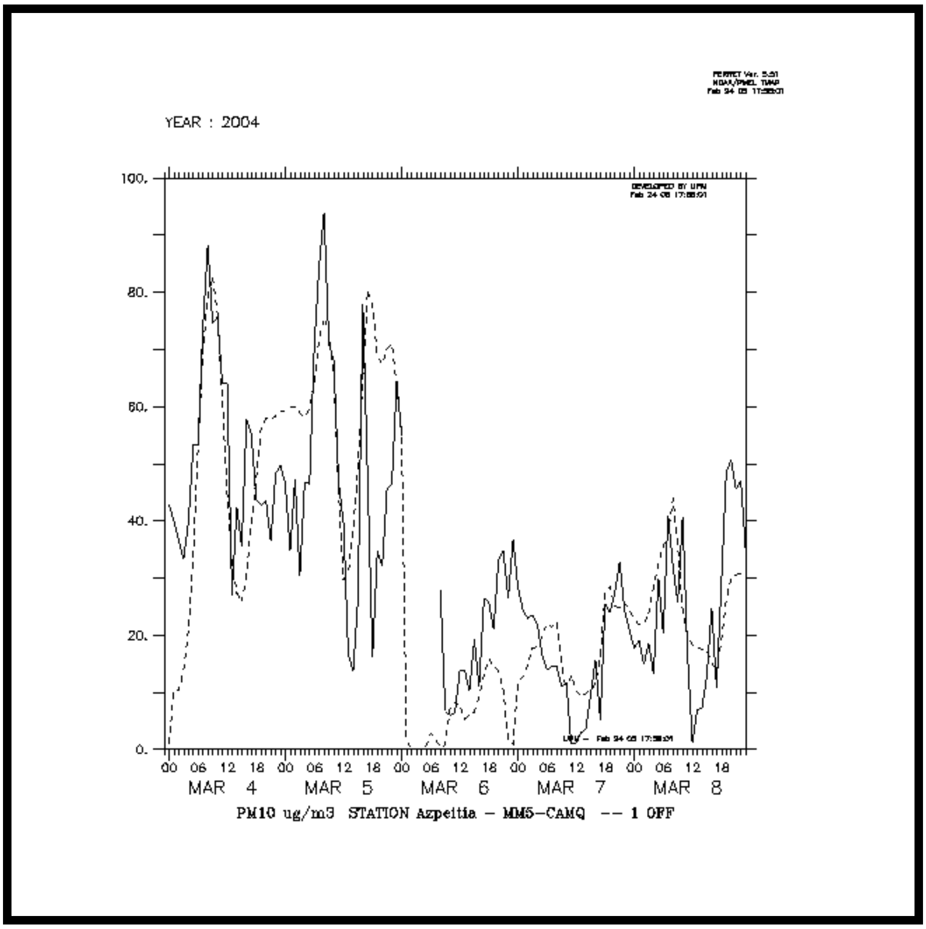

Figure 3. Comparison between PM10 observations and simulated data as produced by MM5-CMAQ-EMIMO modelling system for March, 4-8, 2004 at Azpeitia monitoring station in the 1 km spatial resolution model domain.

3. RESULTS

The results are a huge database of approximately 100 Gbytes of information which should be scanned according to the rules expressed in the different EU Directives to establish the possible exceedances and determine those due to the projected incinerator emissions. The results show that the PCDD/F impact is reduced although in some areas and times the percentage increase can be up to 70 %. The PCDD/F values are not limited in the actual EU Directives but WHO rules indicate that the concentrations should be as low as possible. The levels found are in the order of magnitude of fentogramme (10^{-15}). Figure 4 shows the averaged values between ON and OFF scenarios for the total PCDD/F species (16). Figure 5 shows the percentile 99,8 of the absolute differences between both scenarios for NO2 over the 1 km spatial resolution model domain. Maximum vales are not higher than 65 $\mu g m^{-3}$.

