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ENVIRONMENTAL TECHNOLOGY SERIES

ASSESSMENT OF SOURCES OF AIR, WATER, AND LAND POLLUTION

A GUIDE TO RAPID SOURCE INVENTORY TECHNIQUES AND THEIR USE IN FORMULATING ENVIRONMENTAL CONTROL STRATEGIES

PART ONE: RAPID INVENTORY TECHNIQUES IN ENVIRONMENTAL POLLUTION

BY

ALEXANDER P. ECONOMOPOULOS
DEMOCRITOS UNIVERSITY OF THRACE

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United Nations Environment Programme | World Health Organization | International Atomic Energy Agency | United Nations Industrial Development Organization

Dear Recipient,

The World Health Organization is pleased to provide you with the latest revision to its rapid assessment manual, "Assessment of Sources of Air, Water, and Land Pollution." This document revises an earlier publication, "Management and Control of the Environment" (WHO/PEP/89.1) and was developed under WHO's Global Environmental Technology Network (GETNET). GETNET is a programme to enable authorities at the local, regional, and national levels to identify, assess, and take actions on their own to prevent or eliminate environmental problems which threaten public health.

In 1986, the World Health Organization teamed with three other United Nations agencies - United Nations Environment Programme (UNEP), United Nations Industrial Development Organization (UNIDO), and the International Atomic Energy Agency (IAEA) to form the Inter-Agency Project on Risk Management. The purpose of this programme is to develop an integrated approach to the identification, prioritization, and minimization of important industrial hazards in a given area. This publication represents WHO's contribution to the Inter-Agency Project.

We hope that this publication will be beneficial in identifying priorities for future efforts to reduce environmental pollution in your area. WHO is committed to continually updating the rapid assessment programme and to developing future improvements to the document such as training modules and simplified, computer programmes for use of the document.

Sincerely,

G. Ozolins, Manager
Prevention of Environmental Pollution
Division of Environmental Health

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Note: Appendix I, Environmental Quality Guidelines, is not necessary for use in Part One. It is contained in Part Two.

PREFACE

Environmental management is often referred to as an art rather than as a science. The past twenty years has seen considerable progress toward revising this image. Numerous examples can be cited which show that proper planning can significantly reduce the impact of human activities upon the environment (Economopoulos, JAPCA 37:8, 1987). The difficulties in formulating sound environmental management programmes are especially pronounced in developing countries, and there is a need for practical tools that are suitable for widespread implementation and that permit the standardization of the critical initial stages of the planning process. This book attempts to address these requirements.

Some years ago, WHO published a book entitled Rapid Assessment of Sources of Air, Water and Land Pollution (WHO, offset publication No. 62, 1982), which focused primarily on the source inventory aspects of the management process. Translated into several languages, it has been widely distributed and the procedure described has been the subject of numerous training courses. The Rapid Assessment procedure has been found particularly useful in developing countries in the design of environmental control strategies and policies using relatively modest resources.

More recently, WHO updated and expanded the Rapid Assessment techniques by publishing a book entitled "Management and Control of the Environment" (WHO/PEP/89.1). This book strengthened the inventory portions, provided comprehensive lists of control options for each kind of air or water pollution source, and introduced some easy to use air and water quality models. This book, as well as its predecessor, has been found valuable in developing countries, and two of its reprints have already been exhausted.

In 1991, WHO initiated the Global Environmental Technology Network (GETNET), which had as its prime objective the strengthening, at the local level, of education and training materials on environmental pollution control technologies. This book, which succeeds a previous publication entitled "Management and Control of the Environment", is linked to the GETNET activities and will hopefully be widely used by developing countries to assess their environmental conditions and lead to making the environmental management process more of a science than an art.

The rapid assessment procedure is most useful in making an initial appraisal of the sources and levels of emissions from an area that has little or no previous pollution load data. It is also useful in selecting priority areas to conduct more extensive monitoring surveys; for conducting case studies as part of public health programmes directed at pollution control; and for formulating pollution control policies and regulations for national environmental health activities.

Part I of this book updates the rapid pollution assessment factors and introduces air, water and solid waste inventory and control models. It describes how to initiate a study, including how to organize study teams, how to define study areas, and how to collect, cross-check, organize and process field data so as to generate air, water and solid waste inventories, and, how to produce relevant reports to present to decision or policy makers. The necessary models and data for conducting air, water and solid waste inventories, for defining alternative control measures, and for assessing the pollution load reduction effectiveness of the latter are provided in Chapters 3 to 5. Study organization and implementation aspects are discussed in Chapter 6.

Part II of the book deals with environmental management problems and describes how to assess the current quality of air and water and how to identify land pollution problems; it also describes how to formulate alternative control strategies, how to evaluate their effectiveness and how to define high priority action programmes. The systems analysis approach, which sets the stage in the remainder of this book for the development of rational pollution abatement strategies, is presented in Chapter 7. Management approaches for urban and rural air pollution problems and selected air quality models are presented in Chapter 8, and for water pollution problems and selected water quality models in Chapter 9. Management approaches for municipal solid wastes and hazardous substances are discussed in Chapter 10.

While the focus of this new book is on the revision of the rapid assessment process, the model application techniques for air, water and solid wastes are greatly expanded. There is considerable discussion of various management approaches to consider once an environmental assessment of the area has been completed. The listing of all possible control and prevention strategies would, obviously, constitute an extremely ambitious, if not impossible task. Accordingly, the management approaches described in Chapters 8 to 10 are to be regarded as suggestions for the development of an environmental control strategy for an area. Many of these techniques to reduce pollution have proven to be very powerful and should be given serious consideration in problem analysis and strategy synthesis. The user of this book should make use of the expanded tools and data for conducting or updating their emission inventories and then give serious consideration to the approaches suggested herein. WHO, through the GETNET and its many experts from all fields of environmental technology in over 65 countries, can provide assistance to developing countries in interpreting the results of the rapid assessment and in the selection of management approaches.

Work on this book started before its predecessor, "Management and Control of the Environment", was published, mainly in the form of research addressing the lack of suitable models, for the purposes of the present methodology. The content was discussed at a consultation held in Geneva in June 1991. The first draft was reviewed during a meeting held in Athens in July 1992. Mr. G. Ozolins, Manager, and Mr. D. L. Calkins, Scientist, both from Prevention of Environmental Pollution, Environmental Health Division, WHO Geneva, provided the necessary impetus for the writing of this book and their support and advice throughout the preparation period is gratefully acknowledged.

Thanks are also due to Mr. G. Ozolins, Dr. D. Mage, and Mr. D. Calkins, from the Prevention of Environmental Pollution, Environmental Health Division, WHO Geneva, for reviewing the source inventory and the section on air pollution management and for drafting most of the preface; to Dr. R. Helmer, from the Environmental Health Division, WHO Geneva, for reviewing the water pollution management; to Mr. P. Economopoulos, from the Association of Communities and Municipalities of Attika Region, for his valuable contribution to, and review of, the section on solid wastes management; and, to Mr. E. Giroult, from the Environmental Health Division, WHO Geneva, for reviewing the section on solid wastes management.

CHAPTER 1

INTRODUCTION

1. Introduction

Environmental pollution affects the air we breathe, the water we drink and the food we consume. It also affects the production of food, the general quality of our surroundings and may pose a risk to our health and well-being. Control of environmental pollution is necessary in almost all communities and countries to protect the health of the population. The important question to be answered in each situation, is which pollutants should be controlled, in what way, and to what extent.

This book recommends the systems analysis approach and the simplification of analysis procedures in environmental management, both of which can be particularly effective in the analysis of existing problems and in the synthesis of control strategies:

The systems analysis approach, which is introduced in Chapter 7 of Part Two, is systematically followed in Sections 8.1, 9.1, and 10.1 dealing with the management of the air, water and land pollution problems. The essence of this approach lies in the analysis of existing problems and the identification of the most critical ones, in the setting of definite pollution control objectives and in the development of effective strategies to meet those objectives. The above requires the capability to conduct source inventories, to assess the impact of the released loads into the receivers, to define major control alternatives and to analyze their environmental, economic, and implementation consequences.

The systems analysis approach offers the important practical advantages of high cost-effectiveness and fast implementation, and its results can be impressive indeed. It creates however, particularly demanding analysis requirements, which have to be simplified and addressed through special tools and procedures, if it is to be practical and widely used.

The simplification of analysis procedures down to practical, and yet meaningful levels, while maintaining at the same time a highly integrated environmental management approach in relation to air, water and land pollution, has been the major challenge in the writing of this book.

The environmental management requirements were established through the following procedure: complex problems were decoupled into a series of much simpler ones; inventory and control models, as well as ambient quality models, capable of providing solutions in an effective and practical manner, were carefully selected and/or developed; the most important control measures were classified in categories and existing relevant data and information about their cost/effectiveness and implementation aspects were documented; and, finally, a coherent approach for the collection of the required information from the study area, the analysis and evaluation of the existing problems and the synthesis of truly effective management strategies was formulated, field-tested, and described.

The selection of analysis tools defines to a large extent, on the one hand the magnitude of resources required (manpower, skills, study duration, etc.), and on the other hand the reliability of the management results. The need thus arises for the screening of available models for the purpose of carefully balancing issues such as the accuracy and the reliability of predictions against the importance and relevance of results, ease-of-use and data requirements, or inter-model-compatibility. As ready, off-the-shelf, models meeting the above requirements did not always exist, some models had to be adapted and expanded (e.g. the ECE CORINAIR model for traffic fuel consumption and air emission calculations), while several new models had to be developed (e.g. the air, water and solid wastes inventory and control models presented in Sections 3.2.2, 4.2.2 and 5.2.2, as well as all air quality models presented in Section 8.2).

For most developing nations, where environmental problems are often critical and available resources scarce, environmental management approaches based on the best available control technology tend to be too expensive, while those relying on the imposition of selective controls through local inspectorate decisions and public opinion feedback, tend to be unworkable (lack of inspector skills and other infrastructure requirements, long response times, etc, see Section 7.2.) The alternative systems analysis approach for environmental management, followed in this book, is believed to be better suited for developing nations as it offers a practical procedure for formulating cost-effective strategies, targeted at selected critical problems, as well as detailed action programmes, which facilitate strategy implementation. It is thus hoped that the described procedure can contribute to better health and environmental quality protection, to conservation of valuable resources, and to unobstructed development in a rational and sustainable manner.

Designed as a work-book, this publication contains all the information required to analyze the current situation and to develop adequate management approaches, and additional information, such as conversion factors that facilitate the task. However, the measures derived through the recommended procedure, especially the complex and expensive ones, should not be regarded as final or as suitable for direct implementation, but rather as promising, high potential candidates which require further examination through more detailed feasibility studies.

Making assessments of environmental pollution and devising control strategies should not be viewed as a one-off effort, but rather as an on-going process. After an inventory of pollution loads has been made in a given area or country, it will need to be kept up-to-date and its accuracy improved. Similarly, control strategies will need to be reviewed as to their effectiveness and cost, while the efficiency of implemented measures will need to be monitored and compared with predictions, so as to provide guidance for the future. Assignment of these follow-up responsibilities to a specific government department is necessary, but the involvement of other government experts who would provide data and support to the total effort should be encouraged and stimulated. Examples of the latter are environmental and public health specialists, meteorologists and hydrologists, regional and country wide planning specialists, statisticians with knowledge of industrial and other economic activities, etc. This network of experts could, in a spirit of fruitful cooperation, develop into a highly competent planning body with far reaching impact.

The environmental management techniques described in this book can be used at different levels: municipal or local, provincial or state, and national. At the local and regional level, the management results can be used for addressing the pollution problems in an effective way. At the national level, management plans from various regions can be combined and used in the formulation of a national environmental management policy, which offers notable advantages such as:

- Rationalization of allocated government funds for protection of the environment through clear national priorities;

- Improved implementation through appropriate distribution of relevant responsibilities among the central and local authorities. As a general rule, the implementation of relatively simple measures affecting numerous small local sources can best be handled by local authorities, while that of complex measures affecting larger areas, by central government services. An example of a measure suitable for implementation by local authorities is the Inspection and Maintenance of central heating furnaces, and of measures suitable for implementation by central government are the changes in the fuel type or quality, or the setting of vehicle emission standards. Competent central government control and coordination is highly desirable in relation to the formulation, implementation and follow-up of national environmental plans;

- Valuable input can be offered in the formulation of other government plans and policies, in fields such as land planning, or the rational balancing of industrial and economic development against environmental quality.

CHAPTER 2

SOURCE INVENTORY TECHNIQUES

2.1 Alternative Source Inventory Approaches

2.1.1 Purpose and Objectives

The reliable assessment of the air, water and land polluting loads generated by each source, or by groups of similar sources, in the study area is essential for the identification of the nature, magnitude and origin of the existing pollution problems, as well as for the formulation of rational pollution abatement strategies.

Established methods to provide such information include direct monitoring of waste discharges, computer simulation of source and associated control systems, as well as the rapid assessment technique. In the sections that follow, these methods are described, their advantages and drawbacks outlined, and their possible combined use, so as to maximize the accuracy of the inventory results in a cost effective manner, discussed.

2.1.2 Waste Monitoring Programmes

The direct monitoring of waste sources through sampling and analysis is an obvious approach and one of the earliest and most widely used. This method is indispensable in many cases, especially when the waste discharges from large sources need to be kept under close surveillance, or when environmental services need to verify compliance with the applicable liquid effluent and air emission standards.

The major advantage of the direct waste monitoring method is the accuracy of the inventory results. In the context of environmental management studies however, which are of prime importance here, this method may be extremely time consuming and resource intensive, and even impractical for large and complex study areas. For example:

> Monitoring of the effluents from a leather tannery plant requires careful sampling as well as analysis to determine the concentration of a number of pollutants. As the effluent volume and composition changes significantly during the weekly production cycles, a fair number of samples need to be taken representing all major production phases, while the corresponding effluent rates must be determined. It is rather obvious that the resource requirements for the particular plant are high and could soon become prohibitive for a study area with numerous sources.

> Monitoring of the exhaust emissions from a road vehicle is even more difficult as the rate depends on parameters such as vehicle speed, engine loading, engine and catalyst warm up status, and is thus continuously changing. In addition, a significant part of the emissions, the evaporative ones, are not released via the tail pipe, and the bulk of them not even while the vehicle is running. In cases like this, the on-line measurement of the emissions even

from a single vehicle is difficult, and obviously impractical from an entire fleet.

Based on the above discussion, source monitoring can improve the accuracy of inventories and should be pursued to the extent possible. However, priorities must be set, so as to have all important sources adequately covered. As the latter often account for the bulk of the released loads, accurate monitoring of their wastes contributes substantially to the accuracy of the overall inventory programme. For the same reasons, time and resource constraints that are always present should not lead to a superficial coverage of many sources, and especially to the collection and analysis of few random samples from each source, as the inventory results obtained this way are generally unreliable and highly unpredictable.

2.1.3 Modeling of Pollution Source and Control Systems

The use of mathematical models, which simulate the behavior of certain sources, such as external and internal combustion sources, cement kilns, lime kilns etc, along with the performance of the attached control systems, constitutes one of the most advanced methods for reliably assessing not only the current emissions, but also the impact of possible design and operating modifications.

The disadvantages of the modeling approach include the practical difficulty of developing such models for the great variety of existing sources and control systems, and also the demand for the collection of often hard-to-find process and control system design and operating data during the source survey visits.

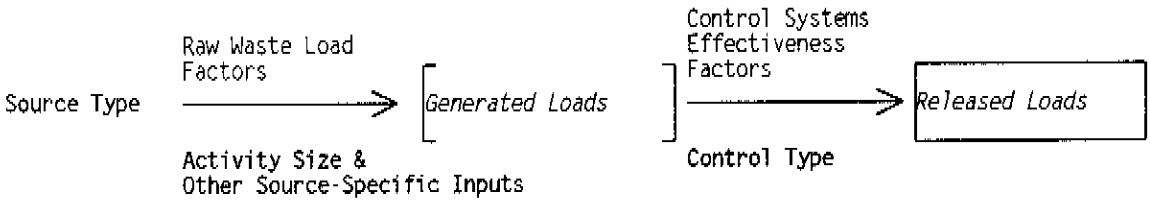
In reality the limited availability of models and the associated difficulties in assembling the required input data during field surveys restrict the application of the modeling approach during source inventory studies. In this book such models are used for predicting the emissions from Light Duty Gasoline Power (LDGP) cars, the flue gas volume from external combustion sources, as well as the drop in the temperature of flue gases passing through stacks. This selected use was deemed necessary for enhancing the accuracy of the air emission inventory results, as well as for generating inputs which are required for the application of air quality models. It should be noted that the sources concerned (LDGP cars and external combustion sources) are important contributors to air pollution problems, particularly in urban areas where they usually play a dominant role.

Validation of certain models under the local circumstances through balanced source monitoring programmes can be particularly beneficial and in some cases necessary, especially when large-scale measures are to be implemented. Verification using the emission model for LDGP cars is highly recommended if local measurements, or infrastructure allowing the generation of local monitoring measurements, exist. On the other hand, certain models such as the flue gas volume model do not need verification because they rely on stoichiometric relations.

2.1.4 The Rapid Assessment Procedure

The rapid assessment methodology provides a particularly effective way of assessing air, water and solid wastes generated by each source, or groups of similar sources, within the study area. In addition, it permits convenient assessment of the effectiveness of alternative pollution control options.

This method is based on the documented, and often extensive, past experience of the nature and quantities of pollutants generated from each kind of source, with and without associated control systems, and, as Figure 2.1.4-1 illustrates, it makes constant use of this experience for predicting the anticipated loads from a given source.



Legend:
Bold: Field survey data
Italic: Model output

Figure 2.1.4-1 Illustration of the rapid assessment approach for estimating the air, water and land pollution loads.

The advantages offered by the Rapid Assessment approach include convenience of use, which makes it possible to conduct integrated source inventories of air, water and land pollution sources in highly complex situations within only a few weeks time and with modest resources. Moreover, despite the simplicity of the method, the end result is often considered more reliable than that from direct source monitoring programmes in cases where shortcuts have to be taken (see also Section 2.1.2 above). Another significant advantage is the possibility of estimating conveniently the effectiveness of alternative control schemes in terms of their polluting load reduction potential. The latter constitutes a major input into the process of formulating rational control strategies.

A major disadvantage of the Rapid Assessment approach is the statistical validity of its inventory predictions. More specifically, the predictions from any given source need to be considered in many cases only as indicative as there is significant variation in normalized emissions between similar sources. Consequently, measures adopted immediately following Rapid Assessment need to be viewed as preliminary, subject to subsequent, more detailed, analysis prior to implementation of strategies.

2.1.5 Combined Approaches

The source inventory approach in this book combines the Rapid Assessment method (see Section 2.1.4) with the selective (and streamlined) use of the modeling method (see Section 2.1.3). The end objective of the above combination is to enhance the accuracy of predictions while maintaining the overall simplicity of use.

Source inventory data and information, which can easily be generated for any study area, can be used for more effective planning of waste and ambient air and water quality monitoring programmes, in cases where extra resources are available and such information is desirable. Indeed:

Through the source inventory procedure described in this book, one can obtain information about the nature (polluting parameters of major interest) and the magnitude of the polluting loads released from each source. In most situations, a few large sources account for the bulk of the released loads (e.g. among 140 tanneries in a study area, the largest plant was found to account for 40 % of the total discharged loads, while the largest five plants contributed about 80 % to the total discharges) and these few dominant sources can be easily identified. Waste monitoring could then be restricted, at least in the initial phases, to the dominant sources, for it is often preferable to have reliable monitoring data from, for example 80 % of the discharges than shortcut data of unpredictable quality from 100 % of the discharges.

Based on the above, a carefully planned combination of the Rapid Assessment and the monitoring approaches could maximize the accuracy of the inventory results within the constraints of available resources.

Data and information from the Rapid Assessment methodology could be used, possibly along with the air and water quality models, for planning more effective ambient monitoring programmes. Information about the important parameters to be measured and about the critical location of the stations can easily be generated and could be a valuable input into the planning process of monitoring networks.

2.2 Screening and Classification of the Pollution and Waste Generating Activities

There are often many types of pollution-generating activities in a study area, and dealing with all of them in the context of an environmental management study, is not practical, nor even feasible. As discussed in Section 2.3 below, the objective of an effective source inventory approach is to assess on an individual basis the very large sources (such as power plants, steel mills, and municipal waste water outfalls) expected to have major impact on the environment of the study area. Other major sources of pollution to be considered are service stations, dry cleaners etc., which collectively have an appreciable impact on the environment.

While almost all industrial activities cause some pollution and produce some waste, relatively few industries (without appropriate air pollution control and waste treatment facilities) are responsible for the bulk of the air, water and land pollution loads generated in a given study area. Careful selection of the major pollution and waste-producing industries can greatly simplify the preparation of the assessment, while still covering most of the pollutants and wastes produced.

Table 2.2-1 presents a list of the industrial sources and processes that account for much of the industrial pollution and waste loads in almost any study area. The table also gives the corresponding Standard Industrial Classification (SIC) numbers (UN 1980, 1989) and indicates whether a specific industry or process is included in the appropriate air, water and solid waste inventory and control models of Sections 3.2, 4.2, and 5.2 respectively. The list could be used in the initial phases of the inventory work as a check list to identify the existing major industrial operations in the study area. The identification of industries to be included in the survey is very important and should be prepared with great care since it forms the basis for the remainder of the work to be completed.

Table 2.2-1 List of activities included in the air, water, and solid waste inventory and control models, classified under the SIC system, UN (1989).

			Emissions[a]	Effluents[a]	Solid Wastes[a]
0	**Activities not Adequately Defined**				
	Consumer Solvent Use		*		
	Surface Coating		*		
1	**Agriculture, Hunting, Forestry & Fishing**				
11	*Agriculture and Hunting*				
	111	Agriculture and Livestock Production	*	*	*
12	*Forestry and Logging*				
	121	Forestry	*		
2	**Mining and Quarrying**				
21	*Coal Mining*		*		*
22	*Crude Petroleum & Natural Gas Production*		*		
23	*Metal Ore Mining*		*		*
29	*Other Mining*		*		*
3	**Manufacturing**				
31	*Manufacture of Food, Beverages & Tobacco*				
	311/2	Food Manufacturing			
	3111	Slaughtering, preparing and preserving meat	*	*	*
	3112	Manufacture of dairy products		*	
	3123	Canning and Preserving Fruits & Vegetables		*	*
	3114	Canning, preserving & Processing of fish	*	*	*
	3115	Manufacture of vegetable & animal oils & fats		*	*
	3116	Grain mill products	*	*	
	3117	Bakery products		*	
	3118	Sugar factories and refineries		*	
	3121	Food products not elsewhere classified	*	*	*
	3122	Alfalfa dehydrating	*		
	313	Beverage Industries			
	3131	Distilling, rectifying and blending spirits		*	*
	3132	Wine industries		*	
	3133	Malt liquors and malt	*	*	
	3134	Soft drinks		*	

Table 2.2-1 (Continued)

Code	Description	Emissions[a]	Effluents[a]	Solid Wastes[a]
32	***Textile, Wearing Apparel & Leather***			
321	Manufacture of Textiles			
3210	Manufacture of textiles		*	
322	Manufacture of Wearing Apparel, Except Footwear			
3211	Spinning, weaving and finishing textiles	*		*
3214	Carpet and rug manufacture			*
323	Manufacture of Leather and Products of Leather			
3231	Tanneries and leather finishing		*	*
34	***Paper & Paper Products, Printing & Publishing***			
341	Manufacture of Paper and Paper Products	*	*	*
342	Printing Publishing and Allied Industries	*		*
35	***Manufacture of Chemicals, & Chemical, Petroleum, Coal, Rubber & Plastic Products***			
351	Manufacture of Industrial Chemicals			
3511	Basic industrial chemicals except fertilizers	*	*	*
3512	Manufacture of fertilizers and pesticides	*	*	
3513	Resins, Plastics & fibers except glass	*	*	
352	Manufacture of Other Chemical Products			
3521	Manufacture of paints, varnishes & lacquers	*		*
3522	Manufacture of drugs and medicines		*	*
3523	Manufacture of soap & cleaning preparations	*	*	
3529	Chemical products not elsewhere classified	*	*	
353	Petroleum Refineries	*	*	*
354	Manufacture of Misc. Products of Petroleum and Coal	*	*	*
355	Manufacture of Rubber Products			
3551	Tyre & tube industries		*	*
36	***Non-metallic Mineral Products, Except Products of Petroleum & Coal***			
361	Manufacture of Pottery, China and Earthenware	*		
362	Manufacture of Glass and Glass Products	*	*	
369	Manufacture of Other Non-Metallic Mineral Products			
3691	Manufacture of structural clay products	*		
3692	Cement, Lime and Plaster	*		
3699	Products not elsewhere classified	*		
37	***Basic Metal Industries***			
371	Iron and Steel Basic Industries	*	*	*
372	Non-ferrous Metal Basic Industries	*	*	*
38	***Fabricated Metal Products, Machinery & Equ't***			
381	Fabricated Metal Products, Except Machinery	*	*	*
384	Manufacture of Transport Equipment			
3841	Ship building and repairing			*

Table 2.2-1 (Continued)

	Emissions[a]	Effluents[a]	Solid Wastes[a]
4 Electricity Gas and Water			
41 *Electricity, Gas and Steam*			
4101 Electricity light & power	*	*	*
6 Wholesale and Retail Trade			
61 *Wholesale Trade*	*		
62 *Retail Trade*	*	*	
63 *Restaurants and Hotels*			
631 Restaurants, Cafes, and other Eating & Drinking		*	
632 Hotels, Rooming Houses, Camps and Other Lodging		*	
7 Transport, Storage and Communication			
71 *Transport and Storage*			
711 Land Transport	*		
712 Water Transport	*		
713 Air Transport	*	*	
719 Services Allied to Transport			
7192 Storage and warehousing	*	*	*
9 Community, Social and Personal Services			
92 *Sanitary and Similar Services*	*	*	*
93 *Social and Related Community Services*		*	
931 Education Services		*	
932 Medical, Dental and Other Health Services			*
94 *Recreational & Cultural Services*		*	
95 *Personal and Household Services*			
952 Laundries, Laundry Services and Cleaning	*		

[a] An asterisk in the column below indicates that the relevant industry or process is included in the appropriate air, water or solid waste inventory and control models of Sections 3.2.2, 4.2.2 and 5.2.2 respectively.

2.3 General Description of the Rapid Assessment Procedure

As discussed in Section 2.1.4, and as shown in Figure 2.1.4-1, the calculation of the released loads from a given source is based on the use of appropriate waste load factors, which reflect the existing relevant experience from the measured performance of similar sources. Each waste load factor, e_j, is defined as the normalized released load of pollutant j expressed in kg/(unit of activity) of the particular source under consideration.

Sections 3.2.1, 4.2.1, and 5.2.1 present the rationale for the selection of the most appropriate "unit of activity" for each kind of source. Basically, the selected "activity unit" must bear a close and proportional relationship to the pollutant loads generated; it must also offer convenience during field-work (available field activity data must be commonly expressed in terms of the selected unit). The former makes the waste load factors, e_j, independent of the source size and activity level, and allows it to be expressed mathematically in the following form, as a function of several parameters:

e_j = f′(Source type, (2.3-1)
Process or design particularities,
Source age and technological sophistication,
Source maintenance and operating practices,
Type and quality of the raw materials used,
Type, design and age of the control systems employed,
Type/design of control systems employed in other media,
Ambient conditions, etc.)

The dependence of the waste factors e_j on parameters such as those included in Equation (2.3-1) above, cannot be expressed in a continuous function form due to the discreet nature of most parameters (e.g. the type of control systems employed), and the lack of sufficient information in relation to the remaining ones. A discreet functional form yielding a series of waste factor values, each valid under a specific set of common and important parameter combinations, is used instead.

The above leads into the tabular constructs for the air, liquid and solid waste inventory and control models, which are presented in Sections 3.2.2, 4.2.2 and 5.2.2 and described in Sections 3.2.1, 4.2.1 and 5.2.1 respectively. These models introduce the impact of all major parameters into the assessment of the load released, while providing at the same time a precise definition of the data requirements from the field surveys. Sections 3.2.4, 4.2.4, and 5.2.4 elaborate on the latter.

Based on the above, the air, liquid and solid waste models presented in Sections 3.2.2, 4.2.2 and 5.2.2 provide values for the waste load factors, as well as guidance for the data to be collected from the study area. The applicable waste load factors along with the collected data can then be introduced into (blank photocopies of) the Working Tables, which are given in Section 3.2.3, 4.2.3 and 5.2.3.

In the above Working Tables the activity level of each source must be expressed in (1000 units/year). This activity value can then be multiplied directly by the waste load factors, which are always expressed in (kg/unit), to yield the released loads for all pollutants of major interest, expressed in (tons/year). The Working Tables provide room for listing not only the waste load factors and the source type and activity data, but also the computed inventory results. The latter can also be added together to provide partial or overall totals, e.g. for the loads released from a particular industry and/or for the loads released within the entire study area. This way, the field survey data are organized and documented in a concise manner, along with the applicable factors and the source inventory results.

Sections 3.2.4, 4.2.4 and 5.2.4 provide examples on how the air, liquid and solid waste inventory and control models of Sections can be used, along with the Working Tables of Sections 3.2.3, 4.2.3 and 5.2.3, to define the data requirements, to list the field survey results and to compute the released loads.

An important practical question, which often arises during source inventory studies, is when one should collect field data and compute the released loads for each source individually, and when one is justified to do so for a group of similar sources jointly. The answer is obvious for the relatively few large sources (e.g. an electric power plant), for which calculations on an individual basis are required, as well as for groups of numerous small sources of similar type and with similar controls (e.g. space heating furnaces), for which joint calculations are necessary. In the latter case the combined overall activity (e.g. the total heating oil consumed by the space heating furnaces in 1000 tons/year) is entered in the Working Tables and the overall waste loads produced jointly from all such sources are computed.

Between the very large individual sources and the groups of numerous but very small sources, there is a grey area, for which the decision on how to proceed must be based on careful judgment as it may significantly affect both the amount of work involved and the accuracy of the results. As a general rule, when numerous small to medium size sources exist within our study area or sub-area, one should try first to classify them into one or more groups, for which common sets of waste load factors apply, and calculate their combined waste load releases. This has some distinct advantages, since data about the combined overall activity are often easily available from government sources and industrial associations, etc (see Section 6.3.3) and these data are often reliable. Moreover, the entire assessment procedure is greatly simplified and a clearer overall picture is obtained. The classification however of the small sources in groups of similar type, and especially the distribution of the known overall activity among the groups, is not always straightforward and some pertinent information from knowledgeable persons is usually required.

As an example let us assume that in a study area 140 tanneries are operating, one of which is known to be large, half a dozen of them to be of medium size, and the rest small. A sensible inventory approach would be to visit the large and the biggest of the medium-size tanneries so as to calculate their effluent loads on an individual basis. For the remaining ones, one should try to obtain data about their collective output (i.e. tons of hides processed annually) as well as information about the process used (e.g. chrome or vegetable tanning) and the kinds of control systems employed (e.g. no control or primary sedimentation). On the basis of this information one could then form a number of groups, each of which comprises tanneries of the same process and of the same effluent controls. Assume for example that the information collected indicated that about 80 % of the hides are chrome tanned and that no controls are used as the effluents are discharged directly into the sewerage system. Under such circumstances two groups need to be considered, one comprising all production lines employing chrome tanning, and a second one comprising the remaining production lines employing vegetable tanning. The collective activity of the former is 80 % of the known total for all small plants, while the collective activity of the latter accounts for the remaining 20 %.

2.4 Validity of Waste Load Factors

The waste load factors listed in the inventory and control models of Sections 3.2, 4.2, and 5.2 relate, as we have seen, to major production or other industrial activity sectors. These factors have been obtained from a multitude of different books, documents, and scientific articles gathered from different parts of the world. They have subsequently been evaluated and cross checked before being inserted into the models. Particular attention has been given to the reliability of the factors, as this is directly related to the validity of inventory results. There are however, certain limitations associated with the use of factors, which must be considered:

For any given activity, the waste load factors vary from source to source, and this variation is sometimes very significant. Such variations are often the results of different operating practices, but may also reflect differences in the design and layout of the equipment. The factors provided are selected to represent as much as possible, average or typical conditions. As a result it can be expected that the waste load predictions on any individual source basis may occasionally differ significantly from the actual waste loads generated. Overall load predictions for several similar plants, e.g. the total polluting loads in the effluents of many tanneries operating in a given area should however, be reasonably accurate.

The accuracy of the factors provided is not uniform as it depends on the nature of the source, on the pollutant generating mechanisms, and on the extent of the characterization and measurement studies done. As an example, the SO_2 emission factors from external and internal combustion sources can be considered very accurate since they are stoichiometrically related to the sulfur content of the fuel. No other emission factors for combustion sources bear such a close relationship to a well defined and known parameter (the sulfur content) and they are thus less accurate. Furthermore, some of them, are based on relatively few measurements and exhibit wider variation.

The question often arises as to the validity of factors across different countries, especially those derived in industrialized countries when applied to developing countries. For example, because of differences in source inspection and maintenance, or because of differences in the size of a "typical" plant, somewhat higher factors could be justified. However, extensive use of the Rapid Assessment procedure (WHO, 1982), for over a decade in many parts of the world has shown that this is not a significant problem.

The general conclusion so far is that the application of the Rapid Assessment procedures should generally be expected to produce acceptable accuracy for the management purposes intended. The accuracy could be improved in cases where information about local factors is available and assessments should be derived from these whenever possible. Such refinements, along with the increase in the number of experienced personnel, are expected to improve results and in turn, the quality of environmental management.

2.5 Bibliography

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CHAPTER 3

AIR EMISSION INVENTORIES AND CONTROLS

3.1 Compilation of Air Emission Inventories Under Present and/or Strategy Target Conditions

This chapter presents four models, two of which can be used for computing the air emission loads generated under present and strategy target conditions, while the remaining two can be used to calculate the flue gas volume from external combustion furnaces, as well as the gas temperatures at the stack exit point, as a function of the inlet gas temperature. The output from the latter models, along with the inventory results, are necessary for assessing the impact of point sources on the air quality, as well as for formulating appropriate mitigation strategies (see Chapter 8).

Among the inventory models provided in this chapter, that of Section 3.2.2 represents a general one applicable to all sources of interest in the study area. This model provides five columns listing the emission factors (see Section 3.2.1 below) for the "conventional" pollutants TSP, SO_2, NO_x, CO, and VOC, as well as a sixth column reserved for other important substances, as the case may be, for each source considered. The procedural aspects for the calculation of the air emission loads are presented in Section 2.3 and demonstrated through an example in Section 3.2.4. In this model, the particularly important source category of Light Duty Gasoline Powered (LDGP) cars, is covered through a simplified procedure, allowing the computation of the typical annual emissions in urban areas with temperate climate under typical driving patterns.

The model in Section 3.3 focuses on the computation of the LDGP car emissions and supplements the above general model by providing a more elaborate computational procedure, which allows the user to derive emission factors adapted to local driving habits and to the prevailing annual or seasonal climatic conditions. The use of this model is described in Sections 3.3.2.1 and 3.3.3.1 and is demonstrated through examples in Sections 3.3.2.2 and 3.3.3.2.

To conclude this discussion on the source inventory, some remarks are warranted in relation to the procedure followed for the computation of road traffic emissions and justification of the particular emphasis placed on this source category:

> The importance of road traffic emissions in urban areas stems from their dominance in terms of the emitted loads, the low level of their release, and from their adverse spatial distribution (the highest emission densities are generally encountered in the highest population density areas). As a result, the impact of road traffic emissions on urban air quality and on the health of the general population is significant.
>
> Assessment of the emissions from LDGP cars, by far the most important category of road vehicles, presents particular difficulties as these emissions are highly variable and dependent on a number of parameters, such as the age and size distributions of the vehicles in the fleet, the severity and the period of enactment of the emission standards legislation, local driving patterns, and local annual or seasonal climatic conditions.

From the published data and information about the LDGP car emission factors, those from the U.S. EPA (1989) and from the Commission of the European Communities (1989) stand out clearly for their completeness. The U.S. EPA data reflect a situation not representative of developing countries since most of the U.S. fleet now uses catalytic converter technologies (strict measures have been imposed since 1980) and comprises vehicles of unusually large size. The CEC legislation on the other hand followed the evolution of engine design, and the periodically updated emission standards closely reflected the improvements obtained from the progress in the conventional (non catalytic) engine design technologies. Only from 1993 will catalytic technologies become mandatory through CEC regulations. Furthermore, the European fleet comprises a relatively high proportion of small vehicles, which are more suitable for the congested European city traffic conditions.

Based on the above, the CEC data appear to be representative for most countries and are used in this book. Nonetheless, the use of local factors, if available, is encouraged, especially for countries where the local car production is not export oriented and/or without reasonably strict vehicles emission standards, as higher emissions than the computed ones may be anticipated.

From the analysis of the CEC data, two models have been derived and are presented here. A simple one, which is suitable for computing typical annual emissions in congested urban areas with temperate climate, has been streamlined and incorporated in the general emission load model of Section 3.2.2. A specific model, allowing users to derive more accurate factors on the basis of local driving habits and on the prevailing annual or seasonal climatic conditions, is presented in Section 3.3.

The flue gas volume model presented in Section 3.4, allows convenient assessment of the actual gas volume from external combustion sources as a function of the easily measured (or assumed) CO_2 concentrations. This information is required for estimating the ambient concentrations from point sources through the application of dispersion models (see Section 4.2.1). As the majority of point sources, for which air quality models are applied are industrial or utility boilers, the present model should cover a significant part of the gas volume data requirements.

The stack temperature drop model presented in Section 3.5 allows convenient computation for the stack-gas exit temperature, as a function of the stack-gas inlet temperature and other variables (physical stack height and diameter, and flue gas volume). It should be noted that although the flue gas exit temperature is a key variable for the use of air quality models, only the stack gas inlet temperature is usually known from literature and/or from direct measurements. The present model holds for both insulated and non-insulated stacks and addresses the input requirements of the air quality models by properly interfacing the raw data which are normally available from field surveys.

3.2 Model for Compiling Air Emission Inventories and Assessing the Effectiveness of Applicable Controls

3.2.1 Introduction

The quantities of emissions released into the atmosphere from any industrial or other activity depend, in general, on a number of parameters. Thus, the emission E of pollutant j could be expressed in a mathematical form as follows:

E_j = f(Source type, (3.2.1-1)
Unit of activity,
Source size,
Process or design particularities,
Source age and technological sophistication,
Source maintenance and operating practices,
Type and quality of the raw materials used,
Type, design and age of the control systems employed,
Ambient conditions, etc.)

The source type defines the kind of pollution generating activity in somewhat broad terms, e.g. cement manufacturing, vehicle traffic, external fuel combustion. More precise definition is provided through other parameters as discussed below. Obviously, the source type is a parameter which is closely related to the type and quantity of pollutants emitted.

Through the source type parameter alone it is possible to simplify very substantially the source inventory and the air pollution management tasks by excluding right from the start numerous activities with relatively minor air pollution potential.

The unit of activity, referred to simply as unit hereafter, defines an acceptable way of expressing the activity of a given source. Suitably defined units can be used to provide a measure of the services offered (e.g. the mileage of the vehicles in relation to the traffic in a study area, or the aircraft landing and take off cycles in relation to an airport), of the raw materials consumed (e.g. the fuel oil burned by an industrial boiler) or of the products manufactured (e.g. the quantity of cement produced by a cement manufacturing plant).

Selection of the most suitable unit for each type of activity is important, as the unit must have a direct relation to the pollutant loads emitted, and must offer convenience in obtaining the required data during the field work. For example, the activity of an industrial boiler could be characterized by the quantity of fuel used, or by the quantity of steam generated. The former is directly related to pollutant emissions, while the latter only indirectly (other parameters such as the overall thermal efficiency of the boiler are involved). Moreover, in practice is it easier to obtain reliable data on fuel consumption (both on a plant, as well as on a regional basis) than on the quantities of steam generated. Hence, a unit related to fuel consumption would then be appropriate for characterizing the activity of the boiler.

In some cases alternative units are provided to facilitate the field work. For example, in the case of road vehicles, units related to the distance driven or the fuel consumed can be used.

Source size, although a key parameter, is only indirectly related to the normalized emissions rate (emission loads per unit activity). In general, economies of scale allow better design and operation, as well as stricter emission controls for larger size units. Moreover, for industrial sources, selection of the particular process to be used is often dictated by plant size. It is for these reasons that emission standards are generally significantly stricter for large plants.

In the context of the present methodology the effects of plant size on the normalized emission loads can be taken into consideration only in cases where the source size affects the process selection. In some important cases however, as in the calculation of emissions from vehicle traffic, separate vehicle size categories are considered.

Process or design particularities are very much related to the kinds and to the quantities of pollutants emitted from industrial sources. For example, different kinds of kilns in the production of lime and cement, or different types of furnaces in the metallurgical industry result in greatly varying emission rates.

Source age and technological sophistication are important parameters, as they often significantly affect the emission loads. The aging of a source causes higher emissions as systems tend to fail more frequently and their operation tends to depart from the new equipment specifications. In addition, older systems do not take full advantage of technological innovations, which tend to yield environmentally friendlier performance. Naturally, the technological sophistication does not only depend on the age of the source alone, but also on the environmental legislation, as well as on enforcement aspects.

A well known example of the impact exerted by the age of the source and the severity of legislation on emissions is in the case of motor vehicles. Continuing improvements in engine design over the past 20 years have resulted in the production of vehicles with progressively diminishing emissions. Age aspects of light duty passenger cars are dealt with here in detail as they play a dominant role in urban air pollution.

Source maintenance and operating practices is another parameter significantly affecting emission loads. Fortunately, for the vast majority of industrial sources, proper maintenance and operation is also intimately related to production quality and costs and for this reason is usually practiced to acceptable standards. For smaller sources however, improper maintenance and operation is the rule rather than the exception, despite the associated economic losses.

A particularly important example of the impact of improper maintenance on emissions is in the case of internal and external combustion sources (industrial or domestic boilers and motor vehicles). Proper maintenance practices for certain of these sources are described in our emissions model, as they offer potent control alternatives for urban air pollution problems, along with significantly lower fuel consumption and economic savings as well.

The type and the quality of the raw materials used is in may cases intimately related to the types and to the quantities of pollutants emitted. In industrial processes the type and the quality of raw materials available often dictate the process to be used and the emission loads released by them. However, the most important, and perhaps the most striking impact, is in the case of internal and external combustion sources, where the type and the quality of fuel used exert a dominant impact on the urban air quality. Based on the above, it is not surprising that possible improvements in the type and in the quality of the fuel used, offer some of the most potent air pollution management options. In our emissions model the general subject of the raw materials type and quality is treated with particular attention due to its significant practical importance.

The type, design, and age of the control systems employed determine the removal efficiencies of the source emissions and are thus intimately related to the loads eventually released into the atmosphere. It should be noted that all parameters discussed so far in this section are associated with the generation of emissions and their reduction at source level. Only this one deals with the reduction of the emissions once they have been generated by the source.

The **type** of the control system employed defines by itself the capabilities and limitations (and hence the control efficiency range) for the source under consideration. Analytical **design characteristics** allow a better insight and a more accurate assessment of the control system efficiency, but relevant data are difficult to collect in practice and difficult to use. The **age** of the control system affects the emissions due to the progressive downgrading of the performance with time, but, most importantly, due to the generally more relaxed design specifications of the past. Old age of equipment tends thus to be associated with lower design efficiencies.

In our inventory model the type of control system is used as the leading parameter for assessing the control system performance. The age of the control system is an additional parameter, which is used in selected cases. Detailed assessments on the basis of specific design characteristics are however not addressed, as typical design practices are assumed.

The ambient conditions may significantly affect the rate of emissions. For example, wind velocity and/or rainfall affect the TSP emissions from roads and material storage facilities, while temperature affects considerably the road traffic emissions. The impact of the ambient conditions has been incorporated in our emissions model for selected sources.

The above discussion leads into the important practical question of how the emission load E_j could be expressed as a direct and explicit function of all the parameters that may affect it for all pollutants j of interest.

The first step in this direction is to define the emission factor e_j for pollutant j, through the following relation:

$$e_j = \frac{E_j,\ \text{kg/yr}}{\text{Source activity, Units/yr}} \qquad (3.2.1\text{-}2)$$

The emission factor e_j is normally expressed as kg/unit and is assumed to be independent of the source size and the source activity (or production) level. The basis for this important assumption is the way the activity units are selected. Indeed, as discussed above, a key criterion in the selection of the activity units is their direct and proportional relation to the emission loads generated. From the above and from Equation (3.2.1-1) we obtain:

e_j = f'(Source type, (3.2.1-3)
Process or design particularities,
Source age and technological sophistication,
Source maintenance and operating practices,
Type and quality of the raw materials used,
Type, design and age of the control systems employed,
Ambient conditions, etc.)

The emission factor e_j is used extensively hereafter, as the key objective of the air emissions model is to define the value of e_j for every significant source and for every pollutant of interest j.

The dependence of the emission factors e_j on the parameters discussed above and listed in Equation (3.2.1-1), cannot, in most cases, be expressed in a continuous function form due to the discreet nature of most parameters (e.g. type of fuel or type of control equipment used), and to the frequent lack of sufficient information in relation to the remaining parameters. A discreet functional form yielding a series of emission values, each valid under a specific set of common and important parameter combinations, is used instead.

The discreet rather than the continuous nature of the emission factor values leads into the tabular construct of the model in Section 3.2.2, into which the source types are organized on the basis of the UN Standard Classification of Industries and Services. Under each activity listed, all important individual sources are included (e.g. under Gypsum manufacturing, the Rotary Ore Dryers, the Raw Mills and the Calciners are included); for each such source all major alternative processes are listed (e.g. in Gypsum manufacturing and under Calciners, the Flash and the Continuous Kettle Calciners are listed); and for each such process all major control alternatives are provided (e.g. in Gypsum manufacturing, under Calciners and under the Continuous Kettle Calciners the Uncontrolled, the Fabric Filter and the Electrostatic Precipitator control alternatives are provided). For each such combination of parameters the applicable emission factors are given for the pollutants of interest.

The impact of the raw materials type and quality is either expressed directly through a relation (e.g. in the case of the SO_2 and TSP emission factors in several external combustion activities), indirectly through the listing of alternative processes (the process selection often depends on the raw materials available), or is described in the footnotes. Similar provision is made for the remaining parameters, whenever their impact becomes important. The impact of the ambient conditions (as well as of the local driving patterns) for light duty passenger cars is examined separately in Section 3.3 because of its particular importance for urban pollution.

The tabular structure and the form of Section 3.2.2 constitutes a rather elaborate air emissions model by introducing the impact of all major parameters into the assessment of the air emissions releases, and by providing a precise definition of the data requirements from field surveys. The model of Section 3.2.2 is thus a valuable tool for source inventory studies, not only for computing the emissions, but also for providing guidance on the data to be collected during the field survey work, as well as for organizing and presenting such data in a concise manner (see also Sections 3.2.3 and 3.2.4 below).

In addition, the model in Section 3.2.2 should be a valuable tool in air pollution management studies as it provides a clear picture of the existing sources and emissions and, along with it, a fairly comprehensive list of the available alternative process modifications and control equipment options for each activity and each source therein, as well as identification of the parameters that exert a particular influence on the emissions and quantification of relevant changes (e.g. quantification of the impacts from possible changes in the types and qualities of the fuel used). The above constitute key elements in the analysis of air pollution problems and the formulation of effective control strategies for any given urban or industrial area.

Finally, the model in Section 3.2.2 is useful in Environmental Impact Assessment Studies as it provides, in a convenient form, quantification of the impacts of alternative process and emission control system selections for most sources and activities of interest.

