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Atmospheric Pollution by Iceland Volcano Lava Dispersion - the Brussels Case

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Abstract

In April 2010 the Icelandic Eyjafjallajökull stratovolcano emitted large clouds of volcanic ashes that provoked chaotic situations for the air traffic of the Northern hemisphere. The impact of the resulting atmospheric pollution may have widespread effects on the health of the populations living in the affected regions. For this reason, the study of the airborne particles brought by the ash clouds must cover not only their concentrations expressed in $\mu g/m^3$, but also their size, shape and chemical composition. Our results revealed that during the eruption days, some periods with a higher concentration of the coarse particles (between 2.5 and 10 μm) were observed. The sphericity (R1) and roughness (R2) parameters showed specific characteristics of the particles, suggesting long distance of their origin. Furthermore, an increase up to 4 times more in the At% of the elements K, Al, Ca, Na and Si, which characterize the felsic lava, was observed during the eruption period.

Keywords: *Iceland eruption, felsic lava, long distance transport, airborne particles, granulometery, micromorphology and chemistry*

Rezumat. Poluarea atmosferică datorată dispersiei lavei vulcanului islandez – cazul orașului Bruxelles

În aprilie 2010, stratovulcanul islandez Eyjafjallajökull a aruncat nori mari de cenușă vulcanică care au generat situații haotice pentru traficul aerian din emisfera nordică. În urma acestui fenomen, impactul poluării atmosferice poate avea foarte multe efecte asupra sănătății populației care trăiește în regiunile afectate. Din acest motiv, studiul particulelor aeriene aduse de către norii de cenușă trebuie să cuprindă nu numai concentrațiile lor exprimate în $\mu g/m^3$, dar și dimensiunea, forma și compoziția lor chimică. Rezultatele au arătat că în zilele erupției au fost înregistrate unele perioade cu concentrări mai mari ale particulelor macrogranulare (între 2,5 și 10 μg). Sfericitatea (R1) și rugozitatea (R2) au indicat caracteristici specifice ale particulelor, sugerând distanța mare față de locul de origine. Mai mult, în timpul erupției s-a înregistrat o creștere de până la 4 ori a elementelor K, AL, Ca, Na și Si, caracteristice lavei riolitice.

Cuvinte-cheie: *erupția islandeză, lava riolitică, transport pe distanțe mari, particule aeropurtate, granulometrie, micromorfologie și chimie*

Introduction

Along the mid-oceanic ridges, two tectonic plates diverge from one another. New oceanic crust is formed by hot molten rock slowly cooling and solidifying. The crust is very thin along the mid-oceanic ridges due to the pull of the tectonic plates. Iceland is a region of frequent volcanic activity, due to its location astride the Mid-Atlantic Ridge, where the North American and Eurasian Plates are moving apart, and also over the Iceland hotspot, which greatly enhances the volcanic activity. It is estimated that a third of all the basaltic lava erupted throughout the world in recorded history has been produced by Icelandic eruptions. The release of pressure due to the thinning of the crust leads to adiabatic expansion, and the partial mixing of the mantle causing volcanism and creating new oceanic crust (Kristijansson et al. 1975; Mattsson and Hoskuldsson 2003).

The Icelandic Eyjafjallajökull stratovolcano entered a new eruption phase in April 2010. The volcano has periodically emitted large clouds of volcanic ashes that provoked chaotic situations for the air traffic of the Northern hemisphere. As a consequence of the volcanic eruption in Iceland, on April 14, combined with the advection of air masses from the North, the air traffic over large areas of Western Europe was suspended, for security reasons, from the afternoon of Thursday April 15th.

Lava is molten rock expelled by a volcano during an eruption. This molten rock is formed in the interior of some planets, including Earth, and some of their satellites. When first erupted from a volcanic vent, lava is a liquid at temperatures ranging from 700°C to 1,200°C (1,300°F to 2,200°F). Up to 100,000 times as viscous as water, lava can flow great distances before cooling and solidifying, due to its thixotropic and shear thinning properties.

The densest minerals, ferro-magnesian silicates, form at the highest temperatures, whereas less dense minerals form when the magma cools down. Mineral types forming in molten rock often grow unrestricted to a very large size, and can have a fine crystal form. There are seven basic types of lava, which reflect the main types of volcanic rock which the lava is composed of: Basalt, Andesite, Dacite, Rhyolite, Carbonatite, Natrocabonatites, Komatite. Igneous rocks, which form lava flows when erupted, can be classified into three chemical types; felsic, intermediate, and mafic. Felsic (or silicic) lava Felsicor silicic. Most Silicic lava flows are extremely viscous, and typically fragment as they extrude, producing blocky autobreccias.

