Importance of coal and the quantification of important environmental impacts from coal activity in Vietnam

Loi Dinh Chinh[1,2] and S. H. Gheewala[1,*]

[1]The Joint Graduate School of Energy and Environment,
King Mongkut's University of Technology Thonburi,
126 Pracha-Uthit Road, Bangmod, Tungkru, Bangkok 10140.

[2]Mine Environment Department,
Institute of Mining Science and Technology,
No.3 Phan Dinh Giot Street, Hanoi, Vietnam.

*Corresponding author: Shabbir_g@jgsee.kmutt.ac.th

Abstract: Coal has a huge potential in natural resources in Vietnam. It is a safe transporting fuel and also an important fossil fuel supplying for power production (32.6% of total suppliers), for cement production (15%) and remain for other sectors. In addition there are about 4,000 tonnes of clean coal exported annually. It therefore contributes to the energy security and supports the socioeconomic development of Vietnam. By means of assessing in a "cradle-to-grave" method, the quantification of emissions and impacts from coal production can be performed. The processes of coal production are divided into coal extraction, cleaning/preparation and transportation.

Through the methodology of life cycle assessment, the quantitative results in the whole life cycle of coal production show that dust pollution is concentrated only in coal extraction (99%), the air emissions coming mainly from the coal extraction (60%). However, the emissions from the coal screening/preparation constitute a substantial fraction (35%). For alternative transportation they are quite small, below 5%. The impacts of wastewater are only from mining wastewater (62 g/tonne raw coal).

Keywords: Quantification of emissions, life cycle inventory, coal production, Vietnam.

1. Overview of coal production in Vietnam

Coal is a fossil fuel, developed for a long time in Vietnam, with a history of over 120 years. Most of the coal extracted is mainly in Quang Ninh coal basin with estimated reserves of 3.52 billion tonnes down to 300 meters. A major part of the coal is anthracite. Recently the Red River Delta deposit has been discovered with an estimation of over 35 billion tonnes of brown coal. The coal output was 11.7 million tonnes in 1998, 10.85 million tonnes in 2000, and 14 million tonnes in 2002 [1].

In Vietnam, coal plays an important role for the period of industrialization and modernization at this time. Coal is a fuel for many sectors and industries (shown in Table 1), in which the electricity generation needs more coal than other sectors (40% of total domestic coal needs). Besides that, coal is exported to get the foreign exchange for Vietnam. The coal sector contributes to the national budget with the total amount of 500 billions VND annually (about 31 million USD). In addition, it provides jobs for 90,000 people [2]. Therefore, it is one of important sectors contributing substantially to the economic development of Vietnam.

Table 1. Coal consumption ratio of households: *(million tonnes)*.

No.	Consumer	2002	2005
I	***Domestic need***s	10.40	12÷13
1	Thermal power plants	4.04	5.3÷5.6
2	Cement	1.67	2.5÷2.7
3	Bricks, limestone	1.39	1.4÷1.6
4	Other industries	1.00	1.1÷1.2
5	Firing and other	2.30	1.7÷1.9
II	***Export***	4.00	4.0÷5.0

Although the coal-fired power plant accounts for only 13.6% of the total electricity in Vietnam [3], it is a steady source providing backup support for the grid when the electricity supply from hydropower has seasonal problems (e.g. during drought).

The life cycle of coal is does not end at coal production (extraction and preparation) but also includes coal use (firing coal to get thermal energy and/or materials for other processes). However, in this paper the various end-uses of coal are not considered, so the final output is the clean coal. The anthracite production in Vietnam is divided into two processes that are coal extraction and coal screening/preparation, including transportation between the two stages.

+ Coal Extraction:

There are two different methods to extract coal, open-pit mining (surface mining) and underground mining depending on the proximity of the seam body to the surface. In open-pit mining, the first step is to remove the topsoil layer. This is called overburden and is often placed near the mines in large piles. Then, the coal is exposed and extraction is done by explosives. Machinery is be used for stripping, drilling, blasting, and excavating coal and solid waste to trucks. Coal is transported to the screening/preparation and solid waste was transported to landfill. Removing the topsoil and excavating the coal is accomplished in different ways with the varying distances. Different means are used for transport, such as conveyor, truck or railway.