3.2.2 Model for Air Emission Inventories and Controls

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U	kg/U
	MAJOR DIVISION 0. **ACTIVITIES NOT ADEQUATELY DEFINED**							
	Consumer Solvent Use[1]	(Person)*(year)					4.2	
	Surface Coating							
	Paint	tn consumed					560	
	Varnish	tn consumed					500	
	Lacquer	tn consumed					770	
	Enamel	tn consumed					420	
	Primer (Zinc Chromate)	tn consumed					660	
	MAJOR DIVISION 1. **AGRICULTURE, HUNTING, FORESTRY AND FISHING**							
111	**Agricultural and Livestock Production**							
	Open Burning of Agricultural Materials							
	Field Crops	tn	11.0			58	9.0	
		1000 m^2 of land	5.0			26	4.0	
	Vine Crops	tn	3.0			26	3.0	
		1000 m^2 of land	1.7			15	1.7	
	Weeds	tn	8.0			42	4.5	
		1000 m^2 of land	5.8			30	3.2	
	Orchard Crops	tn	3.0			26	4.0	
		1000 m^2 of land	1.0			9	1.4	
	Forest Residues	tn	8.0			70	9.0	
		1000 m^2 of land	12.6			110	14.0	
121	**Forestry**							
	Charcoal Manufacturing							
	Uncontrolled	tn	133		12	172	157	
	Afterburners	tn	25		12	34	31	
	MAJOR DIVISION 2. **MINING AND QUARRYING**							
210	**Coal Mining**							
	Coal Cleaning							
	Coal Drying							
	Fluidized Bed Dryer							
	Uncontrolled	tn of dried coal	10	0.22	0.07		0.05	
	Cyclone	tn of dried coal	6	0.22	0.07		0.05	

1. The listed factor includes evaporation losses from the use of polishes, waxes, deodorants etc. and tts value is related to the standard of living of people in the study area. A lower value than the listed one may be is more appropriate for areas with low standard of living.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
	Wet Scrubber	tn of dried coal	0.05	0.13	0.07		0.05		
	Flash Drier								
	Uncontrolled	tn of dried coal	8						
	Cyclone	tn of dried coal	5						
	Wet Scrubber	tn of dried coal	0.2						
	Multilouvered Drier								
	Uncontrolled	tn of dried coal	13						
	Cyclone	tn of dried coal	4						
	Wet Scrubber	tn of dried coal	0.05						
220	**Crude Petroleum and Natural Gas Production**								
	Desulfurization of Natural Gas[2]	1000 m^3		$14.2(1-e)H_2S$					
		1000 m^3		$16.6(1-e)S$					
		tn of gas		$17.1(1-e)H_2S$					
		tn of gas		$20(1-e)S$					
2302	Non-Ferrous Ore Mining								
	Metallic Mineral Processing (Low Moisture Ore)								
	Uncontrolled								
	Crushing								
	Primary	tn	0.2						
	Secondary	tn	0.6						
	Tertiary	tn	1.4						
	Dry Grinding								
	Gravity Discharge	tn	1.2						
	Air Swept	tn	14.4						
	Drying	tn	9.8						
	Fabric Filter or Scrubbers	tn	1.5						
	Leadbearing Ore Crushing and Grinding								
	Pb Ores	tn	3.0					Pb	0.15
	Zn Ores	tn	3.0					Pb	0.006
	Cu Ores	tn	3.2					Pb	0.006
	Pb-Zn Ores	tn	3.0					Pb	0.06
	Cu-Pb Ores	tn	3.2					Pb	0.06
	Cu-Zn Ores	tn	3.2					Pb	0.006
	Cu-Pb-Zn Ores	tn	3.2					Pb	0.06

2. (a) "e" is fractional efficiency of sulfur recovery plants with typical values as follows:
for uncontrolled 2-stage sulfur recovery plant: from 0.920 to 0.950
for uncontrolled 3-stage sulfur recovery plant: from 0.950 to 0.975
for uncontrolled 4-stage sulfur recovery plant: from 0.960 to 0.990
for controlled sulfur recovery plant : from 0.990 to 0.999

(b) "H_2S" is the mole percent of H_2S in natural gas (1 mole % H_2S = 0.966 weight % H_2S or 0.856 weight % Sulfur), while "S" is the weight percent of sulfur in the natural gas.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U	kg/U
2901	Stone Quarrying, Clay and Sand Pits							
	Sand and Gravel[3]	tn	0.134					
	Stone Quarrying and Processing[4]							
	Uncontrolled							
	Wet Quarry Drilling	tn	0.4					
	Blasting	tn	?					
	Batch Drop							
	Truck Unloading	tn	0.17					
	Truck Loading							
	Conveyor	tn	0.17					
	Front End Loader	tn	29.					
	Conveying	tn	1.7					
	Drying	tn	17.5					
	Crushing							
	Primary+Secondary Crushing							
	Dry Materials	tn	0.14					
	Wet Materials	tn	0.009					
	Tertiary Dry Materials	tn	0.93					
2902	Chemical and Fertilizer Mineral Mining							
	Phosphate Rock Processing							
	Drying or Calcining							
	Drying							
	Uncontrolled	tn	2.9					
	Low Pres Venturi Scrubber	tn	0.29					
	High Pres Venturi Scrubber	tn	0.06					
	Calcining							
	Uncontrolled	tn	7.7					
	Low Pres Venturi Scrubber	tn	0.77					
	High Pres Venturi Scrubber	tn	0.16					
	Product Grinding							
	Uncontrolled	tn	1.5					
	Fabric Filter	tn	0.01					
	Transfer and Storage	tn	1					
	Open Storage Piles	tn	20					

3. Emission factors apply in cases where granular materials are found in near-surface alluvial deposits and in processing operations involving initial dry screening followed by wet processing for screening and silt removal to produce washed sand and gravel. In situations where silt is removed by air blowing, a significant portion of the raw material may be blown in the air resulting in very high dust emissions.
4. Emissions from the material hauling are not included as they can be computed separately (see factors listed in group 711).

Model for Air Emission Inventories and Controls - Cont'd

SIC# PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
MAJOR DIVISION 3. **MANUFACTURING**								
DIVISION 31. **MANUFACTURE OF FOOD, BEVERAGES AND TOBACCO**								
3111 Meat Smokehouses								
Uncontrolled	tn	0.15			0.3	0.18		
Low Voltage ESP or Afterburner	tn	0.05			0.0	0.075		
3114 Fish Processing (Canning & Manufacture of by-products)								
Steam Tube Driers	tn	2.5					H_2S	0.05
Direct Fired Driers	tn	4.0					H_2S	0.05
3116 Grain Mills								
Feed Mills, Uncontrolled	tn	4.9						
Wheat Milling								
Uncontrolled	tn	38.0						
Cyclones & Fabric Filters	tn	0.8						
Durum Milling, Uncontrolled	tn	3.0						
Rye Milling,								
Uncontrolled	tn	38.0						
Cyclones & Fabric Filters	tn	0.8						
Oat Milling, Uncontrolled	tn	1.25						
Rice Milling, Uncontrolled	tn	2.97						
Soybean Milling, Uncontrolled	tn	11.73						
Dry Corn Milling, Uncontrolled	tn	6.25						
Wet Corn Milling, Uncontrolled	tn	6.24						
3121 Starch Manufacturing								
Uncontrolled	tn	4.0						
Controlled[5]	tn	0.01						
3122 Alfalfa Dehydrating								
Primary Cyclone								
No Secondary Controls	tn	5						
Medium Energy Wet Scrubber	tn	0.5						
Meal Collector Cyclone								
No Secondary Controls	tn	2.6						
Fabric Filter	tn	0.03						
Pellet Cooler Cyclone								
No Secondary Controls	tn	3						
Fabric Filter	tn	0.03						
3133 Beer Brewing	tn of cereal	4.0				1.3		
m^3 of beer	0.8				0.25			

5. TSP emissions from the various corn cleaning, grinding, and screening operations can be controlled by centrifugal gas scrubber.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
3133	Wine Production	m^3 of wine					0.35		
	DIVISION 32. **TEXTILE, WEARING APPAREL & LEATHER INDUSTRIES**								
321	Textile Fabric Printing	tn of fabric					142		
3211	Cotton Ginning								
	Uncontrolled	tn of cotton	7.0						
	Cyclones, in-line filters etc	tn of cotton	4.48						
	DIVISION 33. **MANUFACTURE OF WOOD & WOOD PRODUCTS, INCLUDING FURNITURE**								
331	**Manufacture of Wood and Wood and Cork Products, Except Furniture**								
	Plywood Veneer								
	Fugitive Emissions								
	Log Debarking & Sawing	tn of logs	0.187						
	Plywood Cutting & Sanding	m^2 of plywood	0.05						
	Sawdust Handling	tn of Sawdust	0.5						
	Dryers	$1000m^2$					12		
	DIVISION 34. **MANUFACTURE OF PAPER AND PAPER PRODUCTS. PRINTING AND PUBLISHING**								
341	**Manufacture of Paper and Paper Products**								
	Sulfate (Kraft) Pulping								
	Digester, Brown Stock Washer Multiple Effect Evaporator								
	Uncontrolled	tn						H_2S	0.58
								Merc	1.15
	Recovery Boiler								
	Recovery Boiler & Direct Contact Evaporator								
	Uncontrolled	tn	90.	3.5		5.5		H_2S	6
								Merc	1.5
	Venturi Scrubber	tn	24.	3.5		5.5		H_2S	6
								Merc	1.5
	Venturi+Auxilliary Scrubber	tn	7.5	3.5		5.5		H_2S	6.
								Merc	1.5
	ESP	tn	1.	3.5		5.5		H_2S	6.
								Merc	1.5
	ESP+Auxilliary Scrubber	tn	1.5	3.5		5.5		H_2S	6.
								Merc	1.5
	Recovery Boiler Without Direct Contact Evaporator								
	Uncontrolled	tn	115.			5.5		H_2S	0.05
	ESP	tn	1.			5.5		H_2S	0.05

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
	Smelt Dissolving Tank								
	Uncontrolled	tn	3.5	0.1		5.5		H_2S	0.1
								Merc	0.15
	Mesh Pad	tn	0.5	0.1		5.5		H_2S	0.1
								Merc	0.15
	Scrubber	tn	0.1			5.5		H_2S	0.1
								Merc	0.15
	Lime Kiln								
	Uncontrolled	tn	28.	0.15		0.05		H_2S	0.25
								Merc	0.1
	Scrubber or ESP	tn	0.25			0.05		H_2S	0.25
								Merc	0.1
	Miscellaneous Sources	tn						Merc	0.25
	Sulfite Pulping								
	Digester Blow Pit or Dump Tank								
	Uncontrolled	tn		3.-35.					
	MgO Base System								
	Process Changes	tn		2.0					
	Scrubber	tn		0.5					
	Process Changes+Scrubber	tn		0.1					
	All Exhausts through Recovery Systems	tn		0.0					
	NH_3 Base System								
	Process Changes	tn		12.5					
	Process Changes+Scrubber	tn		0.2					
	Na Base System								
	Process Changes+Scrubber	tn		1.					
	Calcium Base System	tn		33.5					
	Recovery System								
	MgO Base System								
	Multicyclone+Venturi Scrub.	tn	1.	4.5	0.5				
	NH_3 Base System								
	NH_3 Absorption+Mist Elim.	tn	0.35	3.5					
	Na Base System								
	Sodium Carbonate Scrubber	tn	2.	1.					
	Acid Plant[6]								
	NH_3 Base System								
	Scrubber	tn		0.2					
	Na Base System	tn		0.1					
	Calcium Base System								
	Scrubber	tn		4.					

6. Necessary in pulp mills with insufficient or nonexistent recovery systems.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U	kg/U
342	**Printing and Publishing and Allied Industries**							
	Graphic Arts							
	Small Applications[7]	(Capita)*(year)					0.4	
	Major Printing Lines[8]							
	Web Offset							
	Publications							
	Printing Line							
	Uncontrolled	tn of ink					240	
	Incineration	tn of ink					12	
	Printed Product	tn of ink					160	
	Newspapers							
	Printed Product	tn of ink					50	
	Web Letterpress							
	Publications							
	Printing Line							
	Uncontrolled	tn of ink					240	
	Incineration	tn of ink					12	
	Printed Product	tn of ink					160	
	Newspapers	tn of ink					0	
	Rotogravure							
	Printing Line							
	Uncontrolled	tn of ink					712	
	Carbon Adsorption	tn of ink					230	
	Incineration	tn of ink					249	
	Printed Product	tn of ink					38	
	Flexography							
	Printing Line							
	Uncontrolled	tn of ink					712	
	Carbon Adsorption	tn of ink					285	
	Incineration	tn of ink					285	
	Printed Product	tn of ink					38	
	Publication Gravure Printing[9]							
	Uncontrolled	tn of ink					1480	
	Controlled (Old Presses)	tn of ink					370	
	Controlled (New Presses)	tn of ink					220	

7. (a) Large sources contribute most of the emissions for graphic arts operations.
   (b) The listed factor is expressed in kg/year/capita, it provides an overall estimate for the numerous small sources which are difficult to be identified separately, and can be used only in the case of developed countries.
8. The VOC emission factors for the plant operations (dryer and other print-line components) are listed separately from these for the printed product, as the former are subject to controls.
9. (a) Control devices can be of the solvent recovery (carbon adsorption) and of the solvent destruction type (thermal or catalytic oxidation) type, the former being more common.
   (b) The 75% overall control level represents 84% capture efficiency and 90% control efficiency (the U.S. EPA guideline recommendation for old existing presses). The 85% overall control level represents the Best Demonstrated Control Technology for new plants.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
DIVISION 35.	**MANUFACTURE OF CHEMICALS & OF CHEMICAL, PETROLEUM, COAL, RUBBER & PLASTIC PRODUCTS**								
351	**Manufacture of Industrial Chemical**								
3511	Basic Industrial Chemicals Except Fertilizers								
	Phthalic Anhydride								
	Oxidation of o-xylene Process								
	Main Process Stream								
	Uncontrolled	tn	69	4.7		151			
	Scrubber & Incinerator	tn	3	4.7		6			
	Incinerator	tn	4	4.7		8			
	Incinerator+Steam Generator	tn	4	4.7		8			
	Pretreatment								
	Uncontrolled	tn	6.4						
	Scrubber & Incinerator	tn	0.3						
	Incinerator	tn	0.4						
	Distillation								
	Uncontrolled	tn	45.				1.2		
	Scrubber & Incinerator	tn	2.				<0.1		
	Incinerator	tn	2.				<0.1		
	Oxidation of naphthalene								
	Uncontrolled	tn	28.			50			
	Incinerator	tn	6.			10			
	Scrubber	tn	0.3			50			
	Pretreatment								
	Uncontrolled	tn	2.5						
	Incinerator	tn	0.5						
	Scrubber	tn	0.1						
	Distillation								
	Uncontrolled	tn	19.				5		
	Incinerator	tn	2.				1		
	Scrubber	tn	0.2				<0.1		
	Chlor-Alkali Production								
	Mercury Cell Process								
	Air Blowing the Cell Brine	tn						Cl_2	2.5
	Blow Gases from Liquefaction								
	Uncontrolled	tn						Cl_2	50
	Water Absorber	tn						Cl_2	5
	Caustic or Lime Absorber	tn						Cl_2	0.5
	Loading of Chlorine								
	Storage & Tank Car Vents	tn						Cl_2	8.25
	Diaphragm Cell Process								
	Blow Gases from Liquefaction								
	Uncontrolled	tn						Cl_2	30
	Water Absorber	tn						Cl_2	3
	Caustic or Lime Absorber	tn						Cl_2	0.5

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
	Loading of Chlorine								
	Storage & Tank Car Vents	tn						Cl_2	8.25
	Hydrochloric Acid (by-product process[10]								
	Uncontrolled	tn						HCl	3.0
	Final Scrubber	tn						HCl	0.2
	Hydrofluoric Acid from fluorospar & H_2SO_4								
	Spar drying, transfer & silos								
	Uncontrolled	tn	70.5						
	FFs, Covers, Additives	tn	1.3						
	Tail Gas								
	Uncontrolled	tn		22.5				HF	12
								SiF_4	15.0
	Caustic Scrubber	tn		0.3				HF	0.1
								SiF_4	0.15
	Sulfuric Acid[11]								
	Without Acid Mist Controls								
	From Recovered S	tn of 100% H_2SO_4		7(100-e)				SO_3	0.29
	From Bright Virgin S	tn of 100% H_2SO_4		7(100-e)				SO_3	0.85
	From Dark Virgin S	tn of 100% H_2SO_4		7(100-e)				SO_3	1.66
	Sulfide Ores	tn of 100% H_2SO_4		7(100-e)				SO_3	2.15
	Spent Acid	tn of 100% H_2SO_4		7(100-e)				SO_3	1.15
	ESP or Mist Eliminator	tn of 100% H_2SO_4		7(100-e)				SO_3	0.05
	Nitric Acid from Catalytic oxidation of NH_3								
	Weak Acid Tail Gas								
	Uncontrolled	tn of 100% acid			22.0				
	Catalytic NO_x Reduction								
	with Natural Gas	tn of 100% acid			0.2				
	with Hydrogen	tn of 100% acid			0.4				
	with 25% NG 75% H_2	tn of 100% acid			0.5				
	Extended Absorption	tn of 100% acid			1.0				
	High Strength Acid Plant	tn of 100% acid			5.0				
	Phosphoric Acid								
	Wet Process[12]								
	Uncontrolled	tn of P_2O_5	5.5[13]					F_2	59.4
	Controlled	tn of P_2O_5	3.0					F_2	0.6

10. With chlorine added to an organic compound such as benzene, toluene and vinyl chloride.
11. "e" is the process conversion efficiency of SO_2 into SO_3. Typical values for single absorption plants are 95 to 98% and for double absorption plants about 99.7%. For single absorption plants equipped with alkaline SO_2 absorbers, a value of 99.7% should be also used.
12. The wet process is used predominantly in the production of fertilizers.
13. Phosphate rock is assumed to be delivered dried or calcined to the plant. If drying or calcining takes place, the added TSP emissions must be computed (see SIC No 2902).

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
	Thermal Process								
	Controlled	tn of P_2O_5	1.0						
	Lead Oxide & Inorganic Pigments								
	Lead Oxide Production								
	Barton Pot (After FF)	tn	0.32					Pb	0.22
	Calcining Furnace								
	Uncontrolled	tn	7					Pb	7.0
	Scrubber	tn	1.23					Pb	1.23
	Cyclone + FF	tn	0.07					Pb	0.07
	Pigment Production								
	Red Lead								
	Uncontrolled	tn	0.5					Pb	0.5
	Scrubber	tn	0.088					Pb	0.088
	Cyclone + FF	tn	0.005					Pb	0.005
	White Lead								
	Uncontrolled	tn	0.28					Pb	0.28
	Scrubber	tn	0.05					Pb	0.05
	Cyclone + FF	tn	0.003					Pb	0.003
	Chrome Pigments Production								
	Uncontrolled	tn	0.065					Pb	0.065
	Scrubber	tn	0.011					Pb	0.011
	Cyclone + FF	tn	0.001					Pb	0.001
	Ammonia Production[14]								
	With Natural Gas as Fuel	tn	0.072	0.022	2.7	7.97	4.73	NH_3	2.1
	With Distillate Oil as Fuel	tn	0.450	1.319	2.7	8.02	4.94	NH_3	2.1
	Sodium Carbonate (Soda Ash) Production								
	Natural Process (Recovery from natural deposits)[15]								
	Predryer - Rotary steam heated								
	Uncontrolled	tn	1.55						
	Venturi Scrubber	tn	0.03						
	Calciner								
	Gas Fired - Uncontrolled	tn	184						
	Coal Fired - Uncontrolled	tn	195	0.007					
	Cyclone & ESP	tn	0.975-0.08						
	Bleacher - Rotary gas fired								
	Uncontrolled	tn	155						
	Cyclone & ESP	tn	0.02						

14. The natural gas feedstock is assumed to be desulfurized. If natural gas desulfurization takes place, the additional SO_2 emissions need to be considered (see SIC No 2200). Loading of storage tanks and ships may be an additional source of significant NH_3 emissions if proper controls are not applied.

15. Significant TSP emissions, which may arise from crushing and dissolving operations, elevators, conveyor transfer points, product loading and storage piles, have not been included.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
	Dryer								
	Rotary steam tube								
	Uncontrolled	tn	33						
	Venturi Scrubber	tn	0.4						
	Fluid bed steam tube								
	Uncontrolled	tn	73						
	Cyclone+Venturi Scrubber	tn	0.09						
	Synthetic (Solvay) Process[16]								
	Uncontrolled	tn	25					NH_3	2
	Controlled	tn	0.25						
	Calcium Carbide Production[17]								
	Coke Dryer								
	Uncontrolled	tn	1.	1.5					
	Controlled	tn	0.13	1.5					
	Electric Furnace								
	Circular Charging Conveyor								
	Controlled	tn	0.17						
	Furnace Main Stack								
	Uncontrolled	tn	12.	1.5					
	Controlled	tn	0.39	1.5					
	Tap fume vents								
	Controlled	tn	0.07						
	Furnace Room vents								
	Uncontrolled	tn	13.						
	Controlled	tn	0.07						
	Primary and Secondary Product Crushing								
	Controlled	tn	0.57						
	Adipic Acid (from cyclohexane or cyclohexanol)								
	Raw Material Storage	tn					3.3		
	Cyclohexane Oxidation								
	Uncontrolled (after scrubber)	tn				58	20		
	Carbon Adsorber	tn				58	1		
	Flaring	tn				2	6		
	CO boiler	tn				0.5	0.0		
	Thermal Incinerator	tn				0.0	0.0		
	Nitric Acid Reaction								
	Uncont'led (after NO_x absorber)	tn			27				
	Scrubber, Flaring or Combustion	tn			8				
	Thermal Reduction[18]	tn			0.5				

16. Significant fugitive TSP emissions from limestone handling and processing operations, product drying operations, and dry solids handling (conveyance and bulk loading) have not been included.
17. Controls devices for TSP used are Fabric Filters of Wet Scrubbers. The CO generated from closed furnaces is either used as fuel for other processes of Flared.
18. In the thermal reduction, the offgases containing the NO_x are reacted with excess fuel in a reducing atmosphere.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
	Refining, Drying, Cooling, Storing								
	Controlled (Fabric Filter)	tn	0.5		0.3		0.3		
	Lead Alkyl Manufacture								
	Electrolytic Process	tn						Pb	0.5
	Sodium/Lead Alloy Process								
	Process Vents								
	Tetraethyl Lead Production								
	Uncontrolled	tn						Pb	2.0
	Low Energy Wet Scrubber	tn						Pb	0.25
	High Energy Wet Scrubber	tn						Pb	0.06
	Fabric Filter	tn						Pb	0.02
	Tetramethyl Lead Production								
	Uncontrolled	tn						Pb	75.0
	Low Energy Wet Scrubber	tn						Pb	9.4
	High Energy Wet Scrubber	tn						Pb	2.25
	Fabric Filter	tn						Pb	0.75
	Sludge Pits								
	Uncontrolled	tn						Pb	0.6
	Low Energy Wet Scrubber	tn						Pb	0.08
	High Energy Wet Scrubber	tn						Pb	0.002
	Fabric Filter	tn						Pb	0.001
	Recovery Furnace								
	Uncontrolled	tn						Pb	28.0
	Low Energy Wet Scrubber	tn						Pb	3.5
	High Energy Wet Scrubber	tn						Pb	0.84
	Fabric Filter	tn						Pb	0.28
	Maleic Anhydride by Oxidation of Benzene								
	Uncontrolled	tn				680	87		
	Carbon Adsorption	tn				680	87		
	Thermal or Catalytic Incineration	tn				3.4	0.4		
	Terephthalic Acid								
	Uncontrolled	tn				19	19.8		
	Carbon Adsorption	tn				19	2.0		
	Thermal Oxidation	tn				1.0	1.0		
3512	Manufacture of Fertilizers and Pesticides								
	Urea Production (from NH_3 & CO_2)[19]								
	Solution Formation & Concentration								
	Uncontrolled	tn	0.0105					NH_3	9.12

19. Emission sources are generally controlled with wet scrubbers due to easy recycling of the dissolved Urea collected. Emissions from the bagging operations are controlled by Fabric Filters. Emissions from the solution synthesis and concentration operations, from the solids screening and coating are small and are generally not controlled.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
	Solids Formation								
	Non Fluidized Bed Prilling								
	Uncontrolled	tn	1.85					NH_3	0.43
	Wet Scrubber	tn	0.032					NH_3	0.43
	Fluidized Bed Prilling								
	Agricultural Grade								
	Uncontrolled	tn	3.1					NH_3	1.46
	Wet Scrubber	tn	0.39					NH_3	1.46
	Animal Feed Grade								
	Uncontrolled	tn	1.8					NH_3	2.07
	Wet Scrubber	tn	0.24					NH_3	1.04
	Drum Granulator								
	Uncontrolled	tn	120.					NH_3	1.07
	Wet Scrubber	tn	0.115					NH_3	1.07
	Rotary Drum Cooler[20]								
	Uncontrolled	tn	3.72					NH_3	0.0256
	Wet Scrubber	tn	0.1						
	Bagging - Uncontrolled	tn	0.095						
	Ammonium Nitrate (from HNO_3 & NH_3)								
	High Density Prilling Process								
	Uncontrolled	tn	5.8					NH_3	37.8
								HNO_3	0.52
	Wet Scrubbing	tn	0.74						
	Low Density Prilling Process								
	Uncontrolled	tn	86.9					NH_3	18.8
								HNO_3	0.52
	Wet Scrubbing	tn	1.2						
	Rotary Drum Granulator Process								
	Uncontrolled	tn	157.5					NH_3	48
								HNO_3	0.52
	Wet Scrubbing	tn	0.43						
	Pan Granulators Process								
	Uncontrolled	tn	23.1					NH_3	17.8
								HNO_3	0.52
	Wet Scrubbing	tn	0.33						
	Ammonium Sulfate[21]								
	Rotary Driers								
	Uncontrolled	tn	23.00				0.74		
	Wet Scrubbers	tn	0.12				0.11		
	Fluidized Bed Dryers								
	Uncontrolled	tn	109.00				0.74		
	Wet Scrubbers	tn	0.14				0.11		

20. Required only for Pan granulation and for some agricultural grade prills.

21. Produced as a caprolactam By-product, as a coke oven By-product, or synthetically by reacting ammonia with sulfuric acid.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
	Ammonium Phosphates (from H_3PO_4 & Anhydrous NH_3)								
	Controlled	tn	0.15					F_2	0.04
								NH_3	0.07
	Normal Superphosphates (from Phosphate rock & H_2SO_4)								
	Controlled	tn of Product	0.76					F_2	0.36
		tn of P_2O_5 content	4.20					F_2	2
	Triple Superphosphates (from Phosphate Rock & H_3PO_4)[22]								
	Run-of-the-Pile								
	Controlled	tn of Product	0.04					F_2	0.04
		tn of P_2O_5 content	0.10					F_2	0.1
	Granular								
	Controlled	tn of Product	0.10					F_2	0.056
		tn of P_2O_5 content	0.26					F_2	0.14
3513	Manufacture of Synthetic Resins, Plastic Materials and Man-Made Fibbers Except Glass								
	Styrene-Butadiene Copolymer (Rubber)								
	Emulsion Crumb Product								
	Monomer Recovery								
	Uncontrolled	tn					2.6		
	Absorber or Flaring	tn					0.26		
	Blend/Coagulation Tank & Dryers	tn					2.93		
	Emulsion Latex Product	tn					8.55		
	Polypropylene & Copolymers								
	Uncontrolled	tn	1.5				0.35		
	Vapor Recovery and/or Flares	tn	0.2				0.03		
	Polyvinyl Chlorides & Copolymers								
	Uncontrolled	tn	17.5				8.5		
	Vapor Recovery and/or Flares	tn	1.7				0.8		
	Rayon Manufacturing - Viscose Process	tn						H_2S	50.4
								CS_2	251
	Cellulose Acetate, Filter Tow	tn					112		
	Cellulose Acetate & Triacetate (yarn)	tn					199		

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22. (a) Emissions from the reactor, den and granulator are controlled by scrubbers using recycled gypsum pond water.
(b) Emissions from the dryer, cooler, screens, mills, product transfer systems & storage buildings are controlled by cyclones for the removal of dust, before they are sent to wet scrubbers.
(c) Fabric Filters are used in the preliminary ground rock handling activities.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U	kg/U
	Polyesters (e.g. Dacron), Melt Spun							
	Staple	tn	25.2				0.6	
	Yarn	tn	0.03				0.05	
	Acrylic, Dry Spun							
	Uncontrolled	tn					40	
	Controlled[23]	tn					32	
	Modacrylic, Dry Span	tn					125	
	Acrylic and Modacrylic, Wet Spun	tn					6.75	
	Acrylic, Inorganic Wet Spun							
	Homopolymer	tn					20.7	
	Copolymer	tn					2.75	
	Nylon 6, Melt Spun							
	Staple	tn	0.01				3.93	
	Yarn	tn					0.45	
	Nylon 66, Melt Spun							
	Uncontrolled	tn	0.5				2.13	
	Catalytic Incinerators etc	tn	0.1				0.31	
	Polyolefin, Melt Spun	tn	0.01				5	
	Spandex (polyurethane fibber)							
	Dry Spun	tn					4.23	
	Reaction Spun	tn					138	
	Vinyon, Dry Spun	tn					150	
352	Manufacture of Other Chemical Products							
3521	Manufacture of Paints, Varnishes and Lacquers							
	Paint Manufacture							
	Uncontrolled	tn	10.0				15	
	Afterburners	tn	1.0				0.15	
	Varnish Manufacture							
	Uncontrolled	tn					185	
	Afterburners	tn					1.9	

23. Scrubbers and Condensers are used in the spinning cells and in the dryers. Carbon adsorption is used in tank vents and in mixing and filtering operations. Distillation columns are also used to recover solvent from condenser, scrubber and wash water.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
3523	Manufacture of Soap and Cleaning Preparations								
	Spray-Dried Detergents								
	Uncontrolled	tn	45.0						
	Cyclones	tn	7.0						
	Cyclones & Spray chamber	tn	3.5						
	Cyclones & Packed Scrubber	tn	2.5						
	Cyclones & Venturi Scrubber	tn	1.5						
	Cyclones & Wet Scrubber	tn	0.544						
	Cyclones & Wet Scrubber & ESP	tn	0.023						
3529	Manufacture of Chemical Products not Elsewhere Classified								
	Carbon Black								
	Main Process Vent								
	Oil Furnace Process								
	Uncontrolled	tn	3.27	0.0	0.28	1400	75	H_2S	30
	Flare	tn	1.35	25.0		122.	1.85	H_2S	1.0
	CO Boiler & Incinerator	tn	1.04	17.5	4.65	0.88	0.99	H_2S	0.11
	Thermal Process	tn	0.	0.		0.	0.		
	All Other Systems								
	Fabric Filters	tn	0.37	0.27	0.4	0.	0.73		
	Printing Ink								
	Uncontrolled	tn	1.0				235		
	Scrubber/Condenser & Afterburner	tn					< 23.5		
	Trinitrotoluene								
	Batch Process								
	Nitration Reactors								
	With Fume Recovery	tn			12.5			HNO_3	0.5
	With Acid Recovery	tn			27.5			HNO_3	46.0
	Nitric Acid Concentrators	tn			18.5			SO_3	3.7
	Sulfuric Acid Concentrators								
	ESP	tn		7.	20.			SO_3	26.5
	ESP & Scrubber	tn		0.	20.			SO_3	2
	Red Water Incinerator								
	Uncontrolled	tn	12.5	1.	13.				
	Wet Scrubber	tn	0.5	1.	2.5				
	Sellite Exhaust	tn		29.5				SO_3	2.45
	Continuous Process								
	With Fume Recovery	tn	0.13	0.12	7.5			HNO_3	0.5
	With Acid Recovery	tn	0.13	0.12	5.0			HNO_3	0.01
	Nitrocellulose	tn		34.7	14.			HNO_3	19.0
								SO_3	0.245

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U	kg/U
353	**Petroleum Refineries**							
	Petroleum Refining[24]							
	Misc Operations[25]	m^3 of crude					0.4	
	Fluid Catalytic Cracking (FCC)							
	Uncontrolled	m^3 of FCC feed	0.695	1.413	0.204	39.2	0.63	
	CO Boiler	m^3 of FCC feed	0.695	1.413	0.204			
	ESP & CO Boiler	m^3 of FCC feed	0.126	1.413	0.204			
	Desulfurization of Sour Gas[26]	kg of Sulfur in Gas		2(100-e)/100				
		kg of Sulfur Recovered		2(100-e)/e				
	Rail Tank & Tank Trucks Filling							
	Gasoline Loading							
	Splash Loading	m^3 of Gasoline					1.43	
		tn of Gasoline					1.94	
	Submerged Loading[27]							
	Normal Service	m^3 of Gasoline					0.59	
		tn of Gasoline					0.80	
	Vapor Balance Serv	m^3 of Gasoline					0.98	
		tn of Gasoline					1.33	
	Vapor Controlled	m^3 of Gasoline					0.05	
		tn of Gasoline					0.07	
	Jet Naphtha Loading							
	Splash Loading	m^3 of Gasoline					0.43	
		tn of Gasoline					0.58	
	Submerged Loading							
	Normal Service	m^3 of Naphtha					0.18	
		tn of Naphtha					0.24	
	Vapor Balance Serv	m^3 of Naphtha					0.30	
		tn of Naphtha					0.40	
	Loading of Barges							
	Gasoline	m^3 of Gasoline					0.41	
		tn of Gasoline					0.55	

24. Emissions due to fuel burning are not accounted for and should be computed separately (see SIC No 410).

25. VOC emissions from typical sources within a refinery, such as storage tanks, API separators, blowdowns, fugitive sources etc are included. The listed factor is based on detailed VOC emissions estimates in several refineries.

26. "e" is the percent efficiency of the sulfur recovery plant. Typical values are for 2-stage plant controlled 92-95%, for 3-stage plant uncontrolled 95-97.5%, 4-stage plant uncontrolled 96-99%, and for controlled plant 99-99.9%.

27. In the Vapor Balance Service the cargo truck retrieves the vapors displaced during the underground tank filling in service stations (see below, SIC 620). This operation increases the VOC concentration in the air within the empty truck and causes higher VOC emissions when the truck is filled. It should be noted in this regard that most of the VOC emissions reduction achieved through the balanced vapor filling of the service stations submerged tanks is offset by the resultant increased emissions in the Truck Filling Station, unless of course a vapor recovery system is used in the latter.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U	kg/U
	Crude Oil	m^3 of Crude Oil					0.12	
		tn of Crude Oil					0.137	
	Jet Naphtha	m^3 Jet Naphtha					0.15	
		tn of Naphtha					0.20	
	Loading of Ships/Ocean Barges							
	Gasoline	m^3 of Gasoline					0.215	
		tn of Gasoline					0.291	
	Crude Oil	m^3 of Crude Oil					0.073	
		tn of Crude Oil					0.083	
	Jet Naphtha	m^3 Jet Naphtha					0.06	
		tn of Naphtha					0.08	
354	**Manufacture of Miscellaneous Products of Petroleum and Coal**							
	Asphaltic Concrete Plants[28]							
	Conventional Hot-Mix (Batch & Continuous mix processes)							
	Uncontrolled	tn	22.5	146S	18	19	14	
	Precleaner	tn	7.5	146S	18	19	14	
	High Efficiency Cyclone	tn	0.85	146S	18	19	14	
	Spray Tower	tn	0.2	73S	18	19	14	
	Baffle Spray Tower	tn	0.15	73S	18	19	14	
	Multiple Centrifugal Scrubber	tn	0.035	73S	18	19	14	
	Orifice Scrubber	tn	0.02	73S	18	19	14	
	Venturi Scrubber	tn	0.02	73S	18	19	14	
	Baghouse	tn	0.01	146S	18	19	14	
	Dryer Drum Hot Mix							
	Uncontrolled	tn	2.45					
	Cyclone or Multicyclone	tn	0.34					
	Low Energy Scrubber	tn	0.04					
	Venturi Scrubber	tn	0.02					
	Asphalt Roofing[29]							
	Asphalt Blowing							
	Saturant							
	Uncontrolled	tn of Asphalt	3.6			0.14	0.73	
	Controlled	tn of Asphalt	0.25				0.015	
	Coating							
	Uncontrolled	tn of Asphalt	13.4			1.87		
	Controlled	tn of Asphalt				0.1		
	Shingle Saturation							
	Uncontrolled	tn of Asphalt	1.57			0.13	0.13	
		tn of Shingle	0.25			0.01	0.05	

28. (a) "S" is the weight percent content of sulfur in the fuel oil used.
 (b) Fugitive dust emissions are not included in the listed factors.
 (c) Fuel burning emissions are included in Conventional but not in Drum Mix plants. (d) VOC emission factor for Drum Mix plans is not available.

29. Control devices include afterburners, high velocity air filters, low voltage ESP and wet scrubbers. Blowing operations are controlled by afterburners.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
	Controlled	tn of Shingle	0.03				0.09		
	Coke Production (By-product Method)[30]								
	Coal Crushing								
	Cyclone	tn of Coke	0.055						
	Coal Preheating[31]								
	Uncontrolled	tn of Coke	1.75						
	Scrubber	tn of Coke	0.125						
	Wet ESP	tn of Coke	0.006						
	Wet Coal Charging / Larry Car								
	Uncontrolled	tn of Coke	0.24	0.01	0.015	0.3	1.25	NH_3	0.01
	Sequential Charging	tn of Coke	0.008						
	Scrubber	tn of Coke	0.007						
	Door Leak	tn of Coke	0.27	0.005	0.005	0.3	0.75	NH_3	0.03
	Coke Pushing								
	Uncontrolled	tn of Coke	0.58			0.035	0.1	NH_3	0.05
	ESP	tn of Coke	0.225						
	Venturi Scrubber	tn of Coke	0.09						
	Baghouse	tn of Coke	0.045						
	Mobile Quench-Car Scrubber	tn of Coke	0.036						
	Coke Quenching								
	Quenching with Dirty Water (>5000 ml/l TDS)								
	Uncontrolled	tn of Coke	2.62						
	Baffles	tn of Coke	0.65						
	Quenching with Clean Water (>1500 ml/l TDS)								
	Uncontrolled	tn of Coke	0.57						
	Baffles	tn of Coke	0.27						
	Combustion of Coke Oven Gas								
	Uncontrolled	tn of Coke	0.234	2.[32]					

DIVISION 36. **MANUFACTURE OF NONMETALLIC MINERAL PRODUCTS EXCEPT PRODUCTS OF PETROLEUM & COKE**

362 **Manufacture of Glass and Glass Products**

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U
36201	Glass and Glass Products[33]						
	Melting Furnace						
	Container Glass						
	Uncontrolled	tn	0.7	1.7	3.1	0.1	0.1
	Low Energy Scrubber	tn	0.4	0.9	3.1	0.1	0.1
	Venturi Scrubber	tn	0.1	0.1	3.1	0.1	0.1
	Fabric Filter or ESP	tn		1.7	3.1	0.1	0.1

30. One ton of bituminous coal yields approximately 0.7 tn of Coke and 280 to 350 m^3 of gas.
31. Coal preheating is used only in few plants.
32. Typical SO_2 factor based on the assumptions of 0.8% S content of coal & on 33% of S transfer from coal to coke oven gas.
33. Emissions from the combustion of fuel are included.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
	Flat Glass								
	Uncontrolled	tn	1.0	1.5	4.0	0.1	0.1		
	Low Energy Scrubber	tn	0.5	0.8	4.0	0.1	0.1		
	Venturi Scrubber	tn		0.1	4.0	0.1	0.1		
	Fabric Filter or ESP	tn		1.5	4.0	0.1	0.1		
	Pressed or Blown Glass								
	Uncontrolled	tn	8.7	2.8	4.3	0.1	0.2		
	Low Energy Scrubber	tn	4.2	1.3	4.3	0.1	0.2		
	Venturi Scrubber	tn	0.5	0.1	4.3	0.1	0.2		
	Fabric Filter or ESP	tn	0.1	2.8	4.3	0.1	0.2		
	Forming and Finishing								
	Container Glass	tn					4.4		
	Pressed and Blown Glass	tn					4.5		
	Glass Fibber Manufacture[34]								
	Wool Glass Fibber (Uncontrolled)								
	Raw Materials Handling	tn	1.9						
	Glass Furnace								
	Electric	tn	0.25	0.02	0.14	0.025		F	0.001
	Gas-Regenerative	tn	11.	5.	2.5	0.13		F	0.06
	Gas-Recuperative	tn	14.	5.	0.85	0.13		F	0.06
	Gas-Unit Melter	tn	4.5	0.3	0.15	0.13		F	0.06
	Forming	tn	1.				0.15		
	Oven Curing (Flame attenuation)	tn	3.		1.	1.8	3.5		
	Textile Glass Fibber (Uncontrolled)								
	Raw Materials Handling	tn	1.9						
	Glass Furnace								
	Gas-Regenerative	tn	1.	1.5	10.	0.25			
	Gas-Recuperative	tn	8.	15.	10.	0.5			
	Gas-Unit Melter	tn	3.		10.	0.45			
	Forming	tn	0.5						
	Oven Curing and Cooling	tn	0.6		1.3	0.75			
369	**Manufacture of Other Non-Metallic Mineral Products**								
3691	Manufacture of Structural Clay Products								
	Bricks and Clay Products								
	Raw Materials Handling[35]								
	Drying								
	Uncontrolled	tn of material dried	35						
	Cyclone	tn of material dried	9.						
	Cyclone+Scrubber	tn of material dried	3.5						

34. (a) Emissions from the combustion of fuel are included.
    (b) Control technologies employed include wet ESPs, low and high pressure drop wet scrubbers, low and high temperature thermal incinerators.

35. Because of process variations, some raw material handling steps may be partially or completely omitted.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
	Grinding								
	Uncontrolled	tn of material ground	38.						
	Cyclone	tn of material ground	9.5						
	Cyclone+Scrubber	tn of material ground	3.8						
	Storage								
	Uncontrolled	tn of material stored	17.						
	Cyclone	tn of material stored	4.						
	Cyclone+Scrubber	tn of material stored	1.7						
	Curing and Firing[36]								
	Tunnel Kilns								
	Gas Fired	tn of bricks	0.012	0.	0.09	0.03	0.0045	F_2	0.5
	Oil Fired	tn of bricks	0.29	1.98S	0.525	0.06	0.0165	F_2	0.5
	Coal Fired	tn of bricks	0.34A	3.65S	0.73	0.71	0.008	F_2	0.5
	Coal/Gas Fired	tn of bricks	0.16A	0.31S	0.81			F_2	0.5
	Sawdust Fired	tn of bricks	0.12					F_2	0.5
	Periodic Kilns								
	Gas Fired	tn of bricks	0.033	0.	0.25	0.075	0.015	F_2	0.5
	Oil Fired	tn of bricks	0.44	2.93S	0.81	0.095	0.025	F_2	0.5
	Coal Fired	tn of bricks	9.42	6.06S	1.18	1.19	0.015	F_2	0.5
3692	Manufacture of Cement, Lime and Plaster								
	Lime Manufacturing[37]								
	Coal Storage and Processing (If Coal is used as fuel)								
	Coal Storage								
	Open Piles	tn lime	0.5						
	Semi-Enclosed Piles	tn lime	0.25						
	Compartments	tn lime	0.1						
	Silos	tn lime	0.1						
	Coal Crushing and Screening								
	Uncontrolled	tn lime	0.18						
	FF	tn lime	0.002						
	Coal Grinding								
	(Semi) Direct Fired Syst	tn Lime	0.0						
	Indirect Fired System								
	Uncontrolled	tn Lime	10.						
	Fabric Filter	tn Lime	0.1						
	Raw Material Storage	tn Lime	0.16						
	Crushing & Screening								
	Uncontrolled	tn Lime	1.5						
	Fabric Filter	tn Lime	0.0005						

36. (a) "S" is the percent sulfur in the fuel.
(b) "A" is the percent ash in the coal.
(c) Emissions from the combustion of fuel are included. (d) Control of the kiln gases by scrubbers can reduce fluoride emissions by 95%.
(d) Coal fired kilns are rather rare since coal tends to affect product quality.

37. (a) "S" is the percent sulfur in the fuel.
(b) Emissions from fuel combustion, as well as fugitive dust emissions are included.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U	kg/U
	Crushed Material Storage							
	Open Piles	tn Lime	1.0					
	Semi-Enclosed Piles	tn Lime	0.5					
	Compartments	tn Lime	0.2					
	Silos	tn Lime	0.2					
	Raw Material Conveying							
	Uncontrolled	tn Lime	1.2					
	Fabric Filter	tn Lime	0.01					
	Raw Material Calcining							
	Vertical Shaft Kiln							
	Uncontrolled	tn Lime	3.0	0.9S	0.1	2.0		
	Cyclone	tn Lime	1.0	0.9S	0.1	2.0		
	Multicyclones	tn Lime	0.75	0.9S	0.1	2.0		
	Vertical Double Inclined Kilns							
	Uncontrolled	tn Lime	10.5	0.9S	0.1	2.0		
	Cyclone	tn Lime	3.6	0.9S	0.1	2.0		
	Multicyclones	tn Lime	2.6	0.9S	0.1	2.0		
	Parallel Flow/Counterflow Regenerative Kilns							
	Uncontrolled	tn Lime	8.	0.9S	0.1	2.0		
	Cyclone	tn Lime	2.8	0.9S	0.1	2.0		
	Multicyclones	tn Lime	2.	0.9S	0.1	2.0		
	Annular Kilns							
	Uncontrolled	tn Lime	12.	0.9S	0.1	2.0		
	Cyclone	tn Lime	4.2	0.9S	0.1	2.0		
	Multicyclones	tn Lime	3.	0.9S	0.1	2.0		
	Rotary Short Kiln/Air Suspension Preheater							
	Uncontrolled	tn Lime	40.	0.36S	1.5	1.0		
	Cyclone	tn Lime	14.	0.36S	1.5	1.0		
	Multicyclones	tn Lime	9.	0.36S	1.5	1.0		
	ESP	tn Lime	0.6	0.36S	1.5	1.0		
	Fabric Filter	tn Lime	0.2	0.36S	1.5	1.0		
	Rotary Long Kiln							
	Uncontrolled	tn Lime	140.	0.36S	1.5	1.0		
	Cyclone	tn Lime	49.	0.36S	1.5	1.0		
	Multicyclones	tn Lime	35.	0.36S	1.5	1.0		
	ESP	tn Lime	2.	0.36S	1.5	1.0		
	Fabric Filter	tn Lime	0.4	0.36S	1.5	1.0		
	Calcimatic Kiln							
	Uncontrolled	tn Lime	25.	0.9S	0.1	1.0		
	Cyclone	tn Lime	8.7	0.9S	0.1	1.0		
	Multicyclones	tn Lime	6.2	0.9S	0.1	1.0		
	Lime Cooling							
	Grate Cooler							
	Uncontrolled	tn Lime	20.					
	Cyclones	tn Lime	4.					
	Multicyclones	tn Lime	2.					
	Fabric Filters	tn Lime	0.1					
	Planetary, Rotary, or Vertical Shaft Coolers	tn Lime	0.0					

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U	kg/U
	Lime Packaging / Shipping	tn Lime	0.12					
	Lime Hydration							
	Uncontrolled	tn of lime	35.00					
	Scrubber	tn of lime	0.04					
	Cement Manufacturing[38]							
	Typical Well-Controlled Plant	tn of cement	1.9	1.02	2.15			
	Coal Storage and Processing (If Coal is used as fuel)							
	Coal Storage (Only if Coal is Used as Fuel)							
	Open Piles	tn clinker	0.5					
	Semi-Enclosed Piles	tn clinker	0.25					
	Compartments	tn clinker	0.1					
	Silos	tn clinker	0.1					
	Coal Crushing and Screening (Only if Coal is Used as Fuel)							
	Uncontrolled	tn clinker	0.18					
	Fabric Filter	tn clinker	0.002					
	Coal Grinding							
	(Semi) Direct Fired Syst	tn Clinker	0.					
	Indirect Fired System							
	Uncontrolled	tn Clinker	10.					
	Fabric Filter	tn Clinker	0.1					
	Raw Materials Storage	tn clinker	0.14					
	Raw Materials Crushing & Screening							
	Primary & Secondary Crushing							
	Uncontrolled	tn clinker	4.2					
	Cyclone	tn clinker	0.85					
	Multicyclone	tn clinker	0.63					
	Fabric Filter	tn clinker	0.02					
	Tertiary Crushing[39]							
	Uncontrolled	tn clinker	5.1					
	Cyclone	tn clinker	1.0					
	Multicyclone	tn clinker	0.77					
	Fabric Filter	tn clinker	0.026					
	Raw Material Conveying							
	Uncontrolled	tn clinker	1.5					
	Good Control (FF)	tn clinker	0.075					

38. Emissions from the combustion of fuel are included.
39. Tertiary crushing of the raw materials to a fairly small size facilitates grinding. However, plugging or gumming of the crushers due to the presence of sticky materials often prevents tertiary crushing.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U	kg/U
	Raw Material Grinding & Calcining[40]							
	Dry Process Kiln							
	Uncontrolled	tn clinker	128	1.02	2.15			
	Multicyclone+ESP	tn clinker	0.34	1.02	2.15			
	Baghouse	tn clinker	0.16	1.02	2.15			
	Wet Process Kiln							
	Uncontrolled	tn clinker	120.	1.02	2.15			
	ESP	tn clinker	0.39	1.02	2.15			
	Baghouse	tn clinker	0.57	1.02	2.15			
	Clinker Cooler							
	Grate Cooler							
	Uncontrolled	tn clinker	10.6					
	Cyclones	tn clinker	2.2					
	Multicyclones	tn clinker	0.530					
	Gravel Bed Filters	tn clinker	0.160					
	ESP	tn clinker	0.048					
	Baghouse	tn clinker	0.010					
	Planetary or Rotary Cooler	tn clinker	0.0					
	Clinker Storing							
	Open Piles	tn clinker	5.4					
	Semi-Enclosed Piles	tn clinker	2.4					
	Compartments	tn clinker	0.12					
	Silos	tn clinker	0.12					
	Clinker Grinding							
	Tube Mill / Open Cycle							
	Uncontrolled	tn clinker	10.6					
	ESP or FF	tn clinker	0.05					
	Tube Mill / Closed Cycle or Roller Mill							
	Uncontrolled	tn clinker	85					
	ESP or FF	tn clinker	0.43					
	Cement Storing in Silos	tn clinker	0.13					
	Cement Shipment							
	Bulk Loading	tn clinker	0.1					
	Packaging							
	Uncontrolled	tn clinker	2.2					
	FF	tn clinker	0.01					

40. (a) In typical dry-process installations, a portion of the hot gases from the calcining kilns is fed in the grinding mills for drying the raw meal. Gas from grinders-dryers and kilns is thus combined and treated in a common installation.
(b) The listed SO_2 emission factor is based on German studies indicating SO_2 removal efficiencies through reactions with alkaline dust from 88% to 100%. Higher SO_2 emissions are obtained only if the SO_2 exceeds the alkaline content of the raw meal.
(c) The U.S. EPA, on the basis of limited data, reports SO_2 removal from 21% to 45% and suggests the use of the following SO_2 emissions factors: For coal fired kilns: 5.4+3.6*S, for fuel oil fired kilns 5.4+2.2*S and for Gas fired kilns 5.4, where S is the weight % sulfur in the fuel used.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
3699	Manufacture of Non-Metallic Mineral Products not Elsewhere Classified								
	Gypsum Manufacture								
	Rotary Ore Dryers								
	Uncontrolled	tn	5-60						
	Fabric Filter	tn	0.02						
	Raw Mills								
	Roller Mills								
	Uncontrolled	tn	1.3						
	Fabric Filter	tn	0.06						
	ESP	tn	0.05						
	Impact Mills								
	Uncontrolled	tn	50						
	Fabric Filter	tn	0.01						
	Calciners								
	Flash Calciners								
	Uncontrolled	tn	19						
	Fabric Filter	tn	0.02						
	Continuous Kettle Calciner								
	Uncontrolled	tn	21						
	Fabric Filter	tn	0.003						
	ESP	tn	0.05						
	Concrete Batching								
	Process Emissions (Uncontrolled)	tn	0.05						
	Wind Erosion								
	Sand & Aggregate Storage	$(1000\ m^2)$*yr	142.						
	Vehicle Traffic								
	(Unpaved Road)	Vehicle km Travelled	4.5						
	Perlite Manufacturing								
	Perlite Expansion Vertical Furnace								
	Uncontrolled	tn	10.5						
	Fabric Filter	tn	0.1						
DIVISION 37.	**BASIC METAL INDUSTRIES**								
371	**Iron and Steel Basic Industries**								
	Gray Iron Foundries[41]								
	Cupola[42,43]								
	Uncontrolled	tn	6.9	0.6S		73		Pb	0.32
	Single Wet Cap	tn	4.0	0.3S		73		Pb	0.19

41. (a) For one ton of gray iron product, about 143 kg of Coke are required.
    (b) The emission factors account also for the fugitive dust sources, as well as for the emissions caused by the burning of coke.
42. "S" is the percent sulfur in the coke.
43. CO emission factor of 7.0 must be used in cases where afterburners are installed.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
	Impingement Scrubber	tn	2.5	0.3S		73		Pb	0.12
	Scrubber	tn	1.6	0.3S		73		Pb	0.07
	High Energy Scrubber	tn	0.4	0.3S		73		Pb	0.02
	Baghouse	tn	0.3	0.6S		73		Pb	0.01
	Afterburner + ESP	tn	0.7	0.6S		7		Pb	0.03
	Electric Arc Furnace								
	Uncontrolled	tn	6.3		0.16	9.75	0.09		
	Baghouse	tn	0.2		0.16	9.75	0.09		
	Electric Induction Furnace								
	Uncontrolled	tn	0.5					Pb	0.026
	Baghouse	tn	0.1					Pb	0.005
	Reverberatory Furnace								
	Uncontrolled	tn	1.1					Pb	0.038
	Baghouse	tn	0.1					Pb	0.004
	Iron and Steel Mills								
	Sintering[44]								
	Windbox								
	Uncontrolled	tn of sinter	4.35			22			
	Dry ESP	tn of sinter	0.8						
	Wet ESP	tn of sinter	0.085						
	Venturi Scrubber	tn of sinter	0.235						
	Cyclone	tn of sinter	0.5						
	Fabric Filter	tn of sinter	0.1						
	Braker and Hot Screens								
	Uncontrolled	tn of sinter	3.4						
	Venturi Scrubber	tn of sinter	0.295						
	Baghouse	tn of sinter	0.05						
	Blast Furnace[45,46]								
	Uncontrolled Casthouse[47]	tn	0.3						
	Furnace with Local Evaculation	tn	0.65						

44. (a) Sintering is used in some plants to convert fine size raw materials (iron ore, coke breeze, limestone, mill scale & flue dust) into agglomerated product of suitable size to be charged into the blast furnace.
(b) About 2.5 tons of raw materials, including water & fuel, are required to produce 1 ton of product sinter.