The study of the airborne particles brought by the ash clouds should cover not only their concentrations expressed in µg/m³, but also their size, shape and chemical composition. Apart from the damage to the jet engines, an estimation of the impact of the resulting atmospheric pollution on the health of the populations living in the regions affected by the volcanic clouds can only be based on this kind of information.

The objective of the present report is to provide data about the concentration, the micromorphology and the chemical components of the airborne particles brought by the ash clouds emitted during this exceptional volcanic phenomenon and found in the air of the Brussels urban region.

Methods and Materials

For this study we used specific methods and instrumentation that are adapted for the investigation of the proposed objectives.

The Brussels telemetric network for air pollution consists of 11 measuring sites, situated in different urban environments: traffic, residential, industrial and urban background. The PM10 mass concentration is measured in six measuring sites: Molenbeek (R001), Berchem (B011), Uccle (R012), Brussels naval port (N043), Meudon park (MREU1) and at the Brussels Environmental Institute in Woluwe (WOL1) (Fig. 1).

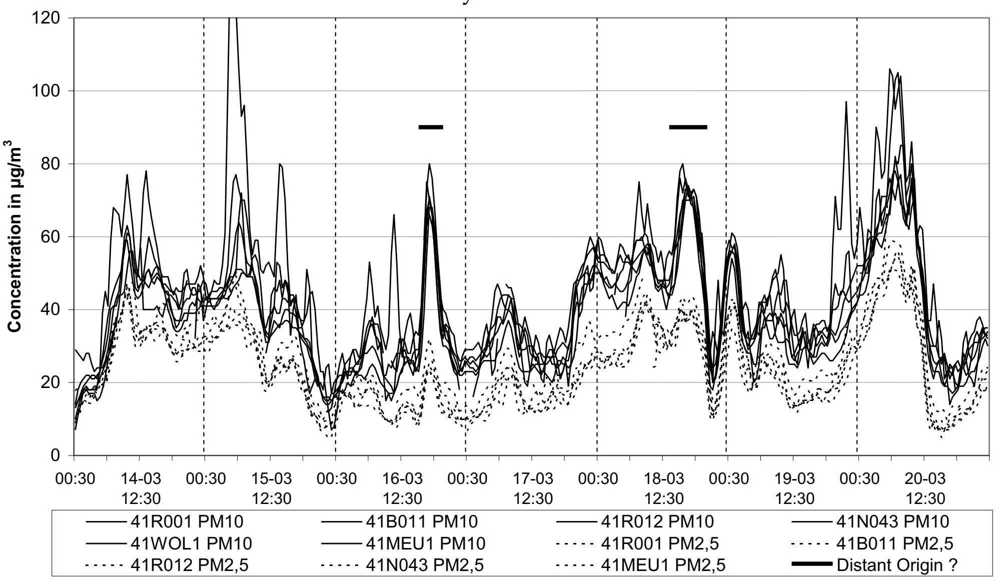

Fig. 1: Evolution "PM10-Fdms" and PM2,5-F" dms at Brussels Measuring Sites
(Period: Wednesday 14 – Tuesday 20 April 2010)

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With the exception for the WOL1 site, the mass concentration for PM2.5 is measured along with PM10 in five of the six PM10 measuring sites. All PM mass concentration instruments are continuous TEOM 1400Ab analyzers (*Tapered Element Oscillating Microbalance*), equipped with FDMS 8500 system (*Filter Dynamics Measurement System*). Thus, the dynamic evolution of the mass concentration can be followed, while the mass concentration results on a 24-hour basis are relatively close to those of the gravimetric reference method. At the Brussels Institute for Environmental Management (WOL1), the particulate number concentration, expressed as the number of particulates per liter air, is also measured for 31 different classes, ranging from 0.25 μm to 32 μm, by means of a Grimm Laser light scattering spectrometer, model 365.

At two of the PM10 measuring sites (Uccle and Woluwe), and at the local university (ULB) particles were also collected on filters by use of low volume samplers, in order to investigate for their physical and chemical properties.