When the coal seams do not lie close enough to the surface, the cost of removal of the overlying soil and excavation of coal are expensive. It means that the coal seams are deeper so surface mining techniques cannot be applied and underground mining techniques must be used. In underground mining the two methods applied at present are “room-and-pillar” and “longwall” depending on the stability of geological conditions and the thickness of seams. The mining operations include cutting, drilling, blasting, loading to conveyor, and hauling. Auxiliary operations include ventilation, drainage, power, communications, and lighting. After that, the raw coal is transported from the coal destination (from the coal mouth) to preparation factories or storage.

+ Coal cleaning/preparation:

The next step is to transport the coal to the preparation plants, where the main function is to improve the quality of the coal (remove unnecessary matter, such as rock, metals, wood, etc.), primarily for export reasons. The coal is then washed and sorted into different classes according to size. In the plant, the coarse sorting is done by hand followed by classification by screening. From the screening or preparation plants, the coal is transported to coal ports where it is either loaded directly on small ships or first loaded on coal barges that take the coal out into the bay for reloading on huge ships for export.

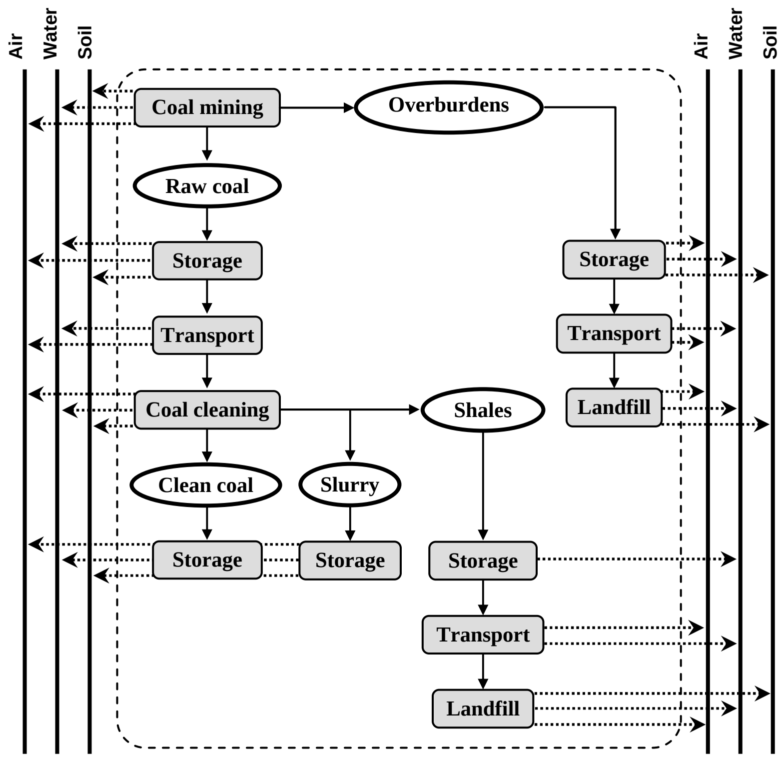


Figure1. The process blocks and emissions in coal production.

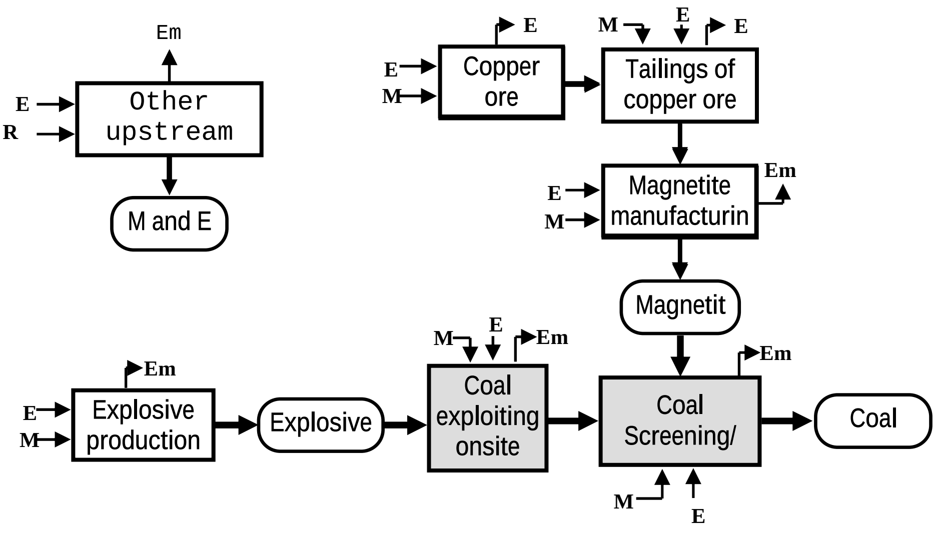
The system boundary and impacts are generally described in Fig. 1. The oval boxes represent the product, and the square boxes, the processes.