45. (a) Production of one ton of iron requires 1.4 tons of ore, 0.5 to 0.65 tons of Coke, 0.25 tons of limestone or dolomite, and 1.8 to 2.0 tons of Air.
(b) By-products consist of 0.2 to 0.4 tons of slag and 2.5 to 3.5 tons of blast furnace gas containing up to 50 kg of dust.
(c) Emissions from the use of the blast furnace gas (after dedusting) are not included in the factors listed here and need to be computed separately.

46. (a) Blast Furnace Gas controls, typically (settling chamber or cyclone)+(wet scrubber)+(high energy wet scrubber or ESP), are often considered part of the process since cleaning of the Blast Furnace Gas is required before it can be used as a fuel.
(b) The listed TSP emission factors do not include these from blast furnace slips (39.5 kg/tn of hot metal per slip).

47. Typical of older furnaces.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U	kg/U
	Basic Oxygen Furnaces							
	Furnace for Melting & Refining							
	Uncontrolled	tn	14.25					
	Open Hood with ESP	tn	0.065					
	Open Hood with Scrubber	tn	0.045					
	Closed Hood with Scrubber	tn	0.0034					
	Charging, Tapping, Transfer	tn	0.25					
	Electric Arc Furnaces							
	Uncontrolled							
	Carbon Steel	tn	25			69		
	Alloy Steel	tn	5.65			69		
	Control of Primary Emissions	tn	0.15					
	Control of Primary & Secondary Emissions	tn	0.0215					
	Open Hearth Furnaces							
	Uncontrolled	tn	10.55			9		
	Fabric Filter of ESP	tn	0.22					
	Ferroalloy Production (Electric Smelting Furnaces)[48]							
	FeSi (50%)							
	Uncontrolled - Open Furnace	tn	35					
	Uncontrolled - Covered Furnace	tn	46					
	Baghouse	tn	0.9					
	High Energy Scrubber	tn	0.24					
	Low Energy Scrubber	tn	4.5					
	FeSi (75%)							
	Uncontrolled - Open Furnace	tn	158					
	Uncontrolled - Covered Furnace	tn	103					
	Low Energy Scrubber	tn	4					
	FeSi (90%)							
	Uncontrolled - Open Furnace	tn	282					
	Si Metal (98%)							
	Uncontrolled - Open Furnace	tn	436					
	Baghouse	tn	16					
	FeMn (80%)							
	Uncontrolled - Open Furnace	tn	14					
	Baghouse	tn	0.24					
	High Energy Scrubber	tn	0.8					
	FeMn (1% Si)							
	Uncontrolled - Covered Furnace	tn	6					
	Uncontrolled - Sealed Furnace	tn	37					
	High Energy Scrubber	tn	0.25					
	FeCr (High Carbon)							
	Uncontrolled - Open Furnace	tn	78					
	ESP	tn	1.2					

48. Given percentages in the alloys refer of the main alloying element in the product.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U	kg/U
	SiMn							
	Uncontrolled - Open Furnace	tn	96					
	Uncontrolled - Sealed Furnace	tn	-					
	High Energy Scrubber	tn	2.1					
	Low Energy Scrubber	tn	0.15					
	Steel Foundries							
	Electric Arc Furnace							
	Uncontrolled	tn	6.5		0.1			
	ESP	tn	0.33		0.1			
	Baghouse	tn	0.1		0.1			
	Venturi Scrubber	tn	0.26					
	Open Hearth Furnace							
	Uncontrolled	tn	5.5		0.005			
	ESP	tn	0.18		0.005			
	Baghouse	tn	0.006		0.005			
	Venturi Scrubber	tn	0.14					
	Open Hearth Oxygen Lanced Furnace							
	Uncontrolled	tn	5					
	ESP	tn	0.175					
	Baghouse	tn	0.05					
	Venturi Scrubber	tn	0.175					
	Electric Induction Furnace							
	Uncontrolled	tn	0.05					
372	**Non-Ferrous Metal Basic Industries**							
	Primary Copper Smelting							
	Uncontrolled	tn of Copper Ore	62	530				
		tn of Copper	248.0	2120				
	Hot ESP (200-340 C)	tn of Copper Ore	15.5	530				
		tn of Copper	62	2120				
	Cold ESP (120 C)	tn of Copper Ore	2.5	530				
		tn of Copper	10	2120				
	Single Contact H_2SO_4 Plant	tn of Copper Ore	2.5	25.2				
		tn of Copper	10	100.7				
	Double Contact H_2SO_4 Plant	tn of Copper Ore	2.5	8				
		tn of Copper	10	32				
	Secondary Copper Smelting and Alloying							
	Copper Scrap							
	Cupola (Uncontrolled)	tn	0.002					
	Reverberatory Furnace							
	Uncontrolled	tn	2.6					
	Fabric Filter	tn	0.2					
	Electric Arc Furnace							
	Uncontrolled	tn	2.5					
	Fabric Filter	tn	0.5					

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U	kg/U
	Electric Induction Furnace							
	Uncontrolled	tn	3.5					
	Fabric Filter	tn	0.25					
	Copper Insulated Wire							
	Cupola							
	Uncontrolled	tn	120					
	ESP	tn	5.0					
	Copper and Brass Scrap							
	Cupola							
	Uncontrolled	tn	3.5					
	ESP	tn	1.2					
	Brass and Bronze							
	Reverberatory Furnace							
	Uncontrolled	tn	18					
	Fabric Filter	tn	1.3					
	Rotary Furnace							
	Uncontrolled	tn	150					
	ESP	tn	7					
	Crucible or Pot Furnace							
	Uncontrolled	tn	11					
	ESP	tn	0.5					
	Electric Arc Furnace							
	Uncontrolled	tn	5.5					
	Fabric Filter	tn	3.0					
	Electric Induction Furnace							
	Uncontrolled	tn	10					
	Fabric Filter	tn	0.35					
	Alumina Production (Bayer Process from Bauxite)[49]							
	Bauxite Grinding							
	Uncontrolled	tn of Bauxite	3					
	Spray Tower	tn of Bauxite	0.9					
	Floating bed scrubber	tn of Bauxite	0.85					
	Quench Tower+Spray Screen	tn of Bauxite	0.5					
	Alumina Hydroxide Calcining							
	Uncontrolled	tn of Alumina	100					
	Spray Tower	tn of Alumina	30					
	Floating bed scrubber	tn of Alumina	28					
	Quench Tower	tn of Alumina	17					
	ESP	tn of Alumina	2					

49. From 1.4 to 3.3 tons of Bauxite Ore processed, one ton of Alumina is produced. One ton of the later yields 526 kg of Aluminum.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
	Primary Aluminum Production (from Alumina)[50]								
	Prebaked Cell Method								
	Anode Baking Furnace								
	Uncontrolled	tn of Aluminum	1.5					F^-	0.5
	Spray Tower	tn of Aluminum	0.375					F^-	0.035
	ESP	tn of Aluminum	0.375					F^-	0.035
	Dry Alumina Scrubber	tn of Aluminum	0.03					F^-	0.0055
	Prebaked Reduction Cells								
	Uncontrolled (total)	tn of Aluminum	47	10S				F^-	22
	Fugitive	tn of Aluminum	2.5	0.5S				F^-	1.1
	Multiple Cyclones	tn of Aluminum	9.8					F^-	13.5
	Dry Aluminum Scrubber	tn of Aluminum	0.9					F^-	0.3
	Dry ESP+Spray Tower	tn of Aluminum	2.25					F^-	2.4
	Spray Tower	tn of Aluminum	8.9					F^-	2.6
	Floating Bed Scrubber	tn of Aluminum	8.9					F^-	2.15
	Coated FF Dry Scrubber	tn of Aluminum	0.9					F^-	1.9
	Cross Flow Packed Bed	tn of Aluminum	13.15					F^-	6.05
	Dry+Secondary Scrubber	tn of Aluminum	0.35					F^-	0.35
	Vertical Sodeberg Cell Method								
	Vertical Sodeberg Cells								
	Uncontrolled (total)	tn of Aluminum	39	10S				F^-	22
	Fugitive	tn of Aluminum	6	0.5S				F^-	3.3
	Spray Tower	tn of Aluminum	8.25					F^-	1.3
	Venturi Scrubber	tn of Aluminum	1.3					F^-	0.35
	Multiple Cyclones	tn of Aluminum	16.5					F^-	16.4
	Dry Alumina Scrubber	tn of Aluminum	0.65					F^-	0.25
	Scrubber+ESP+Spray Screen and Scrubber	tn of Aluminum	3.85					F^-	
	Horizontal Sodeberg Cell Method								
	Horizontal Sodeberg Cells								
	Uncontrolled (total)	tn of Aluminum	49	10S				F^-	17
	Fugitive	tn of Aluminum	5	0.5S				F^-	1.7
	Spray Tower	tn of Aluminum	11.					F^-	5.1
	Floating Bed Scrubber	tn of Aluminum	9.7					F^-	1.4
	Scrubber+Wet ESP	tn of Aluminum	0.9					F^-	0.2

50. (a) "S" is the weight percent sulfur in the prebaked anodes.
(b) The listed TSP factors include particulate fluorides.
(c) The listed F^- factors include gaseous, as well as particulate fluorides.
(d) If controls are applied, the fugitive, as well as controlled stack emissions need to be computed.
(e) In older plans cells may not be constructed with covers for the collection of fumes and this may increase drastically the fraction of the uncontrolled fugitive emissions.
(f) For the production of one ton of Aluminum the basic energy and material requirements are as follows:

Electricity	13.2 to 18.7 MWH
Alumina	1.89 to 1.92 tons (2.7 to 6.3 tons of Bauxite)
Carbon Electrodes	0.45 to 0.55 tons
Electrolyte Fluoride	0.03 to 0.10 tons.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
	Wet ESP	tn of Aluminum	0.9					F^-	0.6
	Dry Alumina Scrubber	tn of Aluminum	0.9					F^-	0.3
	Secondary Aluminum Production								
	Pretreatment								
	Sweating Furnace								
	Uncontrolled	tn of Al pretreated	7.25						
	Fabric Filter	tn of Al pretreated	1.65						
	Smelting								
	Crucible Furnace								
	Uncontrolled	tn of Al	0.95						
	Reverberatory Furnace								
	Uncontrolled	tn of Al	2.15						
	Fabric Filter or ESP	tn of Al	0.65						
	Demagging (Chlorination)								
	Uncontrolled	tn of Cl_2	500						
	Fabric Filter	tn of Cl_2	25						
	Primary Lead Smelting								
	Fugitive Emissions	tn of Pb	16.74					Pb	2.5
	Ore Crushing								
	Uncontrolled	tn of crushed ore	1.0					Pb	0.15
	Fabric Filter	tn of crushed ore	0.01					Pb	0.0015
	Sintering (updraft)								
	Uncontrolled	tn of Pb	106.5	275.				Pb	87
	Centrifugal Collector	tn of Pb	16.	275.				Pb	13
	ESP	tn of Pb	3.2	275.				Pb	2.61
	Fabric Filter	tn of Pb	3.2	275.				Pb	2.61
	H_2SO_4 Plant (Single Contact)	tn of Pb	0.32	9.6				Pb	0.26
	H_2SO_4 Plant (Dual Contact)	tn of Pb	0.32	5.5				Pb	0.26
	Elemental S Recovery Plant	tn of Pb	0.32	27.5				Pb	0.26
	Dimethylaniline Absorption	tn of Pb	0.32	8.25				Pb	0.26
	Ammonia Absorption	tn of Pb	0.32	17.9				Pb	0.26
	Blast Furnace								
	Uncontrolled	tn of Pb	180.5	22.5				Pb	29
	Centrifugal Collector	tn of Pb	27.1	22.5				Pb	4.35
	ESP	tn of Pb	5.4	22.5				Pb	0.9
	Fabric Filter	tn of Pb	5.4	22.5				Pb	0.9
	H_2SO_4 Plant (Single Contact)	tn of Pb	0.54	0.8				Pb	0.1
	H_2SO_4 Plant (Dual Contact)	tn of Pb	0.54	0.5				Pb	0.1
	Elemental S Recovery Plant	tn of Pb	0.54	2.25				Pb	0.1
	Dimethylaniline Absorption	tn of Pb	0.54	0.7				Pb	0.1
	Ammonia Absorption	tn of Pb	0.54	1.5				Pb	0.1
	Dross Reverberatory Furnace								
	Uncontrolled	tn of Pb	10.					Pb	2.4
	Centrifugal Collector	tn of Pb	1.5					Pb	0.36
	Fabric Filter	tn of Pb	0.3					Pb	0.07
	Materials Handling								
	Uncontrolled	tn of Pb	2.4						

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
	Fabric Filter	tn of Pb	0.07						
	Secondary Lead Processing								
	Pretreatment								
	Sweating Furnace								
	Fugitive Emissions	tn of Pb	1.3					Pb	0.55
	Uncontrolled	tn of Pb	25.5					Pb	6
	Controlled	tn of Pb	0.25					Pb	0.06
	Smelting								
	Fugitive Emissions	tn of Pb	8.2					Pb	2.19
	Reverberatory Furnace								
	Uncontrolled	tn of Pb	162	40				Pb	32
	Controlled	tn of Pb	0.5	40				Pb	0.1
	Blast (Cupola)								
	Uncontrolled	tn of Pb	153	27				Pb	52
	Controlled	tn of Pb	1.12	27				Pb	0.15
	Refining								
	Kettle Refining								
	Uncontrolled	tn of Pb	0.02					Pb	0.006
	Controlled	tn of Pb							
	Kettle Oxidation								
	Fabric filter	tn of PbO	<20.0					PbO	<20.0
	Storage Battery Production								
	Uncontrolled[51]	1000 Batteries	63.2					Pb	6.94
	Controlled	1000 Batteries	3.2					Pb	0.5
	Primary Zinc Smelting								
	Pyrometallurgical Process								
	Fugitive Emissions	tn of Zinc	3.85						
	Roasting								
	Multiple Hearth Roaster								
	Uncontrolled	tn of Zinc	113	1100					
	Cyclone + ESP	tn of Zinc	0.5	1100					
	H_2SO_4 Plant	tn of Zinc	0.34	33					
	Suspension Roaster								
	Uncontrolled	tn of Zinc	1000.	1100					
	Cyclone + ESP	tn of Zinc	4.	1100					
	H_2SO_4 Plant	tn of Zinc	3.	33					
	Fluidized Bed Roaster								
	Uncontrolled	tn of Zinc	1083.	1100					
	Cyclone + ESP	tn of Zinc	4.	1100					
	H_2SO_4 Plant	tn of Zinc	3.2	33					
	Sinter Plant								
	Uncontrolled	tn of Zinc	62.5	110					
	Cyclone	tn of Zinc	24.1	110					
	Cyclone + ESP	tn of Zinc	8.25	110					

51. A fabric filter is considered an integral part of the lead oxide mill, if any.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U	kg/U
	Retorting (Uncontrolled)							
	Vertical Retort	tn of Zinc	7.15					
	Electric Retort	tn of Zinc	10					
	Electrolytic Process							
	Fugitive Emissions	tn of Zinc	1.26					
	Roasting							
	Multiple Hearth Roaster							
	Uncontrolled	tn of Zinc	113	1100				
	Cyclone + ESP	tn of Zinc	0.5	1100				
	H_2SO_4 Plant	tn of Zinc	0.34	33				
	Suspension Roaster							
	Uncontrolled	tn of Zinc	1000	1100				
	Cyclone + ESP	tn of Zinc	4	1100				
	H_2SO_4 Plant	tn of Zinc	3	33				
	Fluidized Bed Roaster							
	Uncontrolled	tn of Zinc	1083	1100				
	Cyclone + ESP	tn of Zinc	4	1100				
	H_2SO_4 Plant	tn of Zinc	3.2	33				
	Electrolytic Process							
	Uncontrolled	tn of Zinc	3.3					
	Secondary Zinc Smelting							
	Pretreatment							
	Sweating							
	Reverberatory Furnace							
	Clean Metallic Scrap	tn of Scrap	0.					
	General Metallic Scrap							
	Uncontrolled	tn of Scrap	6.5					
	Fabric Filter	tn of Scrap	0.1					
	Residual Scrap							
	Uncontrolled	tn of Scrap	16.					
	Fabric Filter	tn of Scrap	0.24					
	Rotary Furnace							
	Uncontrolled	tn of Scrap	9.					
	Fabric Filter	tn of Scrap	0.14					
	Muffle Furnace							
	Uncontrolled	tn of Scrap	10.7					
	Fabric Filter	tn of Scrap	0.16					
	Kettle Furnace							
	Clean Metallic Scrap	tn of Scrap	0.					
	General Metallic Scrap							
	Uncontrolled	tn of Scrap	5.5					
	Fabric Filter	tn of Scrap	0.08					
	Residual Scrap							
	Uncontrolled	tn of Scrap	12.5					
	Fabric Filter	tn of Scrap	0.2					
	Electric Resistance Furnace							
	Uncontrolled	tn of Scrap	$< 5.$					
	Fabric Filter	tn of Scrap	< 0.7					

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U	kg/U
	Crushing & Screening							
	Uncontrolled	tn of Scrap	2.2					
	Fabric Filter	tn of Scrap	0.02					
	Sodium Carbonate Leaching							
	Crushing & Screening							
	Uncontrolled	tn of Scrap	2.2					
	Fabric Filter	tn of Scrap	0.02					
	Calcining							
	Uncontrolled	tn of Scrap	44.5					
	Fabric Filter	tn of Scrap	0.7					
	Melting							
	Kettle (Pot) Melting							
	Uncontrolled	tn Zn	0.05					
	Refining							
	Retort & Muffle Distillation							
	Uncontrolled	tn Zn	23					
	Fabric Filter	tn Zn	0.35					
	Graphite Rod Distillation	tn Zn	0.0					
	Retort Distillation/Oxidation	tn ZnO	15					
	Muffle Distillation/Oxidation	tn ZnO	15					
	Retort Reduction							
	Uncontrolled	tn Zn	23.5					
	Fabric Filter	tn Zn	0.35					
	Galvanizing	tn Zn Used	2.5					

MAJOR DIVISION 4. **ELECTRICITY GAS AND WATER**

410 Electricity Gas and Steam[52]

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U	kg/U
	Gaseous Fuels							
	Natural Gas[53]							
	Utility Boilers	1000 Nm^3	0.048	15.6S	8.8f[54]	0.64	0.028	
		tn	0.061	20S	11.3f	0.82	0.036	
	Industrial Boilers	1000 Nm^3	0.048	15.6S	2.24	0.56	0.092	
		tn	0.061	20S	2.87	0.72	0.118	
	Domestic Furnaces	1000 Nm^3	0.048	15.6S	1.6	0.32	0.127	
		tn	0.061	20S	2.05	0.41	0.163	
	Stationary Gas turbines	1000 Nm^3	0.224	15.6S	6.62	1.84	0.673	
		tn	0.287	20S	8.91	2.36	0.863	

52. (a) "S" is the weight percent of Sulfur in the fuel.
    (b) "A" is the weight percent of Ash in the solid fuel.
    (c) "N" is the weight percent of Nitrogen in the fuel.
53. Typical sulfur content of Natural Gas is 0.000615 %.
54. For tangentially fired boilers use 5.6f kg/1000 Nm^3. The load reduction coefficient "f" is computed from Equation $f = 0.3505 - 0.005235\ L + 0.0001173\ L^2$, where L is the mean boiler load, %. A typical mean boiler load is 87 %.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
		MWH	0.138	9.6S	4.08	1.14	0.415		
	Liquefied Petroleum Gas (LPG)								
	Industrial Boilers	m^3 (Liq)	0.031	0.004	1.51	0.37	0.06		
		tn	0.060	0.007	2.9	0.71	0.12		
	Domestic Furnaces	m^3 (Liq)	0.031	0.004	1.07	0.22	0.09		
		tn	0.060	0.007	2.05	0.42	0.17		
	Liquid Fuels								
	Distillate Fuel Oil								
	Industrial & Commercial Boilers	tn	0.28	20S	2.84	0.71	0.035	SO_3	0.28S
	Residential Furnaces	tn	0.365[55]	20S	2.60	0.71	0.354	SO_3	0.28S
	Stationary Gas Turbines	tn	0.710	20S	9.62	2.19	0.791		
		MWH	0.369	10.4S	5.01	1.14	0.415		
	Residual Fuel Oil[56]								
	Utility Boilers								
	Uncontrolled	tn	P	20S	8.5[57]	0.64	0.127	SO_3	0.25S
	ESP - Low Efficiency	tn	0.5P	20S	8.5	0.64	0.09	SO_3	0.25S
	ESP - High Efficiency	tn	0.1P	20S	8.5	0.64	0.09	SO_3	0.25S
	Scrubber	tn	0.45P	1.5S	8.5	0.64	0.09		
	Industrial & Commercial Boilers[58]	tn	P	20S	7.0[59]	0.64	0.163	SO_3	0.25S
	Waste Lub Oil[60]								
	Industrial & Commercial Boilers	tn	8.1A	20S	2.7	0.67	0.13	Pb	5.6P
	Domestic Heaters	tn	8.6A	20S	2.7	0.67	0.13	Pb	6.8P
	Solid Fuels								
	Anthracite Coal[61]								
	Pulverized Coal Furnace								

55. In the absence of boiler I/M programs, smoke emission factors may be closer to 1.6 kg/tn.

56. "P", the uncontrolled TSP emission factor, is function of the sulfur content of fuel oil and is computed from Equation $P = 0.4 + 1.32\ S$

57. Use 5.3 kg/tn for tangentially fired boilers, 13.3 for vertical fired boilers and 8.5 for all other boiler types.

58. (a) In the absence of boiler I/M programs, the average smoke emission factor can exceed that in the table by about 60%, Economopoulos (1987).
    (b) In cases where very effective boiler I/M programs are implemented, the average smoke emission factor can be lower by up to 45% of that listed in the table, Economopoulos (1991).

59. If the nitrogen content of the fuel is known, the NO_x emission factor can be computed more accurately from the empirical formula $(3.25+59.2\ N^2)$.

60. (a) Typical values of "A" and "S" in lub oils are 0.65 % and 0.5 %.
    (b) "P" is the weight percent of Lead (Pb) in the fuel. The value of P depends on the lead content of the gasoline used. In the U.S.A. the average values of P dropped from 1 % in 1970 (catalytic cars and unleaded gasoline were not in use) to 0.11 % in 1982-83 (three years after the introduction of catalytic cars and unleaded gasoline) and to 0.04 % in 1985-86 (six years after the introduction of catalytic cars and unleaded gasoline).

61. Typical Ash and Sulfur contents are 8.1% & 0.9% for Meta Anthracite, 9.4% & 0.6% for Anthracite, and 12.4% & 2% for Semianthracite respectively (dry basis).

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U	kg/U
	Uncontrolled	tn	5A	19.5S	9.0	0.3	0.055	
	Cyclone	tn	1.25A	19.5S	9.0	0.3	0.055	
	ESP - High Efficiency	tn	0.36A	19.5S	9.0	0.3	0.055	
	Fabric Filter	tn	0.01A	19.5S	9.0	0.3	0.055	
	Travelling Grate Stoker							
	Uncontrolled	tn	4.6	19.5S	5.0	0.3	0.055	
	Cyclone	tn	>1.2	19.5S	5.0	0.3	0.055	
	Hand Fed Units	tn	5.0	19.5S	1.5	45.0	9.0	
	Bituminous & Subbituminous Coal[62]							
	Pulverized Coal / Dry Bottom Furnace							
	Uncontrolled	tn	5A	19.5S	10.5[63]	0.3	0.055	
	Multiple Cyclones	tn	1.25A	19.5S	10.5	0.3	0.055	
	ESP - High Efficiency							
	- Low S Coal+No Cond'ning	tn	0.33A	19.5S	10.5	0.3	0.055	
	- Otherwise	tn	>0.01A	19.5S	10.5	0.3	0.055	
	Fabric Filter	tn	0.01A	19.5S	10.5	0.3	0.055	
	Flue Gas Desulfurization	tn	0.05A	1.95S	10.5	0.3	0.055	
	Pulverized Coal / Wet Bottom Furnace							
	Uncontrolled	tn	3.5A	19.5S	17.	0.3	0.055	
	Multiple Cyclones	tn	0.88A	19.5S	17.	0.3	0.055	
	ESP - High Efficiency							
	- Low S Coal+No Cond'ning	tn	0.227A	19.5S	17.	0.3	0.055	
	- Otherwise	tn	>0.007A	19.5S	17.	0.3	0.055	
	Fabric Filter	tn	0.007A	19.5S	17.	0.3	0.055	
	Flue Gas Desulfurization	tn	0.035A	1.95S	17.	0.3	0.055	
	Cyclone Furnace							
	Uncontrolled	tn	A	19.5S	18.5	0.3	0.055	
	ESP - High Efficiency	tn	0.065A	19.5S	18.5	0.3	0.055	
	Fabric Filter	tn	0.002A	19.5S	18.5	0.3	0.055	
	Spreader Stoker Furnace							
	Uncontrolled	tn	30	19.5S	7.0	2.5	0.055	
	Multiple Cyclones	tn	8.5	19.5S	7.0	2.5	0.055	
	Overfeed Stoker Furnace							
	Uncontrolled	tn	8.0	19.5S	3.25	3.0	0.055	
	Multiple Cyclones	tn	4.5	19.5S	3.25	3.0	0.055	
	Underfeed Stoker Furnace							
	Uncontrolled	tn	7.5	15.5S	4.75	5.5	1.05	
	Multiple Cyclones	tn	5.5	15.5S	4.75	5.5	1.05	
	Hand Fired Furnace	tn	7.5	15.5S	1.5	45.0	9.0	

62. (a) In Bituminous coals. typical Ash and Sulfur contents are 4.9% & 0.8% for Low Volatility coals, 2.9 & 0.6% for Medium Volatility coals, 6.5% & 1.3% for High Volatility A coals, 5.4% & 1.4% for High Volatility B coals, and 9.1% & 2.6% for High Volatility C coals respectively (dry basis).

(b) In Subbituminous coals typical Ash and Sulfur contents are, 4.7% & 1% for A type, 2.8% & 0.5% for B type, and 13.2 % & 0.4% for C type respectively (dry basis).

63. For tangentially fired boilers use 7.5 kg/tn.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U	kg/U
	Lignite[64]							
	Pulverized Coal Furnace							
	Uncontrolled	tn	3.1A	15S[65]	6.[66]	0.3	0.055	
	Cyclones	tn	0.93A	15S	6.	0.3	0.055	
	ESP - Older Units	tn	0.16A	15S	6.	0.3	0.055	
	ESP - High Efficiency	tn	>0.016A	15S	6.	0.3	0.055	
	Fabric Filter	tn	0.016A	15S	6.	0.3	0.055	
	Flue Gas Desulfurization	tn	0.031A	1.5S	6.	0.3	0.055	
	Cyclone Furnace							
	Uncontrolled	tn	3.3A	15S	8.5	0.3	0.055	
	Cyclones	tn	A	15S	8.5	0.3	0.055	
	ESP - Older Units	tn	0.165A	15S	8.5	0.3	0.055	
	ESP - High Efficiency	tn	>0.017A	15S	8.5	0.3	0.055	
	Fabric Filter	tn	0.017A	15S	8.5	0.3	0.055	
	Spreader Stoker Furnace							
	Uncontrolled	tn	3.4A	15S	3.0	2.5	0.055	
	Multiple Cyclones	tn	A	15S	3.0	2.5	0.055	
	Overfeed Stoker							
	Uncontrolled	tn	1.5A	15S	3.0	3.0	0.055	
	Multiple Cyclones	tn	0.84A	15S	3.0	3.0	0.055	
	Underfeed Stoker							
	Uncontrolled	tn	1.5A	15S	3.0	5.5	1.05	
	Multiple Cyclones	tn	1.1A	15S	3.0	5.5	1.05	
	Wood & Bark							
	Wood Boilers	tn	4.4	0.015	0.34	13.0	0.85	
	Wood-Bark Mixture Boilers							
	Uncontrolled	tn	3.6	0.075	0.34	13.0	0.85	
	Multicyclone	tn	2.7	0.075	0.34	13.0	0.85	
	Bark Boilers							
	Uncontrolled	tn	24	0.2	0.34	13.0	0.85	
	Multiple Cyclones	tn	4.5	0.2	0.34	13.0	0.85	
	Wood Stoves							
	Conventional Units	tn	15	0.2	1.4	140.0	46.0	
	Low emitting non-catalytic	tn	9.6	0.2		130.0		
	Low emitting catalytic	tn	6.6	0.2	1.0	39.0	21.6	
	Residential Fireplaces	tn	14.0	0.2	1.7	85.0	43.0	
	Bagasse	tn	8.0	0.0	0.6			

64. (a) "A" is the weight percent of Ash in the fuel (wet basis as fired)
(b) "S" is the weight percent of Sulfur in the fuel (wet basis as fired)
(c) Typical Ash and Sulfur contents are 8.8 to 9.5 % & 0.8 to 1.1 % (dry basis).

65. For more accurate estimate compute the SO_2 emission factor from the relation $(20-1.44*Na_2O)*S$, where Na_2O is the percent content of the ash in alkali constituents.

66. Use 7.0 kg/tn for front wall fired and horizontally opposed wall fired units. Use 4.0 kg/tn for opposed wall fired units. Lignites with very high humidity and low calorific values may yield significantly lower NO_x emissions.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U	kg/U
MAJOR DIVISION 6.	**WHOLESALE AND RETAIL TRADE**							
610	**Wholesale Trade**							
	Bulk Fuel Terminals							
	Storage of Fuels[67]							
	Floating Roof Tanks							
	Gasoline	(m^3 storage capacity)*year					1.14	
	Crude Oil	(m^3 storage capacity)*year					0.435	
	Jet Naphtha	(m^3 storage capacity)*year					0.415	
	Jet Kero	(m^3 storage capacity)*year					0.019	
	Distillate Oil	(m^3 storage capacity)*year					0.015	
	Fixed Roof Tanks							
	Gasoline	(m^3 storage capacity)*year					13.1	
	Crude Oil	(m^3 storage capacity)*year					2.8	
	Jet Naphtha	(m^3 storage capacity)*year					3.8	
	Jet Kero	(m^3 storage capacity)*year					0.19	
	Distillate Oil	(m^3 storage capacity)*year					0.17	
	Truck Filling Stations							
	Gasoline Loading							
	Splash Loading	m^3 of Gasoline					1.43	
		tn of Gasoline					1.94	
	Submerged Loading[68]							
	Normal Service	m^3 of Gasoline					0.59	
		tn of Gasoline					0.80	
	Vapor Balance Serv	m^3 of Gasoline					0.98	
		tn of Gasoline					1.33	
	Vapor Controlled	m^3 of Gasoline					0.05	
		tn of Gasoline					0.07	
	Jet Naphtha Loading							
	Splash Loading	m^3 of Gasoline					0.43	
		tn of Gasoline					0.58	
	Submerged Loading							
	Normal Service	m^3 of Naphtha					0.18	
		tn of Naphtha					0.24	
	Vapor Balance Serv	m^3 of Naphtha					0.30	
		tn of Naphtha					0.40	

67. The listed emission factors yield the VOC emissions in kg/year.
68. In the Vapor Balance Service the cargo truck retrieves the vapors displaced during the underground tank filling in service stations (see below, SIC 620). This operation increases the VOC concentration in the air within the empty truck and causes higher VOC emissions when the truck is filled. It should be noted in this regard that most of the VOC emissions reduction achieved through the balanced vapor filling of the service stations submerged tanks is offset by the resultant increased emissions in the Truck Filling Station, unless a vapor recovery system is used in the latter.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U	kg/U
620	**Retail Trade**							
	Service Stations Operation							
	Filling the Underground Tanks							
	Splash Filling	m^3 of Gasoline					1.5	
		tn of Gasoline					2.03	
	Submerged Filling	m^3 of Gasoline					1.0	
		tn of Gasoline					1.353	
	Balanced Vapor Filling	m^3 of Gasoline					0.16	
		tn of Gasoline					0.217	
	Vehicle Refuelling							
	Uncontrolled	m^3 of Gasoline					1.4	
		tn of Gasoline					1.894	
	Balanced Vapor Filling	m^3 of Gasoline					0.212	
		tn of Gasoline					0.287	

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U	kg/U
MAJOR DIVISION 7.	**TRANSPORT, STORAGE AND COMMUNICATION**							
711	**Land Transport**[69]							
	Light Duty Gasoline Powered Cars <3.5 tn							
	Evaporative Emissions[70]							
	Hot Soak Emissions[71]							
	Cars with Carburettors	1000 km					$9.4/L_{trip}$	
	Cars with Fuel Injection	1000 km					$0.7/L_{trip}$	
	Running Losses	1000 km					0.1 to 1.	
	Diurnal Losses							
	Uncontrolled	Car*yr					2.635	
	Evaporative Controls[72]	Car*yr					0.0694	

69. (a) "S" is the weight percent of sulfur in the fuel. Typical values for Gasoline are 0.039% to 0.15% & for Diesel 0.2% to 0.5%.
    (b) "P" is the average Lead content of the Gasolines used in gr/lt. In Unleaded Gasoline Lead concentrations are low (<0.013 gr/lt), while typical values in Premium Gasolines are 0.15 to 0.4 gr/liter.
70. (a) The evaporative emissions can be divided into the Running Losses (occurring while the vehicle is being driven), the Hot Soak Losses (evaporation of fuel, mainly from the carburettor bowl and tank, each time the vehicle stops with hot engine) and Diurnal Losses (expansion and emission of vapor, mainly from fuel tank, due to the daily diurnal temperature variations).
    (b) The relevant emission factors depend on ambient temperature and on gasoline volatility. To account for these effects, the listed factors should be multiplied by appropriate "correction factors". As a guidance for the choice of the latter, the applicable "correction factors" for the EC countries are given below:

	Diurnal Losses	Hot Soak Emissions	Running Losses
Belgium, France, Luxembourg	1.0	0.9	0.9
Portugal, Spain	1.3	0.8	0.8
Greece, Italy	2.1	1.2	1.2
Ireland, U.K.	2.5	2.2	2.0
Denmark, Germany, Netherlands	1.0	1.0	1.0

    (c) Estimates of evaporative emissions based on the listed factors are considered high. An alternative model allowing assessment of evaporative emissions as function of the climatic conditions and Gasoline volatility is given in Section 3.3.3.
71. "L_{trip}" is the average distance, in km, a car is driven each time its engine starts.
72. Evaporative controls employ canisters filled with activated carbon, to which all fuel system vents are connected. Any diurnal or hot soak VOC emissions will thus be absorbed by the carbon and retained in the canister. The carbon is purged of VOC during driving by drawing air back through the canister and into the engine, where it is burnt.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
	Exhaust Emissions[73]								
	Car Production Period up to 1971								
	Urban Driving								
	Engine < 1400 cc	1000 km	0.07	1.9S	1.64	45.6	3.86	Pb	0.13P
		tn of Fuel	0.74	20S	17.29	480.6	40.69	Pb	1.35P
	Engine 1400-2000 cc	1000 km	0.07	2.22S	1.87	45.6	3.86	Pb	0.15P
		tn of Fuel	0.63	20S	16.87	411.6	34.85	Pb	1.35P
	Engine > 2000 cc	1000 km	0.07	2.74S	2.25	45.6	3.86	Pb	0.19P
		tn of Fuel	0.51	20S	16.42	332.8	28.17	Pb	1.35P
	Suburban Driving								
	Engine < 1400 cc	1000 km	0.05	1.15S	2.01	25.13	2.03	Pb	0.08P
		tn of Fuel	0.87	20S	35.01	437.4	35.32	Pb	1.35P
	Engine 1400-2000 cc	1000 km	0.05	1.4S	2.51	25.13	2.03	Pb	0.09P
		tn of Fuel	0.71	20S	35.91	359.7	29.05	Pb	1.35P
	Engine > 2000 cc	1000 km	0.05	1.66S	3.03	25.13	2.03	Pb	0.11P
		tn of Fuel	0.60	20S	36.50	302.5	24.43	Pb	1.35P
	Highway Driving								
	Engine < 1400 cc	1000 km	0.05	1.2S	2.02	16.66	1.32	Pb	0.08P
		tn of Fuel	0.83	20S	33.59	277.0	21.94	Pb	1.35P
	Engine 1400-2000 cc	1000 km	0.05	1.49S	3.13	16.66	1.32	Pb	0.10P
		tn of Fuel	0.67	20S	42.06	224.1	17.76	Pb	1.35P
	Engine > 2000 cc	1000 km	0.05	1.81S	3.59	16.66	1.32	Pb	0.12P
		tn of Fuel	0.55	20S	39.64	183.7	14.55	Pb	1.35P
	Car Production Period 1972-1977								
	Urban Driving								
	Engine < 1400 cc	1000 km	0.07	1.66S	1.64	33.42	3.07	Pb	0.11P
		tn of Fuel	0.84	20S	19.75	402.4	36.95	Pb	1.35P
	Engine 1400-2000 cc	1000 km	0.07	1.92S	1.87	33.42	3.07	Pb	0.13P
		tn of Fuel	0.73	20S	19.43	347.5	31.90	Pb	1.35P
	Engine > 2000 cc	1000 km	0.07	2.2S	2.25	33.42	3.07	Pb	0.15P
		tn of Fuel	0.64	20S	20.42	303.3	27.85	Pb	1.35P
	Suburban Driving								
	Engine < 1400 cc	1000 km	0.05	0.94S	2.01	16.96	1.51	Pb	0.06P
		tn of Fuel	1.06	20S	42.73	360.3	32.0	Pb	1.35P
	Engine 1400-2000 cc	1000 km	0.05	1.11S	2.51	16.96	1.51	Pb	0.08P
		tn of Fuel	0.90	20S	45.02	304.4	27.03	Pb	1.35P
	Engine > 2000 cc	1000 km	0.05	1.24S	3.03	16.96	1.51	Pb	0.08P
		tn of Fuel	0.81	20S	48.84	273.2	24.26	Pb	1.35P
	Highway Driving								
	Engine < 1400 cc	1000 km	0.05	0.98S	2.02	19.98	1.19	Pb	0.07P
		tn of Fuel	1.02	20S	41.10	406.6	24.13	Pb	1.35P

73. (a) The emission factors listed are based on a mean ambient temperature of 20 °C & on the following assumptions:
For Urban Driving: Av speed= 25 km/h; Av trip length = 8 km; Cold/hot starts: 75/25
For Suburban Driving: Av speed= 60 km/h; Av trip length =12 km; Cold/hot starts: 75/25
For Highway Driving : Av speed=100 km/h; Av trip length >20 km; Cold/hot starts: 75/25
(b) Use Model of Section 3.3 for emissions under local climatic & driving conditions.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
	Engine 1400-2000 cc	1000 km	0.05	1.19S	3.13	19.98	1.19	Pb	0.08P
		tn of Fuel	0.84	20S	52.41	335.1	19.89	Pb	1.35P
	Engine > 2000 cc	1000 km	0.05	1.34S	3.59	19.98	1.19	Pb	0.09P
		tn of Fuel	0.75	20S	53.73	298.7	17.73	Pb	1.35P
	Car Production Period 1978-1980								
	Urban Driving								
	Engine < 1400 cc	1000 km	0.07	1.39S	1.50	28.44	2.84	Pb	0.09P
		tn of Fuel	1.00	20S	21.65	410.0	40.93	Pb	1.35P
	Engine 1400-2000 cc	1000 km	0.07	1.68S	1.72	28.44	2.84	Pb	0.11P
		tn of Fuel	0.83	20S	20.47	337.6	33.70	Pb	1.35P
	Engine > 2000 cc	1000 km	0.07	2.13S	1.97	28.44	2.84	Pb	0.14P
		tn of Fuel	0.66	20S	18.48	266.5	26.61	Pb	1.35P
	Suburban Driving								
	Engine < 1400 cc	1000 km	0.05	0.88S	1.90	13.54	1.37	Pb	0.06P
		tn of Fuel	1.14	20S	43.04	307.5	31.11	Pb	1.35P
	Engine 1400-2000 cc	1000 km	0.05	1.1S	2.18	13.54	1.37	Pb	0.07P
		tn of Fuel	0.91	20S	39.47	245.4	24.83	Pb	1.35P
	Engine > 2000 cc	1000 km	0.05	1.35S	2.48	13.54	1.37	Pb	0.09P
		tn of Fuel	0.74	20S	36.86	201.1	20.34	Pb	1.35P
	Highway Driving								
	Engine < 1400 cc	1000 km	0.05	1.03S	2.96	10.47	1.00	Pb	0.07P
		tn of Fuel	0.97	20S	57.25	202.7	19.45	Pb	1.35P
	Engine 1400-2000 cc	1000 km	0.05	1.23S	3.34	10.47	1.00	Pb	0.08P
		tn of Fuel	0.81	20S	54.21	170.2	16.33	Pb	1.35P
	Engine > 2000 cc	1000 km	0.05	1.47S	3.71	10.47	1.00	Pb	0.10P
		tn of Fuel	0.68	20S	50.44	142.3	13.65	Pb	1.35P
	Car Production Period 1981-1984								
	Urban Driving								
	Engine < 1400 cc	1000 km	0.07	1.39S	1.58	23.40	2.84	Pb	0.09P
		tn of Fuel	1.00	20S	22.74	337.3	40.93	Pb	1.35P
	Engine 1400-2000 cc	1000 km	0.07	1.68S	1.92	23.40	2.84	Pb	0.11P
		tn of Fuel	0.83	20S	22.77	277.8	33.70	Pb	1.35P
	Engine > 2000 cc	1000 km	0.07	2.13S	2.57	23.40	2.84	Pb	0.14P
		tn of Fuel	0.66	20S	24.12	219.3	26.61	Pb	1.35P
	Suburban Driving								
	Engine < 1400 cc	1000 km	0.05	0.88S	1.98	9.26	1.37	Pb	0.06P
		tn of Fuel	1.14	20S	45.01	210.3	31.11	Pb	1.35P
	Engine 1400-2000 cc	1000 km	0.05	1.1S	2.35	9.26	1.37	Pb	0.07P
		tn of Fuel	0.91	20S	42.61	167.8	24.83	Pb	1.35P
	Engine > 2000 cc	1000 km	0.05	1.35S	3.03	9.26	1.37	Pb	0.09P
		tn of Fuel	0.74	20S	44.98	137.5	20.34	Pb	1.35P
	Highway Driving								
	Engine < 1400 cc	1000 km	0.05	1.03S	3.26	6.71	1.00	Pb	0.07P
		tn of Fuel	0.97	20S	63.16	129.8	19.45	Pb	1.35P
	Engine 1400-2000 cc	1000 km	0.05	1.23S	3.70	6.71	1.00	Pb	0.08P
		tn of Fuel	0.81	20S	60.04	109.0	16.33	Pb	1.35P
	Engine > 2000 cc	1000 km	0.05	1.47S	4.47	6.71	1.00	Pb	0.10P
		tn of Fuel	0.68	20S	60.68	91.11	13.65	Pb	1.35P

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
	Car Production Period 1985-1992								
	Urban Driving								
	Engine < 1400 cc	1000 km	0.07	1.27S	1.50	15.73	2.23	Pb	0.09P
		tn of Fuel	1.10	20S	23.75	248.3	35.25	Pb	1.35P
	Engine 1400-2000 cc	1000 km	0.07	1.62S	1.78	15.73	2.23	Pb	0.11P
		tn of Fuel	0.86	20S	22.02	194.7	27.65	Pb	1.35P
	Engine > 2000 cc	1000 km	0.07	1.85S	2.51	15.73	2.23	Pb	0.13P
		tn of Fuel	0.76	20S	27.11	169.7	24.09	Pb	1.35P
	Suburban Driving								
	Engine < 1400 cc	1000 km	0.05	0.80S	2.06	6.99	1.05	Pb	0.05P
		tn of Fuel	1.25	20S	51.26	173.7	26.11	Pb	1.35P
	Engine 1400-2000 cc	1000 km	0.05	0.97S	2.31	6.99	1.05	Pb	0.07P
		tn of Fuel	1.03	20S	47.62	144.3	26.68	Pb	1.35P
	Engine > 2000 cc	1000 km	0.05	1.17S	3.14	6.99	1.05	Pb	0.08P
		tn of Fuel	0.85	20S	53.81	119.9	18.02	Pb	1.35P
	Highway Driving								
	Engine < 1400 cc	1000 km	0.05	0.96S	2.85	3.56	0.69	Pb	0.07P
		tn of Fuel	1.04	20S	59.18	73.9	14.26	Pb	1.35P
	Engine 1400-2000 cc	1000 km	0.05	1.08S	3.10	3.56	0.69	Pb	0.07P
		tn of Fuel	0.93	20S	57.21	65.85	12.71	Pb	1.35P
	Engine > 2000 cc	1000 km	0.05	1.36S	4.09	3.56	0.69	Pb	0.09P
		tn of Fuel	0.74	20S	60.29	52.5	10.13	Pb	1.35P
	Cars with Uncontrolled 3-way Catalytic Converters[74]								
	Urban Driving								
	Engine < 1400 cc	1000 km	0.07	1.74S	1.31	10.24	1.29		
		tn of Fuel	0.80	20S	15.13	118.0	14.83		
	Engine 1400-2000 cc	1000 km	0.07	2.05S	1.13	6.46	0.60		
		tn of Fuel	0.68	20S	10.97	62.9	5.85		
	Engine > 2000 cc	1000 km	0.07	2.35S	1.13	6.46	0.60		
		tn of Fuel	0.60	20S	9.56	54.9	5.1		
	Suburban Driving								
	Engine < 1400 cc	1000 km	0.05	1.10S	1.74	5.15	0.61		
		tn of Fuel	0.91	20S	31.53	93.4	11.10		
	Engine 1400-2000 cc	1000 km	0.05	1.23S	1.43	2.96	0.28		
		tn of Fuel	0.81	20S	23.19	48.18	4.49		
	Engine > 2000 cc	1000 km	0.05	1.48S	1.43	2.96	0.28		
		tn of Fuel	0.68	20S	19.27	40.0	3.73		
	Highway Driving								
	Engine < 1400 cc	1000 km	0.05	1.32S	2.23	2.58	0.40		
		tn of Fuel	0.76	20S	33.80	39.1	6.00		
	Engine 1400-2000 cc	1000 km	0.05	1.37S	1.83	1.29	0.17		
		tn of Fuel	0.73	20S	26.56	18.8	2.41		
	Engine > 2000 cc	1000 km	0.05	1.72S	1.83	1.29	0.17		
		tn of Fuel	0.58	20S	21.16	15.0	1.92		

74. Hot & Cold Urban Driving Cycle and Extra Urban Driving Cycle emission and fuel consumption measurements of TNO (TNO, 1990), modelled by A. Economopoulos.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
	Cars with Controlled 3-way Catalytic Converters[75]								
	Urban Driving								
	Engine < 1400 cc	1000 km	0.07	1.61S	0.20	1.71	0.24		
		tn of Fuel	0.87	20S	2.46	21.21	2.95		
	Engine 1400-2000 cc	1000 km	0.07	1.94S	0.25	1.49	0.19		
		tn of Fuel	0.72	20S	2.57	15.39	1.93		
	Engine > 2000 cc	1000 km	0.07	2.23S	0.25	1.49	0.19		
		tn of Fuel	0.63	20S	2.24	13.41	1.68		
	Suburban Driving								
	Engine < 1400 cc	1000 km	0.05	1.02S	0.33	1.33	0.19		
		tn of Fuel	0.98	20S	6.52	25.96	3.69		
	Engine 1400-2000 cc	1000 km	0.05	1.16S	0.34	1.04	0.13		
		tn of Fuel	0.86	20S	5.79	17.88	2.19		
	Engine > 2000 cc	1000 km	0.05	1.40S	0.34	1.04	0.13		
		tn of Fuel	0.71	20S	4.81	14.87	1.82		
	Highway Driving								
	Engine < 1400 cc	1000 km	0.05	1.22S	0.24	0.90	0.11		
		tn of Fuel	0.82	20S	3.89	14.76	1.76		
	Engine 1400-2000 cc	1000 km	0.05	1.30S	0.25	0.54	0.06		
		tn of Fuel	0.77	20S	3.91	8.29	0.95		
	Engine > 2000 cc	1000 km	0.05	1.63S	0.25	0.54	0.06		
		tn of Fuel	0.61	20S	3.12	6.60	0.76		
	Heavy Duty Gasoline Powered Vehicles > 3.5 tn								
	Urban Driving	1000 km	0.4	4.5S	4.5	70	7	Pb	0.31P
		tn of Fuel	3.5	20S	20	300	30	Pb	1.35P
	Suburban Driving	1000 km	0.45	3.7S	7.5	55	5.5	Pb	0.25P
		tn of Fuel	2.4	20S	40	300	30	Pb	1.35P
	Highway Driving	1000 km	0.6	3.3S	7.5	50	3.5	Pb	0.22P
		tn of Fuel	3.6	20S	45	300	20	Pb	1.35P
	Light Duty Diesel Powered Vehicles < 3.5 tn[76]								
	Urban Driving	1000 km	0.2	1.16S	0.7	1	0.15		
		tn of Fuel	3.5	20S	12	18	2.6		
	Suburban Driving	1000 km	0.15	0.84S	0.55	0.85	0.4		
		tn of Fuel	3.5	20S	13	20	9.5		
	Highway Driving	1000 km	0.3	1.3S	1	1.25	0.4		
		tn of Fuel	4.7	20S	15	19.	6.1		

75. Hot & Cold Urban Driving Cycle and Extra Urban Driving Cycle emission and fuel consumption measurements by TNO (TNO, 1990), modelled by A. Economopoulos.

