ASSESSING THE ATMOSPHERIC POLLUTION OF ENERGY FACILITIES FOR SUPPORTING ENERGY POLICY DECISIONS

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ABSTRACT

The impacts of different energy facilities on the environment and human health are a matter of interest and concern throughout the world. For example, fossil fuels are one of the energy sources of more undesirable effects on the environment, but this energy is still one of the most competitive at the market, especially for the developing countries. However, it is necessary to find out a balance between the costs of achieving a lower level of environmental and health injury and the benefits of providing electricity at a reasonable cost.

With a view to solving the current deficit in energy production (mainly in electricity generation) in the light of major transformations in the energy sector, the Cuban Government is evaluating ways of incorporating new sources and technologies and the expansion of existing capabilities. In this context non-fossil energy sources will play an increasingly important role.

The present work shows the results obtained in the frame of the IAEA Technical Cooperation Project CUB7007. The project integrated several tools and methodologies in the field of air quality modelling and its assessment, emissions measurement and nuclear techniques.

The main objective was to assess atmospheric pollution from various energy facilities for supporting energy policy decisions by incorporating nuclear techniques (proton-induced X-ray emission, neutron activation and X-ray fluorescence) for estimating the elementary composition of particulate matter.

As a result, national laboratories in the application of nuclear and non-nuclear techniques to support environmental studies were consolidated, especially for the analysis of emissions in chimneys and ambient air sampling. Besides, all energy technologies considered in the national strategy of development were assessed.

METHODOLOGY

The work performed can be divided into three phases: monitoring of air pollutants emissions and urban air quality, air pollution modelling and analysis of particulate matter samples with nuclear techniques.

Starting from the equipment supplied by the IAEA under the technical cooperation project CUB7007, the following activities were performed :

- Monitoring of pollutants gases and particulates emission in several national industries from the energy sector: gas turbines, combined cycle gas, internal combustion engines, power plants, oil refineries, steel, cement and asphalt plant.
- Annual campaign of air quality monitoring at three points in Havana (PM_{10} and $PM_{2.5}$) throughout 2012.

Location of air quality sampling points at Havana City

The emission monitoring of gases and total particulate matter were conducted using a combustion gas analyzer TESTO-350 XL and an ISOSTACK-BASIC automatic sampler, respectively.

Moreover for low volume sampling (LVS) of particulate matter (PM_{10} and $PM_{2.5}$) in urban air, TECORA and DERENDA samplers were used.

TECORA LVS at point 2

A total of 291 samples of particulate matter were obtained: INHEM (97), CUBAENERGIA (139) and CUJAE (55). The following analysis were performed to the collected samples :

- Gravimetric analysis using a Sartoriuos microbalance ME5.
- Organic and elemental carbon analysis. Since there are not national capabilities, the samples were taken to the National Centre for Environmental Health (ISC III), Atmospheric Pollution Area, Madrid, Spain.
- PIXE analysis. Since there are not national capabilities, PIXE analysis was conducted at the Ruđer Bošković institute (RBI), Zagreb, Croatia.
- ICP-MS analysis.

Another stage of the project was the use of air quality models to assess the transport of air pollutants and their environmental impact. AERMOD model system was used to evaluate the dispersion of air pollution from 0 to 50 Km and WRF-CALMET-CALPUFF from 50 to 300 Km. Moreover, the WRF-CHIMERE model system was used to assess the formation of tropospheric ozone.