The analysis of the particles was performed by taking into consideration the fact that particles smaller than 2.5-3μm, constitute a health hazard by their simple presence, regardless of their mineralogical and chemical composition (Buringh and Opperhuizen 2002; Harrison et al. 2001; Ruuskanen 2001). In addition, the chemical compositions of the particles were analyzed by Scanning Electron Microscopy (SEM), X-Ray diffraction and light polarizing microscopy. Estimation of particle size distribution for a large number of particles was based on their planar projection in a JSM 5410 JEOL scanning electron microscope (Franck and Herbarth 2002).

Our estimation of the particle size distribution is a result of particle projection on a plane. The value of the particle area, A [in square micrometer], is defined as the surface of the particle enclosed within the projected border, P (the perimeter in micrometer). This must be compared to the classical size parameter that is the diameter (D) of the smallest circle enclosing the whole plane projection of the particle (Alshibli et al. 2004; Vanderstaeten et al. 2008). Using SEM, a series of parameters were measured on a large number of particles: the projected surface (A, in square micrometer), the projected perimeter (P, in micrometer) and the projected long and short axis (L_1 and L_2, in micrometer). From these values, two dimensionless ratio parameters, R1 and R2, were computed for a large number of particles (Zaady et al. 2009), characterizing the roughness and the elongation of the particles.

The first parameter, R1 [in micrometer], is defined as $R1=4\pi A/P^2$. This parameter characterizes the irregularity of the contour of the particle, i.e. the roughness of the particle surface, as compared to the smoothness of a perfectly spherical surface (Alshibli et al. 2004; Vanderstraeten et al. 2008). This quantity equals the value of 1 when the projection of the particle on the surface analyzed by the microscope is a perfect circle (Zaady et al. 2009). The second parameter R2 refers to the elongation of the particle and corresponds to the projected major axis, L_1, divided by the minor axis, L_2, of the smallest ellipse enclosing the planar projection of the particle.

The nature of the filter sampling is such that the particles that are captured must have a linear size between 1μm and 10μm. Particles larger than 10μm almost systematically rebound from the filter, whilst most of the particles smaller than 1 μm pass through it without being captured.

Statistical analysis - The statistical analysis concerns the particles collected on filter at three measuring stations Uccle, Woluwe and ULB located in the Brussels urban area, in order to characterize the difference in area and shape of atmospheric particles collected on the 16th, 17th and 18th of April 2010. One-way ANOVA, with Tukey test (Sokal and Rohlf 1995) was used to test differences in parameter means between the sites and days. Differences were considered statistically significant when $P<0.05$. Our comprehensive approach allowed us to calculate the particle size distribution, their roughness and sphericity and compare between the data regarding the changes in the chemical element compositions throughout the whole year, during normal period as expressed by non agriculture period (April) and during the eruption period (Vanderstraeten et al. 2007; Zaady et al. 2008).

Results

Following the eruption on April 14, 2010, the PM10 and PM2.5 mass concentration measured at the surface in Brussels did not exhibit any unusual concentration level (Fig. 2). The PM10 levels were normally higher than those of the PM2.5 and the differences observed between the PM10 levels, measured at different sites for most of the time, express the typical local influences. However, on Friday, April 16th between 16:00 and 19:00 h UT and on Sunday, April 18th between 14:00 and 19:00 h UT, the PM10 mass concentrations at the different measuring sites were quite similar and the differences between the PM10 and the PM2.5 levels were much more pronounced than during the rest of the considered period.