76. (a) In the case of a fleet of old vehicles with poor state of maintenance and poor fuel quality, the emission factors listed need to be multiplied as follows:

TSP: 1.6
CO: 1.1
VOC: 10.0
NOx: 0.9

(b) Based on the Central Bureau of Statistics, Netherlands, the TSP (Smoke) emissions from Urban, Suburban and Highway driving are 1.1, 0.55 and 0.5 kg/1000 km respectively.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U	kg/U
	Heavy Duty Diesel Powered Vehicles 3.5-16 tn[77]							
	Urban Driving	1000 km	0.9	4.29S	11.8	6.0	2.6	
		tn of Fuel	4.3	20S	55.	28.	12.	
	Suburban Driving	1000 km	0.9	4.15S	14.4	2.9	0.8	
		tn of Fuel	4.3	20S	70.	14.	4.	
	Highway Driving	1000 km	0.9	4.15S	14.4	2.9	0.8	
		tn of Fuel	4.3	20S	70.	14.	4.	
	Heavy Duty Diesel Powered Trucks > 16 tn[78]							
	Urban Driving	1000 km	1.6	7.26S	18.2	7.3	5.8	
		tn of Fuel	4.3	20S	50.	20.	16.	
	Suburban Driving	1000 km	1.6	7.43S	24.1	3.7	3.0	
		tn of Fuel	4.3	20S	65.	10.	8.	
	Highway Driving	1000 km	1.3	6.1S	19.8	3.1	2.4	
		tn of Fuel	4.3	20S	65.	10.	8.	
	Heavy Duty Diesel Powered Buses > 16 tn[79]							
	Urban Driving	1000 km	1.4	6.6S	16.5	6.6	5.3	
		tn of Fuel	4.3	20S	50.	20.	16.	
	Suburban Driving	1000 km	1.2	5.61S	18.2	2.8	2.2	
		tn of Fuel	4.3	20S	65.	10.	8.	
	Highway Driving	1000 km	0.9	6.11S	13.9	2.1	1.7	
		tn of Fuel	4.3	20S	65.	10.	8.	
	Light Duty LPG Powered Vehicles < 3.5 tn[80]							
	Without Catalytic Converters							
	Urban Driving	1000 km			1.24	3.3	1.35	
		tn of Fuel			21	56	23	
	Suburban Driving	1000 km			1.3	1.76	1.15	
		tn of Fuel			29	39	26	
	Highway Driving	1000 km			2.75	1.15	1.03	
		tn of Fuel			51	21	19	
	With 3-way Controlled Catalytic Converters							
	Urban Driving	1000km			0.3	1.9	0.7	
		tn of Fuel			4.4	28	10.3	
	Motorcycles							
	Engines < 50 cc 2-Stroke	1000 km	0.12	0.36S	0.05	10	6	
		tn of Fuel	6.7	20S	2.8	550	330	

77. Based on the Central Bureau of Statistics, Netherlands (1983), the TSP (Smoke) emissions from Urban, Suburban and Highway driving are 5.4, 2.0 and 1.4 kg/1000 km respectively.

78. As above.

79. Based on the Central Bureau of Statistics, Netherlands (1983), the TSP (Smoke) emissions from Urban, Suburban and Highway driving are 5.1, 1.8 and 1.0 kg/1000 km respectively.

80. The listed emission factors are valid only for properly converted (into LPG use) and well adjusted engines. Otherwise, the emission factors are in the same order as these for Light Duty Gasoline Powered Vehicles < 3.5 tn.

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
	Engines > 50 cc 2-Stroke	1000 km	0.12	0.6S	0.08	22	15		
		tn of Fuel	4	20S	2.7	730	500		
	Engines > 50 cc 4-Stroke	1000 km		0.76S	0.30	20	3		
		tn of Fuel		20S	8	525	80		
	Fugitive Dust from Vehicle Traffic[81]								
	Unpaved Roads[82]								
	Plant Roads								
	Copper Smelting	1000 km	12.5f						
	Iron & Steel Production	1000 km	5.9f						
	Sand & Gravel Processing	1000 km	3.5f						
	Stone Quarrying/Processing	1000 km	10.4f						
	Coal Mining / Access Road	1000 km	3.8f						
	Coal Mining / Haul Road	1000 km	6.2f						
	Coal Mining / Scraper Road	1000 km	12.5f						
	Rural Roads								
	Gravel	1000 km	3.7f						
	Dirt	1000 km	21.f						
	Crushed Limestone	1000 km	7.1f						
	Paved Roads[83]								
	City Roads[84]								
	Local Streets (Width<10m)								
	< 500 vehicles/d	1000 km	15					Pb	0.018
	Collector Streets (Width>10m)								
	500-10000 vehicles/d	1000 km	10					Pb	0.018
	Major Streets / highways								
	>10000 vehicles/d	1000 km	4.4					Pb	0.018

81. Emission factors account for entrained particles with diameters < 30 μ.

82. (a) $f = S(W^{0.7})(w^{0.5})$, where S is the average vehicle speed in km/hr, W is the average vehicle weight in tons, and w is the average number of wheels per vehicle.

    (b) The listed emission factors apply per 1000km driven in dry weather (during days with < 0.25 mm of precipitation).

    (c) The emission factors for PM_{15} or PM_{10} particles are 50% and 36% respectively of the listed TSP emission factors (PM_{10} & PM_{15} are particles with diameters <10 & <15 μ respectively).

    (d) Periodic (monthly) application of petroleum resin products over a dust control season (e.g. four summer months) yields typical control efficiencies of the order of 60% for the TSP and 70% for PM10 particles.

83. The emission factors for PM_{15} or PM_{10} particles are 40% & 36% respectively of the listed TSP emission factors for local and collector streets, 45% & 41% respectively of the listed TSP emission factors for major streets/highways and 60% & 54% respectively for Freeways/Expressways (PM_{10} & PM_{15} are particles with diameters <10 & <15 μ respectively).

84. Limited data suggest control efficiencies of 34% and 37% for PM_{10} particles from Vacuum Sweeping and Improved Vacuum Sweeping respectively (PM_{10} are particles with aerodynamic diameter < 10 μ).

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
	Freeways / Express Ways								
	>50000 vehicles/d	1000 km	0.35					Pb	0.018
	Industrial Roads[85]	1000 km	120						
712	**Water Transport**								
	Ships in Berth[86,87]								
	Motorships	Ship-days in berth	6.8	136S	90.7	0.036	4.1		
	Steamships	Ship-days in berth	7.5	19.5	22.7	20.8	14.9		
713	**Air Transport**								
	Landing and Take off of Aircraft								
	Typical Carrier[88]	Landing+Take off	0.99	1.5	14.2		20.4		
	Aircraft Refuelling								
	Jet Naphtha	m^3					0.40		
		tn					0.54		
719	**Services Allied to Transport**								
7192	Storage and Warehousing								
	Grain Elevators								
	Country Elevators	tn	3.7						
	Inland Terminal Elevators	tn	4.8						
	Export Elevators	tn	5.0						

85. For PM_{15} particles, limited data suggest control efficiencies of up to 58% for vacuum sweeping (46% for TSP), (69-0.231*V)% efficiency for Water Flushing and (96-0.263*V)% efficiency for Water Flushing followed by Sweeping, where V is the number of vehicle passes since application.
86. "S" is the weight percent of sulfur in the fuel used
87. The number of steamships and motorships days-in-berth, if not directly known, can be computed from the number of ship calls per year and the average mooring time. Typical mooring times in hours are as follows: 6 for passenger ships, 45 for freighters and general ships, 24 for container vessels < 40000 GRT, 36 for container vessels > 40000 GRT, 40 for bulk transport vessels < 40000 GRT, 50 for bulk transport vessels > 40000 GRT, 36 for tankers < 40000 GRT, 48 for tankers > 40000 GRT.
88. Given factors are overall averages for a typical airport, Economopoulos (1980).

Model for Air Emission Inventories and Controls - Cont'd

SIC#	PROCESS	UNIT (U)	TSP kg/U	SO_2 kg/U	NO_x kg/U	CO kg/U	VOC kg/U		kg/U
MAJOR DIVISION 9.	**COMMUNITY, SOCIAL AND PERSONAL SERVICES**								
920	**Sanitary and Similar Services**								
	Municipal/Domestic Type of Wastes								
	Open Burning								
	Municipal Refuse	tn	8	0.5	3.	42.	21.5		
	Automobile Components[89]	tn	50	0.0	2.	62.	21.0		
	Municipal Waste Combustion								
	Mass-Burn Combustors								
	Uncontrolled	tn	19	0.85	1.8	1.1	0.0532	Pb	0.09
	ESP or FF	tn	0.19	0.85	1.8	1.1	0.0532	Pb	0.011
	Modular Starved-Air Combustors								
	Uncontrolled	tn	0.95	0.85	2.2	0.17	0.0532	Pb	0.06
	ESP or FF	tn	0.015	0.85	2.2	0.17	0.0532	Pb	0.001
	Refuse Derived Fuel (RDF) Fired Combustors								
	Uncontrolled	tn	40	0.85	2.5	1.8	0.0532	Pb	0.065
	ESP or FF	tn	0.04	0.85	2.5	1.8	0.0532	Pb	0.014
	Industrial / Commercial Refuse Combustion								
	Multiple Chamber/Uncontrolled	tn	3.5	1.25	1.5	5.0	1.5		
	Single Chamber / Uncontrolled	tn	7.5	1.25	1.0	10.0	7.5		
	Trench / Uncontrolled								
	Wood	tn	13	0.1	4.0				
	Rubber Tires	tn	138						
	Municipal Refuse	tn	37	2.5					
	Pathological Wastes								
	Uncontrolled	tn	8.0	0.	3.0	0.	0.		
	Sewage Sludge Incinerators								
	Multiple Hearth Incinerators								
	Uncontrolled	tn of dried sludge	42	10	5.5	36	3.15	Pb	0.05
	Scrubber[90]	tn of dried sludge	0.89	2.	2.5	2	3.15	Pb	0.02
	Fluidized Bed Incinerators								
	Uncontrolled	tn of dried sludge	?	10.	4		1.16	Pb	7
	Scrubber	tn of dried sludge	0.33	2.	2.2	2	1.16	Pb	0.03
	Electric Infrared Incinerators								
	Uncontrolled	tn of dried sludge	4	10.	4				
	Scrubber	tn of dried sludge	1	2.	3				
952	**Laundries, Laundry Services, and Cleaning and Dyeing Plants**								
	Dry Cleaning	(Capita)*(year)					0.6		

89. Upholstery, belts, hoses and tires burned together.
90. Impingement, Venturi and/or cyclone scrubber.

3.2.3 Working Table for Assessing the Air Emission Loads

Data and Calculations Sheet for Air Emissions (# ___ of ___)

SOURCE	UNIT (U)	SOURCE SIZE	TSP		SO_2		NO_x		CO		VOC		OTHER		
		10^3U/y	Fact kg/U	Load tn/y	Fact kg/U	Load tn/y	Fact kg/U	Load tn/y	Fact kg/U	Load tn/y	Fact kg/U	Load tn/y	Pollutant	Fact kg/U	Load tn/y
Sub Total (from Present Sheet)															
Sub Total (from Previous Sheets															
Sub Total															

Note: U =Unit
Fact=Waste Load Factor

3.2.4 Example

The Problem:

A lime manufacturing plant operating within our study area is to be surveyed. Determine the data requirements, collect the necessary information and assess the emission loads:

Solution of the Problem:

1. From Appendix II we find Lime, a non metallic mineral product, classified under the Standard Industrial Classification (SIC) Code # 369. Use of Appendix II facilitates the finding of a particular activity in Section 3.2.3.

2. From Section 3.2.3 inspection of the Lime manufacturing emissions model yields the following data input requirements:
   - (a) Are the kilns using coal or other type of fuel?
   - (b) If Coal is used:
     - (i) Quantity of Coal used (tn/year if annual emission estimates are desirable)
     - (ii) Coal Storage (Open piles, Semi-enclosed piles, Compartments, or Silos)
     - (iii) Control system for the Coal crushing and screening (uncontrolled or Fabric filter)
     - (iv) The system used for Coal grinding (Semi Direct, Direct, or Indirect fired)
     - (v) If Indirect fired grinding systems are used what controls are installed (uncontrolled or Fabric Filter).
   - (c) Quantity of Lime Produced (tn/year if annual emission estimates are desirable)
   - (d) Sulfur content of fuel used, in weight %. (for estimating the SO_2 emissions)
   - (e) Control system for the Raw material crushing and screening (uncontrolled or Fabric Filter)
   - (f) Storage of crushed material (Open or Semi-enclosed pile, Compartment or Silo)
   - (g) Control for the raw material conveying system (uncontrolled or Fabric filter)
   - (h) Type of kiln used for the Raw material calcining (Vertical shaft kiln, Vertical double inclined kilns, Parallel flow/counterflow regenerative kilns, ...)
   - (i) Controls used in the calcining kiln (Uncontrolled or controlled and in the latter case, which of the listed controls is used)
   - (j) Type of Lime cooler used (Grate, Planetary, Rotary or Vertical Shaft cooler)
   - (k) Control used in the Grate cooler (if used) (Uncontrolled, Cyclones, Multicyclones or Fabric Filter)

3. Assume that from the plant survey visit the following data were obtained in relation to the above questionnaire:

   (a) Coal is not used as fuel
   (c) Lime production is 18,000 tn/year
   (d) The sulfur content of the residue oil used is 4 % (S = 4)
   (e) Raw material crushing and screening is uncontrolled
   (f) Crushed material is stored in open piles
   (g) Raw material conveying systems are uncontrolled
   (h) The calcining kiln is of the vertical shaft type
   (i) The calcining kiln is controlled by multicyclones
   (j) Lime cooling is by vertical shaft cooler (lower part of kiln).

4. The above plant survey data, along with the necessary information from the emission load model (see Section 3.2.2), can be inserted in the working Table given in Section 3.2.3. The latter can be used for computing the annual emissions from each major source within the lime manufacturing plant.

   Table 3.2.4-1 shows how data and information can be entered and how emissions can be computed. It should be noted that in the Working Table the emission factors are expressed as kg/Unit, while the activity of each source is entered in 1000 Units/Year. As a result, multiplication of each emission factor by the source activity yields the emission load expressed in tons/year. For example, the TSP emission factor for the raw material conveying is 1.2 (kg TSP per ton of Lime) and the source activity is 18 (thousand tons of Lime production per year). Their multiplication yields 21.6 tons of TSP emissions per year.

Table 3.2.4-1 Example use of the working table of Section 3.2.3

Data and Calculations Sheet for Air Emissions (# _1_ of _1_)

SOURCE	UNIT (U)	SOURCE SIZE 10^3U/y	TSP Fact kg/U	TSP Load tn/y	SO_2 Fact kg/U	SO_2 Load tn/y	NO_x Fact kg/U	NO_x Load tn/y	CO Fact kg/U	CO Load tn/y	VOC Fact kg/U	VOC Load tn/y	OTHER Pollutant	OTHER Fact kg/U	OTHER Load tn/y
3692 Manufacture of Cement, Lime & Plaster															
Lime Manufacturing															
Raw Mat Storage	tn	18	0.16	2.9											
Crush & Screening															
Uncontrolled	tn	18	1.5	27											
Crushed Mat Storage															
Open Piles		18	1.0	18											
Raw Mar. Conveying															
Uncontrolled	tn	18	1.2	21.6											
Raw Mat. Calcining															
Vert Shaft Kilns															
M/cyclones	tn	18	0.75	13.5	.9*4	64.8	0.1	1.8	2.0	36					
Lime Packaging															
& Shipping	tn	18	0.12	2.3											
Sub Total (from Present Sheet)				85.3		64.8		1.8		36					
Sub Total (from Previous Sheets															
Sub Total															

Note: U =Unit

Fact=Waste Load Factor

3.3 Model for the Exhaust and Evaporative Emissions from LDGP Vehicles Under Specific Driving, Climatic and Gasoline Volatility Conditions

3.3.1 Introduction

Light Duty Gasoline Powered (LDGP) vehicles are the dominant source of NOx, CO and VOC emissions in most large urban areas. All three of the above pollutants are precursors to photochemical smog, which appears with increasing frequency and intensity in many urban regions and affects large populations.

Photochemical smog (ozone, nitrogen dioxide, peroxy acetyl nitrate and many other substances in small amounts) is formed through atmospheric reactions, under the influence of sunlight and heat, from the primary pollutants NO_x, CO and VOC. The speed of the reactions leading to smog formation increases significantly during the summer, when both the intensity of the sunlight and the temperatures are elevated.

The NO_x, CO and VOC emission factors are considerably dependent on the daily mean temperature and on the driving patterns (average vehicle speed, percent of engine starts with cold engine, and mean length of each trip). During the peak ozone months all of the above parameters may deviate considerably from their annual averages (temperature is obviously higher, while the driving patterns are often affected by the summer vacations and/or tourism) and may deviate even further from the typical conditions on which the derivation of the emission factors listed in Section 3.2.2 was based. Yet, the calculation of the seasonal emissions may be important if the problem of photochemical pollution is to be addressed.

Because of the particular importance of LDGP vehicle emissions in urban pollution, their significant regional and seasonal variability, and their special importance during the ozone peak season, two models are presented in Sections 3.3.2 and 3.3.3 that allow users to custom fit the emission factors on the basis of the local and seasonal ambient conditions and driving patterns. The model in Section 3.3.2 focuses on exhaust emissions, while that of Section 3.3.3 on Evaporative VOC ones.

3.3.2 The Exhaust Emissions Model

3.3.2.1 Description of the Model

The basic input for our exhaust emissions model for LDGP vehicles is from the original ECE CORINAIR report (1980), as well as from the Exhaust emission measurements provided by TNO (1989-1990). From the former, information about exhaust emissions from conventional non catalytic cars was obtained, while from the latter, laboratory measurements relevant to the catalytic cars were used.

Based on the TNO measurements, an exhaust emissions and fuel consumption model for catalytic cars was developed (Economopoulos, 1992), which supplemented the exhaust emissions information for conventional cars provided by the ECE CORINAIR report.

The above extended model, which is capable of predicting the emissions for all types of LDGP vehicles, was used in the analysis of the functional dependence of the exhaust emissions on all parameters that are known to exert a significant effect (daily or seasonal mean temperature, the average vehicle speed, the fraction of cold engine starts, f_{cs}, and mean length of each trip, L, the age of a conventional vehicle or the type of catalytic system used, and the cylinder displacement of its engine). The end product of this analysis is described by the following relations (Economopoulos, 1992):

$$e = e^{hot} \left[1 + f_{cs} \frac{m_{0.75} - 1}{0.75} \right] , \qquad (3.3.2.1\text{-}1)$$

where

$$e^{hot} = f(\text{Average speed, Cylinder displacement, Year of conventional car manufacturing or type of catalytic system used}) \qquad (3.3.2.1\text{-}2)$$

and

$$m_{0.75} = f(\text{Mean temperature, Average trip length, Conventional or catalytic technology used}) \qquad (3.3.2.1\text{-}3)$$

The hot-start NO_x, CO, VOC and fuel consumption factor e^{hot} can be conveniently obtained as a function of the average speed, cylinder displacement, and year of car manufacture from the graphs in Figures 3.3.2.1-1 to 3.3.2.1-4. These factors represent the emissions and the fuel consumption for the distances traveled while the car engine is hot (cooling water temperature above 70 ^oC).

While the car runs with cold engine its emissions and its fuel consumption are different from the hot-start ones. This difference is especially pronounced in the case of cars equipped with catalytic converters. As most of the times the cars are ignited with cold engines, and run a fair fraction of their average trip before their engine gets hot, the hot start emission and fuel consumption factor e^{hot} need to be corrected so as to compensate for the cold start effects. This correction is achieved by Equation 3.3.2.1-1 through the use of the emission or fuel consumption factor multiplier $m_{0.75}$.

If f_{cs}=0.75 (meaning that in 75% of the cases the cars are ignited with cold engines and in 25% of the cases with hot engines) then, from Equation 3.3.2.1-1 we obtain:

$$e = (e^{hot})(m_{0.75}) \qquad (3.3.2.1\text{-}4)$$

The value of f_{cs}=0.75 is considered reasonable and, in the absence of local data, it can be accepted. In that case, $m_{0.75}$ is a direct multiplier of e^{hot} according to Equation 3.3.2.1-4 and this justifies its name (emission or fuel consumption factor multiplier).

For the computation of the actual (cold-start compensated) emission and fuel consumption factors, e, the values of $m_{0.75}$ are needed. These can be conveniently obtained through the graphs in Figures 3.3.2.1-5 to 3.3.2.1-8 for NO_x, CO, VOC and fuel consumption, as a function of the daily, seasonal or annual temperature, the average length of each vehicle trip, L, and the technology used (conventional or catalytic).

In summary, for the estimation of the NO_x, CO, VOC and fuel consumption factors we need information about the following:

Average speed

Cylinder displacement,

Year of manufacture for conventional cars or type of catalytic system used

Mean daily, seasonal or annual temperature,

Average length of trip,

Technology type (conventional or catalytic)

Based on the above we obtain the values of e^{hot} and $m_{0.75}$ for NO_x, CO, and VOC and fuel consumption using the diagrams of Figures 3.3.2.1-1 to 3.3.2.1-4 and 3.3.2.1-5 to 3.3.2.1-8 respectively. The above values of e^{hot} and $m_{0.75}$ are inserted in Equation 3.3.2.1-1 to obtain the sought factors for NO_x, CO, and VOC emissions and fuel consumption.

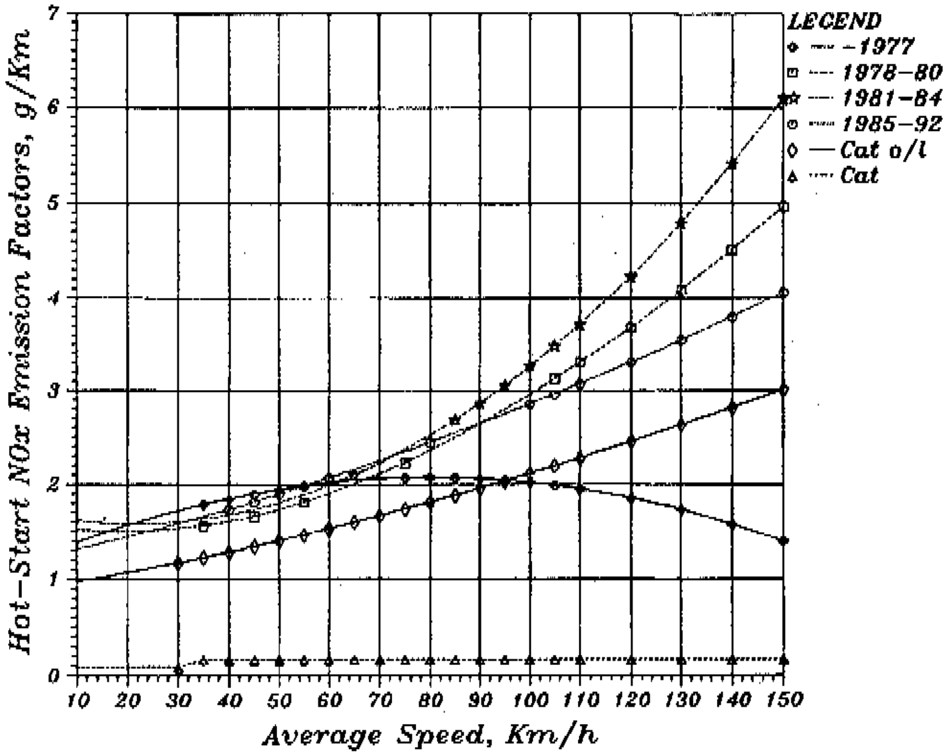

Figure 3.3.2.1-1a Hot-start **NOx** emission factors for LDGP cars with < **1400 cc** engines (**Cat o/l** = catalytic 3-way open loop, **Cat** = catalytic 3-way controlled)

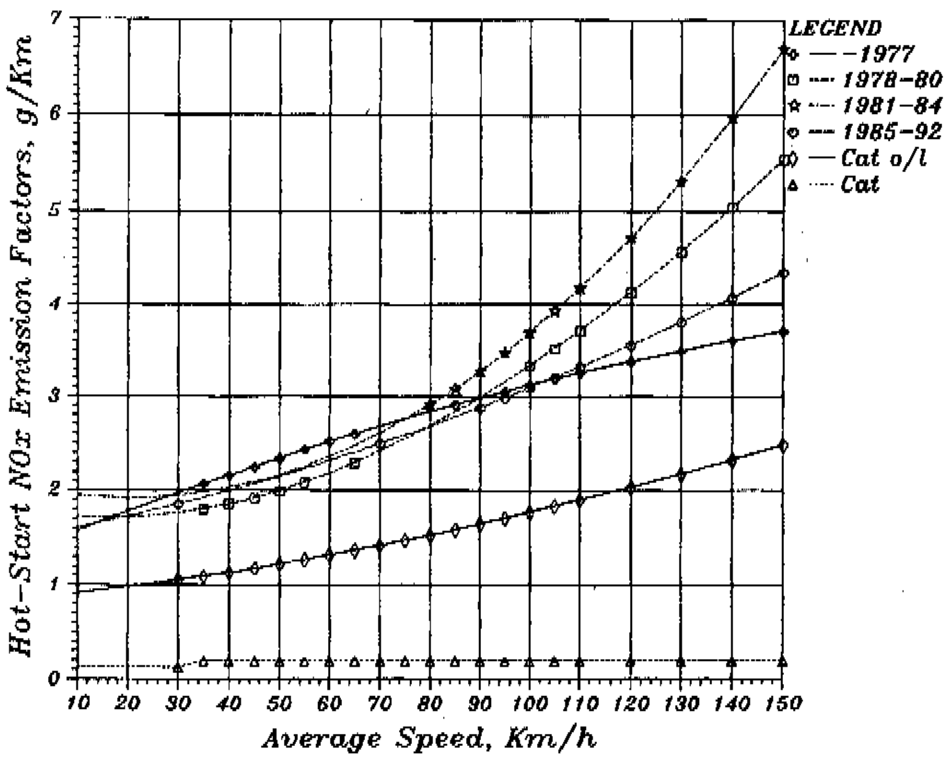

Figure 3.3.2.1-1b Hot-start **NO_x** emission factors for LDGP cars with **1400-2000 cc** engines (**Cat o/l** = catalytic 3-way open loop, **Cat** = catalytic 3-way controlled).

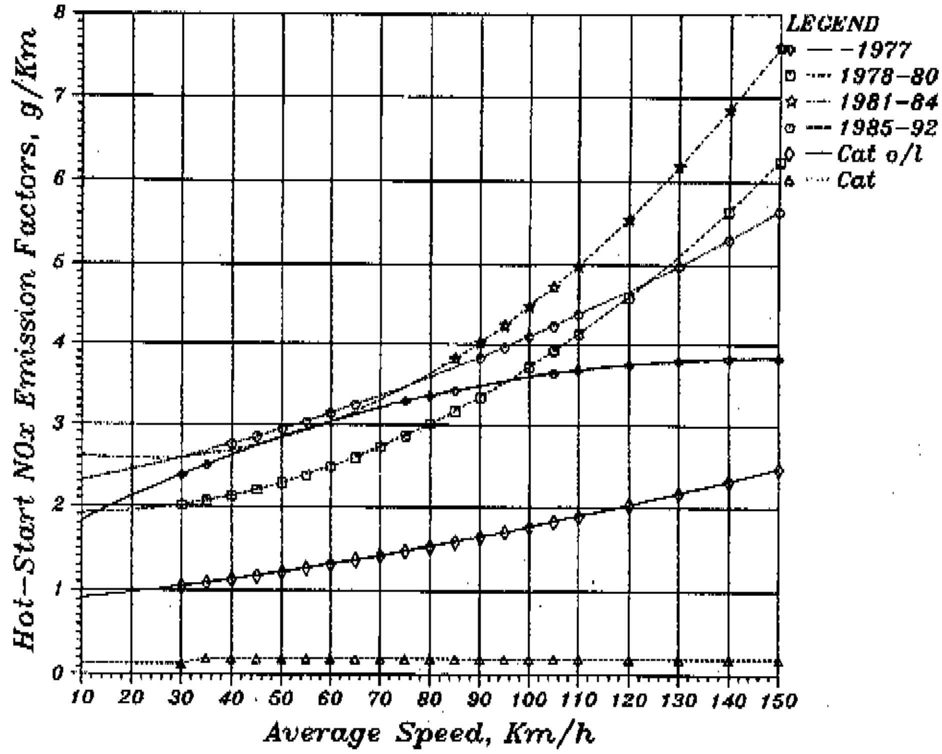

Figure 3.3.2.1-1c Hot-start NO_x emission factors for LDGP cars with > 2000 cc engines (**Cat o/l** = catalytic 3-way open loop, **Cat** = catalytic 3-way controlled)

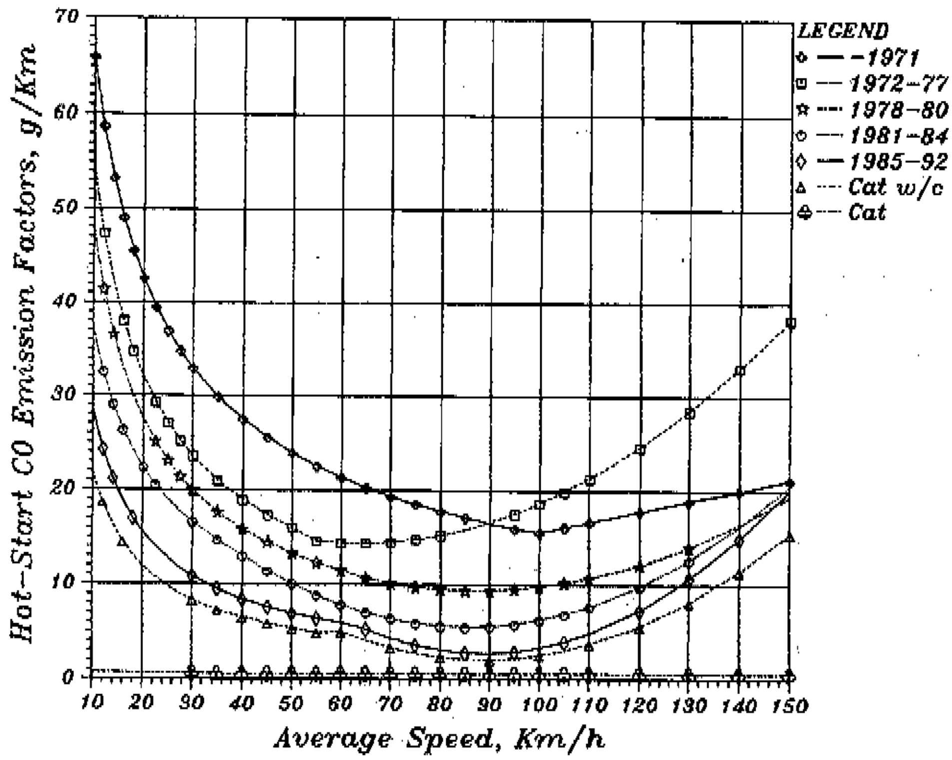

Figure 3.3.2.1-2 Hot-start CO emission factors for LDGP cars (**Cat o/l** = catalytic 3-way open loop, **Cat** = catalytic 3-way controlled)

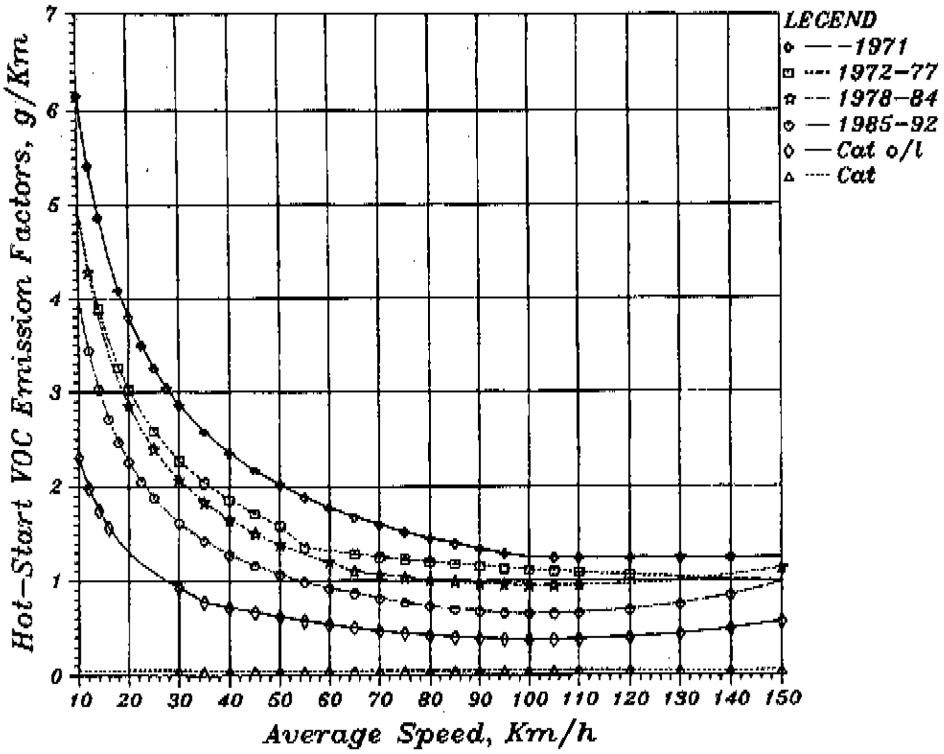

Figure 3.3.2.1-3 Hot-start **VOC** emission factors for LDGP cars (**Cat o/l** = catalytic 3-way open loop, **Cat** = catalytic 3-way controlled)

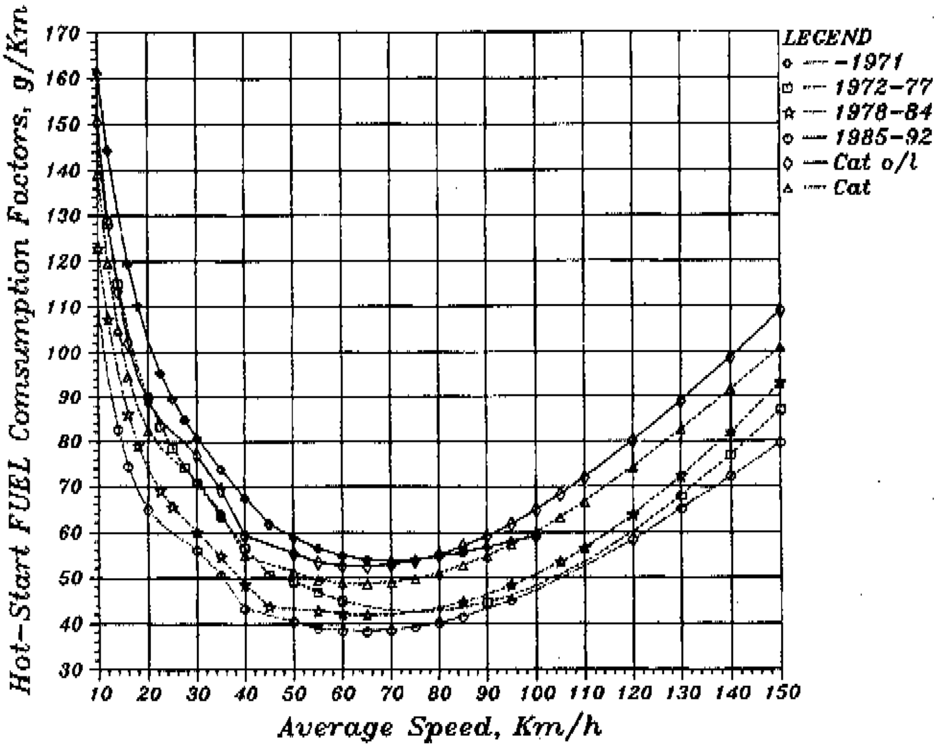

Figure 3.3.2.1-4a Hot-start **fuel consumption** factors for LDGP cars with < 1400 cc engines (**Cat o/l** = catalytic 3-way open loop, **Cat** = catalytic 3-way controlled)

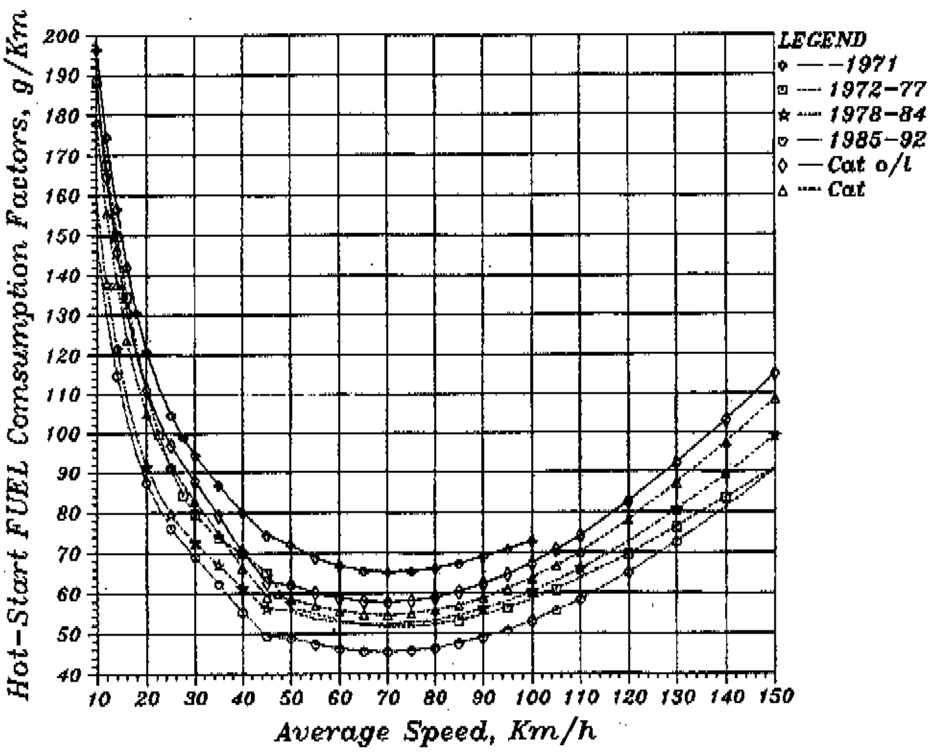

Figure 3.3.2.1-4b Hot-start **fuel consumption** factors for LDGP cars with **1400-2000 cc** engines (**Cat o/l** = catalytic 3-way open loop, **Cat** = catalytic 3-way controlled)

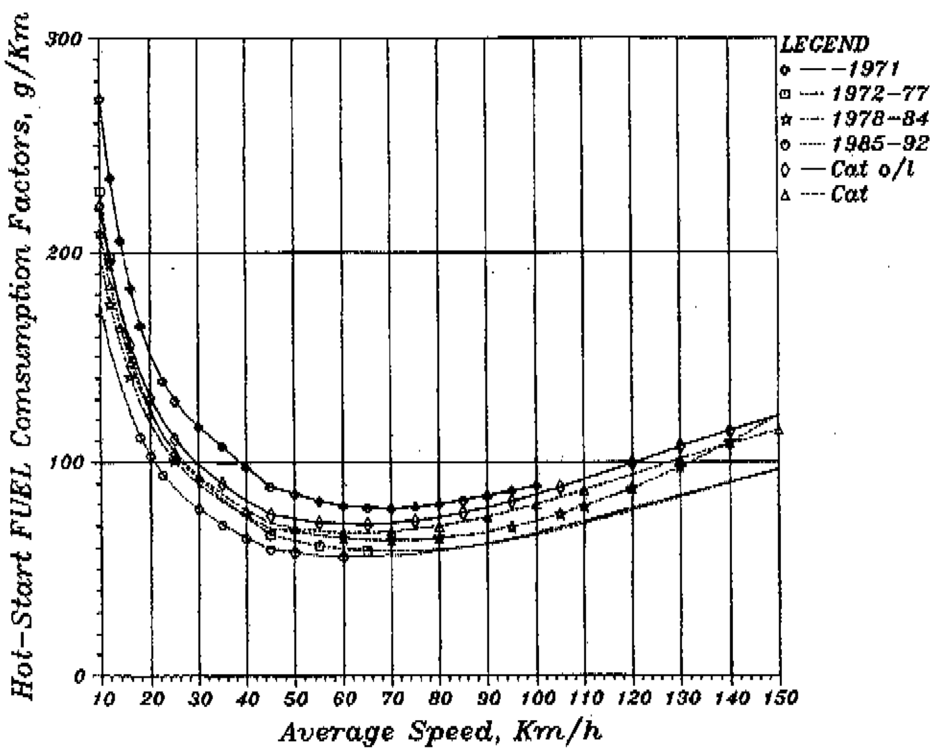

Figure 3.3.2.1-4c Hot-start **Fuel consumption** factors for LDGP cars with > **2000** cc engines (**Cat o/l** = catalytic 3-way open loop, **Cat** = catalytic 3-way controlled)

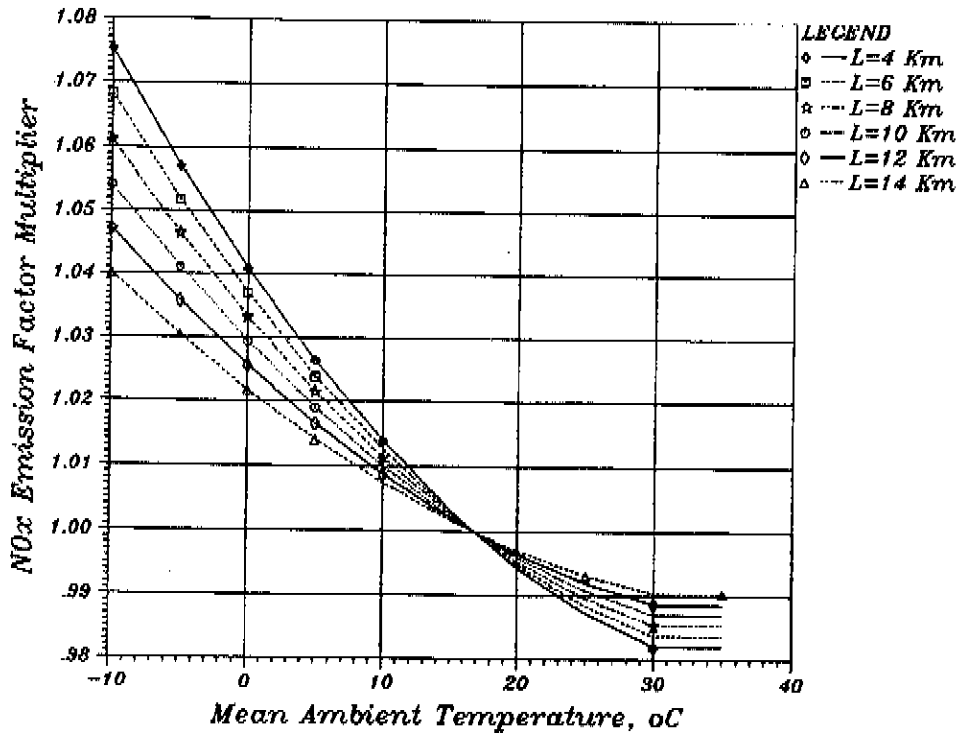

Figure 3.3.2.1-5a NO_x emission factor multiplier for conventional (non-catalytic) LDGP cars, as function of the average temperature and trip length

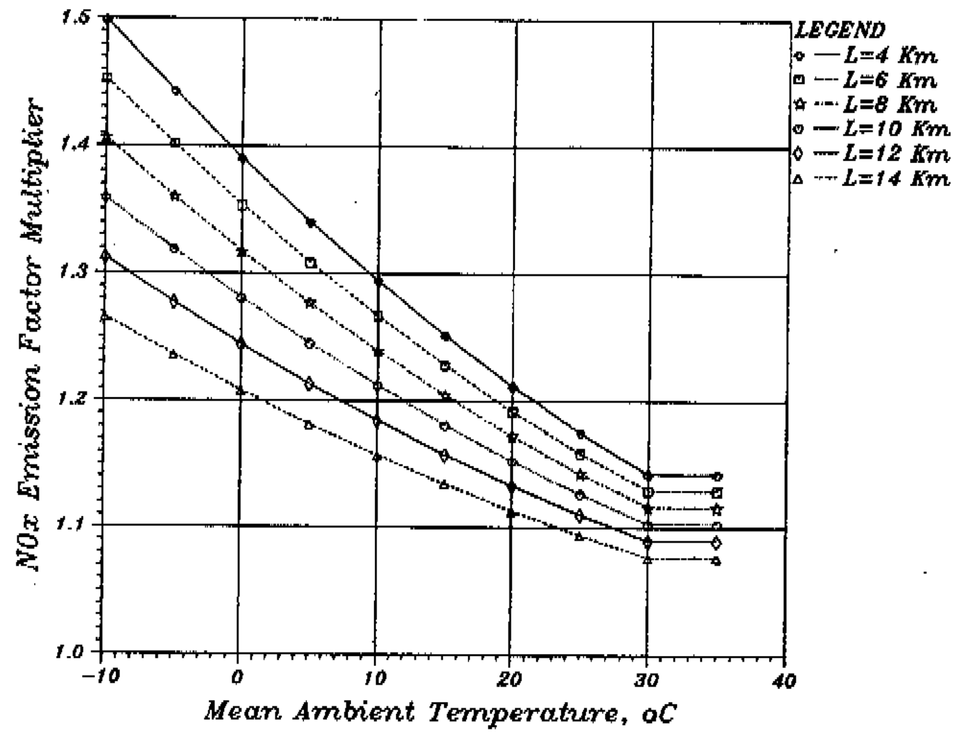

Figure 3.3.2.1-5b NO_x emission factor multiplier for LDGP cars with **3-way open loop catalyst** and < **1400 cc** engine, as function of the average temperature and trip length