RESULTS

The summary of the gravimetric and carbon analysis from air quality monitoring are shown in the tables below:

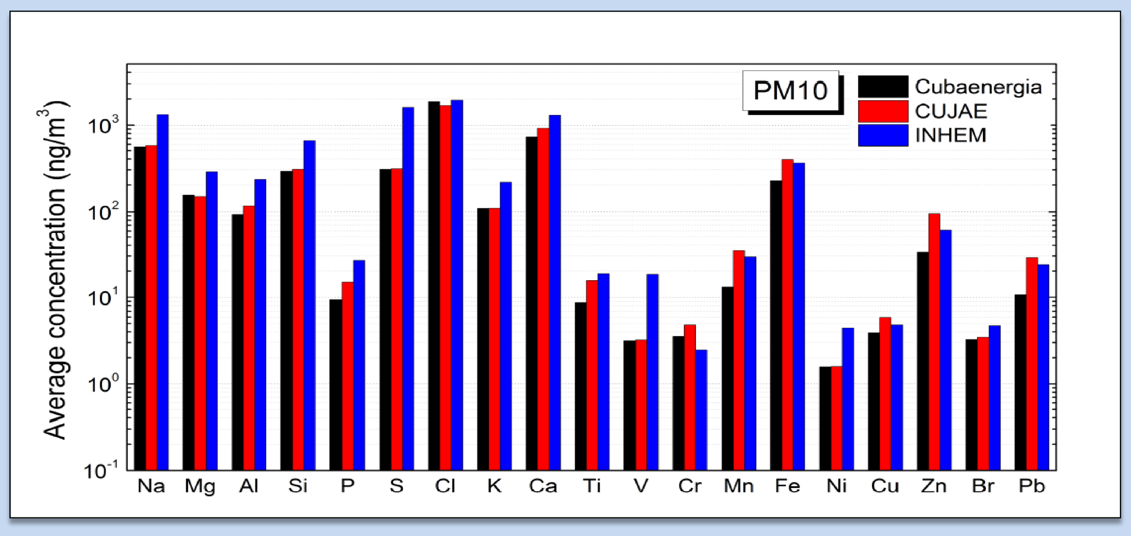
Monitoring points	Particle fractions		Minimum	Maximum	Average
(1) INHEM	PM_{10}	(µg/m³)	15.7	89.8	37.4
	$PM_{2.5}$		6.1	43.6	20.1
	$PM_{2.5}$ / PM_{10} (%)		25.8	70.4	53.6
(2) CUBAENERGÍA	PM_{10}	(µg/m³)	2.1	77.6	24.4
	$PM_{2.5}$		1.0	33.3	12.2
	$PM_{2.5}$ / PM_{10} (%)		13.8	84.4	50.6
(3) CUJAE	PM_{10}	(µg/m³)	7.3	68.2	24.9
	$PM_{2.5}$		3.9	41.2	12.9
	$PM_{2.5}$ / PM_{10} (%)		34.0	73.0	52.0

Statistical parameters of daily concentrations of PM_{10} and $PM_{2.5}$. January-December 2012

		Concentrations (µg/m³)			
		(1)INHEM	(2)CUBAENERGÍA	(3) CUJAE	Average
$PM_{2.5}$	Total mass	16.8	14.5	15.1	15.2
	Elemental carbon	6	4.6	15.1	4.4
	Organic carbon	3.8	2.5	3	3.1
	Total carbon	9.8	7.2	2.1	7.7
PM_{10}	Total mass	29	3.27	0.31	28.9
	Elemental carbon	5	2.2	8.2	3.3
	Organic carbon	7	9.5	3.3	5.3
	Total carbon	13	1.8	1.5	8.6

Average concentrations of organic, elemental and total carbon (ug / m³) in $PM_{2.5}$ and PM_{10}. January-February 2012

The results of PIXE analysis to 182 samples collected from January to April 2012 (92 samples of PM_{10} and 90 samples of $PM_{2.5}$) are shown in the next figure.



19 elements (Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Pb and Br) were identified in both particle sizes samples.