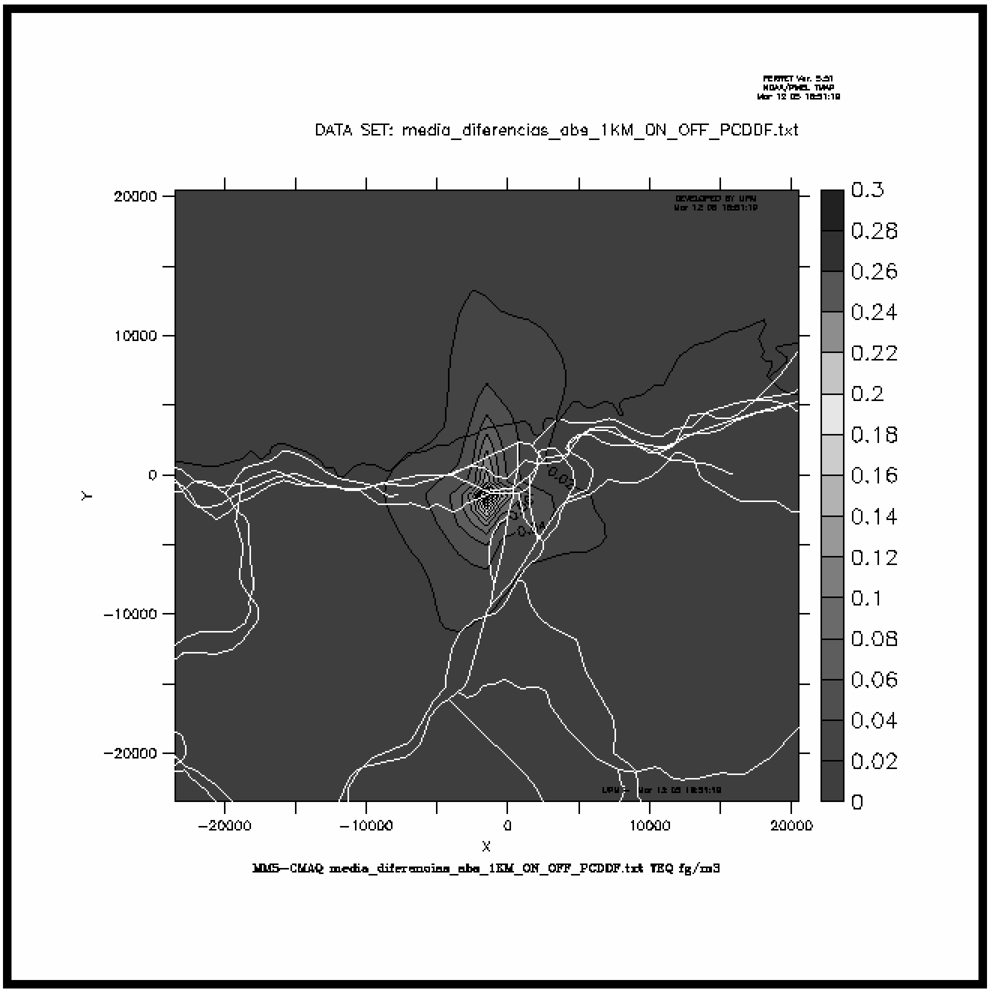

Figure 4. Average (60 days) of the differences between scenarios ON and OFF for the dioxins and furans for the 1 km spatial resolution model domain. Maximum differences are up to 0,5 10^{-15} TEQ g/m3.

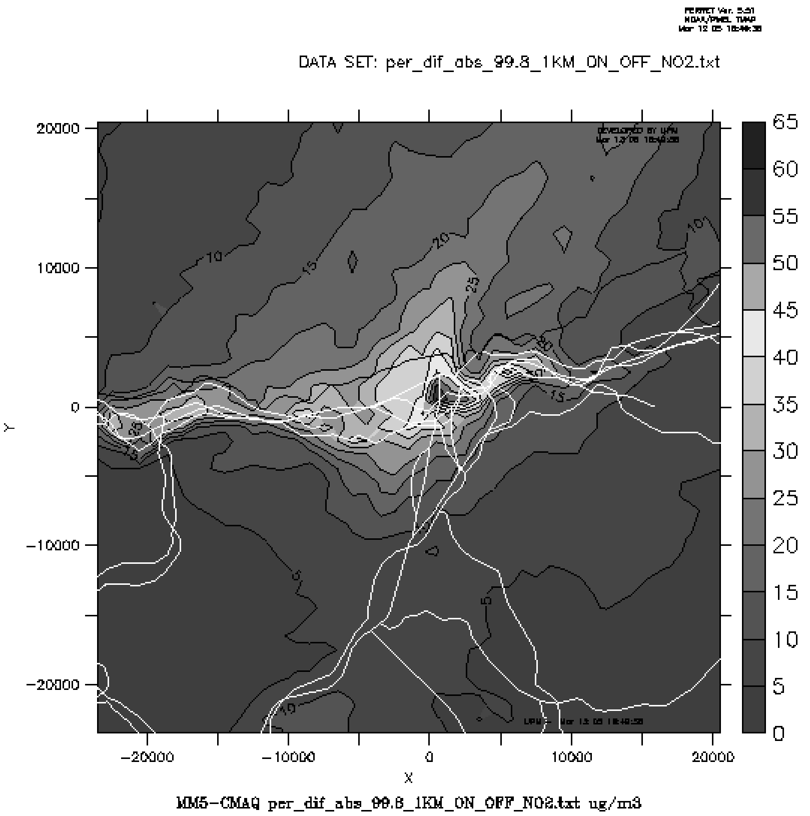

Figure 5. Percentile 99,8 of the absolute differences between scenarios ON and OFF for NO2 in the 1 km spatial resolution model domain. Maximum differences are about 65 $\mu g m^{-3}$

3. CONCLUSION

We have implemented the MM5-CMAQ-EMIMO model domain to study the impact of a projected incinerator in the suburban areas of San Sebastián (Basque Country, Spain). The system has been proved to be an excellent tool for such a type of studies since it is capable to analyze with high accuracy differences in the order of magnitude of fentogrammes (dioxins and furans). The system has also been used to compare the results with those obtained with actual large industrial plants located in the area and compare the impacts with those expected to be obtained by the projected incinerator. The study has cover the criteria pollutants (CO, NOx, SO2, PM10 and O3), EU Directive metals and PAH (Nickel, Cadmium, Arsenic and B[a]P) and 16 dioxins and furans (10 dioxins and 6 furans) following the chemical mechanism proposed by Hutzell W.T. (2002) (EPA, USA).

4. ACKNOWLEDGEMENTS

We would like to thank W.T. Hutzell for the PCDD/F mechanism implemented into the CMAQ modeling system. PSU/NCAR and EPA (US) for the MM5-CMAQ modeling system. Basque Country Government for the air quality monitoring, meteorological and industrial datasets.

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