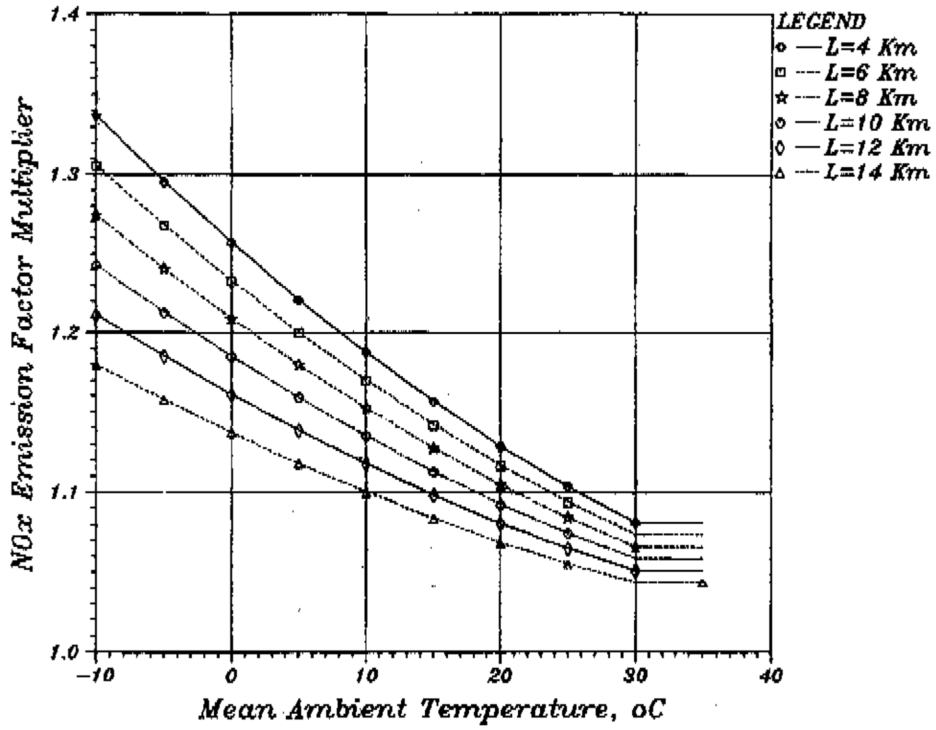

Figure 3.3.2.1-5c **NO_x** emission factor multiplier for LDGP cars with **3-way open loop catalyst** and > **1400 cc** engine, as function of the average temperature and trip length

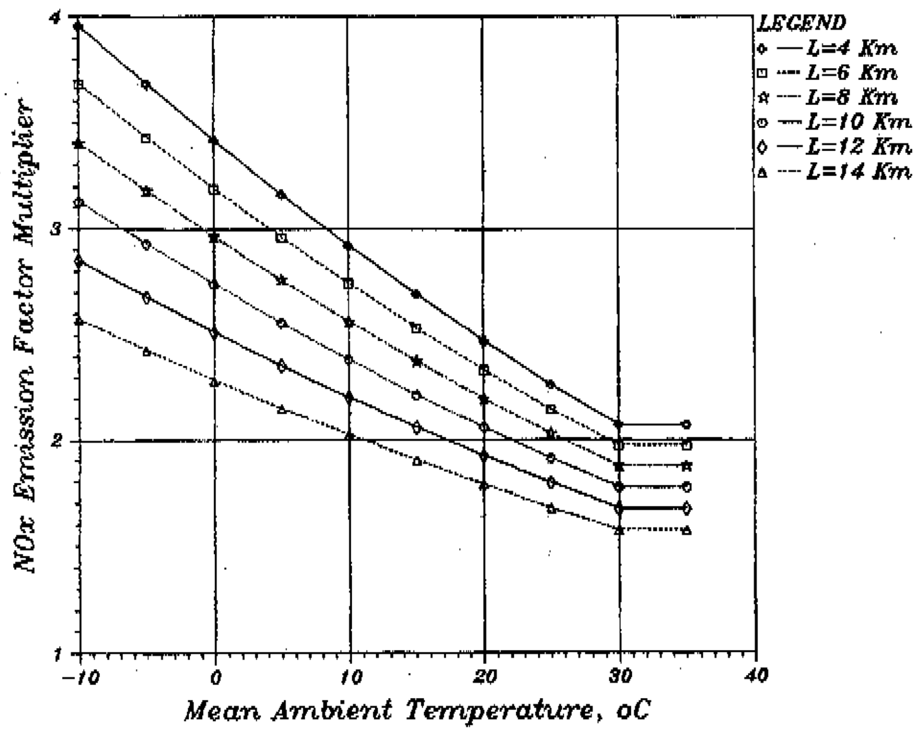

Figure 3.3.2.1-5d **NO_x** emission factor multiplier for LDGP cars with 3-way **controlled** catalyst and < **1400 cc** engine, as function of the average temperature and trip length

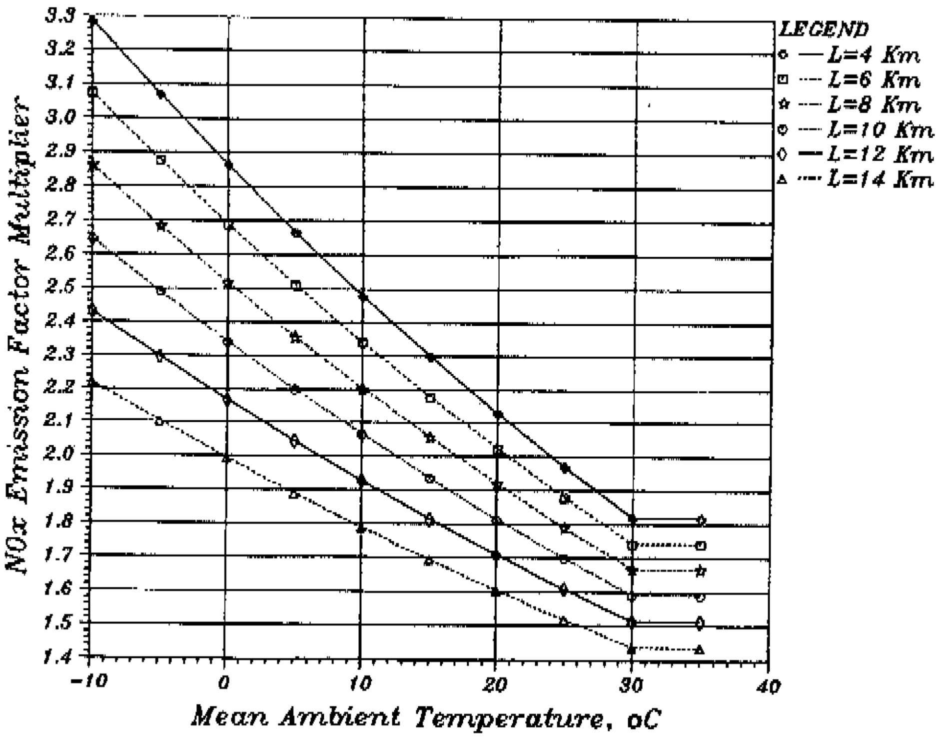

Figure 3.3.2.1-5e **NO_x** emission factor multiplier for LDGP cars with **3-way controlled catalyst** and **> 1400** cc engine, as function of the average temperature and trip length

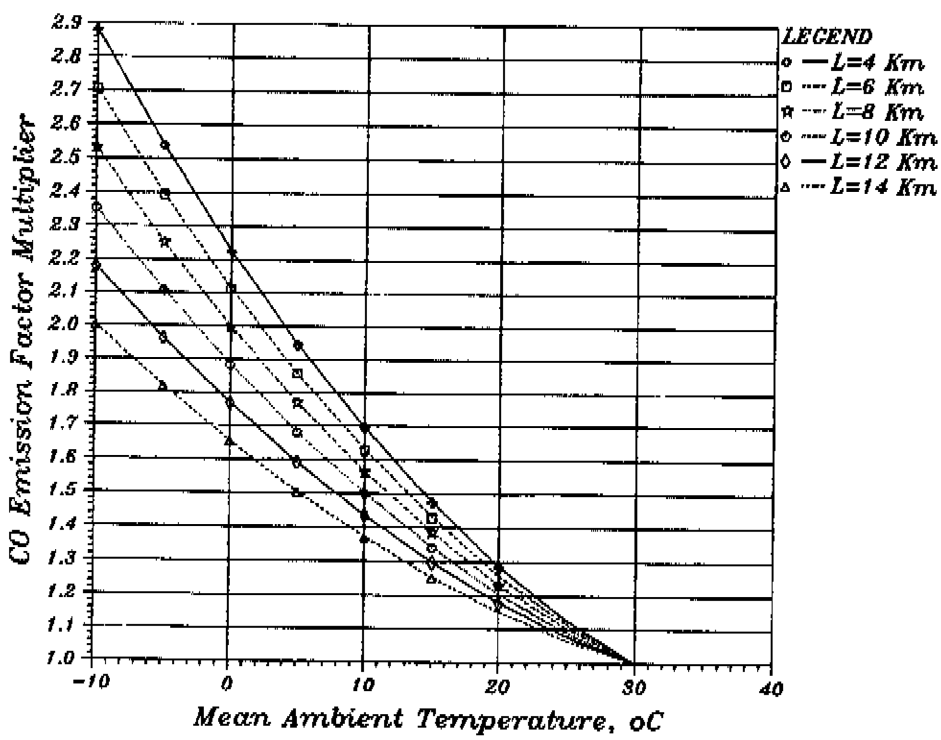

Figure 3.3.2.1-6a **CO** emission factor multiplier for **conventional** (non-catalytic) LDGP cars, as function of the average temperature and trip length

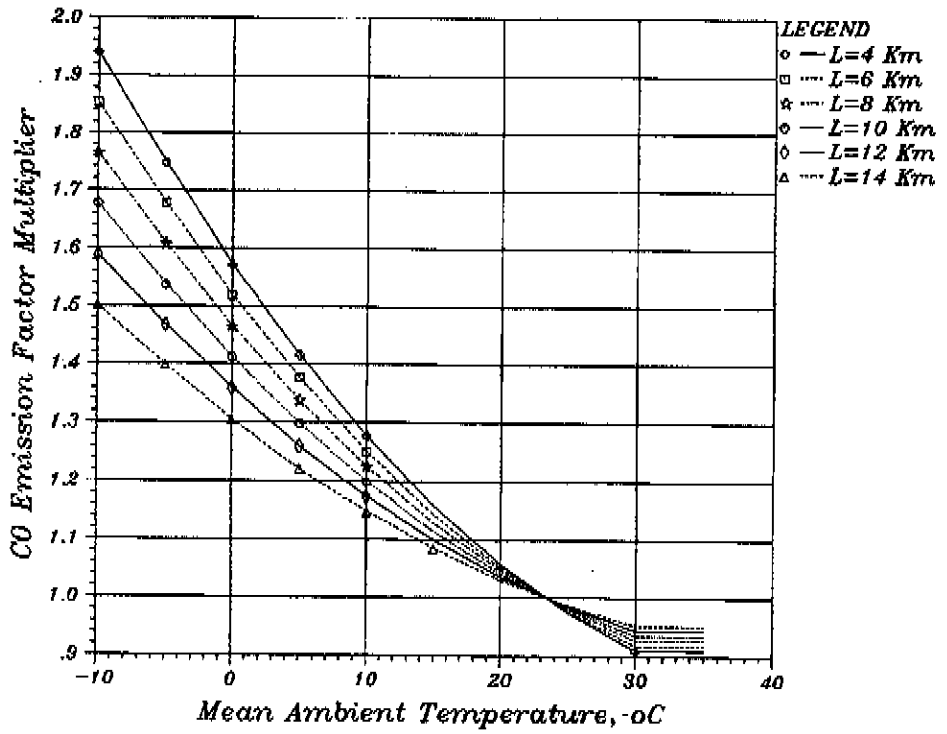

Figure 3.3.2.1-6b CO emission factor multiplier for LDGP cars with **3-way open loop catalyst** and < **1400 cc** engine, as function of the average temperature and trip length

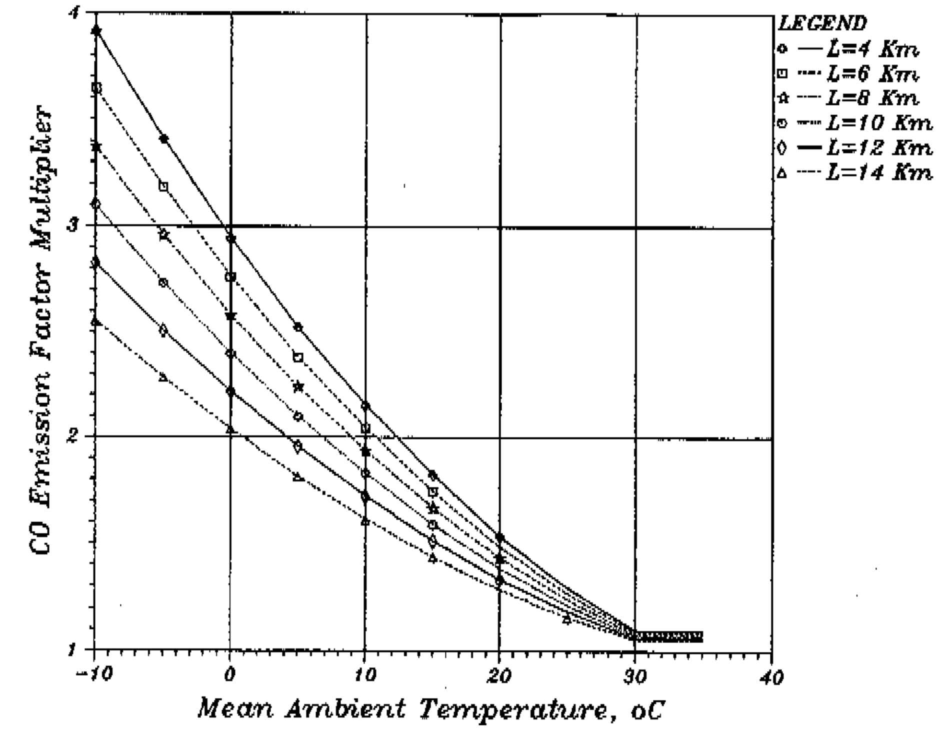

Figure 3.3.2.1-6c CO emission factor multiplier for LDGP cars with **3-way open loop catalyst** and > **1400 cc** engine, as function of the average temperature and trip length

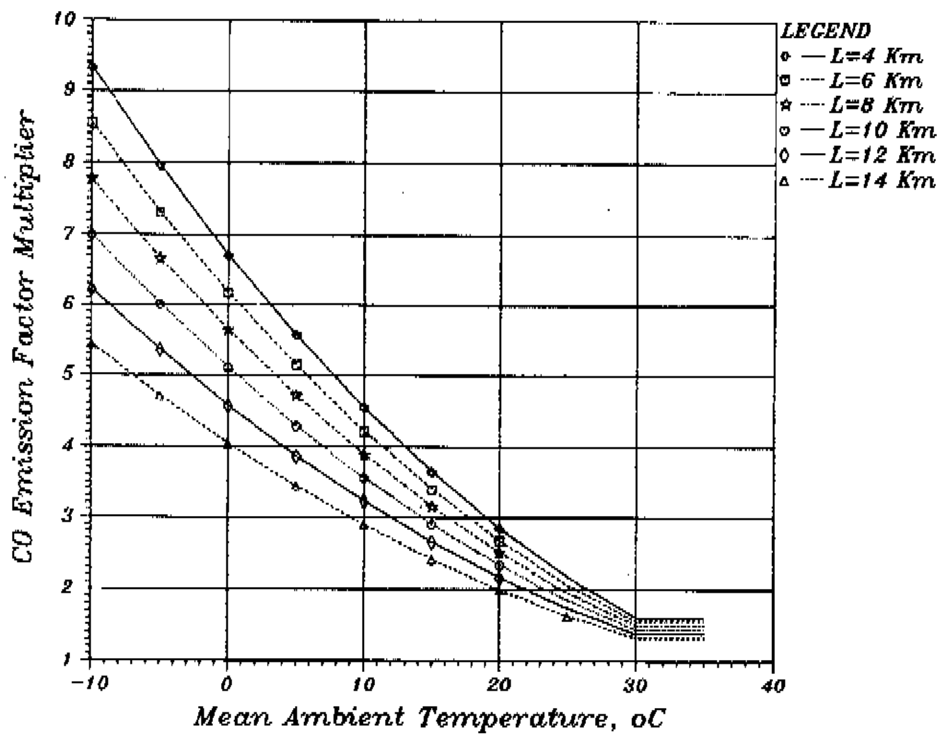

Figure 3.3.2.1-6d **CO** emission factor multiplier for LDGP cars with **3-way controlled catalyst** and < **1400 cc** engine, as function of the average temperature and trip length

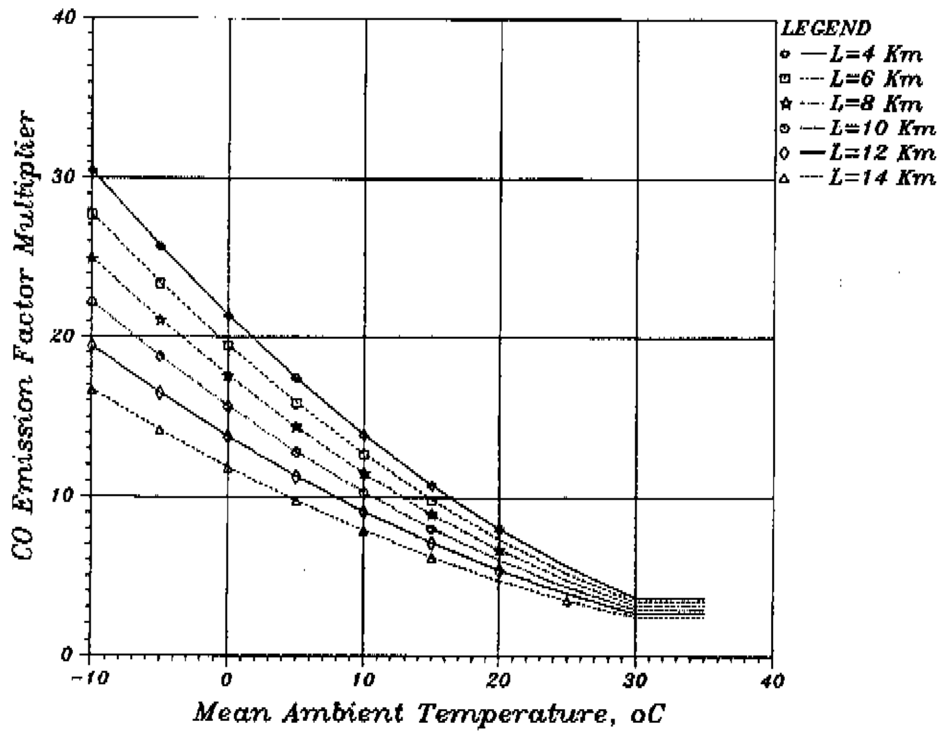

Figure 3.3.2.1-6e **CO** emission factor multiplier for LDGP cars with **3-way controlled catalyst** and > **1400 cc** engine, as function of the average temperature and trip length

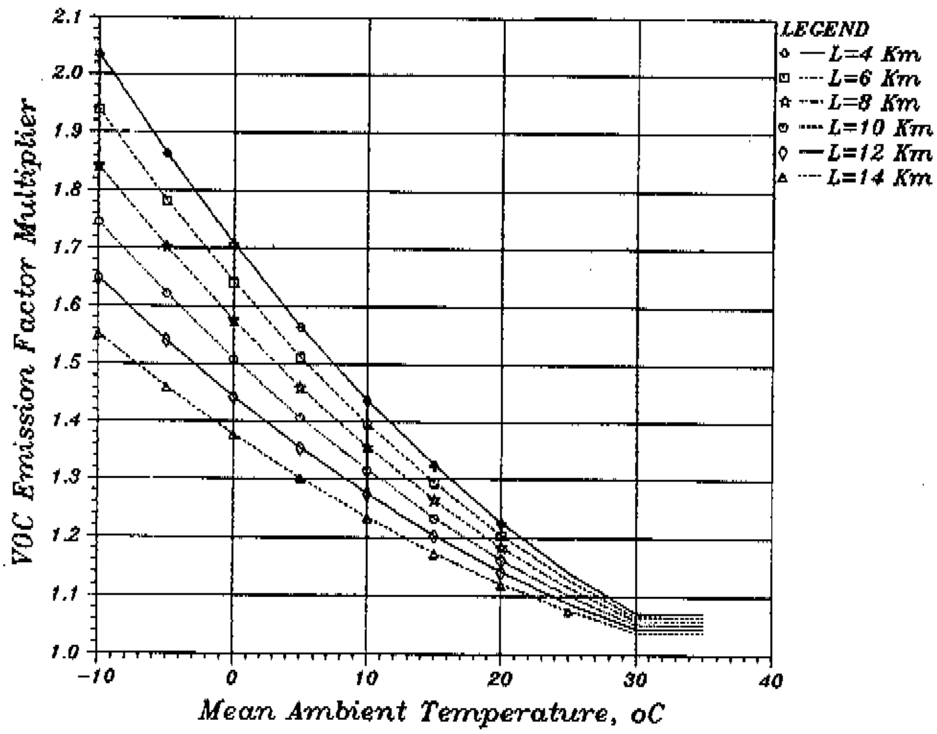

Figure 3.3.2.1-7a **VOC** emission factor multiplier for **conventional** (non-catalytic) LDGP cars, as function of the average daily, seasonal, or annual temperature and trip length

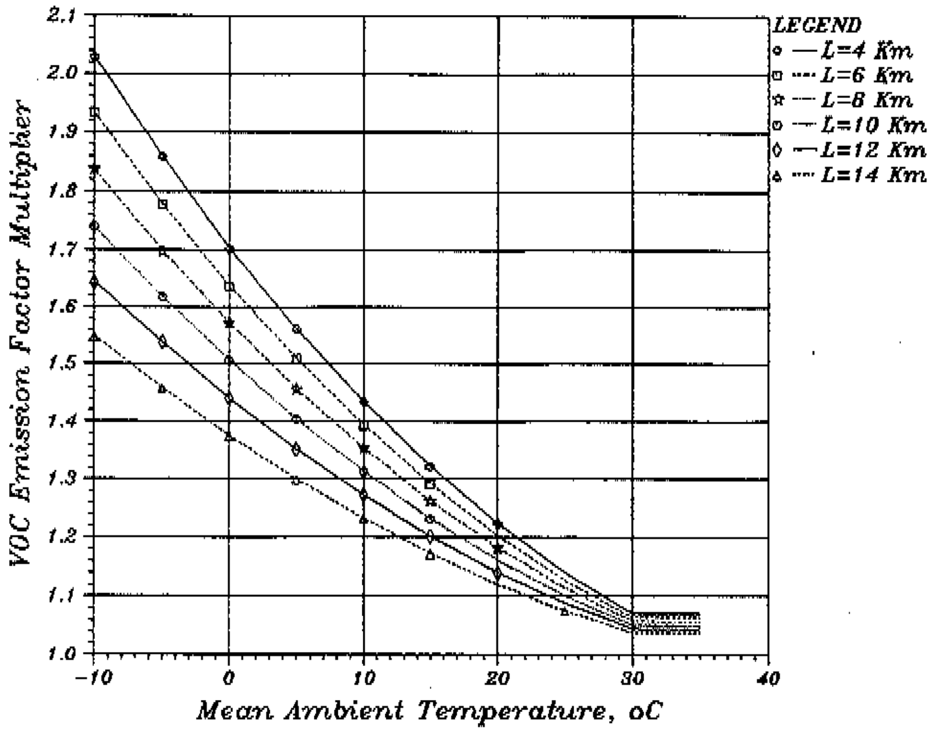

Figure 3.3.2.1-7b **VOC** emission factor multiplier for LDGP cars with **3-way open loop catalyst** and < **1400 cc** engine, as function of the average temperature and trip length

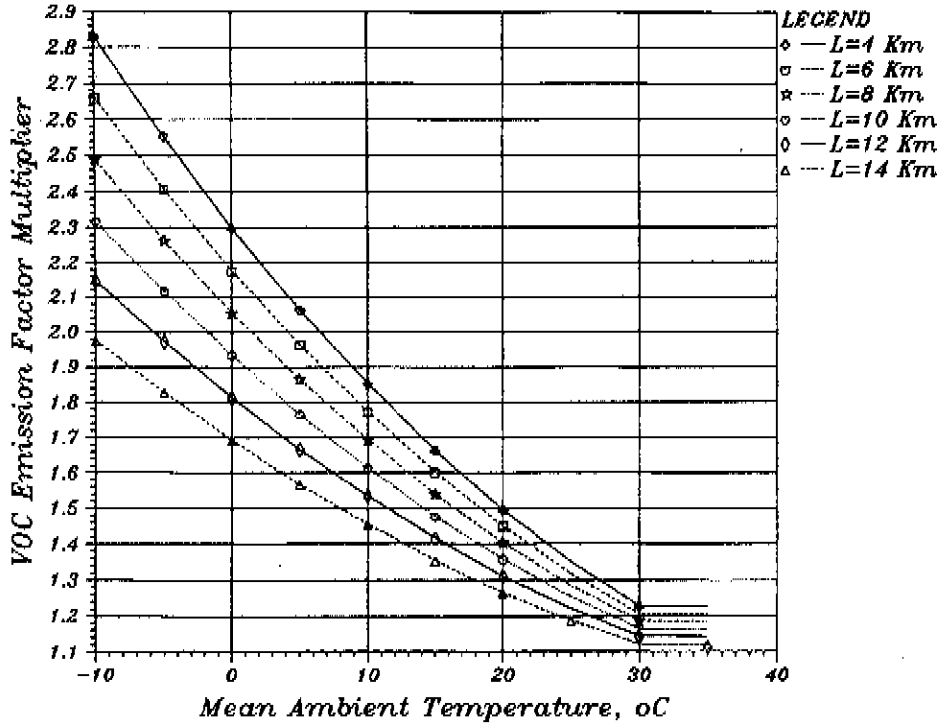

Figure 3.3.2.1-7c **VOC** emission factor multiplier for LDGP cars with **3-way open loop catalyst** and > **1400 cc** engine, as function of the average temperature and trip length

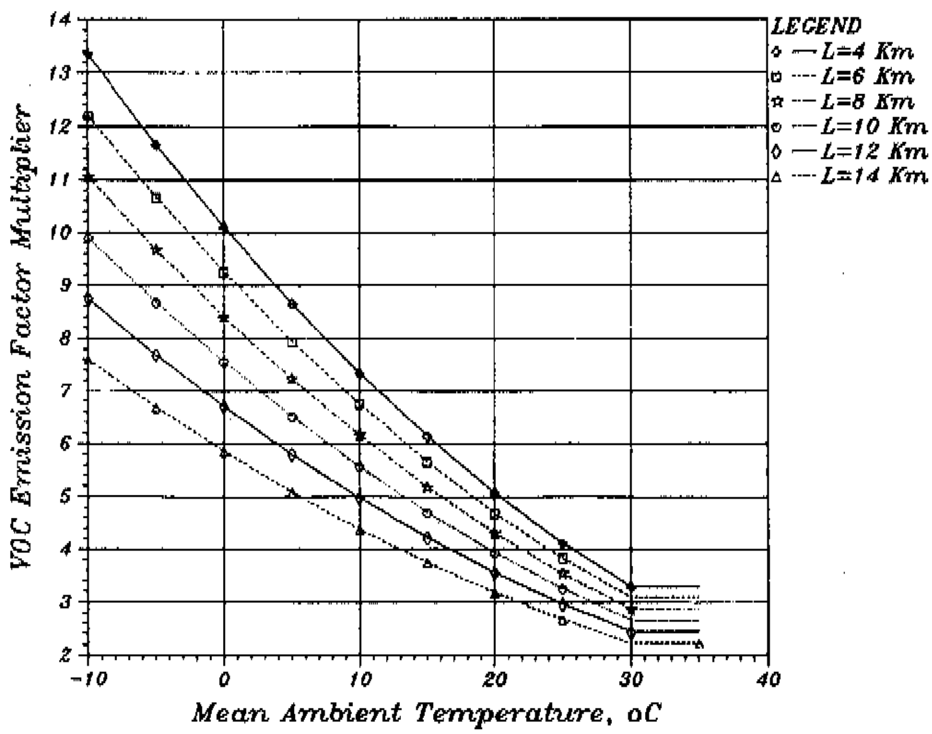

Figure 3.3.2.1-7d **VOC** emission factor multiplier for LDGP cars with **3-Way controlled catalyst** and < **1400 cc** engine, as function of the average temperature and trip length

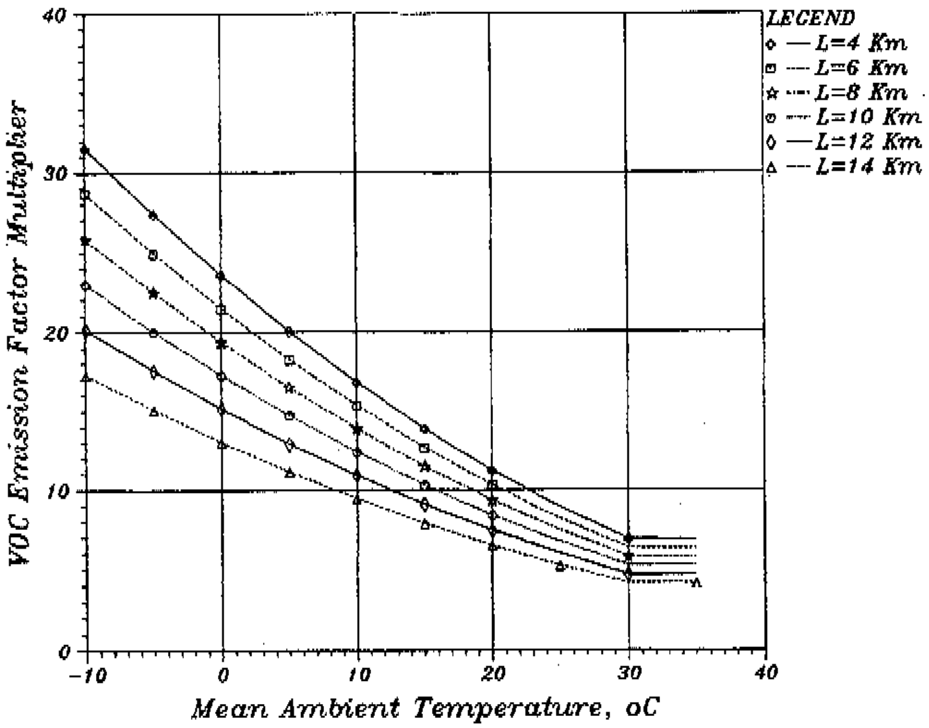

Figure 3.3.2.1-7e VOC emission factor multiplier for LDGP cars with **3-Way controlled catalyst** and > **1400** cc engine, as function of the average temperature and trip length

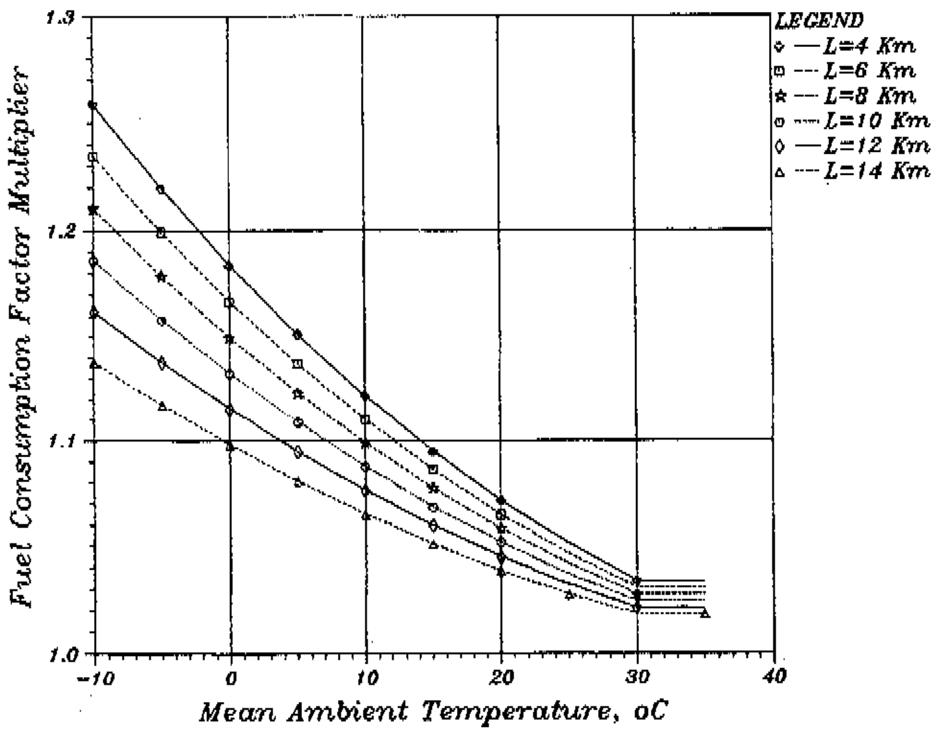

Figure 3.3.2.1-8 **Fuel consumption** factor multiplier for LDGP cars, as function of the average temperature and trip length

3.3.2.2 Example

The Problem:

Assume that we need to compute the NO_x, CO and VOC emission factors, as well as the fuel consumption factor, for small (<1400 cc engines) conventional (non catalytic) cars manufactured in the period 1985-1992.

The factors are to be computed for an average speed of 25 km/h, for a mean ambient temperature of 20 ^oC, for an average trip length of 8 km and for a cold start fraction 0.75 (f_{cs}=0.75).

Solution of the Problem:

From Figure 3.3.2.1-1a we obtain e^{hot} for NO_x 1.5 g/km
From Figure 3.3.2.1-2 we obtain e^{hot} for CO 12.8 g/km
From Figure 3.3.2.1-3 we obtain e^{hot} for VOC 1.89 g/km
From Figure 3.3.2.1-4a we obtain e^{hot} for fuel cons. 59.9 g/km

From Figure 3.3.2.1-5a we obtain $m_{0.75}$ for NO_x 1.00
From Figure 3.3.2.1-6a we obtain $m_{0.75}$ for CO 1.23
From Figure 3.3.2.1-7a we obtain $m_{0.75}$ for VOC 1.18
From Figure 3.3.2.1-8 we obtain $m_{0.75}$ for fuel cons. 1.06

Introducing the above e^{hot} - $m_{0.75}$ pairs in Equation 3.3.2.1-1, along with f_{cs}=0.75, we obtain:

Emission factor for NO_x 1.5 g/km
Emission factor for CO 15.7 g/km
Emission factor for VOC 2.2 g/km
Fuel consumption factor 63.4 g/km

It can be seen that the emission factors listed in Section 3.2.2 are identical to the above. This is because the ambient temperature and the local driving conditions assumed here are the same as the default values used in the model in Section 3.2.2.

3.3.3 The Evaporative VOC Emissions Model

3.3.3.1 Description of the Model

The evaporative VOC emissions model for LDGP vehicles presented in this section is based on the data published by CONCAWE (1987). It should be noted that the factors listed in the inventory model of Section 3.2.2 are based on the CORINAIR study, ECE (1989), and that predictions based on the above data sets differ considerably.

The reason for employing a different data set in our present model than that used in Section 3.2.2, is that the latter allow only a qualitative assessment of the impact of the local climatic and gasoline volatility conditions. In addition, while data from CONCAWE report are rather scant and their extrapolation had to be based on 1970 & 1972 data from the U.S. Bureau of Mines, the origin of the CORINAIR data is rather unclear. In conclusion, the completeness, and probably the accuracy, of both data sets leaves a lot to be desired. Under such conditions, one may wish, to predict the evaporative emissions by both methods so as to have a better idea of the prediction discrepancies, as well as to define the limits of a probable valid range, with the predictions from the CONCAWE set being closer to the lower limit and these from the CORINAIR set to the upper limit. At any rate, the data in the CONCAWE report are better founded and the resulting predictions appear more reasonable.

As in the inventory model of Section 3.2.2, the evaporative VOC emissions have been divided into three categories: The **Hot Soak losses**, which occur when its hot engine is turned off, due to evaporation of fuel, mainly in the carburetor bowl and tank; The **Running Losses**, which occur while the vehicle is being driven; The **Diurnal Losses**, which occur while the vehicle is stationary with its engine off and are due to the expansion and emission of vapour, mainly from the fuel tank, as a result of the daily diurnal ambient temperature variations.

The emission factors for all three categories depend on the average daily, seasonal or annual temperature, T_{mean} in ^{o}C, as well as on the gasoline volatility as expressed by the **R**eid **V**apour **P**ressure, (a standardised vapour pressure measurement, made at 38 ^{o}C with a vapour/liquid ratio 4:1), RVP in kPa. In addition, the Hot Soak emissions per km depend on the average distance a car is driven each time its engine starts, L_{trip} in km, while the Diurnal Losses depend on the average daily temperature variation for the day, season or year of reference, DT in ^{o}C.

The emission factors for the Hot Soak and Running losses are listed in Table 3.3.3.1-1 below as a function of the T_{mean}, gasoline RVP and L_{trip} as gr/km (or as kg/1000 km). The listed figures were derived from the original data given in the CONCAWE report and were converted in a form compatible with that in Table 3.2.2.

The emission factor for the diurnal losses, $e_{diurnal}$, expressed as kg/(car*year), can be easily computed from Equation (3.3.3.1-1) below:

$$e_{diurnal} = -9.125+0.1862*DT+0.2263*(T_{mean}+DT/2)+0.0803*RVP \quad (3.3.3.1\text{-}1)$$

The predictions from the above model apply for cars with carburettors and with no evaporative controls.

Table 3.3.3.1-1 Hot Soak and Running Losses as Function of Climatic Conditions & Gasoline Volatility for LDGP cars

T_{mean} °C	RVP 60 kPa gr/km	RVP 70 kPa gr/km	RVP 80 kPa gr/km	RVP 90 kPa gr/km	RVP 100 kPa gr/km	RVP 120 kPa gr/km
Small Cars (< 1400 cc)						
Hot Soak Emissions						
-10.0				.765/L_{trip}	1.00/L_{trip}	1.59/L_{trip}
- 5.0				.824/L_{trip}	1.03/L_{trip}	1.47/L_{trip}
- 0.5		.412/L_{trip}	.647/L_{trip}	.824/L_{trip}	1.09/L_{trip}	1.79/L_{trip}
3.5		.441/L_{trip}	.676/L_{trip}	.882/L_{trip}	1.24/L_{trip}	2.06/L_{trip}
8.0	.500/L_{trip}	.529/L_{trip}	.794/L_{trip}	1.03/L_{trip}		
12.5	.706/L_{trip}	.706/L_{trip}	1.03/L_{trip}			
17.0	.971/L_{trip}	1.12/L_{trip}	1.59/L_{trip}			
21.5	1.38/L_{trip}	1.94/L_{trip}	2.47/L_{trip}			
Running Losses						
-10.0				0.0125	0.0175	0.0274
- 5.0				0.0125	0.0175	0.0299
- 0.5		0.0075	0.01	0.015	0.02	0.0324
3.5		0.0075	0.0125	0.015	0.02	0.0349
8.0	0.0075	0.01	0.0125	0.0175		
12.5	0.0125	0.0125	0.0175			
17.0	0.0175	0.02	0.0274			
21.5	0.02	0.03	0.052			
Large Cars (> 1400 cc)						
Hot Soak Emissions						
-10.0				1.47/L_{trip}	1.76/L_{trip}	2.44/L_{trip}
- 5.0				1.47/L_{trip}	1.94/L_{trip}	2.94/L_{trip}
- 0.5		.794/L_{trip}	1.24/L_{trip}	1.71/L_{trip}	2.21/L_{trip}	3.53/L_{trip}
3.5		.853/L_{trip}	1.35/L_{trip}	1.88/L_{trip}	2.50/L_{trip}	4.24/L_{trip}
8.0	.882/L_{trip}	.971/L_{trip}	1.56/L_{trip}	2.29/L_{trip}		
12.5	1.15/L_{trip}	1.29/L_{trip}	2.00/L_{trip}			
17.0	1.59/L_{trip}	1.94/L_{trip}	2.94/L_{trip}			
21.5	2.21/L_{trip}	3.18/L_{trip}	4.44/L_{trip}			
Running Losses						
-10.0				0.033	0.04	0.056
- 5.0				0.033	0.047	0.066
- 0.5		0.02	0.027	0.04	0.05	0.083
3.5		0.02	0.03	0.043	0.056	0.1
8.0	0.02	0.023	0.037	0.053		
12.5	0.023	0.03	0.047			
17.0	0.033	0.047	0.066			
21.5	0.05	0.073	0.096			

3.3.3.2 Example Application

The Problem:

Compute the annual mean emission factors for Hot Soak, Running Losses and Diurnal Losses, as well as the annual evaporative emissions from the LDGP car fleet in Athens using the Models of Section 3.2.2 and 3.3.3.1 for both small and large cars.

The following climatological and gasoline volatility data are given:

Country:	Greece
City:	Athens
Vehicles:	950,000 (80% with engines < 1400 cc)
Milage:	8,000 km/yr (within the city)
T_{mean}:	17.4 °C
DT:	10.0 °C
L_{trip}:	8 km
RVP:	70 kPa (65 kPa from 1/4-31/10 & 80 kPa from 1/11-31/3)
Note:	Cars with carburettors and with no evaporative controls can be assumed

Solution of the Problem:

From Table 3.2.2 we get both the emission factors, as well as the correction factors for Greece as follows:

$$e_{hot\text{-}soak} = (9.4/8)*1.2 = 1.41 \text{ gr/km}$$
$$e_{running} = 0.55*1.2 = 0.66 \text{ gr/km}$$
$$e_{diurnal} = 2.635*2.1 = 5.53 \text{ kg/car-year}$$

From the above emission factors, the number of cars and the annual milage we get:

$$E_{hot\text{-}soak} = 1.41*8000*950000/10^6 = 10716 \text{ tn/yr}$$
$$E_{running} = 0.66*8000*950000/10^6 = 5016 \text{ tn/yr}$$
$$E_{diurnal} = 5.53*950000/10^3 = 5253 \text{ tn/yr}$$

Total Evaporative **20985** tn/yr

From Table 3.3.3.1-1 and Equation (3.3.3.1-1) we can obtain the sought emission factors for the given T_{mean}, DT, L_{trip} and gasoline RVP values as follows:

For small cars (< 1400 cc):

$e_{hot-soak}$ = (1.12/8) = 0.14 gr/km
$e_{running}$ = 0.02 gr/km

For large cars (> 1400 cc):

$e_{hot-soak}$ = (1.94/8) = 0.242 gr/km
$e_{running}$ = 0.047 gr/km

For both small & large cars

$e_{diurnal}$ = -9.125+0.1862*10+0.2263*(17.4+5)+0.0803*70
= 3.43 kg/car-year

From the above emission factors, the number of cars and the annual mileage we get:

For small cars (< 1400 cc):

$E_{hot-soak}$ = $0.14*8000*760000/10^6$ = 851 tn/yr
$E_{running}$ = $0.02*8000*760000/10^6$ = 122 tn/yr

For large cars (> 1400 cc):

$E_{hot-soak}$ = $0.242*8000*190000/10^6$ = 368 tn/yr
$E_{running}$ = $0.047*8000*190000/10^6$ = 71 tn/yr

For both small & large cars

$E_{diurnal}$ = $3.43*950000/10^3$ = 3259 tn/yr

Total Evaporative **4671** tn/yr

Comparison of the predictions between the two models shows considerable discrepancies, the CORINAIR data set yielding 20985 tn/yr and the CONCAWE data set 4671 tn/yr. The latter appears closer to reality.

3.4 Model for the Flue Gas Volume from External Combustion Sources

3.4.1 Introduction

The emphasis so far in this section is in the presentation of models allowing the assessment of the emission loads from a given source. Loads alone however, may not be sufficient for estimating the impact of the sources in the environment.

Indeed, the following additional information is required for the application of air quality models in the case of point sources (see Section 8.2):

Exit gas volume,
Exit gas temperature,
Stack physical height,
Stack internal diameter,

For area sources (e.g. road traffic, space heating furnaces, small industrial activities etc), the relevant information is somewhat relaxed as only the release height is required.

This section presents a model which allows convenient assessment of the flue gas volume from external combustion sources as a function of the easily measured (or assumed) CO_2 concentration. As the vast majority of point sources for which air quality models are applied, are industrial or utility boilers, the material presented here should cover a significant part of the gas volume data requirements.

3.4.2 Description of the Model

The major parameters which affect the normalized flue gas volume (actual m^3/s at 200 ^oC per ton/hour of ash free and moisture free fuel used) are the fuel type and the CO_2 concentration in the flue gas.

The fuel type defines to a large extent the fractions of the Carbon, Hydrogen, Oxygen and other elements which are present in the fuel and as such affects, through the reactions that take place during the combustion, the volume of the flue gas.

The CO_2 concentration is a good indicator of the excess air used, as the excess air dilutes the CO_2 combustion product. The lower the CO_2 concentration, the higher the excess of air used and the larger the volume of flue gas.

A quantitative expression of the above dependencies is provided by the graphs in Figures 3.4.2-1 to 3.4.2-5, produced with the help of a boiler simulation model, and which, for various common fuels allows direct reading of the normalized flue gas volume as a function of the CO_2.

In cases where CO_2 measurements are not available, one can always make an assumption considering the following maximum CO_2 concentrations (corresponding to combustion zero excess air), the type and size of boiler, and the operating procures:

Table 3.4.2-1 Maximum CO_2 concentration in the flue gas for various fuels

Fuel type	Maximum CO_2 (Vol %, Dry Basis)
Natural Gas (NG) or Liquefied Natural Gas (LNG)	12.2
Liquefied Petroleum Gas	12.2
Distillate Fuel Oil	13.94
Residual Fuel Oil	15.7
Meta Anthracite Coal	19.6
Anthracite Coal	19.6
Semi Anthracite Coal	19.1
Bituminous Low Volatility Coal	18.7
Bituminous Medium Volatility Coal	18.5
Bituminous High Volatility Coal	18.4
Subbituminous Coal	19.15
Lignite	19.35
Peat	19.

Large industrial and utility boilers under close supervision operate with 10 to 20% excess air. Poorly operated boilers, or some types of boilers where control is difficult (e.g. underfed stokers or hand fired units) may operate with much higher percentages of excess air.

For the limiting $(CO_2)_{max}$ concentration from Table 3.4.2-1 above and for any assumed Excess Air percentage, the corresponding CO_2 concentration can be computed from the following relation:

$$CO_2 = \frac{7900*(CO_2)_{max}}{(\text{Excess Air Used, \%})*(100-(CO_2)_{max}) + 7900} \quad (3.4.2\text{-}1)$$

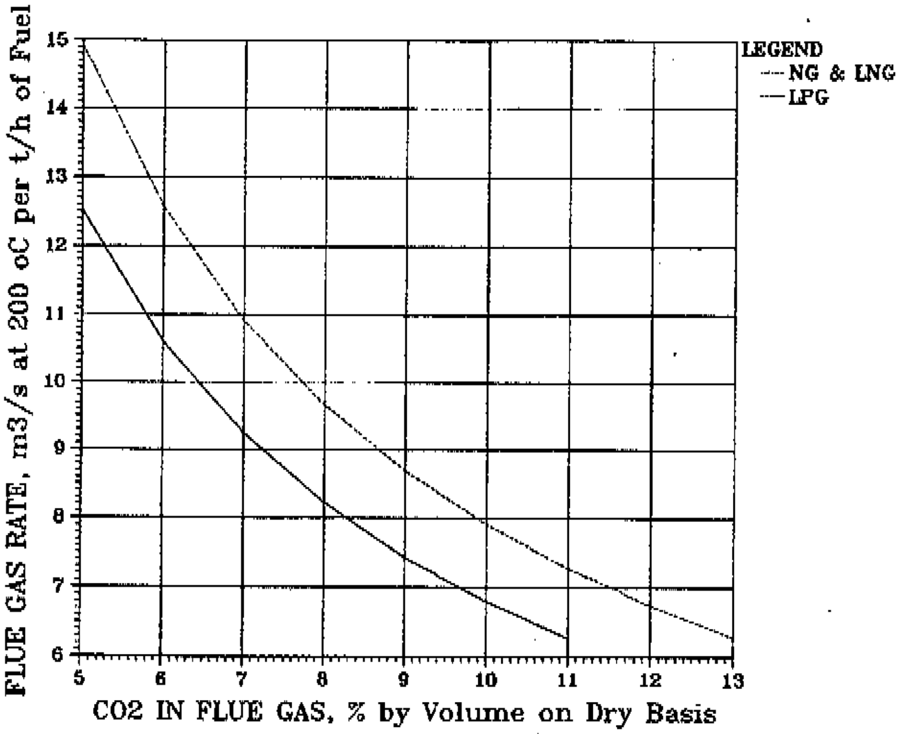

Figure 3.4.2-1 Flue gas volume from external combustion sources firing Natural Gas (NG), Liquefied Natural Gas (LNG) or Liquefied Petroleum Gas (LPG), as function of the CO_2 concentration (volume % on a dry basis) in the flue gas.