The coal activities affect the environment (air, water and soil). The land used for extracting will be reclaimed by planting regularly. The main impacts with high environmental effects are from air and wastewater emissions.

2. Quantification of key environmental impacts

At present, there are many methods for assessing environmental impacts from mining activities. Life cycle assessment is recognized to be a sound environmental management and decision support tool [4]. Using the life cycle inventory can quantify and assess the impacts from production and/or services adequately. This tool attempts to collect and analyze a product in a “cradle-to-grave” method.

The “life” of a product encompasses everything from raw material extraction (e.g., petroleum, iron ore, wood, etc.) to disposal of the product after its use [5,6]. The life cycle of coal in this paper is defined as in Fig. 2. The whole life cycle of coal production is very complicated, for simplicity, the first stage is coal extraction. In this process the material supplied is mainly explosive, that is used for blasting soil and coal in seams. So the sub-consideration is for explosive production. The second process is cleaning/preparation of raw coal, in this process magnetite is used for cleaning coal. The second sub-consideration is the magnetite production. Besides that, all minor materials used for the each process are included if their contribution to the environment are significant, such as steel, iron, cement, diesel, petrol, etc.



Note: E - Energy, Em - Emissions, RM - Raw material, and M -

Figure 2. The system boundary of coal production.

By means of direct measurement and using the database of environmental monitoring system from Vietnam National Coal Corporation (VINACOAL) [7,8], the inputs and outputs related to coal production are inventoried and assessed. The consideration includes coal extraction (working face, tunnels), storage in mine mouth, transportation from mine mouth to preparation/screening plant, and transportation of solid waste to landfill and the landfill itself. On the other hand, in order to trace the resource consumption and emissions from material production and related processes (upstream processes), the calculations and estimations use the data and results from literaturesd ,such as ,atabases from the softwares GEMIS Version 4.2 (Global Emission Model for Integrated Systems) [9], SimaPro v6.0 (Life cycle assessment) [10] and FIRE v6.24 (Factor Information Retrieval for criteria and hazardous air pollutants) [11] and the Australian National Pollutant Inventory [12,13] have been used to estimate air emissions from stages of coal production. The calculation model for inventory process is follows:

$$Q_i = \sum_{1}^{n} Qm_j + \sum_{1}^{k} Qp_j$$

Where: Q_i – Sum of terminal exchanges (i) computed per functional unit

Qm_j – Total amount of emissions from materials supported to process “j” in the production’s system boundary; n is the number of materials supported to the considering process.

Qp_j – Total amount of emissions from directly process “j” in the production’s system boundary; k is the number of considerable processes.

The numbers of materials are for building the infrastructure, machines, and operations (cement, limestone, sand, steel, H_2SO_4, petrol, diesel). The numbers of productions are all processes related to the coal extraction and coal preparation (copper ore extraction, tailings of copper ore, magnetite manufacture, explosive production, coal extraction and coal cleaning). After analysis and calculation the raw resources and energy are inventoried in Table 2. From the results, the raw materials include mainly construction material (clay, limestone, gravel, sand and iron), fuels for operation (coal, crude oil and natural gas), and machine production (iron). The coal consumed in the life cycle of coal production is high because raw coal is used for producing cleaning coal and the coal is used for firing in each process.

Table 2. The resource depletion in the whole life cycle of coal production in Vietnam.

Resource	Unit	Coal extraction	Coal preparation
Clay	kg/tonne	0.2	0.4
Raw coal	kg/tonne	1,458	1,692
Limestone	kg/tonne	0.5	0.7
Gravel	kg/tonne	6	17
Sand	kg/tonne	0.5	0.8
Iron	kg/tonne	1.8	2.4
Water	m^3/tonne	50	168
Natural gas	m^3/tonne	11	19
Crude oil	kg/tonne	179	82

Two main stages of coal production (coal extraction and coal preparation) consume the amount of resources as shown in Table 2. Most of resources (clay, limestone, gravel, sand, iron, water, etc.) in coal preparation are higher than in coal extraction because there are more infrastructure items in coal preparation. However, the operation of vehicles in coal extraction is high, so fuel is used in coal extraction bigger than in coal preparation (69% crude oil is used for coal extraction).