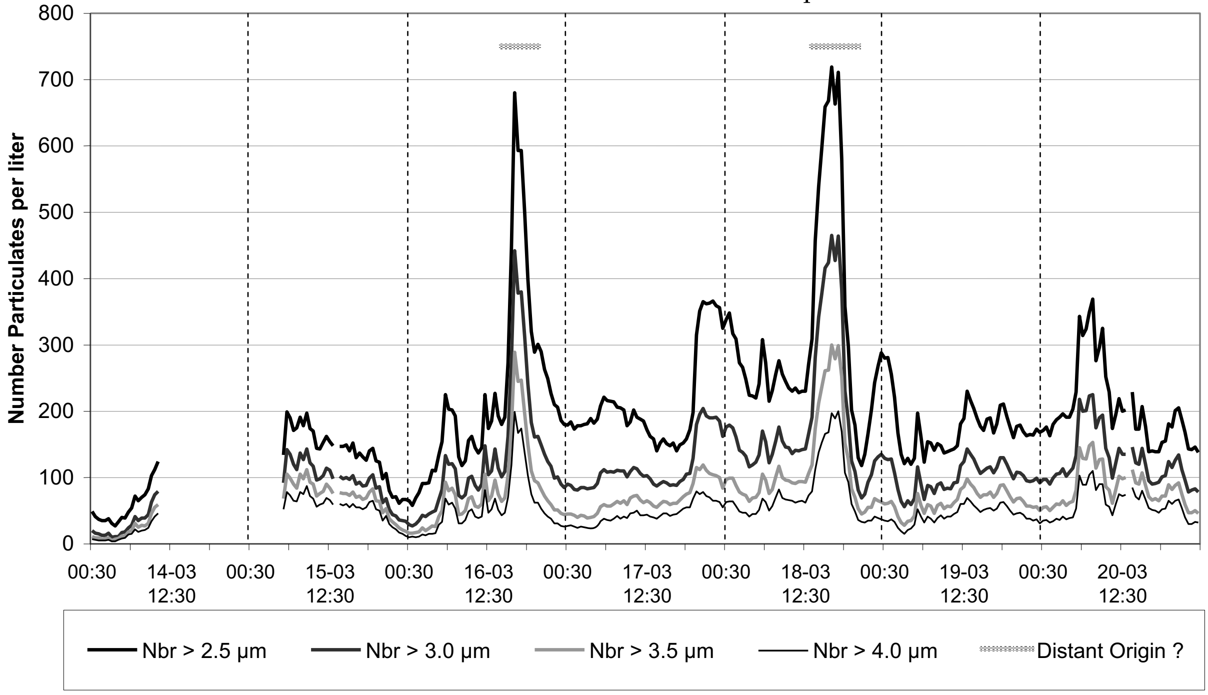

Fig. 2: Number of Particulates "> 2.5 µm" "> 3.0 µm" "> 3.5 µm" "> 4.0µm"
(Period: Wednesday 14 – Tuesday 20 April 2010)

During the two periods (between the eruption period and the regular airborne particle dynamics in Brussels Capital Region), the particulate number concentrations for the coarser fractions peak, as illustrated by Figure 3, representing the particulate number concentration for some classes: ">2.5 µm", ">3.0 µm", ">3.5 µm" and "> 4.0 µm". In both figures (2 and 3), the two periods are indicated by small horizontal lines just above the top of the peaking concentration. The peak measured on April 20th could also be partially due to the eruption, but not exclusively, since important differences in the concentration level are observed between the PM10 concentrations at different stations.

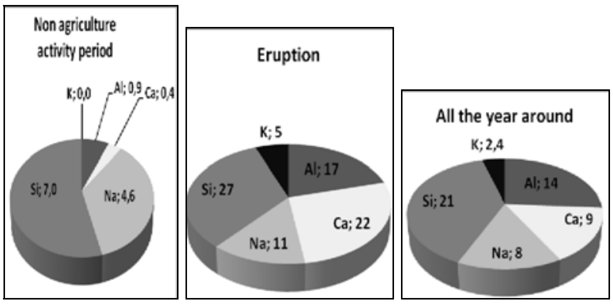

Fig. 3: Comparison between the atmospheric chemistry composition during the whole year, during non agriculture period and during the eruption period

Comparison between the atmospheric chemistry composition during the year, during non agriculture period and during the eruption period showed an increase of up to 4 fold in the At% of the elements K, Al, Ca, Na and Si (Fig. 3) for the eruption period.

The R1 (sphericity) on the three main days of the eruption period was three times higher than that found throughout the whole year and the non agriculture period, while the R2 (roughness) was lower by a factor 2 during the eruption period compared to the other two periods (Table 1).

Table 1 The micromorphological characteristics (R1 and R2) of the airborne particles during the 16, 17 and 18 April 2010 in Brussels

Period of measurement	Sphericity R1=(Long/Short)	Roughness $R2=(4\pi A/P^2)$
During the whole year	0.46±0.2	1.33±0.4
Non agriculture period	0.42±0.1	1.29±0.3
Eruption	1.46±0.4	0.72±0.1

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Discussion

Measurements to obtain PM10 concentrations by means of R&P TEOM 1400Ab continuous instruments were performed at six different sites in the Brussels Capital Region. Three of these sites are representative for the general activities in the city (traffic, domestic heating, business and commercial activities), a fourth one is situated in an industrial area (city naval port) with a lot of traffic and two additional sites are situated in typical city residential environments. The granulometry was measured at the Woluwe site (WOL1), while the micromorphology and the chemistry were measured only in the sites with the filter sampling system; Uccle (R012), Brussels University (ULB) and the Brussels Environmental Institute (WOL1).