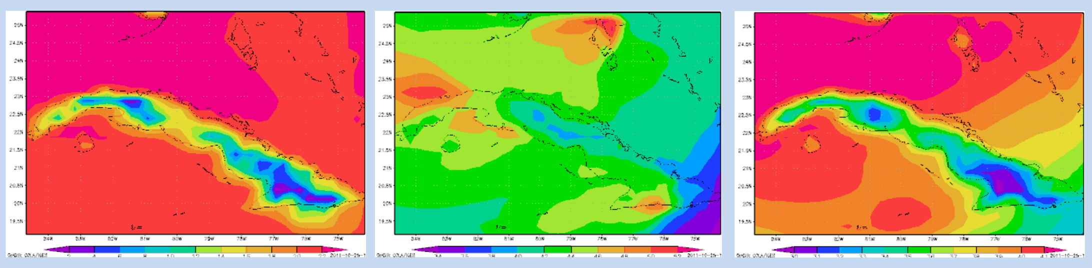
The ICP-MS analysis identified the presence of the following heavy metals: V, Cr, Mn, Ni, Co, Cu, Zn, As, Se, Sr, Ag, Cd, Ba, Pb.

As for the results of the modeling, the most significant achievements lie in:

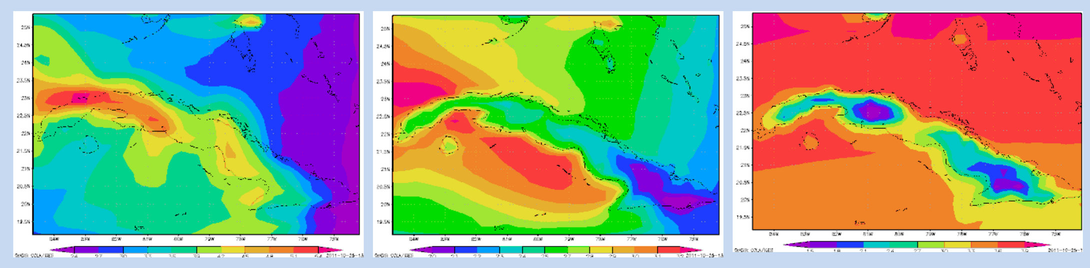
1) The implementation of WRF for modeling the atmospheric circulation in CUBA oriented to air quality diagnostic at different scales:

- photochemical regional models of high complexity (CHIMERE).
- 3D models in regional meteorological domains (CALPUFF)
- local models (AERMOD).

2) The capacity to diagnose the formation of ozone in Cuba using the WRF-CHIMERE models.



Maximum, minimum and average concentrations of O_3 from January 1 to 10, 2009, ppb



Maximum, minimum and average concentrations of O_3 from August 4 to 13, 2009, ppb

CONCLUSIONS

- The annual average concentrations of PM_{10} and $PM_{2.5}$ at INHEM point exceeded the annual air quality standards. The pollution profile of this area is similar to those of peripheral areas in developing countries.
- $PM_{2.5}$ / PM_{10} fraction, is slightly higher at INHEM point , deducing an inefficient control of particulate emissions.
- The $PM_{2.5}$ samples concentrate most of total carbon, prevailing elemental carbon.
- The PM_{10} samples show higher proportion of organic carbon and less proportion of total carbon compared with $PM_{2.5}$ samples.
- Carbon concentrations present in both particle sizes samples are higher than those obtained in Europe and United States studies.
- For PM_{10}, the CUJAE's samples show higher concentrations of metals (Cr, Mn, Fe, Cu, Ni and Pb). The concentrations of the elements associated to soil (Al, Si, P, K, Ca, Ti) and traffic (S, V and Ni) are higher in INHEM's samples. CUBAENERGIA's samples show the lowest levels of elemental concentration. Cl is the main element present in the composition of PM_{10} at the three points, with average concentrations ~ 2000 ng/m3.
- The highest concentrations of S in $PM_{2.5}$ were found in CUBAENERGIA's samples. The elements of the group of metals appear with higher concentrations in the samples from INHEM and CUJAE. The elements associated to traffic showed lower concentrations than those reported for PM_{10} at INHEM point. Cl appears with similar values everywhere, but concentration values are smaller than those in PM_{10} (average concentrations ~ 320 ng/m3).
- As a result of using WRF-CHIMERE models, O_3 concentration were higher during winter season (January).