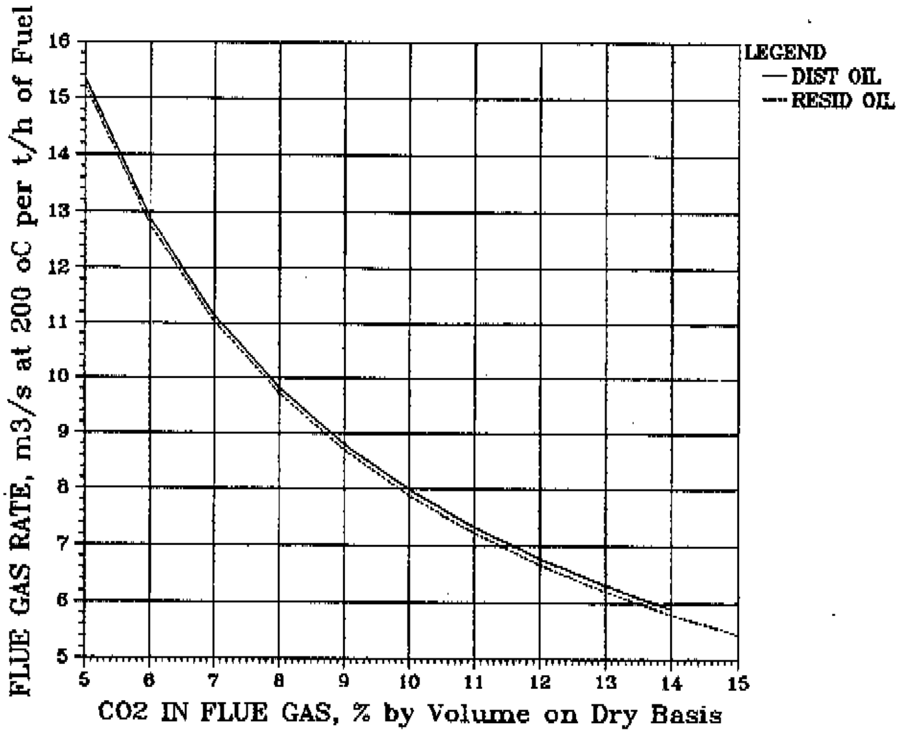

Figure 3.4.2-2 Flue gas volume from external combustion sources firing Distillate and Residue Fuel Oil, as function of the CO_2 concentration (volume % on a dry basis) in the flue gas.

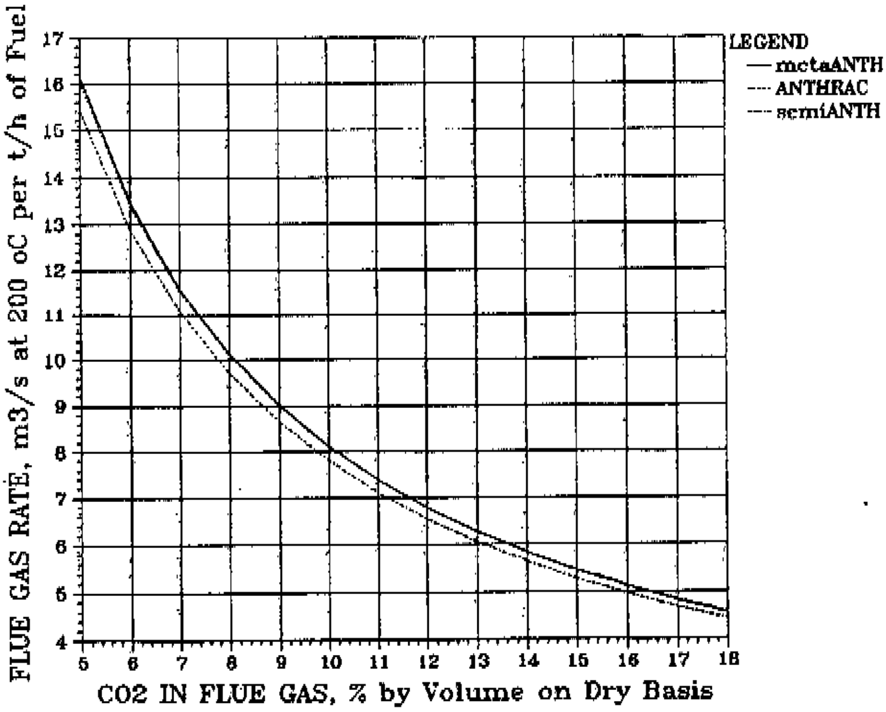

Figure 3.4.2-3 Flue gas volume from external combustion sources firing Meta Anthracite, Anthracite of Semi Anthracite coal, as function of the CO_2 concentration (volume % on a dry basis) in the flue gas. The quantity of coal is on an ash free and moisture free basis.

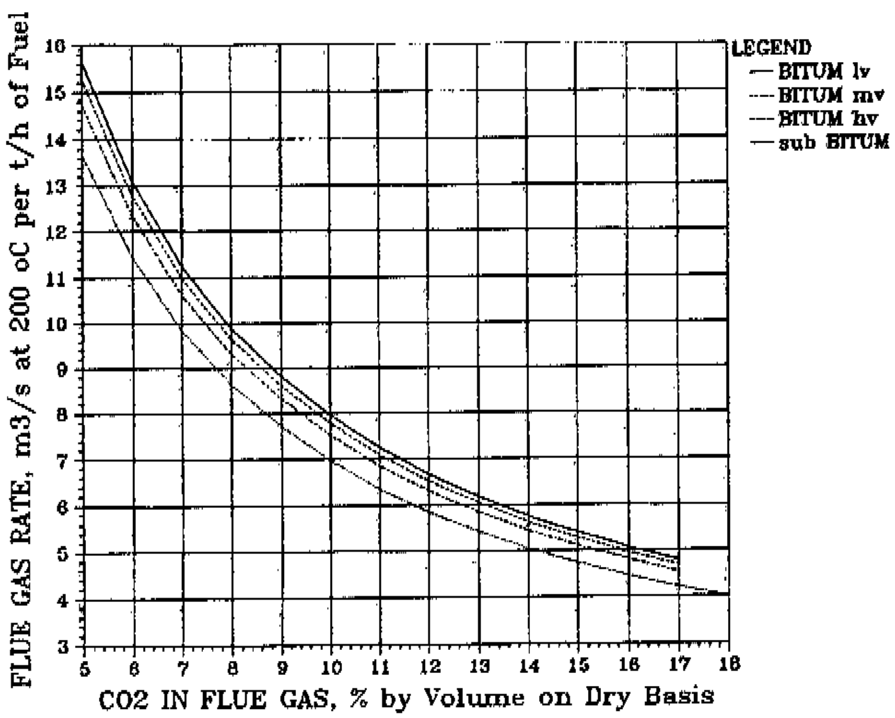

Figure 3.4.2-4 Flue gas volume from external combustion sources firing Bituminous Coal of low, medium, or high volatility (Legend: BITUM lv, mv and hv respectively), and Subbituminous Coal, as function of the CO_2 concentration (volume % on a dry basis) in the flue gas. The quantity of coal is on an ash free and moisture free basis.

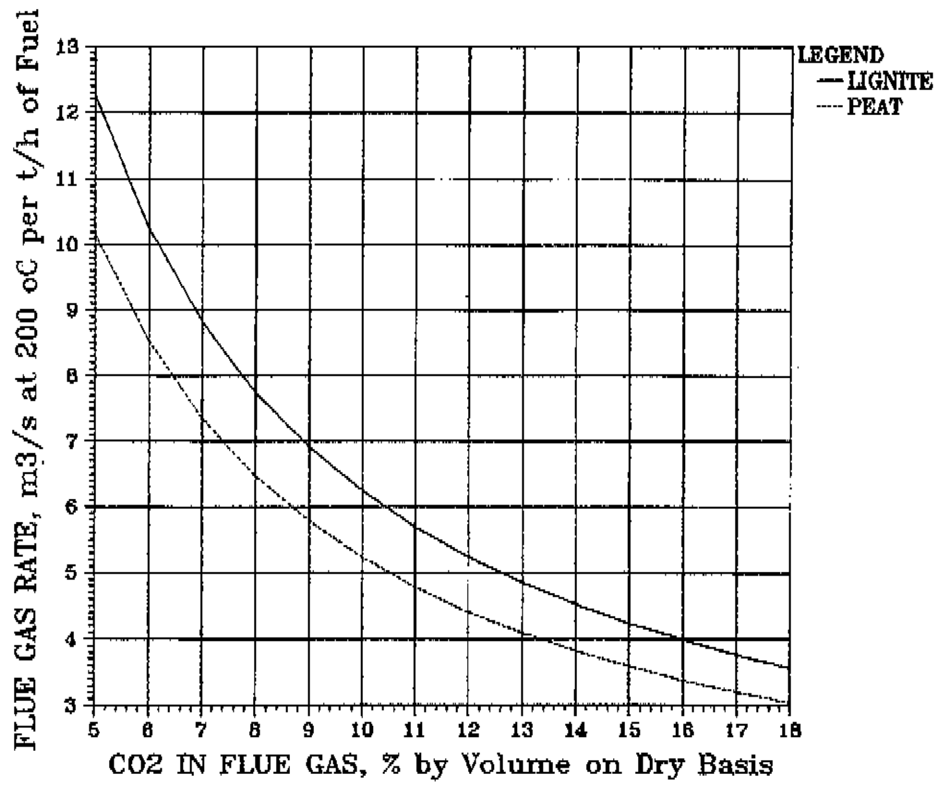

Figure 3.4.2-5 Flue gas volume from external combustion sources firing Lignite and Peat, as function of the CO_2 concentration (volume % on a dry basis) in the flue gas. The quantity of coal is on an ash free and moisture free basis.

3.4.3 Example

The Problem:

A utility boiler firing residue fuel oil consumes 37.5 tons of fuel per hour. Compute the actual flue gas volume for an exit gas temperature of 180 ^oC.

Solution of the Problem:

As the CO_2 concentration in the flue gas is not given, it will have to be assumed. The boiler is large and is firing oil. Under the circumstances we can assume an operation with excess air of about 10%.

From Table 3.4.2-1 the limiting CO_2 concentration is 15.7 %.

From Equation 3.4.2-1 we compute that for 10 % excess air the corresponding CO_2 concentration 14.2%.

From Figure 3.4.2-2 we obtain that the normalized flue gas volume is 5.7 (Am3/s at 200 ^oC per ton/h of fuel used).

Considering that the boiler uses 37.5 tons/hour of fuel, the actual flue gas volume at 180 ^oC is then 5.7*37.5*(273+180)/(273+200) = 205 Am^3/s.

3.5 Model for the Temperature Drop Through Stacks

3.5.1 Introduction

The need to assess the flue gas exit volume and temperature so as to be able to use air quality models has been discussed in Section 3.4.1.

From the nature of the source, or through direct measurement, the temperature is usually known, at the boiler exit or at stack entrance point. For the application of the dispersion models however, we need to know the gas temperature at the stack exit point and also therefore the temperature drop of the gas as it passes through the stack.

3.5.2 Description of the Model

A fair number of parameters affect the temperature drop through the stack, such as the composition of the gas, the length and the diameter of the stack, the gas rate and the gas temperature at the stack entry point, the ambient air temperature, the stack thermal insulation etc.

To simplify the procedure and to present the results in graphic and easy to use form, some simplifying assumptions have to be made. The most important one is the assumption of 2.5 cm of fibreglass equivalent insulation in cases of insulated stacks. The results are plotted in Figures 3.5.2-1 and 3.5.2-2 and allow direct reading of the normalized âT (temperature drop per 10 m of stack height when the temperature difference between the inlet gas and the ambient air is 180 ^oC (inlet gas temperature 200 ^oC and ambient air temperature 20 ^oC)).

The graphs were produced with the help of a stack model which, depending on the physical stack dimensions and the presence or absence of insulation, it computes through an iterative scheme the temperature and the velocity profiles, the physical properties of the flowing gas, and the heat transfer rates, so as to eventually yield the exit gas temperature and the corresponding normalized temperature drop.

In order to use the graphs correctly, the following procedure can be used:

(a) Compute the exit gas volume at 200 ^oC
(b) Use Figures 3.5.2-1 or 3.5.2-2 to obtain the normalized ΔT.

(c) Compute the actual ΔT through the entire stack length from Equation:

$$\Delta T = (\Delta T)_{normalized} \frac{(\text{Stack height, m})}{10} \frac{(T_{inlet\ gas} - T_{air})}{180.} \qquad (3.5.2\text{-}1)$$

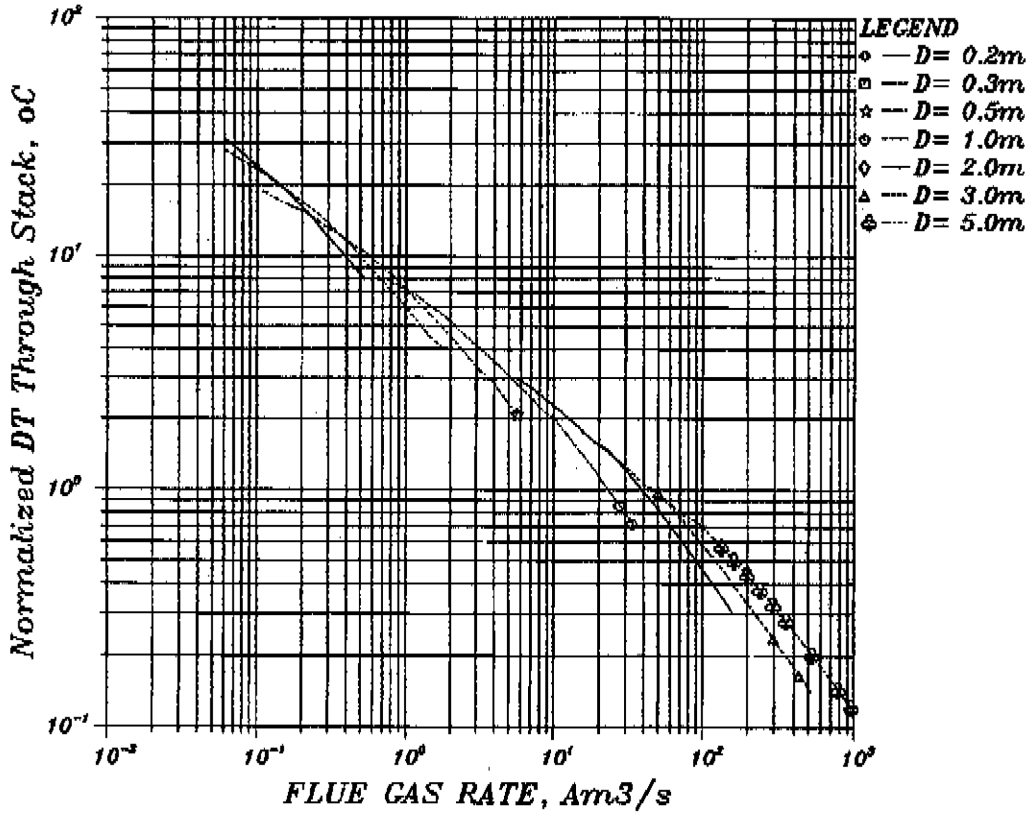

Figure 3.5.2-1 Normalized temperature drop though **non-insulated** stacks (temperature drop per 10 m of stack height when the temperature difference between the inlet gas and the ambient air is 180 °C) as function of the flue gas rate, stack physical height and stack inside diameter.

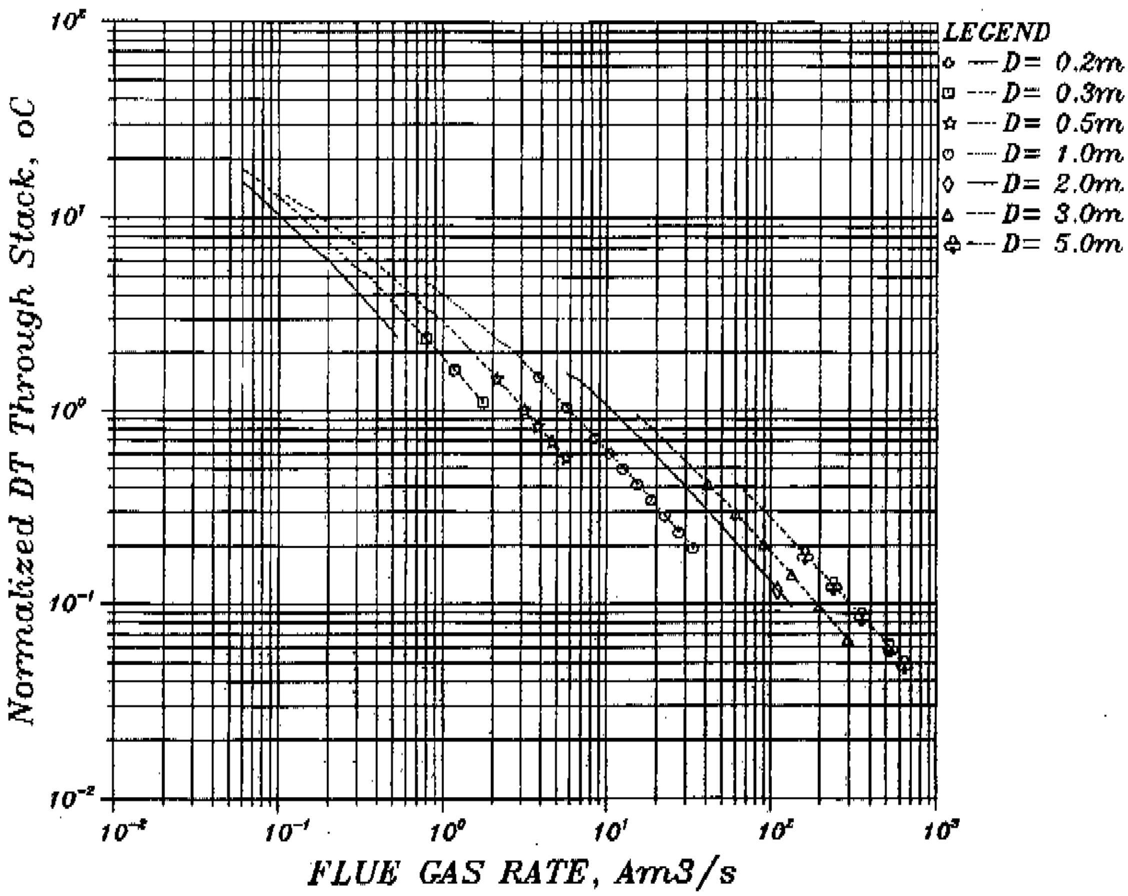

Figure 3.5.2-2 Normalized temperature drop though insulated stacks (temperature drop per 10 m of stack height when the temperature difference between the inlet gas and the ambient air is 180 °C) as function of the flue gas rate, stack physical height and stack inside diameter.

3.5.3 Example

Problem:

The gas from the utility boiler considered in the example in Section 3.4.3 goes though a non-insulated stack of 5 m in diameter and 150 m height before being released into the atmosphere.

Compute the temperature of the gas at the exit point when the temperature at the inlet point is 180 °C and the ambient air temperature is -10 °C.

Solution:

In Section 3.4.3 we calculated that the exit gas volume at 180 °C is 205 Am^3/s. The gas volume at 200 °C is 205*(273+200)/(273+180)=214 Am^3/s.

Figure 3.5.2-1 yields $(\Delta T)_{normalized}$=0.4

Equation 3.5.2-1 yields $\Delta T = 6.5\ ^{o}C$. The exit gas temperature is thus $180-6.5=173.5\ ^{o}C$.

It should be noted that considerably higher temperature drops are obtained in the case of smaller boilers, where the ratio of stack surface to gas rate is much higher.

3.6 Bibliography

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CHAPTER 4

LIQUID WASTE INVENTORIES AND CONTROLS

4.1 Compilation of Liquid Waste Inventories Under Present and/or Strategy Target Conditions

The liquid waste loads and controls model given in Section 4.2.2 provides four columns listing the conventional pollutants BOD_5, SS, Total N, and Total P, as well as a sixth column reserved for toxic and other important substances, as the case may be for each source considered. In addition to the above, the model in Section 4.2.2 is supplemented by Tables 4.2.2-1 to 4.2.2-5, providing more detailed data and information about waste load factors and treatment efficiencies for municipal wastewaters (SIC 920), waste load factors for rain and land runoff, control efficiencies for agricultural industries (SIC 1110 to 1134), and the composition of leachates from municipal solid waste landfill sites.

In the model in Section 4.2.2, if a waste load factor does not appear in the appropriate place in the table, this usually (but not always) means that its value is either small or zero. However, lack of a penetration factor does not mean zero penetration, but rather that the value of this factor is not known. Missing waste load and/or penetration factors for the sources and pollutants of interest could be completed by the study team on the basis of information which might be available from literature or other sources in the study area.

The procedural aspects of the calculation of liquid loads released from various sources in the study area are presented in Section 2.3 and demonstrated through an example in Section 4.2.4.

Before concluding the discussion on liquid waste inventories, some reference to the important category of distributed sources is warranted. Indeed, such sources are known to significantly affect the quality of water receivers, especially surface ones. The nature of runoff water from various types of land (urban, forest, pasture, agricultural) is addressed through the data in Table 4.2.2-3, and factor ranges are provided to give an idea of the rather significant variations encountered from North American and European areas. Even wider variations could be expected from areas with different rain patterns, different fertiliser use, different vegetation and soil types, different population densities, different street cleaning procedures, etc.

The above information allows users to make preliminary assessments of the polluting loads from land runoff, and this facilitates the preliminary analysis of lake or river pollution problems. As these water bodies provide the natural drainage of large catchment basins, the contribution of the surface and underground water runoff to their pollution problems is often dominant. It should be added that rain runoff from urban areas emerges as a significant, if not a dominant, source of pollution in cases where municipal effluents are treated.

In conclusion, the assessment of the polluting loads from land runoff should be viewed only as a preliminary indication of the magnitude of the problem. In cases where sources of this kind appear significant, more detailed analysis may be necessary.

4.2 Model for Compiling Liquid Waste Inventories and Assessing the Effectiveness of Applicable Controls

4.2.1 Introduction

The quantities of effluent loads released into the environment from urban areas or any industrial or other activity depend, in the general case, on a number of parameters. Thus, as in the case of effluents, the load E of pollutant j could be expressed in a mathematical form as follows:

E_j = f(Source type, (4.2.1-1)
Unit of activity,
Source size,
Process or design particularities,
Source age and technological sophistication,
Source maintenance and operating practices,
Type and quality of the raw materials used,
Type, design and age of the control systems employed,
Ambient conditions,
etc.)

The source type defines the kind of pollution generating activity in somewhat broad terms, e.g. poultry processing or beer production. More precise definition is provided through other parameters as discussed below. Obviously, the source type is closely related to the types and to the quantities of pollutants generated.

From the source type information alone, it is possible to exclude, right from the start, numerous activities with relatively minor effluent problems and in this way, to simplify significantly the source inventory and liquid waste management tasks.

The unit of activity, defines an acceptable way of expressing the magnitude of a given source. Suitably defined units can be used to provide a measure of the source (e.g. population of an urban area) or the activity of an industry (raw materials consumed, or products manufactured).

Selection of the most suitable unit for each type of activity is important, as the unit must have a direct relation to the effluent loads generated, and must offer convenience in obtaining the required data during the field work. For example, the magnitude of a tannery source could be characterized by the electricity or the water consumed, by the number of people employed, by the land area occupied, or by the quantities of the hides processed. The latter is much closer related to the effluent loads generated, can be easily obtained, both during plant survey visits and from government sources (usually as a compounded total for all tanneries), and is thus the unit of choice.

Source size, although a key parameter, is only indirectly related to the normalized load rates (pollutant loads per unit of activity). In general, economies of scale allow better design and operation, as well as stricter effluent controls for larger size units. Moreover, for industrial sources, selection of the particular process to be used is some times dictated by plant size. It is for these reasons that effluent standards are generally significantly stricter for large plants.

In the context of the present methodology the effects of plant size on the normalized loads can be taken into consideration only in cases where the source size affects the process selection.

Process or design particularities depend on local factors and on the source size, and may affect the kinds and to the quantities of pollutants generated from industrial sources. For example, depending on the country and on the size of the factory, different processes with different design features are likely to be involved in textile finishing mills.

Little information is available in the literature so as to allow quantification of the impact of such effects on the normalized loads generated from a particular source.

Source age and technological sophistication are important parameters, as they often significantly affect effluent loads. The aging of a source causes higher loads as systems tend to fail more frequently and their operation tends to depart from the new equipment specifications. In addition, older systems do not take full advantage of technological innovations, which tend to yield environmentally friendlier performance. Naturally, technological sophistication does not only depend on the age of the source alone, but also on environmental legislation, as well as on enforcement aspects.

Quantification of the impact of these parameters is possible for some important sources, as for example in the petroleum oil refining category.

Source maintenance and operating practices is another parameter significantly affecting effluent loads. Fortunately, for the vast majority of industrial sources proper maintenance and operation is also intimately related to production quality and costs and for this reason is usually practiced to acceptable standards. For smaller sources however, improper maintenance and operation is the rule rather than the exception, despite the associated economic losses.

Unfortunately, few data are available in the literature to allow the derivation of quantitative relations regarding the impact of maintenance procedures on effluent loads.

The type and the quality of the raw materials used is in may cases intimately related to the types and to the quantities of pollutants emitted. In industrial processes the type and the quality of raw materials available often dictate the process to be used and the effluent loads released by them, and this is generally covered by the effluent loads model of Section 4.2.2.

The type, design, and age of the control systems employed determine the removal efficiencies of the effluent loads and are thus intimately related to the impact of the discharges on the final receivers.

The type of control system employed defines by itself the capabilities and limitations (and hence the control efficiency range) for the source under consideration. Analysis of the control system performance through appropriate models could, in principle, provide a better insight and a more accurate assessment of control system efficiencies. However, as the performance of the control systems depends significantly on the nature of the particular wastes, reliable predictions are not always easy to generate. Moreover, the detailed design data and performance analysis requirements burden the inventory and strategy formulation process very significantly .

The age of the control system may affect the efficiency due to the progressive downgrading of the performance with time, but, most importantly, due to the generally more relaxed design specifications of the past. Old age of equipment tends thus to be associated with lower design efficiencies.

In our inventory model the type of control system is used as the leading parameter for assessing a **typical** control system performance. Detailed assessments on the basis of specific design characteristics are however not addressed, as typical design practices are assumed.

The ambient conditions may significantly affect the rate of the effluent loads. For example, the performance of most treatment processes, especially biological ones, is affected by the ambient temperature. However, this sensitivity is usually compensated by proper sizing of the treatment processes.

The above discussion leads into the important practical question of how the effluent load E_j can be expressed as a direct and explicit function of all the parameters that may affect it for all pollutants j of interest.

The first step in this direction is to define the effluent load factor e_j for pollutant j, through the following relation:

$$e_j = \frac{E_j\text{, kg/yr}}{\text{Source activity, Units/yr}} \qquad (4.2.1\text{-}2)$$

The effluent load factor e_j is normally expressed as kg/Unit and is assumed to be independent of source size and of source activity (or production) level. The basis for this assumption is the way the activity units are selected. Indeed, as discussed above, a key criterion in the selection of the activity units is their direct and proportional relation to the effluent loads generated. From the above and from Equation (4.2.1-1) we obtain:

$$e_j = f'(\text{Source type, Process or design particularities, Source age and technological sophistication, Source Maintenance and Operating Practices, Type and quality of the raw materials used, Type, design and age of the control systems employed, Ambient conditions, etc.}) \quad (4.2.1\text{-}3)$$

The dependence of the emission factors e_j on the parameters discussed above and listed in Equation (4.2.1-3), cannot, in most cases, be expressed in a continuous function form due to the discreet nature of some parameters (e.g. alternative types of treatment systems), and to the frequent lack of sufficient information in relation to the remaining parameters. A discreet functional form yielding a series of emission values, each valid under a specific set of common and important parameter combinations, is used instead.

The discreet rather than the continuous nature of the emission factor values explains the tabular construct of the Model in Section 4.2.2, into which the source types are organized on the basis of the UN Standard Classification of Industries and Services. Under each activity listed, all typical alternative processes are included (e.g. under Tanneries and Leather Finishing (SIC 3231), the Hair Pulp/Chrome Tanning, Hair Save/Chrome Tanning, Hair Pulp of Shave/Non-Chrome Tanning, Re-tanning and Wet Finishing Only), and for each such process all major control alternatives are provided (e.g. Primary Sedimentation, Sulfide Oxidation/Sedimentation, Coagulation/Sedimentation, and Activated Sludge).

The waste load factors are always listed for each uncontrolled source. For the computation of the load factors which are applicable after each alternative treatment installation, two methods are followed:

(a) For single sources, load factors for the treated wastes are directly listed for each alternative type of treatment plant (see for example the Iron and Steel source category, SIC 371).

(b) Multiple sources of similar nature and wastes with similar treatability characteristics are placed in a block, following which, typical treatment processes applicable to all sources in the block, are listed and penetration factors for each pollutant are provided (see for example the tanneries block, SIC 3231). The waste factors for a given source with a given wastewater treatment scheme may be thus computed as the product of each uncontrolled waste factor and the corresponding penetration factor.

The impact of the raw materials type and quality is expressed indirectly through the listing of alternative processes (the process selection often depends on the raw materials available), or described in footnotes. Similar provision is made for remaining parameters, whenever their impact becomes important and relevant information exists.

The tabular structure and the form of Section 4.2.2 provides the basis for an elaborate effluent loads model by introducing the impact of all major parameters into the assessment of the pollutant load releases, as well as by providing a precise definition of the data requirements from field surveys. The model in Section 4.2.2 is thus a valuable tool for source inventory studies, not only for computing effluent loads, but also for providing guidance on the data to be collected during the field survey work, as well as for organizing and presenting such data in a concise manner (see also Sections 4.2.3 and 4.2.4 below).

In addition, the model in Section 4.2.2 should be a valuable tool in water pollution management studies as it provides a clear picture of the existing sources and the effluent load generation and, along with it, a fairly comprehensive list of the available alternative control options for each activity. The above constitute key elements in the analysis of the water pollution problems and the formulation of effective control strategies for any given urban or industrial area.

The model in Section 4.2.2 is also useful in Environmental Impact Assessment Studies as it provides, in a convenient form, quantification of the impact of alternative process and emission control system selections for most sources and activities of interest.

The model in Section 4.2.2 is supplemented by Tables 4.2.2-1 to 4.2.2-5, providing more-detailed data and information about waste load factors and treatment efficiencies for municipal waste-waters (SIC 920), waste load factors for rain and land runoff, control efficiencies for agricultural industries (SIC 1110 to 1134), and the composition of leachates from municipal solid waste landfill sites.

4.2.2 Model for Liquid Waste Inventories and Controls[1,2]

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
MAJOR DIVISION 1. **AGRICULTURE, HUNTING, FORESTRY AND FISHING**								
DIVISION 11. **AGRICULTURE AND HUNTING**								
111 **Agricultural and Livestock Production**[3]								
Beef Cattle, 360 kg aver.								
Slotted floor/Shallow pit[4]	Head*yr	8.0	164	1204	43.8	11.3		
Dairy Cattle, 590 kg aver.[5]								
Free stall barn	Head*yr	15.6	228.5	1533	82.1	12.0		
Milking Center	Head*yr	5.6	21.5		2.5	3.3		
Swine feedlot, 45 kg aver.[6]								
Solid floor/water washed	Head*yr	14.6	32.9	73.	7.3	2.3		
Slotted floor/Pit manure	Head*yr	2.8	32.9	24.8	7.3	2.3		
Sheep, 68 kg average								
Housed/Solid manure	Head*yr	2.6	58.4		23	6.6		
Housed/Liquid manure	Head*yr	4.9	33.2	158.4	4	21.5		

1. If a waste load factor does not appear in the appropriate place, this often (but not always) means that its value is either small or zero. However, lack of a penetration factor for a wastewater treatment plant does not mean zero penetration, but rather that the value of this factor is not known.
2. The listed waste volume factors do not account for cooling water discharges, which may be very significant. The underline assumption here is that, unless otherwise noted, the cooling waters are recycled and only a small portion of them, the blowdown, is discharged along with the effluents.
3. Low density pasture units represent zero level of waste problems, along with the recovery of full fertilizer value. However, the waste from high density confined operations approaches the total loads and thus requires considerable management.
4. In beef cattle feedlots calves enter weighing 270 kg, and after a period of 130 to 180 days they leave as market animals weighing about 477 kg.
   Beef feedlots include shallow and deep pit systems, dirt-flat to moderate slope, dirt-steep slope and paved open slots. The listed factors for shallow pit systems represent the highest loads, as the manure is collected almost daily. In all other systems the manure remains on the floor for a period of time and undergoes decomposition, loosing some of its original organic load strength. For example, in deep pit systems where the manure may remain for 6 to 12 months, the BOD can be reduced by about 40 %, the total Nitrogen can be reduced somewhat due to ammonia losses, but the total phosphorus remains unchanged.
5. In dairy farms each cow produces 9 to 25 kg of milk daily and 1 calve per year.
6. In swine feedlots, feeder pigs enter weighing 25 kg, and after a period of 23 to 25 weeks they leave as 100 kg hogs to be slaughtered.

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
Lambs, 34.9 kg average[7]								
Housed/Solid manure	Head*yr	1.5	33.7		13.5	3.7		
Housed/Liquid manure	Head*yr	2.9	19.2	169	2.5	1.24		
Chicken[8]								
Broilers on feed, 1 kg	Head*yr	21.5	1.61	4.2	3.6			
Layers	(kg of bird)*yr	21.5	1.61	4.2	3.6			
Turkeys[9]								
Breeding birds, 11.4 kg	Head*yr	0.25	14.2		3	2.5		
Market birds, 6.8 kg	Head*yr	0.15	8.4		1.8	1.5		
Ducks, 16 kg average	Head*yr	84	6.4	9.1	N/A	N/A		
Horses / Manure & Bedding	Head*yr	13.6	146		95.3	16.4		
Unaerated lagoon			0.22	0.45	0.44	0.91		
Oxidation Ditch			0.11	0.45	0.25	1.0		

MAJOR DIVISION 3. **MANUFACTURING**

DIVISION 31. **MANUFACTURE OF FOOD, BEVERAGES AND TOBACCO**

311 **Food Manufacturing**

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
3111 Slaughtering, Preparing & Preserving Meat[10,11,12]								
Simple slaughterhouses								
With blood recovered	tn LWK	5.3	6	5.6	0.7	0.05	Oil	2.1
Without blood recovered	tn LWK	5.3	10	8.0	0.7	0.05	Oil	4

7. In lamb feedlots, lambs enter weighing 30 to 41 kg, and after a period of 40 to 150 days they leave as market animals weighing about 45 to 59 kg.
8. Both breeding flocks and the growing birds are normally kept on litter (0.9 and 2.7 kg/bird used respectively), where their wastes are absorbed and remain for prolonged periods. The listed factors represent fresh chicken manure with no estimation for the considerable biodegradation or evaporation. They reflect however the loads in newer installations, where the wastes are regularly washed away.
9. Turkeys, like chicken, are growing on litter and the listed factors do not account for the biodegradation.
10. LWK is an abbreviation for the Live Weight of the animals Killed.
11. The average weight of cattle is 430 kg, of calf 97 kg, of hog 120 kg, and of lamb 52 kg.
12. The edible meat is about 60% of LWK;

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
Complex slaughterhouses	tn LWK	7.4	10.9	9.6	0.84	0.33	Oil	5.9
Packing houses								
Low processing	tn LWK	7.8	8.1	5.9	0.53	0.13	Oil	3
High processing	tn LWK	12.5	16.1	10.5	1.3	0.4	Oil	9
Rendering plants	tn LWK	3.3	2.15	1.13	0.48	0.04	Oil	0.72
Poultry processing								
With blood recovery	1000 birds	37.5	11.9	12.7				5.6
Without blood recovery	1000 birds	37.5	17	12.7				5.6
Primary skimming and air floatation			0.45	0.07			Oil	0.13
Primary skimming and air floatation with coagulant			0.15	0.05			Oil	0.1
Anaerobic and aerobic lagoon			0.046	0.065	0.67		Oil	0.047
Extended aeration and aerobic lagoon			0.04	0.14	0.72		Oil	0.02
Aerobic lagoon and trickling filter			0.025	0.06	0.7		Oil	0.04
2-Stage trickling filter			0.045	0.05	0.7		Oil	0.02

3112 Manufacturing of dairy products[13,14]

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr
Dairies						
Receiving station						
Cans	tn of product	0.68	0.46	0.03	0.49	0.11
Bulk	tn of product	0.08	0.17	0.03	0.06	0.013
Fluid products	tn of product	3.1	3.21	1.5	0.31	0.68
Cultured products	tn of product	3.9	3.21	1.5	0.31	0.68
Butter	tn of product	2.6	1.1	0.4	1.95	0.42
Cottage cheese						
With whey recovery	tn of product	7.7	21.7	3.4		
Natural cheese						
With whey recovery	tn of product	2.3	2.2	0.2	1.56	0.34
Ice cream	tn of product	3	10.9	1.5		
Condensed milk	tn of product	2	6.7	0.83	0.39	0.08
Powder production	tn of product					
Spray drying	tn of product	0.7	22.4		1.3	0.28
Roller drying	tn of product	0.8	26.8		1.56	0.34
Activated sludge			0.071	0.046		0.39
Trickling filter			0.095	0.43		0.39

13. The BOD_5 loads were estimated from the COD loads given in literature, using typical for each project COD/BOD_5 ratios.

14 The typical distribution of products obtained from 1000 lt of milk is as follows: Butter 5 kg, Cheese 10 kg, Condensed milk (45% dry matter) 26 kg, Condensate (30% dry-matter) 40 kg, Skimmed milk powder 9 kg, and Full-milk powder 12 kg.

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
Aerated lagoon			0.155			0.39		
Stabilization pond			0.05			0.39		
Anaerobic digestion			0.7			0.39		
3113 Canning & Preserving of Fruits & Vegetables								
Fruits Processing								
Apricots	tn raw material	29.1	15.4	4.25				
Apple								
All products	tn raw material	3.7	5	0.5				
All prod. except juice	tn raw material	5.4	6.4	0.8				
Juice	tn raw material	2.9	2	0.3				
Canberries	tn raw material	5.8	2.8	0.6				
Citrus	tn raw material	10.1	3.2	1.3				
Sweet cherries	tn raw material	7.8	9.6	0.6				
Sour cherries	tn raw material	12	17.2	1				
Brine cherries	tn raw material	19.9	21.7	1.4				
Cranberries	tn raw material	12.3	10	1.4				
Dried fruit	tn raw material	13.3	12.4	1.9				
Grapefruit								
Canning	tn raw material	72.1	10.7	1.2				
Pressing	tn raw material	1.6	1.9	0.4				
Olives	tn raw material	38.1	43.7	7.5				
Peaches								
Canned	tn raw material	13	14	2.3				
Frozen	tn raw material	5.4	11.7	1.8				
Pears	tn raw matter	11.8	21.2	3.2				
Pickles								
Fresh-packed	tn raw material	8.5	9.5	1.9				
Process-packed	tn raw material	9.6	18.3	3.3				
Salting stations	tn raw material	1.1	8.0	0.4				
Pineapples	tn raw material	13	10.3	2.7				
Plums	tn raw material	5	4.1	0.3				
Raisins	tn raw material	2.8	6	1.6				
Strawberries	tn raw material	13.1	5.3	1.4				
Tomatoes								
Peeled	tn raw material	8.9	4.1	6.1				
Products	tn raw material	4.7	1.3	2.7				
Vegetable Processing								
Asparagus	tn raw material	68.8	2.1	3.4				
Beets	tn raw material	5	19.7	3.9				
Broccoli	tn raw material	45.6	9.8	5.6				
Brussels sprouts	tn raw material	36.3	3.4	10.8				
Carrots	tn raw material	12.1	19.5	12				
Cauliflower	tn raw material	89.4	5.2	2.7				

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
Corn								
Canned	tn raw material	4.5	14.4	6.7				
Frozen	tn raw material	13.3	20.2	5.6				
Dehydrated								
Onion & garlic	tn raw material	19.9	6.5	5.9				
Vegetables	tn raw material	22.1	7.9	5.6				
Dry beans	tn raw material	18	15.3	4.4				
Lima beans	tn raw material	27.1	13.9	10.3				
Mushrooms	tn raw material	22.4	8.7	4.8				
Onions canned	tn raw material	23	22.6	9.3				
Peas								
Canned	tn raw material	19.7	22.1	5.4				
Frozen	tn raw material	14.5	18.3	4.9				
Pimentos	tn raw material	28.8	27.2	2.9				
Potatoes								
All products	tn raw material	10.3	18.1	15.9				
Frozen prod	tn raw material	11.3	22.9	19.4				
Dehydrated prod	tn raw material	8.8	11	8.6				
Sauerkraut								
Canning	tn raw material	3.5	3.5	0.6				
Cutting	tn raw material	0.43	1.2	0.2				
Snap beans								
Canned	tn raw material	15.4	3.1	2				
Frozen	tn raw material	19.9	6	3				
Spinach								
Canned	tn raw material	37.6	8.2	6.5				
Frozen	tn raw material	29.2	4.8	2				
Squash	tn raw material	5.6	16.8	2.3				
Sweet potatoes	tn raw material	4.1	30.1	11.5				

	BOD_5	TSS
Settling or floatation	0.3	0.75
Chemical coagulation	0.2	0.3
Trickling filters	0.12	0.1
Activated sludge	0.07	0.1
Stabilization pond	0.1	0.05

3114 Canning, preserving & processing of fish, crustacean & similar foods

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U	TSS kg/U	Tot N kg/U	Tot P kg/U	Other Pollutants Name	Other Pollutants kg/U
Fish and Seafood Processing Industry								
Catfish processing	tn of product	24	7.3	9.4	0.65		Oil	4.7
Blue crab								
Convent'l Processing	tn of product	1.2	5.2	0.74	1		Oil	0.25
Mechanized Processing	tn of product	38	22.5	12	3.7		Oil	5.6
Shrimp								
Breaded	tn of product	116	84	93	5.9		Oil	20

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
Canned	tn of product	52	82	43	9.5		Oil	31
Frozen	tn of product	115	120	220	10		Oil	29
Tuna	tn of product	25	13.4	10.4	2.1		Oil	7.4
Clam								
Hand shucked	tn of product	4.6	5.1	10.2			Oil	0.14
Mechanized	tn of product	19.5	18.7	6.3			Oil	0.46
Fish meal								
With solubles	tn of product	35	3	0.9			Oil	0.56
Without solubles	tn of product	1.9	62.2	34.8			Oil	22.8
Salmon								
Mechanical buchering	tn of product	18.5	50.8	20.3			Oil	6.5
Hand buchering	tn of product	4	2.1	1.2			Oil	1.5
Sardine	tn of product	8.7	9.2	5.4			Oil	1.7
Herring filet	tn of product	7	32.2	20.9			Oil	6.5
Oyster / steam cleaned	tn of product	98	61.2	155			Oil	1.5
Screening, floatation and extended aeration			0.05	0.05			Oil	0.05
Screening, floatation and aerated lagoon			0.05	0.05			Oil	0.05
3115 Manufacture of vegetable and animal oils and fats								
Olive Oil Expression								
Pressing	tn of oil product	5	210	325				
	tn of olives	1	42	65				
Centrifuging	tn of oil product	7	95	455				
	tn of olives	1.4	19	91				
Sedimentation with Lime								
Anaerobic digestion			0.3					
Edible Oil Refining								
Edible Fats and Oils								
General	tn of product	6.8	24.9	24.6			Oil	28.1
Corn oil	tn of product	1.85	0.3	0.35				
Olive oil	tn of product	57.5	12.9	16.4			Oil	6.5
Dissolved air floatation with chemicals			0.08	0.32			Oil	0.22
Gravity clarifier & oil collection filter			0.08	0.32			Oil	0.22
Biological secondary treatment			0.01	0.01			Oil	0.01

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5	TSS	Tot N	Tot P	Other Pollutants	
			kg/U Pntr	kg/U Pntr	kg/U Pntr	kg/U Pntr	Name	kg/U Pntr
3116 Grain mill products								
Corn								
Wet milling	tn of product	22.4	7.3	5.2				
Dry milling	tn of product	0.7	1.1	1.6				
Wheat								
Normal milling	tn of product		No effluents					
Bulgur milling	tn of product	0.29	0.11	0.1				
Rice								
Normal milling	tn of product		No effluents					
Parboiled milling	tn of product	1.5	1.8	0.07				
Activated sludge			0.21	0.41				
Flow equalization & activated sludge			0.1	0.2				
Flow equalization & activated sludge & stabilization lagoon			0.04	0.09				
Tertiary treatment			0.005	0.01				
3117 Manufacture of bakery products								
Bread	tn of product		0.11		0.004			
Rusk	tn of product		0.11		0.004			
Dry pastry	tn of product		0.7		0.005			
Wet pastry	tn of product		9		0.05			
3118 Sugar factories and refineries								
Beet sugar production	tn of product	23	20	75				
Water conservation & activated sludge			0.09	0.02				
Above & recycling of condenser water			0.004	0.003				
Cane sugar production	tn of product	3-48	2.9	6.3				
Water conservation & activated sludge			0.23	0.05				
Tertiary treatment			0.05	0.004				
3121 Manufacture of food products not elsewhere classified								
Specialty Food Industry								
Prepared dinners	tn of product	12	17	14	0.44	0.19	Oil	15
Frozen bakery products	tn of product	11	23	14	0.3	0.08	Oil	11
Dressing, sauces and spreads	tn of product	2.8	7.5	3.5	0.04	0.03	Oil	5.7
Meat specialties	tn of product	10	10	6.1	0.57	0.1	Oil	4

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
Canned soups & baby foods	tn of product	22	12	7.6	0.47	0.18	Oil	2.4
Tomato-cheese-starch combinations	tn of product	2.9	7.2	6	0.23	0.28	Oil	4.7
Sauced vegetables	tn of product	85	25	21	1.1	0.33		
Sweet syrups, jams & jellies	tn of product	2.4	5.1	1	0.04	0.05	Oil	0.6
Chinese & Mexican foods	tn of product	14	6.9	2.8	0.28	0.14	Oil	3
Breaded frozen products	tn of product	48	26	26	2.6	0.35		
	Stabilization lagoons		0.03	0.05			Oil	0.05
	Activated sludge		0.05	0.08			Oil	0.05
Egg breaking								
US facilities	tn of product	10.3	33					
Dutch facilities	tn of eggs	7.9	12.4					
	Dozen eggs	0.0039	0.006					
	Activated sludge		0.1					
	Rotating disks		0.077					
Wheat, starch gluten	tn of product	9.9	94	81	3.7	1		
Starch and glucose	tn of product	33	13.4	9.7				
Yeast manufacturing	tn of product	150	1125	18.7	127		SO_4	337
	Activated sludge		0.02	0.03				

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
313 Beverage Industries								
3131 Distillery, rectifying and blending spirits								
Grain distilleries[15]	tn anhydrous alcohol	63	216	257				
Aerated lagoon			0.043	0.077				
Activated sludge			0.043	0.077				
Molasses distilleries[16]	tn anhydrous alcohol	63	220	300				
Sugar cane distilleries	tn anhydrous alcohol	113	426					
Wine distilleries	tn anhydrous alcohol	36	210	75				
	tn of grapes	3.6	2.1	0.75				
Aerated lagoon			0.001	0.002				
Activated sludge			0.001	0.004				
3132 Wine production								
Wine production	tn of grapes	2	1.6	0.3				
Rotating biological contactor & sand filter			0.065	0.01				
Activated sludge /Extended aeration			0.055	0.01				
Activated sludge / Conventional			0.03	0.01				
3133 Malt liquors and malt								
Beer manufacturing								
Malting	tn of barley	7.3	5	0.85				
Malting and brewing								
New large plant	m3 of beer	5.4	10.5	3.9				
Old large plant	m3 of beer	11	18.8	7.3				
Primary treatment			0.84	0.37				
Trickling filter / low loading			0.03	0.1				
2 stage trickling filter / high loading			0.1	0.1				
Activated sludge			0.1	0.1				

15. One bushel (35.2 lt or 27.2 kg) of grain yields 17.8 lt of anhydrous alcohol.
16. 2.4 lt of molasses yield 1. lt of anhydrous alcohol.