The observations obtained, especially those on April 16 and 18, support the idea that a common and distant source, situated outside the Brussels urban area, is responsible for the amount of the coarser particulates (PM 2.5 to 10). Nevertheless, as for the concentration of airborne particles, very high PM10 concentrations in the past have been reported during agriculture activity periods (the harvesting and sowing of wheat, corn and barley) (Vanderstraeten et al. 2007; Zaady et al. 2008) and by advection of Sahara sand. Similar to that, during the eruption period PM10 particles were predominant to PM2.5.

Our main results concerning the airborne particle micromorphology and chemistry showed a possible temporal correlation between the eruption period and the regular airborne particle dynamics in Brussels Capital Region (Zaady et al. 2010). These results are complemented by a previous study, which compared the non agricultural work periods (April) with the whole year round (Fig. 3). At least for two short periods the principal origin of the airborne particles is likely to be found in combustion processes (volcanic eruption). The high thickness and strength of the airborne particles, of the eruption period, were the result of their chemistry, which are high in silica, aluminum, potassium, sodium, and calcium, suggesting that their origin were from the Icelandic Eyjafjallajökull felsic stratovolcano. These chemical elements form a polymerized liquid rich in feldspar and quartz, which thus has a higher viscosity than other magma types (intermediate, mafic and ultramafic).

Conclusion

- During the eruption period high concentrations of large particles of PM10 were found.
- An increase of up to 4 fold in the At% of the elements K, Al, Ca, Na and Si, which characterize the felsic lava, was observed during the eruption period.
- The R1 (sphericity) and R2 (roughness) parameters showed specific characteristics of the particles suggesting a long distance from their origin.

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Adoption of NAMEA Air Emission Accounts in Hungary

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Abstract

The current phenomena of accelerating climate change and global warming has urged scientists and policy makers to devise a comprehensive and reliable system to identify the main causes and sources of the adverse processes. NAMEA (National Accounting Matrix including Environmental Accounts") developed by EUROSTAT has gained in popularity as it highlights the impacts of societal action on the environment by linking economic indicators to environmental material flows. The paper reports on the work done in the Hungarian Central Statistical Office to adopt and further develop the NAMEA system and demonstrates the crucial changes occurred in the emission of the major pollutants between 2000 and 2009 taking into consideration economic indicators.

Keywords: air pollution, NAMEA system, pollutants, environmental economic profiles.

Rezumat. Adoptarea conturilor MCNCM pentru emisiile atmosferice in Ungaria

Fenomenele actuale de accelerare a schimbărilor climatice și încălzirii globale au obligat oamenii de știință și autoritățile să conceapă un sistem cuprinzător și fiabil pentru identificarea principalelor cauze și surse ale acestor fenomene adverse. MCNCM (Matricea Contabilității Naționale cu Conturile de Mediu) elaborată de EUROSTAT a devenit tot mai populară, întrucât pune accentul pe impactul activității societății asupra mediului, legând indicatorii economici de fluxurile de mediu. Articolul prezintă rezultatele activității desfășurate în cadrul Oficiului Central de Statistică din Ungaria pentru adoptarea și dezvoltarea continuă a sistemului MCNCM și demonstrează schimbările cruciale care s-au produs în emisiile unor poluanți majori între 2000 și 2009, având în vedere și indicatorii economici.

Cuvinte-cheie: *poluarea aerului, sistemul MCNCM, poluanți, profile economice de mediu*

Introduction

The most important task of environmental policy nowadays is to mitigate the adverse effects of climate change (Hardy, 2003). Since air pollution considerably contributes to the unfavourable process of climate change, it is crucial to be dealt with (OECD, 1995). In order to succeed in tackling air pollution, emissions need to be assigned to economic sectors, helping the elaboration and implementation of environmental policies (Rácz, 1999).