Coal mining activities and the related processes generate many environmental effects. These problems are the local, regional and global impacts. In this paper, only main and adverse impacts (dust pollution, global warming and working site) are mentioned.

+ Dust pollution:

Particulate matter (PM) refers to solid particles that are suspended in the atmosphere, including various compositions of organic and inorganic compounds. In combination with gaseous pollutants, particulate matter may be detrimental to human health. Atmospheric particles may damage materials, reduce visibility, and cause undesirable esthetic effects. It is now recognized that very small particles have a particularly high potential for harm, including adverse health effects [14]. The impact receivers of PM consist of human health, ecological consequences and cultural and recreational values.

However, dust makes a layer on the leaves of plants, reduces the visibility and damages heritage sites and infrastructure. When brought down by rain, it reduces the transparency of water and affects the receiving ecosystem.

In coal extraction, many machine and vehicles are used for excavation of overburden (top soil layer in open pit and solid waste from underground coal mine), so it is the reason for dust pollution. Not only the dust emitted from the truck's engines (burning fossil fuel) but also from loading and unloading coal and overburden, and blasting the soil and stone. The big dust originates from the blasting in mine (77% of total dust emissions from extraction) and the second contributors are loading, and unloading, internal transport (22%) and from the engine combustion of vehicles is very small (about 1%). The dust contribution in the processes of coal preparation and transportation is small because the dust generated is very small in the wet coal cleaning methods (using at present). In the coal preparation plants, dust comes from the loading and unloading coal, screening raw coal, and from the coal piles by wind. Dust generates from the transportation is from the friction between truck and road and coal by the wind. The dust from transportation of coal and solid waste is very high, moreover, it happens mainly in the working sites (internal transportation). By inventory, dust is quantified for all related processes and the results are performed as in Figure 3.

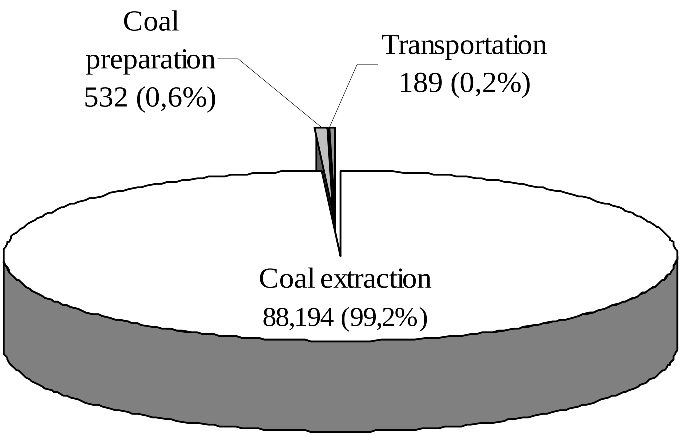


Figure 3. Dust emissions from the whole life cycle of coal production (g PM10/tonne coal).

+ Global warming potential (GWP)

The greenhouse gases are those gases in the atmosphere which, by absorbing thermal radiation emitted by the Earth's surface, have a blanketing effect upon it. The most important of the greenhouse gases is water vapor, but its amount in the atmosphere is not changing directly because of human activities. The important greenhouse gases which are directly influenced by human activities are carbon dioxide, methane, nitrous oxide, the chlorofluorocarbons (CFC) and ozone.

Inventory of all gases emitted from the whole life cycle of coal production. The procedure are carried out directly from coal extraction, coal preparation, and transportation and the indirectly from the materials supply for each process. The results are quantified in term of the global warming potential (GWP). Most of gases contribute to GWP is from the combustion of fuel in engines (transport, excavation, loading and unloading, etc.). However, in coal extraction, amount of gases emit to the air from the exposure of soil and from the coal seam. The air emissions come mainly from the coal extraction, especially for methane (CH_4) (98% total wt. When converted to the CO_2 equivalent (SO_2-eq.), the quantity of air emissions affect global warming is shown in Figure 4. In coal extraction, the main contributors (compounds) to global warming potential are CO_2 and CH_4 (account for 51% of total wt. and 46% of total wt. in coal extraction, respectively). In coal preparation and transport, the contributors are mainly from CO_2 (over 95% of total wt. for the global warming in each process).