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
3134 Soft drinks								
Major plant								
With syrup prepar'on	m3 of product	12.8	3.1	4.3				
Franchise plant								
With no syrup prepar'on								
Bottled	m3 of product	4.3	2.1	0.7				
Canned	m3 of product	2	0.8	0.3				

Aerated lagoon
Activated sludge

DIVISION 32. **TEXTILE, WEARING APPAREL & LEATHER INDUSTRIES**

321 **Manufacture of Textiles**

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
Wool processing[17]								
Ave unscoured stock[18]	tn of wool	544	314	196			Oil	191
							Cr	1.33
							Phenol	0.22
Ave scoured stock	tn of wool	537	87	43			Cr	1.33
							Phenol	0.17
Process-specific								
Scouring	tn of wool	17	227	153			Oil	191
Dyeing	tn of wool	25	22				Cr	1.33
							Phenol	0.17
Washing	tn of wool	362	63					
Carbonizing	tn of wool	138	2	44				
Bleaching	tn of wool	12.5	1.4					
Cotton processing								
Ave compounded[19]	tn of cotton	265	155	70				
Process-specific								
Yarn sizing	tn of cotton	4.2	2.8					
Desizing	tn of cotton	22	58	30				
kiering	tn of cotton	100	53	22				
Bleaching	tn of cotton	100	8	5				

17. The p_H varies widely, from 1.9 to 10.4.
18. The average compounded load factors listed are based on the assumption that only 20 % of the product is mercerized and 10 % is bleached.
19. The average compounded load factors listed are based on the assumption that only 35 % of the product is mercerized, 50 % of the product is dyed and 14 % of the product is printed.

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
Mercerizing	tn of cotton	35	8	2.5				
Dyeing	tn of cotton	50	60	25				
Printing	tn of cotton	14	54	12				
Rayon processing	tn of rayon	42	30	55				
Acetate process.	tn of acetate	75	45	40				
Nylon process.	tn of nylon	125	45	30				
Acrylic process.	tn of acrylic	210	125	87				
Polyester process.	tn of polyester	100	185	95				
Sedimentation			0.6	0.4				
Coagulation / Sedimentation			0.6	0.15				
Anaerobic lagoon			0.2	0.3				
Aerobic lagoon			0.05	0.05				
Activated sludge			0.1	0.05				
323 Manufacture of Leather & Products of Leather								
3231 Tanneries and leather finish[20]								
1. Hair pulp, Chrome tan, retan, wet finish	tn of hides	57	63.5	104.	12		Oil	57.8
							Sulfide	3.35
							Cr	4.76
							Phenol	0.11
2. Hair save, Chrome tan, retan, wet finish	tn of hides	44	67.3	199.	12.8		Oil	13.1
							Sulfide	1.94
							Cr	-
							Phenol	0.24
3. Hair pulp or save, non chrome tan, retan, wet finish	tn of hides	45	63.1	96.7	13.6		Oil	17.3
							Sulfide	3.43
							Cr	0.06
							Phenol	0.39
4. Retan & wet finish (sides)	tn of hides	43	29.2	51	3.8		Oil	6.8
							Sulfide	0.11
							Cr	1.86
							Phenol	0.24

20. Typical weight of big hides (from cattle or horse) is 25-26 kg, while that of small hides (from sheep or goat) 3 kg.

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
5. No beamhouse tanneries (tan, retan & wet finish)	tn of hides	56	39.2	49.2	5		Oil	86.3
							Sulfide	0.01
							Cr	2.21
							Phenol	-
6. Through-the-Blue (hair removal & Chrome tan of cattlehides)	tn of hides	17	130	200	20.3		Oil	17.3
							Sulfide	7.6
							Cr	6.3
							Phenol	0.11
7. Shearling tanneries (tan & finish sheepskins with wool intact)	tn of hides	78	57	77.7	4		Oil	15.3
							Sulfide	0.54
							Cr	7.4
							Phenol	-
8. Pigskin tanneries (same process as that of category 1)	tn of hides	42	115	181	5.7		Oil	64
							Sulfide	12.1
							Cr	4.4
							Phenol	0.03
9. Retan & wet finish (splits)	tn of hides	27	16.9	23.8	3.9		Oil	19.3
							Sulfide	0.03
							Cr	1.07
							Phenol	0.01

Control	BOD_5	TSS	Tot N	Tot P	Other Pollutants Name	kg/U Pntr
Primary sedimentation	0.6	0.42	0.74		Oil	0.34
					Sulfide	1
					Cr	0.62
Sulfide oxidation/sedimentation	0.56	0.32	0.74		Oil	0.39
					Sulfide	0.0
					Cr	0.2
Coagulation with chemical addition and sedimentation	0.52	0.09	0.58		Oil	0.22
					Sulfide	
					Cr	0.125
Activated sludge (extended aeration)	0.02	0.1	0.66		Oil	0.02
					Sulfide	
					Cr	0.01

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
331 **Manufacture of Wood & Wood & Cork Products, Except Furniture**								
Plywood manufacturing	1000 m2	4.1	4	1.1	0.24		Phenol	5
Fiberboard manufacture	tn of product	20	12.5	20				
DIVISION 34. **MANUFACTURE OF PAPER & PAPER PRODUCTS, PRINTING & PUBLISHING**								
341 **Manufacture of Paper and Paper Products**								
3411 Manufacture of pulp, paper and paperboard								
Pulp mils								
Wood pulp								
Mechanical	tn of product							
Sulfate (Kraft)[21]	tn of product	61.3	31	18				
Sulfite	tn of product	92.4	130	26				
Semi chemical	tn of product	47	27	12.5				
Paper mills								
Newsprint paper	tn of product	190	7.5	2				
Kraft coarse paper	tn of product	125	5.5	10.5				
Cigarette paper	tn of product	100	11.5	37.5				
Paperboard/Simple finish	tn of product	200	15	30				
Graphic paper	tn of product		10.5	6.5				

	BOD_5	TSS
Sedimentation	0.75	0.75
Dissolved air floatation	0.65	0.15
Activated sludge	0.05	0.1
Aerated lagoon	0.3	0.1
Stabilization lagooning	0.6	0.1

21. The processes considered are pulping, pulp screening, pulp washing and thickening.

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
DIVISION 35. **MANUFACTURE OF CHEMICALS & OF CHEMICAL, PETROLEUM, COAL, RUBBER & PLASTIC PRODUCTS**								
351 **Manufacture of Industrial Chemicals**								
3511 Manufacture of basic industrial chemicals except fertilizers[22]								
Primary Petrochemicals								
Ethylene	tn of product	3.2	1.8					
Propylene	tn of product	4.4	2.4					
Primary Intermediates								
Ammonia	tn of product	6.9	0.4		0.1		Oil	11
Butanol (Butyl Alcohol)	tn of product	4.6	10.3					
Chlorinate hydrocarbons	tn of product	2.2	0.22					
Ethanol (Ethyl Alcohol)	tn of product	9	14.9					
Ethyl benzene	tn of product	6.9	12					
Methanol (Methyl Alcohol)	tn of product	6.9	4.4				Oil	1.2
Toluene	tn of product	6.9	9.7					
Xylene	tn of product	6.9	15.5					
Secondary Intermediates								
Acetic anhydride	tn of product	18.7	50					
Acetone	tn of product	4.2	12.6					
Acrylates	tn of product	8.3	23					
Acrylonitrile	tn of product	22.9	10					
Butylenes, Butadiene	tn of product	4.4	0.5					
Ethylene glycol (Ethanediol)	tn of product	14.6	29					
Formaldehyde (methanal)	tn of product		-				Oil	0.63
Glycerine, glycols	tn of product	14.6	29					
Phenol, Cumene	tn of product	6.2	34.7					
Styrene	tn of product	23.1	38					
Terephthalic acid	tn of product	8.3	16					
Vinyl chloride	tn of product	0.4	0.5					
Primary Polymers								
Butyl rubber	tn of product	16.7	23.4					
Polyvinyl chloride	tn of product	9.3	2.6					
Dyes and Pigments	tn of product	624.	187.					
Miscellaneous Organics								
Isocyanate	tn of product	31	54					
Parathion	tn of product	22.9	57					
Phenyl glycine	tn of product	31	54					
Tributyl phosphate	tn of product	10.4	13					

22. Waste volumes and BOD loads vary widely. In most cases other pollutants (SS, Nitrogen, Phenol, Oil, heavy metals and cyanide), as well as p_H and color, are present, but factors are not available. When these products are manufactured by petrochemical refineries, rather than from smaller installations, use the compounded factors applicable for refineries (SIC 3530).

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
Activated sludge treatment			0.01					
Chlor-alkali[23]								
Memory cell								
Untreated	tn of Cl_2 product			5.6			Hg	0.15
Treated	tn of Cl_2 product			0.32			Hg	.0001
Diaphragm cell (Metal or Graphic Anodes)								
Untreated	tn of Cl_2 product			3.2			Pb	.046
Treated	tn of Cl_2 product			0.32			Pb	.0025
3512 Manufacture of fertilizers and pesticides								
Nitrogenous Fertilizers								
Ammonium nitrate								
Untreated	tn of product				2.9			
Treated	tn of product				0.1			
Ammonium sulphate								
Untreated	tn of product		0.4		10			
Treated	tn of product				0.1			
Urea								
Untreated	tn of product		0.24		10			
Treated	tn of product				0.1			
Phosphatic Fertilizers								
Phosphoric acid (wet process)	tn of P_2O_5	670		3900	5	17[24]	Fluor	246[25]
							Pb, As, Cr, Hg	1.1
Normal super phosphates (Phosphate rock+H2SO4)	tn of P_2O_5			1.25		0.65	Fluoride	17.5
Triple super phosphates (Phosphate rock+H3PO4)	tn of P_2O_5		0.55			0.32	Fluoride	7.8
N.P.P. fertilizer	tn of product			0.4	0.4		F	0.06

23. Controls in both, the Mercury and the Diaphragm Cell process, comprise Sulfide precipitation and possibly activated carbon treatment.
24. If the Hemihydrate, rather than Dihydrate, process is used, the applicable factor is 8.7.
25. If Fluorosilicic Acid is recovered from the exhaust gases, the applicable factor is 24.6.

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
Total water recycle & treatment of excess effluents[26]				0.0		0.0	Fluoride	0
							Pb,As,Cr,Hg	0
Insecticides, Fungicides, Disinfectants etc								
DDT	tn of Product	5.3					Oil	76
							Chlorobenzene	38
Chlorinated hydrocarbon herbicides	tn of Product	3.6	22.7	9			Phenol	4.9
3513 Manufacture of synthetic resins, plastic and man-made Fibers[27]								
Butadiene-Styrene								
Untreated	tn of product		14					
Butadiene-Nitrile rubber								
Untreated	tn of product		11					
Phenolic resins								
Untreated	tn of product	4.1	33	3.7			Phenol	6.6
Good control	tn of product		3.7	1.5				
Polyethylene								
Low density								
Untreated	tn of product		2.3	2.1				
Good control	tn of product		0.2	0.55				
High density								
Untreated	tn of product		0.5	1.7				

26. The major effluents are from the gypsum filter, as well as from the P_2O_5 condensers and off gas scrubbers. The gypsum filter separates the gypsum by-product (4.75 tn of gypsum per tn of P205) from the phosphoric acid solution.
The washed gypsum can be can be carried away as solid cake (with about 25 % water) and dry-stacked on land as a solid waste. The remaining scrubber/condenser wastes can be recycled through a cooling pond with an area of about 400 m^2 per daily tn of P205 production, or through a cooling tower. The latter reduces drastically the area requirements and is especially suited when fluoride is recovered from the off gas as hydro fluorosilisic acid.
Alternatively, the washed gypsum can be slurried and, mixed with scrubber/condenser waters, can be discharged either directly into the sea, or into a gypsum pond. In the latter case, the settled gypsum is continuously worked with drag lines and transferred to near-by gypsum piles, while the cooled water is recycled back to the process. Depending on the rainfall/evaporation balance, excess water may have to be discharged into the final receiver, but this can be treated so as to have very low loads.
27. The pollutant load factors vary widely

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
High density-solvent								
Good control	tn of product		0.3	0.83				
High density-polyform								
Good control	tn of product		0.05	0.14				
Polypropylene								
Untreated	tn of product		5	1.16			Oil	3
Good control	tn of product		0.42	1.16				
Polystyrene								
Untreated	tn of product		1.1	4.2				
Polystyrene-suspension								
Good control	tn of product		0.22	0.61				
Polystyrene bulk								
Good control	tn of product		0.04	0.11				
PVC-emulsion								
Untreated	tn of product		0.1	15.5				
Good control	tn of product		0.1	0.36				
PVC-suspension								
Good control	tn of product		0.36	0.99				
PVC-bulk								
Good control	tn of product		0.06	0.16				
Rayon								
Untreated	tn of product		44	N/A			Sulfide	3.5
							Zn	12
							Mg	2
							CS_2	1.5
							H_2SO_4	45
							SO_4	540
Good control	tn of product		4.8	8.8				
Nylon (polyamide)								
6+66 resin/Untreated	tn of product		68	4				
6 resin/Good control	tn of product		3.7	2.5				
66 resin/Good control	tn of product		0.66	0.44				
6+66 fibers/Untreated	tn of product		30	3				
6 fibers/Good control	tn of product		1.9	1.3				
66 fibers/Good control	tn of product		0.58	0.39				
Polyesters (e.g. dacron)								
Untreated	tn of product		11.5	6				
Resin/Good control	tn of product		0.78	0.52				
Fiber/Good control	tn of product		0.78	0.52				
Resin+fiber continuous								
Good control	tn of product		0.78	0.52				
Resin+fiber batch								
Good control	tn of product		1.56	1.04				
ABS/SAN								
Untreated	tn of product		11.3	15			H_2SO_4	22
							C_2H_3CN	2

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
Good control	tn of product		0.63	1.2				
Cellophane								
Untreated	tn of product		76.5	38				
Good control	tn of product		8.7	16				
Cellulose acetate								
Untreated	tn of product		38	11				
Resin or fiber								
Good control	tn of product		4.1	2.7				
Resin and fiber								
Good control	tn of product		8.3	5.5				
Acrylic resin								
Untreated	tn of product		25	1.1				
Good control	tn of product		2.75	1.1				
Epoxy resins								
Untreated	tn of product		70	14.5			NaOH	11
Batch & continuous	tn of product		2.1	1.4				
Batch fusion	tn of product		0.25	0.17				
Urea and Melamine resins								
Good control	tn of product		0.2	0.13				

352 **Manufacture of Other Chemical Products**

3522 Manufacture of drugs and medicines

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
Fermentation products	tn of product		2050	834	279	40	Oil	104
Biological & natural exaction								
Blood fractionation	tn of product		210	64	6	4	Oil	0.3
Vaccine production	tn of product		210	64	6	4	Oil	0.3
Chemical synthesis Products	tn of product		270	27	54.5	7.4	Oil	4.5
Mixing, compounding & formulation	tn of product		8.3	1	0.2	0.14	Oil	0.4
Secondary biological treatment			0.1	0.4				

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
3523 Manufacture of soap and cleaning preparations								
Soap Production								
Soap from kettle boiling	tn product	4.5	6	4			Oil	0.9
Soap from fatty acids								
Fatty acids:								
Production	tn product	13.5[28]	12	23			Oil	2.5
Hydrogenation	tn product		1.5	1			Oil	1
Neutralization	tn product		0.1	0.2			Oil	0.05
Glycerine concentration (1st step)	tn product		15	2			Oil	1
Glycerine distillation (2nd step)	tn product		5	2			Oil	1
Soap Processing								
Soap flakes and powders	tn product		0.1	0.1			Oil	0.1
Bar soaps	tn product		3.4	5.8			Oil	0.4
Liquid soaps	tn anhydr soap		0.1	0.1			Oil	0.1
Detergents								
Sulfonation								
Oleum sulfonation	tn anhydr prod		0.2	0.3			Surfact	0.7
							Oil	0.3
Air-SO3 sulfation & sulfonation	tn anhydr prod		3	0.3			Surfact	3
							Oil	0.5
SO3 solvent and vacuum sulfonation	tn anhydr prod		3	0.3			Surfact	3
							Oil	0.5
Sulfamic acid sulfation	tn anhydr prod		3	0.3			Oil	0.5
Chlorosulfonic acid sulfation	tn anhydr prod		3	0.3			Surfact	3
							Oil	0.5
Spray-dried detergents								
W/o use of scrubbers	tn anhydr prod		0.1	0.1			Surfact	0.2
With use of scrubbers	tn anhydr prod		0.8	0.1			Surfact	1.5
							Oil	0.3
Liquid detergents	tn anhydr prod		2				Surfact	1.3
Dry detergent blending	tn anhydr prod		0.1	0.1			Surfact	0.1
Detergent bars & cakes	tn anhydr prod		7	2			Surfact	5
							Oil	0.2

28. The listed factor accounts also for the waste volumes from the fatty acids hydrogenation and neutralization.

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
API Separators							Oil	0.15
Floatation without chemicals							Oil	0.25
Floatation with chemicals							Oil	0.1
Biological treatment			0.1	0.1			Surfactant	0.1
							Oil	0.1
3529 Manufacture of chemical products not elsewhere classified								
Animal glue								
From fleshings	tn of product	421	2500	4250				
From hides	tn of product	457	580	1920				
From chrome stock	tn of product	426	280	400				
Floatation								
Sedimentation								
Biological treatment								
353 Petroleum Refineries[29]								
Topping refinery[30]	1000 m3 of crude	484	3.4	11.7	1.2		Oil	8.3
							Phenol	.034
							Sulfide	.054
							Cr	.007
Cracking refinery[31]	1000 m3 of crude	605	72.9	18.2	28.3		Oil	31.2
							Phenol	4
							Sulfide	0.94
							Cr	0.25

29. The pollutant loads refer to relatively modern refineries, after their API separators.
30. Topping Refineries contains the primary and fundamental processes (atmospheric and vacuum crude oil distillation, steam cracking of gas oils, catalytic reforming, Naphtha- Distillate- and heavy oil-HDS, isomerization, sulfur recovery etc.), but can be considerably more complex as they may include aromatics extraction (BTX), lub oil and asphalt production units.
31. Cracking Refineries are considerably more complex than topping refineries and can be equipped with catalytic cracking, hydrocracking and/or coking (either of these units qualifies a refinery to be in the cracking category).

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
Petrochemical refinery[32]	1000 m3 of crude	726	172	48.6	34.3		Oil	52.9
							Phenol	7.7
							Sulfide	.86
							Cr	.234
Lub oil refinery[33]	1000 m3 of crude	1090	217	71.5	24.1		Oil	120
							Phenol	8.3
							Sulfide	.014
							Cr	.046
Integrated refinery[34]	1000 m3 of crude	1162	197	58.1	20.5		Oil	74.9
							Phenol	3.8
							Sulfide	2
							Cr	0.49
Coagulation and air floatation			0.65	0.67			Oil	0.15
							Phenol	0.1
							Sulfide	1
Activated sludge			0.17	0.25			Oil	0.04
							Phenol	0.1
							Sulfide	0.04
Trickling filter			0.3	0.25			Oil	0.04
							Phenol	0.1
							Sulfide	0.1
Aerated lagoon			0.3	0.8			Oil	0.04
							Phenol	0.1
							Sulfide	0.04
Oxidation pond			0.4	0.55			Oil	0.04
							Phenol	0.1
							Sulfide	0.2
Tertiary treatment			0.03	0.0			Oil	0.0

32. Petrochemical are similar to Integrated refineries, but without lub oil production.
33. Lub Oil Refineries are comparable to integrated refineries, but without the aromatics extraction and petrochemicals production units.
34. Integrated Refineries are the most complex type of refinery comprising all major operations, including cracking, lub oil, and petrochemicals production units.

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
354 Manufacture of Miscellaneous Products of Petroleum and Coal								
Building felt and tar paper	tn of product	50	8	40				
Coke Plant								
Untreated	tn of coke	14.7	3.9		3.5		Phenol CN Thioc/te	0.28 0.61 2.1
Old Plants	tn of coke	9.9	0.7		3.5		Phenol CN Thioc/te	0.28 0.03 0.13
Base level treatment[35]	tn of coke	9.9	0.3		3.5		Phenol CN Thioc/te	.054 .015 0.06
Biological treatment	tn of coke	1.6	0.3		3.5		Phenol CN Thioc/te	0.07 0.02 0.08
355 Manufacture of Rubber Products								
3551 Tire and tube industries	tn of product	37	0.4	1			Oil	0.12
DIVISION 36. **MANUFACTURE OF NONMETALLIC MINERAL PRODUCTS EXCEPT PRODUCTS OF PETROLEUM AND COKE**								
362 Manufacture of Glass and Glass Products								
Plate glass								
Untreated	tn of product	45.9	2.3	690				
Chemical Sedimentation	tn of product	45.9		2.76				
2ary Sedimet'n+Filtr'n	tn of product			.045				
Float glass								
Untreated	tn of product	.14	.001	.002			Oil	.001
Chemical Sedimentation	tn of product	0.14		.001			Oil	.001
2ary Sedimet'n+Filtr'n	tn of product	0.14		.001			Oil	.001
Windshield glass								
Untreated	1000 m^2 of glass	4.9	0.73	4.90			Oil	0.64
Chemical Sedimentation	1000 m^2 of glass	4.9		1.95			Oil	0.64

35. The base level treatment comprises the use of free and fixed ammonia stills, dephenolizers, and recirculated final coolers with cooling tower blowdown.

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
2ary Sedimet'n+Filtr'n	1000 m^2 of glass	4.9		0.24			Oil	0.49
Sheet glass			Only cooling waters					
Rolled glass			Only cooling waters					

DIVISION 37. **BASIC METAL INDUSTRIES**

371 **Iron and Steel Basic Industries**

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
Iron and steel mills								
Blast furnace (Scrubber wastes)								
Untreated	tn of product	12.3		29.3	0.27		Phenol	0.01
							F	.023
							CN	.039
Sedimentation	tn of product	12.3		1.5	0.27		Phenol	0.01
							F	.023
							CN	.039
Chemical coagulation & alkaline chlorination	tn of product	12.3		.13	.018		Phenol	.001
							F	.023
							CN	.0001
Recycling/5% blowdown & alkaline chlorination	tn of product	0.55		.006	.001		Phenol	0.0
							F	.0005
							CN	0.0
Basic oxygen furnace								
Precipitator/quencher								
Untreated	tn of product	0.6		.049				
Floc'tion/sedim'tion	tn of product	0.6		.011				
Venturi/quencher								
Untreated	tn of product	1.9		.146				
Floc'tion/sedim'tion	tn of product	1.9		.034				
Off-gas system								
Untreated	tn of product	0.5		.036				
Floc'tion/sedim'tion	tn of product	0.5		.009				
Electric arc furnace								
Venturi/quencher								
Untreated	tn of product	4.6		0.36				
Floc'tion/sedim'tion	tn of product	4.6		0.09				

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
Open hearth furnace								
Venturi/quencher								
Untreated	tn of product	3.5		0.27				
Floc'tion/sedim'tion	tn of product	3.5		.065				
Hot-rolling mills								
Untreated	tn of product	42		33.9			Oil	1.87
Scale pits	tn of product	42		10.8			Oil	1.87
Deep bed filters	tn of product	42		0.76			Oil	0.25
Settling & WW recycling	tn of product	2.3		0.04			Oil	.015
Cold rolling								
Untreated	tn of product	6.7	2.2	0.71			Oil	2.05
H_2SO_4 pickling								
Carbon steel	tn of product	1.8					Fe	6.4
							SO4	22.1
Stainless steel	tn of product	1.4					Fe	2.6
							SO4	9.1
Alloys	tn of product	1.2					Fe	2.6
							SO4	9.8
HCl pickling								
Carbon steel	tn of product	1.2					Fe	18.4
							Cl	24.8
Stainless steel	tn of product	1.6					Fe	57.8
							Cl	76.2
Alloys	tn of product	1.1					Fe	33.7
							Cl	44.5
Galvanizing								
Untreated								
Hot dip	tn of product	9.4		2.32		0.02	Fe	0.19
							Zn	.007
							Cr	.015
Electrogalvanizing	tn of product	6.9		N/A			Zn	.405
Treated	tn of product			.125			Oil	0.06
							Fe	.007
							Zn	.009
							Cr	.004

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
372 Non-Ferrous Metal Basic Industries								
Primary Aluminum Production								
Alumina from bauxite[36,37]	tn of Alumina			2.4			Oil	0.24
							SO_4	2.3
							Fluor	2.2
							Zn	.008
							Cu	.002
	tn of Aluminum			4.5			Oil	0.46
							SO_4	4.4
							Fluor	4.2
							Zn	.016
							Cu	.003
Aluminum from Alumina								
Anode pre-baking	tn of product			5.0			Oil	0.03
							Fluor	0.12
Reduction cells	tn of product		2.0	14.5	0.04		F_2	5.5
							Fluor	1.5
Secondary Aluminum								
Smelting	tn of product	0.008		1.5				
Casting & foundry	tn of product	0.02					Oil	0.65
Primary Lead								
Untreated	tn of product			350				
Primary zing								
Untreated	tn of product			0.9			Zn	1.8
							SO_4	30

36. From 1.4 to 3.3 tons of Bauxite Ore processed, 1.0 ton of alumina is produced. The latter yields 526 kg of Aluminum.
37. Red muds, 675 kg/tn of alumina, may be discharged as suspended solids if they are not removed from the effluents.

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
381 **Manufacture of Fabricated Metal Products, Except Machinery & Equipment**								
Electroplating[38,39]								
Degreasing baths	1000 m^2						Oil	5
Pickling baths								
Steel	1000 m^2						Fe	25
							Cl^-	0.12
Brass	1000 m^2						Cu	23
							Zn	15
Alkaline pickling for Al	1000 m^2						Al	55
							NaOH	430
Nickel bright	1000 m^2						Ni	25
							SO_4	33
Base treatment							Ni	0.06
Stage I treatment							Ni	0.009
Chromium ornamental	1000 m^2						Cr^6	37
Base treatment							Cr^6	0.06
Stage I treatment							Cr^6	0.009
Zinc bright								
Cyanide bath	1000 m^2						Oil	0.5
							Zn	6.9
							CN	15
							NaOH	50
Non-cyanide bath	1000 m^2						Oil	0.5
							Zn	3
							NaOH	47

38. The Base Treatment comprises neutralization and segregated chemical treatment of organic and chromium VI.
39. The Stage I treatment comprises recycling of cooling water, multi-tank rinsing, reclamation of drag-out, neutralization, and segregated chemical treatment of organic and chromium VI.

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
Acid bath	1000 m^2				0.7		Oil	0.5
							Zn	8.0
Base treatment							Zn	0.02
							NaOH	0.0
Stage I treatment							Zn	0.003
							NaOH	0.0
Copper								
Cyanide bath	1000 m^2						Oil	2
							Cu	10
							CN	20
Acid bath	1000 m^2						Cu	12
							SO4	75
Pyrophosphate bath	1000 m^2						Cu	4.5
Base treatment							Cu	0.03
Stage I treatment							Cu	0.004
							CN	0.002
Cadmium								
Cynanide bath	1000 m^2						Cd	4
							CN	10
							NaOH	6
Base treatment							Cd	0.02
Stage I treatment							Cd	0.002
							CN	0.002
Silver	1000 m^2						Ag	7
							CN	10
Stage I treatment							Ag	0.001
							CN	0.002

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
Tin								
Alkaline bath	1000 m^2						Sn	4
							NaOH	4
Bright acid bath	1000 m^2						Sn	5
Tin fluoroborate bath	1000 m^2						Sn	16
							F/borate	50
Stage I treatment							Sn	0.01
							NaOH	0.0
Lead fluoroborate bath	1000 m^2						Oil	1
							Pb	21
							F/borate	48
Stage I treatment							Pb	0.004
Gold								
Ornamental	1000 m^2						Au	0.3
							CN	0.4
Technical	1000 m^2						Au	2.5
							CN	1.4
Stage I treatment							Au	0.01
							CN	0.002
Brass Cyanide bath	1000 m^2						Zn	3.2
							CN	1.2
Base treatment							Zn	0.02
Stage I treatment							Zn	0.003
							CN	0.002
Lead-tin								
Fluoroborate baths	1000 m^2						Oil	1
							Pb	3.5
							Sn	7
							F/borate	55
Stage I treatment							Pb	0.022
							Zn	0.022

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
Electroless metal bath								
Nickel baths	1000 m^2						Oil	4
							Ni	1.1
							Phosph	4
Copper baths	1000 m^2						Oil	15
							Cu	1.6
Anodizing sulfuric baths	1000 m^2						Al	7.5
							SO4	235
Phosphating baths								
Zinc phosphating	1000 m^2						Zn	3
							Fe	1.8
							Phosph	12
Iron phosphating	1000 m^2						Oil	5
							Phosph	4
Chromating baths								
For aluminum	1000 m^2						Cr	0.8
							F	0.4
For zinc (yellow passivating bath)	1000 m^2						Cr	1.4
							Zn	0.3
For zinc (blue passivating bath)	1000 m^2						Cr.	3.3
							Zn	16
							F	7.5
MAJOR DIVISION 4. <u>ELECTRICITY GAS AND WATER</u>								
410 Electricity Gas and Steam								
4101 Steam turbines	GWH		2.2	286		0.05	Oil	.047
							Cr	.006
							Cu	.005
							Ni	.047
							Zn	.012

4102 Manufacture of City Gas by Coke Ovens — Use effluent model for Coke, See SIC 3540

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	kg/U Pntr
MAJOR DIVISION 6. **WHOLESALE & RETAIL TRADE & HOTELS & RESTAURANTS**								
620 **Retail Trade**								
Shopping centers	employee*yr	21.9	7.3					
631 **Restaurants, Cafes, and Other Eating & Drinking**								
Restaurants	meal*yr	7.3	3.7					
632 **Hotels, Rooming Houses, Camps and other Lodging**								
Motels with restaurant	Bed*yr	70.	21.9					
Campgrounds	(Trailer site)*yr	70	21.9					
	Trailer*yr	108	58.4					
Camps								
No meals served	person*yr	22	7.3					
Luxury	person*yr	140	36.					
Dwellings (seasonal occup)	person*yr	70	21.9					
Parks	person*yr	7.3	3.7					
MAJOR DIVISION 7. **TRANSPORT, STORAGE AND COMMUNICATION**								
713 **Air Transport**								
Airports	Passenger*yr	7.3	3.7					

Model for Liquid Waste Inventories and Controls - Cont'd

	UNIT (U)	WASTE VOLUME m^3/U	BOD_5 kg/U Pntr	TSS kg/U Pntr	Tot N kg/U Pntr	Tot P kg/U Pntr	Other Pollutants Name	Other Pollutants kg/U Pntr
MAJOR DIVISION 9. **COMMUNITY, SOCIAL AND PERSONAL SERVICES**								
920 **Sanitary and Similar Services**								
9200 Community, social and personal services								
Population served by								
Sewers[40]	person*yr	55	18.1	39.2	3.3	0.93	Oil	7.3
Septic tanks[41]	person*yr	7.3	6.9	16				
Primary sedimentation			0.67	0.4	0.925	0.90		
Chemical coagulation			0.25	0.15	0.75	0.15		
High rate trickling filter			0.25	0.21			Bacteria	0.12
Low rate trickling filter			.075	0.19			Bacteria	0.12
Activated sludge / Conventional			0.1	0.12	0.65	0.62	Bacteria	0.25
Activated sludge / Extended aeration			.035	0.12	0.77	0.85	Bacteria	0.25
Waste stabilization ponds			0.2	0.15	0.55	0.60	Bacteria	<<0.10
Biological treatment & chemical coagulation			0.06	0.13	0.86	0.06		
931 **Education Services**								
Schools								
No boarding	student*yr	27	7.3					
Boarding	student*yr	139	29.2					
940 **Recreational and Cultural Services**								
Theaters								
Drive-in	Stall*yr	7.3	3.7					
Indoor	seat*yr	7.3	3.7					
Swimming pools	swimmer*yr	14.6	3.7					

40. The waste volume and loads exhibit the following typical ranges:

Waste volume:	30.	to	110.	m3/capita/yr
BOD_5:	16.4	to	19.7	kg/capita/yr
TSS:	25.5	to	53.	kg/capita/yr
Total N:	2.2	to	4.4	kg/capita/yr
Total P:	0.22	to	1.64	kg/capita/yr
Oil:	3.6	to	11.	kg/capita/yr

For additional parameters see Table 4.2.2-1

41. When septage is treated along with domestic wastes, the proportions should be kept low enough so as not to affect the operation of the treatment plant, otherwise pre-aeration may be required to avert anoxic conditions.

Table 4.2.2-1 Pollutant loads from Sewered Urban Areas (*Source:* S. J. Arceivala, *Marcel Dekker, Inc.*)

Pollutant	Effluent Load factor (g/capita/day)
BOD_5	45 - 54
Chemical Oxygen Demand (Dichromate)	1.6 to 1.9 x BOD_5
Total Organic Carbon	0.6 to 1.0 x BOD_5
Total Solids	170 - 220
Suspended Solids	70 - 145
Grit (inorganic, 0.2 mm and above)	5 - 15
Grease	10 - 30
Alkalinity, as $CaCO_3$	20 - 30
Chlorides	4 - 8
Nitrogen, total, as N	6 - 12
Organic Nitrogen	0.4 x total N
Free Ammonia[a]	0.6 x total N
Nitrite	-
Nitrate	0.0 to 0.05 x total N
Phosphorus, total, as P	0.6 - 4.5
Organic Phosphorus	0.3 x total P
Inorganic (ortho and polyphosphates)	0.7 x total P
Potassium, as K2O	2 - 6
Microorganisms Present in Wastewater	**(count per 100 ml wastewater)**
Total bacteria	10^9-10^{10}
Coliforms	10^6-10^9
Fecal Streptococci	10^5-10^6
Salmonella typhosa	10^1-10^4
Protozoan cysts	up to 10^3
Helminthic eggs	up to 10^3
Virus (plaque forming units)	10^2-10^4

[a]Ammonia in the wastewaters is a by-product of the urea decomposition

Note: The wastewater volume, depending on the standard of living and on local conditions, ranges from 50 to 300 lt/d. In some U.S. and other communities it can even exceed 500 lt/d.

Table 4.2.2-2 Typical Performance Efficiencies for Municipal Wastewater Treatment Processes

Treatment Process	BOD Removal, %	TSS Removal, %	Nitrogen Removal, %	Phosphorus Removal, %	Bacteria Removal, %	Viruses Removal $\log_{10}$ units
Primary Treatment:						
Screening	5-10	2-20			10-20	
Grit Chambers	10-20	20-40			10-20	
Skimming	20-30	20-40			10-20	
Sedimentation	30-35	60-65	7.5	10	25-75	0-1
Secondary Treatment:						
Chemical Coagulation	50-85	70-90	25	85	40-80	0-1
High Rate Trickling Filter	65-95	65-92			80-95	0-1
Low Rate Trickling Filter	90-95	70-92			90-95	0-1
Activated Sludge	85-93	85-90	30-40	30-45	60-90	0-1
Extended Aeration	95-98	85-90	15-30	10-20	60-90	0-1
Aerated Lagoon	70-90				60-96	1-3
Waste Stabilization	70-90		40-50	20-60	60-99.9+	1-4
Tertiary Treatment:						
Disinfection					99-99.9+	0-4

Table 4.2.2-3 Nutrient and Organic loads from rainfall and land runoff (*Source:* S. J. Arceivala, *Marcel Dekker, Inc.*)

Source	Units	Total N as N	Total P as P	BOD	COD	TSS
Direct rainfall	mg/l	0.5-1.5	0.004-0.03		10-20	10-20
Urban stormwater runoff (separate sewers)						
a. Cincinnati[a]	$kg/km^2/yr$	875	105	4,725	31,150	64,050
b. Europe	$kg/km^2/yr$	952	90			
Forest runoff						
a. Several US studies	$kg/km^2/yr$	143-357	2.6-12.8			
b. Swiss pre-Alps	$kg/km^2/yr$	840	4			
c. Diverse forests (Finland)	$kg/km^2/yr$		17-27			
Pastures in Swiss pre-Alps						
Natural	$kg/km^2/yr$	1,650				
Fertilized	$kg/km^2/yr$	1,940				
Agricultural Runoff						
a. Typical Range	$kg/km^2/yr$		7-105[b]			
b. 3 US areas	$kg/km^2/yr$	784	45			
c. Swiss plateau[c]	$kg/km^2/yr$	1,400-3,000	21-50			
d. 7.5-acre US field	$kg/km^2/day$ of rainfall	20	1.7			
e. Irrigation return flows						
Surface	$kg/km^2/yr$	274-2690	103-434			
Subsurface	$kg/km^2/yr$	4,250-18,600	280-906			

[a] Average numbers of bacteria per 100 ml: Total coliforms 58,000; Fecal coliforms 10,900; Fecal Streptococci 20,500.

[b] 0.05-1.0 mg/l as total P, of which 15-50% may be as soluble orthophosphates

[c] Mixed agricultural use, fertilized

Table 4.2.2-4 Efficiency of Treatment Systems for Agro-Industry Wastes (*Adapted from:* E.J. Middlebrooks, *John Willey & Sons*)

Treatment System	Effluent Reduction	
Primary Treatment of By-product recovery		
Sedimentation or Gravity separation	BOD_5	20-30% removal
	TSS	20-50% removal
	Oil	15-20% removal
Dissolved Air Flotation (DAF)	BOD_5	30% removal
	TSS	30% removal
	Oil	60% rem'l to 100-200mg/l
DAF with p_H control & flocculants added	BOD_5	90% removal
	TSS	98% removal
	Oil	95-99% removal
Secondary Treatment		
Anaerobic & aerobic lagoons	BOD_5	95% removal
Anaerobic & aerated & aerobic lagoons	BOD_5	to 99% removal
Anaerobic contact process	BOD_5	90-95% removal
Activated sludge	BOD_5	90-95% removal
Extended aeration	BOD_5	95% removal
Anaerobic lagoons and biodisks	BOD_5	90-95% removal
Tertiary Treatment		
Chlorination	Disinfection	
Sand filter	BOD_5	to 5-10 mg/l
	TSS	to 3-8 mg/l
Microstrainer	BOD_5	to 10-20 mg/l
	TSS	to 10-15 mg/l
Electrodialysis	TDS	90% removal
Ion exchange	Salt	90% removal
Ammonia stripping	NH_3	90-95% removal
Carbon adsorption	BOD_5	to 95% removal
Chemical precipitation	P	85-95% rem'l to 0.5 mg/l
Reverse osmosis	Salt	to 5 mg/l
	TDS	to 20 mg/l
No Discharge		
Spray irrigation		Total removal
Flood irrigation		Total removal
Ponding and evaporation		Total removal

Table 4.2.2-5 Composition of Leachates from Landfills (*Source:* G. G. Tchobanoglous, Theisen, H., and R. Eliassen, *Solid Wastes: Engineering Principles and Management Issues. , McGraw-Hill*)

	Range mg/lt	Typical mg/lt
BOD_5	2,000-30,000	10,000
Chemical Oxygen Demand (COD)	3,000-45,000	18,000
Total Organic Carbon (TOC)	1,500-20,000	6,000
Total Suspended Solids	200-1,000	500
Organic Nitrogen	10-600	200
Ammonia Nitrogen	10-800	200
Nitrate	5-40	25
Total phosphorus	1-70	30
Orthophosphorus	1-50	20
Alkalinity as $CaCO_3$	1,000-10,000	3,000
pH	5.3-8.5	6
Total hardness as $CaCO_3$	300-10,000	3,500
Calcium	200-3,000	1,000
Magnesium	50-1,500	250
Potassium	200-2,000	300
Sodium	200-2,000	500
Chloride	100-3,000	500
Sulfate	100-1,500	300
Iron (total)	50-600	60

Note: For the computation of the waste loads the annual leachate volume is required. Leachates are produced from the decomposition of the solid wastes, and from water that has entered the landfill either directly from rainfall, or from surface drainage and groundwater. If the latter can be assumed negligible, the leachates volume could be conservatively taken as equal to the rainfall volume. Evaporation however, may be significant, not only from the landfill surface, but also from the landfill mass due to the exothermic reactions taking place there.

4.2.3 Working Table for Assessing the Effluent Loads

Data and Calculation Sheet for Liquid Wastes (# ___ of ___)

SOURCE	UNIT (U)	SOURCE SIZE	VOLUME		BOD_5		TSS		Total N		Total P		OTHER		
		10^3U/y	Fact m^3/U	1000 m^3/y	Fact kg/U	Load tn/y	Fact kg/U	Load tn/y	Fact kg/U	Load tn/y	Fact kg/U	Load tn/y	Pollutant	Fact kg/U	Load tn/y
Sub Total (from Present Sheet)															
Sub Total (from Previous Sheets															
Sub Total															

Note: U =Unit

Fact=Waste Load Factor

4.2.4 Example

The Problem:

A textile mill operating within our study area is to be surveyed. Determine the data requirements, collect the necessary information and assess the effluent loads:

Solution to the Problem:

1. From Appendix II we find the manufacture of Textiles classified under the Standard Industrial Classification (SIC) Code # 321. Use of Appendix II facilitates the finding of a particular activity in Section 4.2.2.

2. From Section 4.2.2, inspection of the Textile manufacturing liquid wastes model yields the following input data requirements:

   (a) If wool is processed:
   - Quantity of wool scoured, tn/yr
   - Quantity of wool dyed, tn/yr
   - Quantity of wool washed, tn/yr
   - Quantity of wool carbonized, tn/yr
   - Quantity of wool bleached, tn/yr

   (b) If cotton is processed:
   - Quantity of yarn sized, tn/yr
   - Quantity of cotton desized, tn/yr
   - Quantity of cotton kiered, tn/yr
   - Quantity of cotton bleached, tn/yr
   - Quantity of cotton mercerized, tn/yr
   - Quantity of cotton dyed, tn/yr
   - Quantity of cotton printed, tn/yr

   (c) If rayon is processed:
   - Quantity of textiles, tn/yr

   (d) If rayon is processed:
   - Quantity of textiles, tn/yr

   (e) If rayon is processed:
   - Quantity of textiles, tn/yr

   (f) If rayon is processed:
   - Quantity of textiles, tn/yr

   (g) If rayon is processed:
   - Quantity of textiles, tn/yr

   In addition, if a treatment plant exists, information about its type and its operating status must be collected. Typical treatment installations include: plain sedimentation, chemical coagulation/sedimentation, anaerobic lagooning, aerobic lagooning and activated sludge.

3. Assume that from the plant survey visit the following data were obtained in relation to the above questionnaire:

   (a) Only cotton is processed

Quantity of cotton sized,	840 tn/yr
Quantity of cotton desized,	840 tn/yr
Quantity of cotton kiered,	840 tn/yr
Quantity of cotton bleached,	840 tn/yr
Quantity of cotton mercerized,	290 tn/yr
Quantity of cotton dyed,	420 tn/yr
Quantity of cotton printed,	120 tn/yr

(b) The treatment plant comprises only plain sedimentation.

4. The above plant survey data, along with the necessary information from the liquid waste load model of Section 4.2.2, can be inserted in the working Table given in Section 4.2.3. The latter can be used for computing the annual effluent loads released from the plant.

   Table 4.2.4-1 shows how data and information can be entered and how effluent loads can be computed. It should be noted that in this Working Table:

   (a) Each listed load factor is the product of multiplication of each uncontrolled waste factor and the corresponding penetration factor for the plain sedimentation used. For example, the BOD_5 load factor for untreated cotton sizing is 2.8 kg/tn and the BOD_5 penetration from plain sedimentation is 0.6, Section 4.2.2, SIC 321. Their product, 2.8x0.6=1.7, is the BOD_5 load factor for the treated effluent from cotton sizing.

   (b) The load factors are expressed as kg/Unit, while the activity of each source is entered in 1000 Units/Year. As a result, multiplication of each load factor by the source activity yields the effluent load expressed in tons/year. For example, the BOD_5 load factor for cotton sizing is 1.7 kg/tn of cotton and the source activity is 0.84 thousand tons of cotton sized per year. Their multiplication yields 1.4 tons of BOD_5 per year.

Table 4.2.4-1 Example use of the working table of Section 4.2.3

Data and Calculation Sheet for Liquid Wastes (# _1_ of _1_)

SOURCE	UNIT (U)	SOURCE SIZE 10^3U/y	VOLUME Fact m^3/U	VOLUME 1000 m^3/y	BOD_5 Fact kg/U	BOD_5 Load tn/y	TSS Fact kg/U	TSS Load tn/y	Total N Fact kg/U	Total N Load tn/y	Total P Fact kg/U	Total P Load tn/y	OTHER Pollutant	OTHER Fact kg/U	OTHER Load tn/y
312 Textiles Manufacturing															
Textile Mill Surveyed															
Sizing	tn	0.84	4.2	3.5	1.7	1.4									
Desizing	tn	0.84	22	18.5	34.8	29.2	12.0	10.1							
Kiering	tn	0.84	100	84	31.8	26.7	8.8	7.4							
Bleaching	tn	0.84	100	84	4.8	4.0	2.0	1.7							
Mercerizing	tn	0.29	35	10.2	4.8	1.4	1.0	0.3							
Dyeing	tn	0.42	50	21	36.0	15.1	10.0	4.2							
Printing	tn	0.12	14	1.7	32.4	3.9	4.8	0.6							
Sub Total (from Present Sheet)				222.9		81.7		24.3							
Sub Total (from Previous Sheets															
Sub Total															

Note: U =Unit

Fact=Waste Lead Factor

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CHAPTER 5

SOLID WASTE INVENTORIES

5.1 Compilation of Solid Waste Inventories Under Present and/or Strategy Target Conditions

The procedural aspects for the calculation of the solid waste loads released from various sources in the study area are presented in Section 2.3 and demonstrated through an example in Section 5.2.4.

In the air and liquid wastes examined so far, the pollutants types are fairly well defined. This is not the case however, for the solid and hazardous wastes, as they are often complex mixtures of inert, oily, organic and toxic substances. The classification of such wastes in categories has to be based on their nature, using as criteria for this purpose their land or water pollution potential, as well as the applicable treatment technologies.

In this book and in the model in Section 5.2.2 in particular, the solid waste load factors from the various types of sources are organized according to the system proposed by the World Bank/WHO/UNEP in six broad categories and a number of sub-categories thereof. As this classification of solid and hazardous wastes is important, a brief summary of the categories and their sub-categories follows:

1. **Inorganic Wastes**

   A. *Acids and Alkalis* come mainly from surface preparation and finishing of metals. They are hazardous because of their corrosive action.

   B. *Cyanide Wastes* come mainly from the metal finishing industry and the heat treatment of certain steels. Their acute toxicity makes them hazardous.

   C. *Heavy Metal Sludges and Solutions* come from a wide variety of manufacturing processes such as chlor-alkali, metal plating, tanneries, and textile mills. They are a major hazard because of the toxicity of heavy metals such as arsenic, cadmium, hexavalent chromium, lead, mercury, nickel, zinc and copper.

   D. *Asbestos Wastes* come mainly from demolition or building of power plants, gas works, dock yards, buildings etc, where this material is used. The inhalation of asbestos fibers due to their carcinogenic potential represents a major hazard.

   E. *Other Solid Residues* come mainly from the smelting and refining of metals. Their dusts and sludges contain toxic metals including nickel, arsenic, zinc, mercury, cadmium and lead.

2. **Oily Wastes**

   These are generated primarily from the processing, use and storage of mineral oils. Example are bottom sludges from oil storage tanks and waste cutting oils. They may also contain toxic metals.

3. **Organic Wastes**

A. *Halogenated Solvents* are generated primarily from dry cleaning and metal cleaning operations and to a much smaller extent from degreasing and deoiling processes in the textile and leather industry. The hazards associated with these wastes are a result of their toxicity and relatively high persistence.

B. *Non-Halogenated Solvent Wastes* are generated primarily in the production of paints, inks, adhesives, resins, solvent-based wood preservatives, toiletries, food flavourings cosmetics etc.

C. *PCB Wastes* are generated primarily from the manufacture of PCBs and from the decommissioning of equipment, in which PCBs are used. PCBs are used in industry as dielectric fluids (in electric transformers and capacitors), as well as hydraulic and heat transfer fluids. The hazards associated with these wastes are a result of their high persistence and bioaccumulation.

D. *Paint and Resin Wastes* are generated primarily from a variety of paint formulation and other tertiary chemical processes, and also from the application of paints and resins to finished products. They are typically combinations of solvents and polymeric materials, including, in some cases, toxic metals.

E. *Biocide Wastes* are generated primarily from the manufacture and formulation of biocides and from their use in agriculture.

F. *Organic Chemical Residues* include both halogenated and non-halogenated chemicals, but differ from categories (A) to (E) above in that their presence is not in concentrated form. They are generated by a broad range of industries including petroleum refining manufacture of chemicals, dye stuffs, pharmaceuticals, plastics, rubbers and resins. They are also generated from coal carbonization. Distillation residues and filter materials are common components.

4. **Putrescible Organic Wastes**

These include wastes from the production of edible oils, leftovers from slaughterhouses, tanneries, and other animal based products. In this category we have classified the wastes from agricultural activities, sludges from wastewater treatment plants, which do not contain excessive amounts of toxic substances, as well as the normal municipal refuse.