National Accounting Matrix including Environmental Accounts (NAMEA) is used to highlight the impact of the society on the environment. Developed by EUROSTAT, the NAMEA system builds on national accounts to give detailed insight into the performance of each economic sector and the harmful effects of production and service provision. NAMEA is a complex model containing data of numerous environmental domains (air, water, waste, etc.), which are compared with economic parameters.

The European Strategy for Environmental Accounting (ESEA) regards Air Emissions Accounts as a core module of Environmental Accounts. Air Emissions Accounts record and present data on air emissions in a way that they are compatible with traditional economic statistics. They record emissions in a breakdown by emitting industries and private households activities as delineated in National Accounts. Air Emissions Accounts are linked to the framework of Supply, Use and Input-Output Tables enabling numerous analytical applications. Such kind of integrated environmental-economic analyses are in high demand in the wider policy area of sustainable development (e.g. Lisbon Strategy, EU Sustainable Development Strategy, Global Climate Change, EU policies on Sustainable Consumption and Production etc.).

Beforehand, the HCSO had data on the most common air pollutants – 3 greenhouse gases (CO_2, CH_4, N_2O) and 3 acidifying substances (SO_2, NH_3, NO_X) and non-methane volatile organic compounds (NMVOC) –, covering 5 years (2000-2004). Data were combined with economic variables based on a simplified version of industry classification.

The main aim of the project was to further study the methodology of the compilation of the new NAMEA air tables, and assess the changes occurred in the emission of the major pollutants.

The objectives of our work were as follows:

- implementation of a complex, relevant, maintainable system of the air emission part of NAMEA at the Hungarian Central Statistical Office,
- compilation of national economies' emissions in a breakdown by emitting economic activities for Hungary in time series from 2000 to the latest possible year (2009),
- analysis of the results.

Methodological background

In December 1994, the European Commission submitted a report - 'Guidelines of the European Union concerning environmental indicators and 'green' accounting: the integration of environmental and economic systems' - to the European Council and the European Parliament to describe the relationship between the economic and social system on the one hand, and the economic system and the environment on the other hand. In autumn 1996, the EUROSTAT and the national statistical offices of most Member States agreed upon projects on the production of NAMEA tables (National Accounting Matrix including Environmental Accounts).

The basic idea of NAMEA is to merge economic and environmental data in a consistent way, so it allows for direct comparison of parameters from both ranges on a sectoral level. The core of the framework is a set of tables of economic data and to form a national accounting matrix (NAM) as compiled in national accounts. The environmental accounts (EA) comprises tables containing data in physical units (mass, volume or energy units). The presentation of the data is based on the classification of economic activities, i.e. on NACE (Nomenclature générale des activités économiques dans les Communautés Européennes) Rev. 1 including private households. Thus, the economic performance (e.g. gross value added, persons employed) can be linked to the resources used for production or to the emissions generated (e.g. air pollutants, waste, waste water) in a given year.

This perspective can be used for scientific analysis and to assessment policy measures by comparing the sectoral performance either over time or across countries and the distance from emission reduction targets can also be determined. NAMEA helps to identify the sources of air pollution, too. This system allows an analysis of the performance of an industry where the emissions are normalised by the size of the economy. If a particular industry exhibits a development (e.g. measured as CO_2 emissions per million € output) that diverges from its past performance or from the average of the EU average, the reasons for the differences need to be investigated. The variations can be due to heterogeneous industry classifications, structural differences or technological changes.

The major advantage of the NAMEA Air Emission Accounts is the possibility to interlink data on air emissions with macroeconomic or even social data. That means a coherent set of environmental, social and economic indicators can be derived with a high degree of international comparability of the results and all indicators are closely linked to one another. This is a key basis for integrated economic and environmental analysis and modelling, including cost-effectiveness analyses, scenario modelling and economic and environmental forecasts. This integrated framework allows sectoral policies and indicators to be a part in a comprehensive economic, social, and environmental context.

In 2000, a set of NAMEA for air emissions standard tables was prepared by EUROSTAT and was finalised at the fourth NAMEA workshop. These tables focusing on air emissions also covered some economic data, but they were not to be reported in a matrix format. The standard tables were revised in 2002 in order to improve the comparability of data between countries as well as with other air emission statistics. Meanwhile all Member States have become involved in the compilation of air emission accounts for NAMEA. Some produce and publish NAMEA data on an annual basis, for other EU countries the compilation