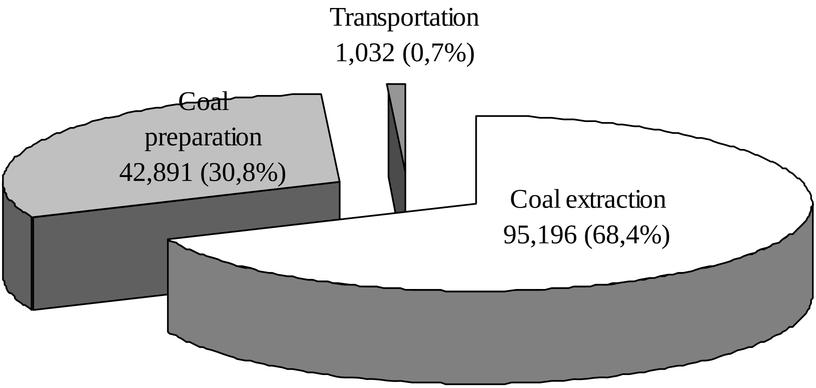


Figure 4. Global warming potential related to coal production's life cycle (g CO_2-eq./tonne coal).

+ Acidification potential (AP)

The acidification for coal production is mainly from SO_2 and NO_x from the air emissions (Figure 5). The two compounds are generated from fuel combustion in engines. Although the operation of vehicles in coal extraction is higher than in the coal preparation, the emissions from the materials in the coal preparation is higher than in coal extraction (38% for coal extraction and 12% for coal extraction). On the other hand, although the equivalent factors of NO_x and SO_2 are nearly equal, the contribution of NO_x is high because the volume of this gas is 2-3 times than SO_2. Consequently, the contribution from coal preparation is substantial to the total acidification potential.

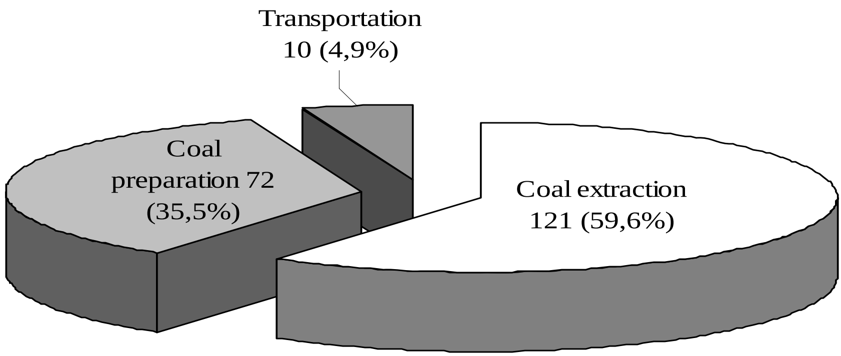


Figure 5. Acidification potential related to the coal production's life cycle (g SO_2-eq./tonne coal).

+ Wastewater:

The wastewater from coal mine is about 3 m^3/tonne as-received coal. It is a big problem affecting the regional ecosystem because the pH value is mostly less than 4.5. In coal preparation the pH value is higher than 5.5, in addition the water used for coal cleaning is circulating (recycle). So, the wastewater from this process seems to be very small. Consequently, the wastewater impacts of coal production are mainly from coal extraction. The acidity from mining wastewater is 61.3 g/tonne raw coal.

3. Conclusions

Using the life cycle analysis to quantify the environmental impacts from coal is a suitable way to consider its effects to environment. The "cradle-to-grave" method can help to quantify adequate amount of emissions.

Through the results, the priority of treatment is found. Consequently, it improves the efficiency of budget used for environment. Air emissions come not only from direct extraction, screening/preparation and transport of coal, but also from materials production. Main air emissions are from coal extraction activities. Therefore, it should improve the efficiency of coal extraction (65% at present), recycle and/or reuse of working tools and equipments.

Dust mostly comes from the coal extraction. However, coal preparation and transport have a substantial contribution to the global warming and acidification. These impacts are specific for coal mine activity. The big problem is to have the dust treatment in the coal extraction (working place) because it is “hot spot” in the life cycle of coal production.

The air emissions are main effects of coal production activities. The mainly contributions come from Methane in coal seam, the CO_2 from combustion of fuel. This is reason for global warming potential in coal production. Besides coal cleaning play an important for coal export, it can effect the environment with substantial portion (over 30%).

This predicted quantity of environmental impacts from coal sector is a foundation for comparison with other energy industry. It is a best consideration for choosing the priority and balance of energy strategy. Therefore, it should carry out other energy sectors in future studies.

Acknowledgments

The authors gratefully acknowledge the Joint Graduate School of Energy and Environment for providing extremely necessary financial assistance and facilities.

Deep thanks are also due to the Institute of Mining Science and Technology (IMSAT), Vietnam National Coal Corporation (VINACOAL), Institute of Vietnam Energy, Vietnam National Energy Corporation (EVN), The Vietnam Machinery Erection Corporation (LILAMA) and most of Coal mine companies in Quang Ninh province providing support during data collection.

References

[1] Vietnam Coal Sector Strategy toward 2010 and oriented to 2020 (2002) Hanoi: Vietnam National Coal Corporation (VINACOAL) (in Vietnamese).

[2] Nuyen, C.N., Vietnam National Coal Corporation with 10 years of foundation and development, News on The Coal Industry, Mining Technology Bulletin, No.1-2005. (In Vietnamese).

[3] MOSTE (2001) *Draft of National Energy Policy in the period of 2010-2020, Programme KHCN-09,* the Building of Strategies and Policies of Sustainable Energy Development, Hanoi: The Conjugate Groups of Vietnam Technology and Science Associates, Ministry of Science, Technology and Environment.

[4] Benetto, E., Rousseaux, P., and Blondin, J. (2004) *Life Cycle Assessment of Coal By-Products Based Electric Power Production Scenarios*, Journal of Fuel, **83**, pp. 957-970.

[5] Curran, M.A. (1996) *Environmental Life Cycle Assessment*, New York: MacGraw-Hill, Inc.

[6] Coltro, L., Garcia, E.E.C., and Queiroz, G.C. (2003) *Life Cycle*

Inventory for Electric Energy System in Brazil, The International Journal of Life Cycle Assessment, Int J LCA, **8**(5), pp. 290-296.

[7] Reports of Environmental Monitoring (2001-2005) VINACOAL.

[8] Ministry of Science, Technology and Environment (MOSTE) and Japan International Cooperation Agency (JCA) (1999) *Research of Environmental Management of Ha Long Bay*, Final Report, November 1999.

[9] Global Emission Model for Integrated Systems (GEMIS) Version 4.2. Available online: http://www.oeko.de/service/gemis/ [last assessed: 02/01/2005]

[10] PRé Consultants, the Netherlands, MO (SimaPro v6.0 Demo) Available online: http://www.pre.nl/simapro/ [last assessed: 23/03/2004]

[11] FIRE v6.24 (Factor Information Retrieval for criteria and hazardous air pollutants) Available online: http://www.epa.gov/ttn/chief/software/fire/ [last assessed: 15/01/2004]

[12] National Pollutant Invention (2002) "Emission Estimation Technique Manual for Combustion Engines", Version 2.2, Commonwealth of Australia. Available online: http://www.npi.gov.au [last assessed: 25/11/2003]

[13] National Pollutant Invention (2001) "Emission Estimation Technique Manual for Mining", Version 2.3, Commonwealth of Australia. Available online: http://www.npi.gov.au [last assessed: 25/06/2004]

[14] Manahan, S.E. (2000) *Environmental Chemistry*, seventh edition, Lewis Publishers, Boca Raton, London, New York, Washington D.C., USA. pp.300, 308.

[15] *Management of Ha Long Bay*, Final Report, November 1999.

[16] Global Emission Model for Integrated Systems (GEMIS) Version 4.2. Available online: http://www.oeko.de/service/gemis/ [last assessed: 02/01/2005]

[17] PRé Consultants, the Netherlands, MO (SimaPro v6.0 Demo) Available online: http://www.pre.nl/simapro/ [last assessed: 23/03/2004]

[18] FIRE v6.24 (Factor Information Retrieval for criteria and hazardous air pollutants) Available online: http://www.epa.gov/ttn/chief/software/fire/ [last assessed: 15/01/2004]

[19] National Pollutant Invention (2002) "Emission Estimation Technique Manual for Combustion Engines", Version 2.2, Commonwealth of Australia. Available online: http://www.npi.gov.au [last assessed: 25/11/2003]

[20] National Pollutant Invention (2001) "Emission Estimation Technique Manual for Mining", Version 2.3, Commonwealth of Australia. Available online: http://www.npi.gov.au [last assessed: 25/06/2004]

[21] Manahan, S.E. (2000) *Environmental Chemistry*, seventh edition, Lewis Publishers, Boca Raton, London, New York, Washington D.C., USA. pp.300, 308.