5. **High Volume/Low Hazard Wastes**

These include wastes which, based on their intrinsic properties, present relatively low hazards. Examples include drilling muds from petroleum and gas extraction, fly ash from fossil fuel fired power plants, mine tailings, or metalliferous slags.

6. **Infectious Wastes**

Include infectious wastes associated with diseased animal tissues, and may originate from slaughterhouses, hospitals etc.

5.2 Model for Compiling Solid Waste Inventories

5.2.1 Introduction

The quantities of solid and hazardous wastes generated from any industrial or other activity depend, in general, on a number of parameters. Thus, the emission E of waste j could be expressed in a mathematical form as follows:

E_j = f(Source type, (5.2.1-1)
Unit of activity,
Source size,
Type and quality of the raw materials used,
Air pollution control systems employed,
Wastewater treatment systems employed,
etc.)

The source type defines the kind of pollution generating activity in somewhat broad terms, e.g. leather tanning or textile finishing. More precise definition is provided through other parameters as discussed below. Obviously, the source type is a parameter which is closely related to the nature and quantity of the wastes generated.

Through the source type parameter alone it is possible to simplify the source inventory and the solid waste management tasks very substantially by excluding, right from the start, numerous activities with relatively minor solid waste generating potential.

The unit of activity, defines the magnitude of a given source. Suitably defined units can be used to provide a measure of the source (e.g. population of an urban area) or the activity of an industry (raw materials consumed, or products manufactured).

Selection of the most suitable unit for each type of activity is important, as the unit must have a direct relation to the effluent loads generated, and must offer convenience in obtaining the required data during the field work. For example, the magnitude of a tannery source could be characterized by the electricity or the water consumed, by the number of people employed, by the land area occupied, or by the quantities of the hides processed. The latter is much more closely related to the effluent loads generated; it can be easily obtained, both during plant survey visits and from government sources (usually as a compounded total for all tanneries), and is thus the unit of choice.

Source size, although a key parameter, is only indirectly related to the normalized load rates (pollutant loads per unit of activity). In large-size sources, economies of scale allow better design and operation, waste-material recycling and reuse (Overcash, 1986), and improved processing and handling (e.g. sludge digestion in wastewater treatment plants), and these can substantially reduce the waste generating potential. On the other hand large-size sources are more likely to be equipped with efficient air and/or effluent control systems, which generate significant quantities of solid and often hazardous wastes (see below).

In the context of the present methodology the above effects of the source size on the normalized loads is taken into consideration through the listing of alternative air and water treatment and waste processing possibilities.

The type and the quality of the raw materials used are in principle intimately related to the quantities and the nature of the solid and hazardous wastes generated. In the treatment of municipal effluents, the presence of toxic wastes in the generated sludge depends on the quality of the received wastewater. In industrial processes the type and the quality of raw materials available often dictate the process to be used. The above are covered by the solid waste loads model of Section 5.2.2.

The use of Air Pollution Control systems inevitably results in the production of solid and hazardous wastes as they capture the pollutants that would have been emitted and convert them into a solid wastes form.

The air pollutant control systems can be distinguished into three basic categories depending on their solid wastes generating potential: thermal or catalytic incinerators, which convert pollutants into less harmful emissions, and the adsorption or refrigeration systems, which capture pollutants in the form of useful liquid products, present the smallest solid wastes pollution potential; dust control systems, such as cyclones, fabric filters and electrostatic precipitators, which operate without the use of water, capture the suspended particulates and yield significant quantities of solid wastes, often of a toxic nature; finally, wet scrubbers remove dust and gaseous pollutants yielding sludges, which, due to their large volume and their hazardous nature present the most difficult disposal problems.

The impact of the above parameters is included in the model in Section 5.2.2, as data are provided, which allow the assessment of the waste quantities generated, both in dry and in wet states, by the air pollution control installations of selected sources.

The use of Wastewater Systems inevitably results in the generation of sludges often of a hazardous nature, as most of the suspended solids settle and the organic materials are digested by bacteria and converted into settled biomass. In this process most of the heavy metals in the wastewater, also find their way into the sludge.

The impact of this parameter is included in the model in Section 5.2.2 as data are provided, which allow the assessment of the waste quantities generated, both in dry and in wet states, by the wastewater treatment installations of selected sources.

The above discussion leads into the practical question of how the waste load E_j could be expressed as a direct and explicit function of all the parameters that may affect it for all waste types j of interest.

The first step in this direction is to define the waste load factor e_j for the waste type j, through the following relation:

$$e_j = \frac{E_j, \text{ kg/yr}}{\text{Source activity, Units/yr}} \qquad (5.2.1\text{-}2)$$

The waste load factor e_j is normally expressed as kg/Unit and is assumed to be independent of the source size and the source activity (or production) level. The basis for this important assumption is the way the activity units are selected. Indeed, as discussed above, a key criterion in the selection of the activity units is their direct and proportional relation to the waste loads generated. From the above and from Equation (5.2.1-1) we obtain:

$$e_j = f(\text{Source type, Type and quality of the raw materials used, Air pollution control systems employed, Wastewater treatment systems employed, etc.}) \qquad (5.2.1\text{-}3)$$

The emission factor e_j is used extensively hereafter, as the key objective of our solid wastes load emissions model is to define the value of e_j for every type of waste j.

The dependence of the waste load factors e_j on the parameters discussed above and listed in Equation (5.2.1-1), cannot, in most cases, be expressed in a continuous function form due to the discreet nature of most parameters (e.g. the type of treatment plant used), and to frequent lack of sufficient information in relation to the remaining parameters. A discreet functional form yielding a series of waste load factors, each valid under a specific set of common and important parameter combinations, is used instead.

The discreet rather than the continuous nature of the emission factor values explains the tabular construct of the Model in Section 5.2.2, into which the source types are organized on the basis of the UN Standard Classification of Industries and Services. Under each activity listed, typical alternative processes are included (e.g. under Tanneries and Leather Finishing (SIC 3231), the Chrome Tanning, Vegetable Tanning, Tanning only, Finishing only, Re-tanning and Finishing), and for each such process the major air pollution and/or effluent control alternatives are listed (e.g. effluent pretreatment or full effluent treatment).

The tabular structure and the form of Section 5.2.2 constitutes a solid wastes inventory model, which introduces the impact of all major parameters into the assessment of the generated waste loads, and provides a precise definition of the data requirements from field surveys. The model in Section 5.2.2 constitutes thus a valuable tool for source inventory studies, not only for computing the waste loads and for providing guidance on the data to be collected during the field survey work, but also for organizing and presenting such data in a concise manner (see also Sections 5.2.3 and 5.2.4 below).

The nature of the solid wastes produced is a key parameter from both, the management and treatment points of view, and the land or water pollution potential. This important issue is addressed by the model of Section 5.2.2 in three ways:

1. The wastes are classified according to the system proposed by the World Bank/WHO/UNEP in six broad categories and a number of sub-categories thereof as follows:

   Inorganic wastes

   A. Acid and alkalis
   B. Cyanide wastes
   C. Heavy metal sludges and solutions
   D. Asbestos residues
   E. Other solid residues

   Oily wastes

   Organic wastes

   A. Spent halogenated solvents
   B. Non-Halogenated solvent wastes
   C. PCB wastes
   D. Paint and resin wastes
   E. Biocide wastes
   F. Organic chemical residues

   Putrescible organic wastes

   High volume/low hazard wastes

Infectious wastes

In Section 5.1 the nature of the wastes in each of the above categories and sub-categories is described, while the major industrial and other activities that generate them are listed.

2. Footnotes provide a short description of the nature and/or additional information about the composition of many types of waste.

3. For municipal solid wastes (belonging in the general category of Putrescible Organic Wastes) typical composition, density, and calorific value data for various countries provided in Table 5.2.2-1. Moreover, Table 5.2.2-2 provides typical property values for individual municipal waste components enabling users to assess the typical moisture content, density, low calorific value and residue on the basis of available waste composition data. Table 5.2.2-3 provides data about the compaction ratio of the various types of solid wastes for alternative compaction degrees enabling users to compute the landfill volume requirements, Section 10.3.2.5.

Any classification scheme, including the one adopted here, aims to classify the wastes produced in broad categories. Such groupings however do not convey sufficient information for management purposes and, as a result, the need arises to consider the hazardous and toxic wastes generated by each type of source separately. In highly industrialized economies this would require a lengthy list of sources. For most developing countries however, the structure and complexity of their chemical and processing industries is considerably simpler, and as a result, the number of source types which are important, is not prohibitively long for rapid assessment procedures. The model in Section 5.2.2 includes many of the types of sources likely to be encountered in developing countries, and especially those which require priority action.

5.2.2 Model for Solid and Hazardous Waste Inventories[1]

	UNIT	Inorganic		Oily	Organic		Putrescible	Low Hazard	Infectious
		*	Kg/U	Kg/U	*	Kg/U	Kg/U	Kg/U	Kg/U
MAJOR DIVISION 1. **AGRICULTURE, HUNTING, FORESTRY AND FISHING**									
111 **Agricultural and Livestock Production**									
Agricultural									
Cotton	tn of product						2500		
Rice	tn of product						800		
Oats	tn of product						1400		
Sugar (Cane)	tn of product						300		
Sugar (Beet)	tn of product						100		
Coffee	tn of product						3500		
Barley	tn of product						1800		
Rye	tn of product						1600		
Maize	tn of product						1500		
Sorghum	tn of product						700		
Soya	tn of product						1600		
Wheat	tn of product						1100		
Other cereals	tn of product						700		
Farm Animals and Poultry[2]									
Bovine Cattle	animal*year						4000		
Sheep	animal*year						1100		
Pigs	animal*year						700		
Chicken	bird*year						20		
Turkeys	bird*year						200		
Horses	animal*year						4000		
MAJOR DIVISION 2. **COAL MINING AND QUARRYING**									
DIVISION 21. **COAL MINING**									
Coal Mining									
Surface Working[3]	tn of product							12100	
Underground Working[4]	tn of product							37	

1. For a description of the waste categories and sub-categories (the latter denoted in the model by the capital letters A to F) see Sections 5.1 and 5.2.1
2. The wastes produced by animal farms are mostly manure, but in the case of chicken and turkeys they contain the litter, which is periodically added
3. Overburden

Model for Solid & Hazardous Waste Inventories - Cont'd

	UNIT	Inorganic *	Inorganic Kg/U	Oily Kg/U	Organic *	Organic Kg/U	Putrescible Kg/U	Low Hazard Kg/U	Infectious Kg/U
DIVISION 23. **METAL ORE MINING**									
2301 Iron Ore Mining									
Surface Working	tn of product							100	
Underground Working	tn of product							2100	
2302 Non-Ferrous Ore Mining									
Copper Ore									
Surface Working	tn of product							2250	
Underground Working	tn of product							75	
Bauxite Ore									
Surface Working	tn of product							6000	
Lead Ore									
Underground Working	tn of product							250	
Zinc Ore									
Underground Working	tn of product							200	
Tungsten Ore									
Underground Working	tn of product							300	
Silver Ore									
Surface Working	tn of product							8350	
Underground Working	tn of product							350	
Uranium Ore									
Surface Working	tn of product							19500	
Underground Working	tn of product							400	
Gold Vein									
Surface Working	tn of product							2400	
Underground Working	tn of product							200	
Gold Alluvial									
Surface Working	tn of product							730	
Other									
Surface Working	tn of product							3450	
Underground Working	tn of product							25	
DIVISION 29. **OTHER MINING**									
2901 Stone Quarrying, Clay and Sand Pits									
Crushed and Broken Stone									
Surface Working	tn of product							80	

4. Low grade coal and parent rock

Model for Solid & Hazardous Waste Inventories - Cont'd

	UNIT	Inorganic *	Inorganic Kg/U	Oily Kg/U	Organic *	Organic Kg/U	Putrescible Kg/U	Low Hazard Kg/U	Infectious Kg/U
Clay									
Surface Working	tn of product							900	
Underground Working	tn of product							20	
Talc, Soapstone, Pyrophyllite									
Surface Working	tn of product							1650	
Underground Working	tn of product							40	
2902 Chemical and Fertilizer Mineral Mining									
Phosphate Rock									
Surface Working	tn of product							2050	
Underground Working	tn of product							10	
Potassium Salts									
Underground Working	tn of product							30	
Gypsum / Surface Working	tn of product							500	
Fluorspar/Underground Working	tn product							200	
Barytes									
Surface Working	tn of product							650	
Underground Working	tn of product							200	
2909 Mining and Quarrying Not Elsewhere Classified									
Abrasives / Surface Working	tn of product							450	
Asbestos / Surface Working	tn of product							3200	
Mica / Surface Working	tn of product							500	
Diatomite / Surface Working	tn of product							1450	
Feldspar / Surface Working	tn of product							1010	
Perlite / Surface Working	tn of product							600	
Pumice / Surface Working	tn of product							100	

MAJOR DIVISION 3. **MANUFACTURING**

DIVISION 31. **MANUFACTURE OF FOOD BEVERAGES AND TOBACCO**

311/2 **Food Manufacturing**

	UNIT	Inorganic *	Inorganic Kg/U	Oily Kg/U	Organic *	Organic Kg/U	Putrescible Kg/U	Low Hazard Kg/U	Infectious Kg/U
Slaughterhouse	tn LWK[5]						35[6]		
	tn LWK								3[7]

5. LWK is the Live Weight of animals Killed
6. Blood, paunch, hooves, etc
7. Infected animals and organs

Model for Solid & Hazardous Waste Inventories - Cont'd

		UNIT	Inorganic		Oily	Organic		Putres-cible	Low Hazard	Infec-tious
			*	Kg/U	Kg/U	*	Kg/U	Kg/U	Kg/U	Kg/U
	Poultry Processing[8]	1000 Birds						35		
	Packing House[9]	tn of product						300		
3113	Canning of Fruits and Vegetables[10]									
	Apples	tn of product						280		
	Beets, carrots	tn of product						210		
	Citrus	tn of product						390		
	Corn	tn of product						660		
	Olives	tn of product						140		
	Peaches	tn of product						270		
	Pears	tn of product						290		
	Peas	tn of product						120		
	Potatoes	tn of product						330		
	Tomatoes	tn of product						80		
	Vegetables, misc.	tn of product						220		
3114	Canning of Fish[11]									
	Fish	tn of product						280		
	Crab, Shrimp	tn of product						570		
3115	Vegetable Oil Refining[12]	tn of product						4.7		
3118	Sugar Refineries[13]	tn of product						N/A		
3121	Starch and Glucose[14]	tn of product						N/A		
313	**Beverage Industries**									
3131	Alcohol Distilleries[15]	tn of product						300		
3133	Beer Brewing[16]	tn of cereal						100		
		m3 of beer						20		

8. Feathers, hooves, inedibles
9. Bones, inedible meat, etc
10. Peels, cores, seeds, etc
11. Inedible fish parts
12. Purification mud soaked in oil
13. Spent beats and canes
14. Corn residues
15. Spent resins, figs, canes, etc
16. Spent hop, grain, residues, yeast

Model for Solid & Hazardous Waste Inventories - Cont'd

	UNIT	*	Inorganic Kg/U	Oily Kg/U	*	Organic Kg/U	Putrescible Kg/U	Low Hazard Kg/U	Infectious Kg/U
DIVISION 32. **TEXTILE, WEARING APPAREL AND LEATHER INDUSTRIES**									
321 **Manufacture of Textiles**									
3211 Wool Processing									
Scouring									
Process[17]	tn of product							95	
Effluent Treatment	tn of product						570[18]		
	(tn of product)						(5700)		
Dyeing and Finishing									
Process[19]	tn of product				D	38			
Effluent Pretreatment	tn of product							25[20]	
	(tn of product)							(100)	
Treatment	tn of product	C	N/A						
3211 Cotton Processing									
Yarn Preparation[21]	tn of product							32	
Weaving[22]	tn of product							11	
Dyeing and Finishing									
Process[23]	tn of product							7	
Effluent Pretreatment	tn of product						0.8[24]		
	(tn of product)						(2.8)		
Effluent Treatment	tn of product						20[25]		
	(tn of product)						(2300)		
3214 Carpet and Rug Manufacture									
Process	tn of product							31	
Pretreatment	tn of product				D	1.2[26]			
	(tn of product)				D	(2)			
Treatment	tn of product	C	2.3[27]						
	(tn of product)	C	(4.9)						

17. Dirt, wool, fly and sweeps
18. Treatment sludge
19. Flock, dye, chemical containers, etc
20. Screening fibers
21. Fiber and yarn
22. Fiber, yarn and cloth
23. Cloth and flock
24. Screening fibers
25. Treatment sludge
26. Pretreatment sludge
27. Treatment sludge. Possible presence of heavy metals

Model for Solid & Hazardous Waste Inventories - Cont'd

	UNIT	Inorganic *	Inorganic Kg/U	Oily Kg/U	Organic *	Organic Kg/U	Putrescible Kg/U	Low Hazard Kg/U	Infectious Kg/U
323 Tanneries and Leather Finishing									
3231 Leather Tanneries[28,29]									
Complete Chromium Tanning (Cow Hides)									
Process	1000 equiv hides	C	910				450		
	(1000 equiv hides)	C	(1770)				(550)		
Effluent Pretreat't	1000 equiv hides	C	90						
	(1000 equiv hides)	C	(390)						
Effluent Treatment	1000 equiv hides	C	300						
	(1000 equiv hides)	C	(2700)						
Complete Vegetable Tanning (Cow Hides)									
Process	1000 equiv hides	C	1200				1000		
	(1000 equiv hides)	C	(1400)				(3350)		
Effluent Preatreat't	1000 equiv hides	C	140						
	(1000 equiv hides)	C	(700)						
Effluent Treatment	1000 equiv hides	C	350						
	(1000 equiv hides)	C	(7000)						
Complete Vegetable Tanning (Sheep Skins)									
Process	1000 equiv hides	C	540				300		
	(1000 equiv hides)	C	(1430)				(440)		
Effluent Preatreat't	1000 equiv hides	C	50						
	(1000 equiv hides)	C	(230)						
Tanning Sections of Hides									
Process	1000 equiv hides	C	4000				90		
	(1000 equiv hides)	C	(8500)				(150)		
Effluent Preatreat't	1000 equiv hides	C	5						
	(1000 equiv hides)	C	(22)						
Leather Finishing Only									
Process	1000 equiv hides	C	75				55		
	(1000 equiv hides)	C	(84)				(161)		
Re-tanning and Finishing									
Process	1000 equiv hides	C	230				910		
	(1000 equiv hides)	C	(250)				(1770)		
Effluent Preatreat't	1000 equiv hides	C	10						
	(1000 equiv hides)	C	(40)						

28. Typical weight of a big hide (from cattle or horse) is 25 to 26 kg, while that of a small hide (from sheep or goat) is 3 kg.
29. The major wastes in this category are toxic ones, containing Cr, Pb, and Zn, as well as putrescible scrap products.

Model for Solid & Hazardous Waste Inventories - Cont'd

	UNIT	*	Inorganic Kg/U	Oily Kg/U	*	Organic Kg/U	Putrescible Kg/U	Low Hazard Kg/U	Infectious Kg/U
DIVISION 34. **MANUFACTURE OF PAPER AND PAPER PRODUCTS**									
3411 Manufacture of Pulp, Paper and Paperboard									
Pulp Mills	tn of product						50[30]		
DIVISION 35. **MANUFACTURE OF CHEMICALS & OF CHEMICAL, COAL, RUBBER & PLASTIC PRODUCTS**									
351 **Manufacture of Industrial Chemicals**									
3511 Manufacture of Basic Industrial Chemicals except Fertilizers									
Chlor-Alkali Plants									
Mercury-cathode cell process	tn of Cl_2	C	40[31]						
Sulfuric Acid	tn							N/A[32]	
Phosphoric Acid (Wet Process)	tn							4750[33]	
Ammonia	tn			N/A[34]					
3511 Ethylene Dichloride	tn				A	6.4[35]			
3511 Phenols									
Chlorobenzene Process	tn				A	12.6[36]			
3512 Pesticides	tn active ingredient				E	200[37]			
	tn active ingredient				E	N/A[38]			

30. Cellulose, lignins, reducing sugars
31. Graphite, purification muds, $CaCO_3$, $Mg(OH)_2$, Hg / Dry basis
32. Spent converter catalyst (V_2O_5)
33. Gypsum / Dry basis
34. Oily condensates from feedstock
35. Organic Chlorinated Compounds
36. Organic Chlorinated Compounds
37. Containers, bags, 1.5% active ingredients
38. Broken emulsion products

Model for Solid & Hazardous Waste Inventories - Cont'd

		UNIT	Inorganic *	Inorganic Kg/U	Oily Kg/U	Organic *	Organic Kg/U	Putrescible Kg/U	Low Hazard Kg/U	Infectious Kg/U
352	**Manufacture of Other Chemical Products**									
3521	Paints, Varnishes and Lacquers									
	Solvent Paints	tn of paint				D	8.3[39]			
	Latex Paints	tn of paint				D	5.8[40]			
3522	Manufacture of Drugs and Medicines									
	Preparation of Active Ingredients									
	Synthetic Organic Medicals[41]	tn of product	C	86[42]		A	100			
		tn of product				B	700			
		tn of product				F	450[43]			
	Fermentation products (Antibiotics)									
	Process	tn of product				B	1200[44]			
		tn of product						2300[45]		
		(tn of product)						(10000)		
	Effluent Treatment	tn of product						3500[46]		
		(tn of product)						(35000)		
	Botanicals[47]	tn of product				A	30			
		tn of product				B	60			
		tn of product						330000		
	Pharmaceutical Preparations[48]	tn of product							N/A[49]	

39. Paint sludge, solvents, heavy metals 4.5%
40. Paint sludge, solvents, Hg 125 g/l
41. Aspirin, tranquillizers and vitamins are some of the products in this category. The listed factors are typical for the average mixture of chemicals. Aspirin may generate less waste, while some tranquillizers and vitamins more than that derived from the listed factors.
42. Zinc 70 kg/tn, As 15 kg/tn, Cr 0.7 kg/tn, Cu 0.1 kg/tn, Hg 0.02 kg/tn
43. Approximately 400 kg/tn are tars, muds, and still bottoms, while 50 kg/tn are contaminated, high inert content wastes (filters and activated carbon)
44. Solvent waste concentrate (Butyl acetate, dissolved fats/proteins)
45. Mycelium (medium on which living organisms are developed) wastes
46. Biological sludge
47. Quinine, reserpine, steroids, and laxatives are some of the products in this category
48. Tablets, Capsules, Liquid preparations
49. Mainly broken glass

Model for Solid & Hazardous Waste Inventories - Cont'd

	UNIT	Inorganic		Oily	Organic		Putres-cible	Low Hazard	Infec-tious
		*	Kg/U	Kg/U	*	Kg/U	Kg/U	Kg/U	Kg/U
353 **Petroleum Refining**									
3530 Petroleum Refineries[50]									
Topping Ref'ry	1000 m^3 feedstock			1311					
Low-Cracking Ref'ry	1000 m^3 feedstock			1675					
High-Cracking Ref'ry	1000 m^3 feedstock			3303					
Lubrication Ref'ry	1000 m^3 feedstock			6140					
3530 Spent Lub Oil Regeneration	m^3			209[51]	F	77[52]			
354 **Manufacture of Misc Products of Petroleum and Coke**									
3540 Coke Ovens	tn of coke				F	5.5[53]			
	1000 m^3 of gas				F	8.25			
355 **Manufacture of Rubber Products**									
3551 Tire and Tube Industries[54]									
Rubber Tires	tn							55	
Other rubber products	tn							175	
DIVISION 37. **BASIC METAL INDUSTRIES**									
371 **Iron and Steel Basic Industries**									
Iron Foundries									
Malleable Iron									
Process	tn of castings	E	142[55]						
		E	600[56]						

50. The major wastes problem constitute the oily sludges, which are often contaminated with heavy metals
51. Approximately 150 kg/tn are oily resins with sulfuric acid and 59 kg/tn oily sludges
52. Purification muds soaked with oil
53. Condensates and sludges with Cr 10 g/m^3, Cu 4 gr/m^3, Mn 102 g/m^3, Ni 5.5 g/m^3, Pb 30.5 g/m3, Zn 96.5 g/m^3, and Oil 20.3 %
54. The wastes from this category comprise rubber, fillers, etc
55. Slag, dust, refractories, along with some heavy metals
56. Casting sand with heavy metals and phenols

Model for Solid & Hazardous Waste Inventories - Cont'd

	UNIT	Inorganic *	Inorganic Kg/U	Oily Kg/U	Organic *	Organic Kg/U	Putrescible Kg/U	Low Hazard Kg/U	Infectious Kg/U
Scrubber	tn of castings	E	32.8[57]						
Wrought Iron									
Process	tn of castings	E	134[58]						
	tn of castings	E	600[59]						
Scrubber	tn of castings	E	31.9[60]						
Iron and Steel Mills									
Blast Furnace									
Process	tn of pig iron							348[61]	
Cyclones	tn of pig iron	E	16.2[62]						
Wet Scrubber	tn of pig iron	E	24.4[63]						
BOF Steel Furnace									
Process	tn of steel							145[64]	
Cyclones	tn of steel	E	16[65]						
Wet Scrubber	tn of steel	E	17.3[66]						
Electric Arc Steel Furnace									
Process	tn of steel							120[67]	
Cyclones	tn of steel	E	12.8[68]						
Wet Scrubber	tn of Steel	E	8.7[69]						
Open Hearth Furnace									
Process	tn of steel							243[70]	
Cyclones	tn of steel	E	13.7[71]						
Continuous Casting	tn of steel	E	0.1[72]					8.7[73]	
Hot Rolling	tn of steel	E	1.74[74]					18.3[75]	
Cold Rolling	tn of steel	E	0.16[76]					0.052[77]	

57. Sludge with Heavy metals
58. Slag, dust, refractories with Heavy metals
59. Casting sand with Heavy metals and phenols
60. Sludge with heavy metals
61. Slag with Cr, Cu, Mn, Ni, Pb, and Zn present
62. Dust with Cr, Cu, Mn, Ni, Pb, and Zn present
63. Sludge with Cr, Cu, Mn, Ni, Pb, and Zn present
64. Slag with Cr, Cu, Mn, Ni, Pb, and Zn present
65. Dust with Cr, Cu, Mn, Ni, Pb, and Zn present
66. Sludge with Cr, Cu, Mn, Ni, Pb, and Zn present
67. Slug with Cr, Cu, Mn, Ni, Pb, and Zn present
68. Dust with Cr, Cu, Mn, Ni, Pb, and Zn present
69. Sludge with Cr, Cu, Mn, Ni, Pb, and Zn present
70. Slag with Cr, Cu, Mn, Ni, Pb, and Zn present
71. Dust with Cr, Cu, Mn, Ni, Pb, and Zn present
72. Sludge with heavy metals
73. Rust Scale
74. Sludge with heavy metals
75. Rust Scale
76. Sludge with heavy metals

Model for Solid & Hazardous Waste Inventories - Cont'd

	UNIT	*	Inorganic Kg/U	Oily Kg/U	*	Organic Kg/U	Putrescible Kg/U	Low Hazard Kg/U	Infectious Kg/U
Pickling	tn of steel	A	22.8[78]						
Tinning	tn of steel	E	5.32[79]						
Galvanizing	tn of steel	E	10.8[80]						
Pickling	tn of steel	A	5.17[81]						
Ferro-Alloy Production									
Ferromanganese									
Process	tn of castings							240[82]	
Wet Scrubber	tn of castings	E	165[83]						
Silicomanganese									
Process	tn of castings							1100[84]	
Wet Scrubber	tn of castings	E	98[85]						
Ferrosilicon	tn of castings	E	338[86]						
Ferrochromium	tn of castings							1901[87]	
Ferronickel									
Process	tn of castings							31084[88]	
Wet Scrubber	tn of castings	E	576[89]						
Steel Foundries									
Process	tn of castings							360[90]	
	tn of castings							780[91]	
Wet Scrubber	tn of castings	E	36.4[92]						

77. Rust Scale
78. Pickling Fluid with heavy metals
79. Sludge with heavy metals
80. Sludge with heavy metals
81. Pickling Fluid with heavy metals
82. Slag with heavy metals
83. Sludge with Heavy metals
84. Slag with heavy metals
85. Sludge with heavy metals
86. Dust with Heavy metals
87. Slag and dust with heavy metals
88. Slag and dust with heavy metals
89. Sludge with heavy metals
90. Slag, dust, and refractories with heavy metals
91. Casting sand with heavy metals and phenols
92. Sludge with heavy metals

Model for Solid & Hazardous Waste Inventories - Cont'd

	UNIT	*	Inorganic Kg/U	Oily Kg/U	*	Organic Kg/U	Putrescible Kg/U	Low Hazard Kg/U	Infectious Kg/U
372 **Non-Ferrous Metal Basic Industries**									
Copper									
Primary Copper Smelting	tn							3000[93]	
	tn	E	17[94]						
	tn	E	155[95]						
Copper Electrolytic Refining	tn	E	2.4[96]						
Secondary Copper Smelting	tn							350[97]	
Aluminum									
Alumina from Bauxite	tn of Alumina							2000[98]	
Primary Aluminum Smelting									
Cast House & Roding Room	tn of Al	E	7.5[99]						
Electrolytic Cells									
Process	tn of Al	E	58.5[100]						
Scrubbers	tn of Al	E	117[101]						
Secondary Aluminum Smelting									
Scrap Smelting									
Wet Scrubber	tn	E	75[102]						
Dross Smelting	tn	E	1400[103]						
Primary Lead Smelting and Refining									
Process	tn							410[104]	
Wet Scrubber	tn	E	89[105]						
Secondary Lead Smelting and Refining									
Soft Lead / Blast Furnace	tn	E	472[106]						
Hard Lead /Cupola Furnace	tn							225[107]	

93. Slag with Cd, Cr, Cu, Hg, Mn, Ni, Pb, Sb, Se, and Zn
94. Dust with Cd, Cr, Cu, Hg, Mn, Ni, Pb, Sb, Se, and Zn
95. Sludge with Cd, Cr, Cu, Hg, Mn, Ni, Pb, Sb, Se, and Zn
96. Sludge with Cd, Cr, Cu, Hg, Mn, Ni, Pb, Sb, Se, and Zn
97. Slag with Cd, Cr, Cu, Hg, Mn, Ni, Pb, Sb, Se, and Zn
98. Red Muds / Dry basis
99. Dust with F, Cu and Pb
100. Spent potliners & skim (F and CN)
101. Potline scrubber sludge (14% F2)
102. Scrubber sludge with Cr, Cu, Pb, and Zn present
103. High salt slag with Cr, Cu, Mn, Ni, Pb, and Zn
104. Slag with Cd, Cr, Cu, Mn, Pb, Sb, and Zn
105. Sludge with Cd, Cr, Cu, Mn, Pb, Sb, Zn, and Hg
106. Slag and scrubber sludge with Cd, Cr, Cu, Mn, Ni, Pb, Sb, Sn, and Zn
107. Slag with Cu, Mn, Ni, Pb, Sb, Sn, and Zn

Model for Solid & Hazardous Waste Inventories - Cont'd

	UNIT	Inorganic *	Inorganic Kg/U	Oily Kg/U	Organic *	Organic Kg/U	Putrescible Kg/U	Low Hazard Kg/U	Infectious Kg/U
White Metal / Reverberatory	tn							166[108]	
Primary Zinc Smelting									
Electrolytic Refining	tn	E	26.1[109]						
Pyrometallurgical Smelting/Ref'g	tn	E	1050[110]						
Primary Tin Smelting and Refining	tn							915[111]	
Primary Antimony Smelting and Refining									
Blast or Reverberatory Furnace[112]	tn							2800[113]	
Electrolytic Process	tn	E	210[114]						
Primary Mercury Smelting and Refining	tn	E	207000[115]						
Primary Titanium Refining	tn	E	330[116]						

3819 Manufacture of Fabricated Metal Products Except Machinery & Equipment not Elsewhere Classified

	UNIT	Inorganic *	Inorganic Kg/U	Oily Kg/U	Organic *	Organic Kg/U	Putrescible Kg/U	Low Hazard Kg/U	Infectious Kg/U
Electroplating of Copper									
Effluent Treatment	tn of Cu anodes	E	9[117]						
Electroplating of Ni									
Effluent Treatment	tn of Ni anodes	E	4.[118]						
Electroplating of Chromium									
Effluent Treatment	tn of Cr_2O_3	E	250[119]						
Electroplating of Zn									
Effluent Treatment	tn of Zn anodes	E	220[120]						

108. Slag with Cd, Cr, Cu, Mn, Ni, Pb, Sb, Sn, and Zn
109. Sludges with Cd, Cr, Cu, Hg, Mn, Pb, Se, and Zn
110. Retort residue with Cd, Cr, Cu, Pb, Se, and Zn
111. Slag with Sn and Pb, and possibly with Sb, As, and Zn
112. Pyrometallurgical Process
113. Slag with Pb, Cu, Zn, and Sb
114. Spent anolyte (As 16 g/m^3, Pb 5 g/m^3, Cu 50 g/m^3, Zn 2 g/m^3, Ni 5 g/m^3, Sb 27 kg/m3, Cr 32 g/m^3, Cd 1 g/m^3)
115. Calcine residue with As, Pb, Cu, Zn, Ni, Hg, Mn, Sb, Cd, and Cr
116. Chlorinator and Condenser Sludges with V, Cr, Zr, Ti, and Cl
117. Cu in sludge (Cyanide may be also present) / Dry basis
118. Ni in sludge / Dry basis
119. Cr in sludge / Dry basis

Model for Solid & Hazardous Waste Inventories - Cont'd

	UNIT	Inorganic *	Inorganic Kg/U	Oily Kg/U	Organic *	Organic Kg/U	Putrescible Kg/U	Low Hazard Kg/U	Infectious Kg/U
384 **Manufacture of Transport Equipment**									
3841 Ship Building and Repairing									
Dry Docks				N/A[121]					
MAJOR DIVISION 4. **ELECTRICITY GAS AND WATER**									
4101 Electricity Generation[122]									
Lignite Power Plants									
Emission Controls	MWH							10.0*A	
Bituminous Coal Power Plants									
Emission Controls	MWH							4.3*A	
Transformers	MWH				A	N/A[123]			
MAJOR DIVISION 9. **COMMUNITY, SOCIAL AND PERSONAL SERVICES**									
920 **Sanitary and Similar Services**									
Municipal Refuse Collection[124]									
Very Low Income Areas[125]	person*year						150		
Developing Areas[126]	person*year						250		
Industrialized Areas[127]	person*year						400		
Very High Income Areas[128]	person*year						900		
Wastewater Treatment Plants[129]									
Primary Sedimentation									

120. Zn in sludge (cyanides may be also present) / Dry basis
121. Oily and toxic sludges from ship cleaning
122. The major waste in this category is the fly ash. "A" is the ash content of coal, weight %
123. Polychlorinated biphenyls
124. Typical composition given in Table 9.2.2-1
125. Lowest income areas in South East Asia
126. Typical cities in Asia, North Africa, and South America
127. Typical Cities in Industrialized Countries
128. Typical cities in wealthy regions of the USA and Gulf
129. The main waste problem from this category is the sludge generated from the wastewater treatment operation. The presence of heavy metals in the sludge varies widely and depends on the type of industries that discharge into the sewerage system and on the pretreatment of their effluents. It can be generally assumed that a fair fraction of the heavy metals in the incoming wastewater find their way into the generated sludge.

Model for Solid & Hazardous Waste Inventories - Cont'd

	UNIT	Inorganic *	Inorganic Kg/U	Oily Kg/U	Organic *	Organic Kg/U	Putrescible Kg/U	Low Hazard Kg/U	Infectious Kg/U
Undigested Sludge	person*year						11		
	(person*year)						(220)		
Digested in separate tanks	person*year						5.8		
	(person*year)						(100)		
Digested on sand beds	person*year						5.8		
	(person*year)						(37)		
Primary Sedimentation and Activated Sludge Treatment									
Undigested	person*year						20.4		
	(person*year)						(510)		
Digested in separate tanks	person*year						12.0		
	(person*year)						(146)		
Digested on sand beds	person*year						12.0		
	(person*year)						(37)		
Activated Sludge Treatment									
Wet Sludge	person*year						16.8		
	(person*year)						(1423)		
Trickling Filtration	person*year						4.4		
	(person*year)						(73)		
Chemical Precipitation									
Wet sludge	person*year						28.8		
	(person*year)						(402)		
Dewatered on sand beds	person*year						28.8		
	(person*year)						(110)		
Septic Tank, digested	person*year						7.3		
	(person*year)						(73)		
Imhoff tank, digested	person*year						6.2		
	(person*year)						(37)		
Potable Water Treatment	$1000m^3$ water							200[130]	
	($1000m^3$ water)							(2000)	
930 **Social and Related Community Services**									
933 Medical, Dental and Other Health Services									
University Hospitals	(bed*year)						1096		364
General Hospitals	(bed*year)						706		243
Obstetrical Clinics	(bed*year)						736		432
Medical Centers	(bed*year)						1400		600
Psychiatric Clinics	(bed*year)						375		63
Homes for Aged	(bed*year)						232		33

* = Subcategory for hazardous wastes (see Sections 5.1 and 5.2.1)
( ) = Waste load factor on a wet weight basis

130. Sediment / Dry basis

Table 5.2.2-1 Typical Properties of Municipal Wastes in Various Countries (page 1 of 2)

	Brazil	Ecuador	Egypt	France	Germany
Waste Factor, kg/cap/d			0.5	1.2	
Putrescible %	47.8	65.5	60.0	15.6	45.5
Paper %	31.5	17.9	13.0	35.3	23.0
Metals %	5.9	1.4	3.0	4.8	4.0
Glass %	4.7	1.7	2.5	11.7	13.0
Textiles %	4.1	3.1	2.5	4.9	
Plastic and rubber %	3.9	2.7	1.5	6.9	7.0
Misc. combustible %		3.0			4.0
Misc. incombustible %		0.9			3.5
Inerts %	2.1	3.8	17.5		
Water content, %				31	
Density, kg/m^3		292			
Low Calor Value,kcal/kg				2,000	

	Holland	India	Israel	Italy	Libya
Waste Factor, kg/cap/d			0.5	0.9	
Putrescible %	53.0	75.2	52.0	45.0	54.1
Paper %	23.0	1.5	21.0	20.0	12.1
Metals %	2.5	0.1	3.0	6.0	6.8
Glass %	8.0	0.2	3.0	5.0	3.3
Textiles %		3.1	4.0	3.0	1.9
Plastic and rubber %	6.5	0.9	12.0	4.0	2.1
Misc. combustible %	4.0	0.2			
Misc. incombustible %	3.0	6.9			
Inerts %		12.0			
Water content, %			45.0	45.0	
Density, kg/m^3		570			
Low Calor Value,kcal/kg			1450	1300	

	Malta	Mexico	Nigeria	Paraguay	Peru
Waste Factor, kg/cap/d	0.7				
Putrescible %	38.0	56.4	76.0	60.8	34.3
Paper %	24.0	16.7	6.6	12.2	24.3
Metals %	8.0	5.8	2.5	2.3	3.4
Glass %	9.0	3.7	0.6	4.6	1.7
Textiles %	11.0	6.0	1.4	2.5	1.7
Plastic and rubber %		5.8	4.0	4.4	2.9
Misc. combustible %					
Misc. incombustible %					
Inert below 10 mm %		5.7	8.9	13.2	31.7
Water content, %	25.0				
Density, kg/m^3					
Low Calor Value,kcal/kg	1560				

Table 5.2.2-1 Continued (page 2 of 2)

	Spain	Tunisia	Turkey	Syria	United Kingdom
Waste Factor, kg/cap/d		0.4	0.7-0.8	0.7	
Putrescible %	50.0	80.8	27-38	40.0	28.0
Paper %	15.0	9.6	8-12	26	37.0
Metals %	3.0	2.1	1-2	3	9.0
Glass %		1.1	1-2	3	9.0
Textiles %		2.9	0.5-0.7	4	3.0
Plastic and rubber %	5.0	1.2	2-5	4.5	3.0
Misc. combustible %	18.0	0.5			1.0
Misc. incombustible %	9.0	0.1			1.0
Inert below 10 mm %		1.8			9.0
Water content, %				54	
Density, kg/m^3		321			150
Low Calor Value,kcal/kg				1500	

	Venezuela	Yemen	Yugoslavia
Waste Factor, kg/cap/d			1.25
Putrescible %	40.4	57.0	23.3
Paper %	34.9	15.5	26.5
Metals %	6.0	13.2	2.5
Glass %	6.6	2.6	7.3
Textiles %	2.0	6.8	3.8
Plastic and rubber %	7.8	2.9	10.9
Misc. combustible %			
Misc. incombustible %			
Inert below 10 mm %	2.3	2.0	
Water content, %			31-47
Density, kg/m^3			
Low Calor Value,kcal/kg			1910

Note: The density of municipal wastes from industrialized and developing countries ranges from 100 to 150 and from 300 to over 550 kg/m^3 respectively.

Table 5.2.2-2 Typical Properties of Municipal Waste Components (*Adapted from:* H. Peavy, D. Rowe and G. Tchobanoglous, *Environmental Engineering: McGraw-Hill*)

	Moisture %		Density kg/m^3		Low Calorific Value kcal/kg		Inert Residue After Combustion %	
	Range	Typ'l	Range	Typ'l	Range	Typ'l	Range	Typ'l
Food Wastes	50-80	70	120-480	290	835-1670	1110	2-8	5
Paper	4-10	6	30-130	85	2,770-4,450	4,000	4-8	6
Cardboard	4-8	5	30-80	50	3,330-4,170	3,900	3-6	5
Plastics	1-4	2	30-130	65	6,665-8,900	7,790	6-20	10
Textiles	6-15	10	30-100	65	3,610-4,440	4,170	2-4	2.5
Rubber	1-4	2	90-200	130	4,990-6,665	5,550	8-20	10
Leather	8-12	10	90-260	160	3,610-4,730	4,170	8-20	10
Garden Trimmings	30-80	60	60-225	105	550-4,440	1,550	2-6	4.5
Wood	15-40	20	120-320	240	4,170-4,730	4,440	0.6	1.5
Misc. organics	10-60	25	90-360	240	2,630-6,210	4,300	2-8	6
Glass	1-4	2	160-480	195	24-60	36	96-99	98
Tin cans	2-4	3	45-160	90	60-287	167	96-99	98
Nonferrous metals	2-4	2	60-240	160			90-99	96
Ferrous metals	2-6	3	120-1,200	320	60-287	167	94-99	98
Dirt, ashes, brick	6-12	8	320-960	480	550-2,780	1,670	60-80	70
Municipal Wastes (USA)	15-40	20			2,220-3,060	2,510		
Uncompacted			90-180	130				
In Compactor Truck			180-450	300				
In Landfill								
Normal Compaction			350-550	475				
Good Compaction			600-750	600				

Table 5.2.2-3 Typical Compaction Ratios of Solid Wastes (Volume as Discarded over Volume in Landfill) (*Source:* G. Tchobanoglous, H. Theissen and R. Eliassen, *Solid Wastes Engineering Principles and Management Issues: McGraw-Hill*)

	Poorly Compacted	Normally Compacted	Well-Compacted
Food wastes	2.0	2.8	3.0
Paper	2.5	5.0	6.7
Cardboard	2.5	4.0	5.8
Plastics	5.0	6.7	10.0
Textiles	2.5	5.8	6.7
Rubber, leather, wood	2.5	3.3	3.3
Garden trimmings	2.0	4.0	5.0
Glass	1.1	1.7	2.5
Nonferrous metal	3.3	5.6	6.7
Ferrous metal	1.7	2.9	3.3
Ashes, masonry	1.0	1.2	1.3

5.2.3 Working Table for Assessing the Solid Waste Loads

Data and Calculation Sheet for Solid Wastes (# ___ of ___)

SOURCE	UNIT (U)	SOURCE SIZE 10^3U/y	INORGANIC Factor kg/U		INORGANIC Load tn/y	OILY Factor kg/U	OILY Load tn/y	ORGANIC Factor kg/U		ORGANIC Load tn/y	PUTRESCIBLE Factor kg/U	PUTRESCIBLE Load tn/y	LOW HAZARD Factor kg/U	LOW HAZARD Load tn/y
Sub Total (from Present Sheet)														
Sub Total (from Previous Sheets)														
Sub Total														

Abbreviation: U = UNIT

5.2.4 Example Application

The Problem:

Our study area comprises a city of 15,000 inhabitants, in which a wastewater treatment plant and a leather tannery operate. Determine the data requirements, collect the necessary information and assess the solid waste loads.

Solution of the Problem:

1. From Appendix II we find that Leather Tanneries are classified under the Standard Industrial Classification (SIC) Code # 3231. The Municipal Refuse Collection and the Wastewater Treatment activities are classified under the (SIC) Code # 92. The use of Appendix II facilitates the location of a particular activity in the model in Section 5.2.2.

2. From Section 5.2.2, inspection of the Leather Tanning, Municipal Refuse Collection and Wastewater Treatment segments of the solid wastes model yields the following input data requirements:

   (a) For the Leather Tannery

      (i) Type of Tannery

         Complete chromium tanning,
         Complete vegetable tanning,
         Only tanning,
         Only finishing, or
         Re-tanning and finishing.

      (ii) Type & Quantity of hides processed

      (iii) Type of wastewater treatment

         None,
         Primary, or
         Secondary.

   (b) For the Municipal Refuse collection

      (i) Standard of living in the study area

         Very low income area,
         Area in a developing country,
         Area in an industrialized country, or
         Very high income area.

      (ii) Presence of any significant refuse recycling at the source activity, which may affect the generated loads.

(c) For the wastewater treatment plant

(i) Population served

(ii) Type of treatment

Primary only,
Primary & activated sludge,
Activated sludge only,
Trickling filtration, or
Chemical precipitation.

(iii) Sludge digestion and dewatering

3. Assume that from the field survey work the following data were obtained in relation to the above questionnaire:

(a) For the Leather Tannery

(i) Type of Tannery:

Complete chromium tanning

(ii) Type & Quantity of hides processed:

Cow hides, 45,000/yr

(iii) Existence of a wastewater treatment plant:

Yes

(b) For the Municipal Refuse collection

(i) *Standard of living in the study area:*

Typical of developing country

(ii) *Presence of any significant refuse recycling at the source activity, which may affect the generated loads:*

None

(c) For the wastewater treatment plant

(i) *Population served:*

15,000 (the entire population of the city)

(ii) *Type of treatment:*

Primary & activated sludge,

(iii) *Sludge digestion and dewatering*

Sand beds

4. The above plant survey data, along with the necessary information from the solid wastes load model of Section 5.2.2, can be inserted in the working Table provided in Section 5.2.3. The latter can be used for computing the annual solid waste loads generated within the study area.

   Table 5.2.4-1 shows how data and information can be entered and how the solid waste loads can be computed. It should be noted that in this Working Table the load factors are expressed as kg/Unit, while the activity of each source is entered in 1000 Units/Year. As a result, multiplication of each load factor by the source activity yields the solid waste load expressed in tons/year. For example, the factor for putrescible solid wastes from the Municipal refuse collection is 250 kg/(person*yr) and the source activity is 15 thousand persons*yr. Their multiplication yields 15*250=3750 tons of putrescible solid wastes generated annually.

Table 5.2.4-1 Example use of the working table of Section 5.2.3

Data and Calculation Sheet for Solid Wastes (# _1_ of _1_)

SOURCE	UNIT (U)	SOURCE SIZE 10^3U/y	INORGANIC Factor kg/U		INORGANIC Load tn/y	OILY Factor kg/U	OILY Load tn/y	ORGANIC Factor kg/U		ORGANIC Load tn/y	PUTRESCIBLE Factor kg/U	PUTRESCIBLE Load tn/y	LOW HAZARD Factor kg/U	LOW HAZARD Load tn/y
3231 Leather Tanneries														
Complete Cr Tanning Process	1000 hides	0.045 0.045	910 (1770)	C C	41.0 (80)						450 (550)	20.3 (25)		
Effluent Treat.	1000 hides	0.045 0.045	300 (2700)	C C	13.5 (122)									
92 Sanitary & Similar Services														
Refuse collect'n	pers*y	15									250	3750		
Wastewater Treat. Prim+Act sludge Sand beds	pers*y	15 15									12 (37)	180 (555)		
Sub Total (from Present Sheet)				C C	55 (202)							3950 (4330)		
Sub Total (from Previous Sheets)														
Sub Total														

Abbreviation: U = UNIT

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CHAPTER 6

STUDY IMPLEMENTATION ASPECTS

6.1 Resource and Time Requirements for Environmental Management Studies

As every study area is unique in some respects, it is difficult to make detailed step-by-step planning in advance. Hence, the study team should have the flexibility to collect whatever data and information they feel are suitable for their study and plan visits to data sources and industry. It is also important that both regulatory agency officials and survey team members understand the environmental management procedure, including its managerial and administrative support requirements. The following sections briefly describe the resource and time requirements, which have to be considered when planning a management study.

6.1.1 Personnel and Support Requirements

The environmental management approach described in this book allows the identification of environmental problems, assessment of their intensity, analysis of alternative mitigation options and the outline of effective environmental policies. Despite the fact that the material is organized so as to present a step-by-step guidance on most aspects, the nature and importance of environmental management studies makes it worthwhile to select the best qualified engineers and scientists as study members.

Usually, the study team will have to deal with air, water and land pollution problems in the study area and for this reason it should comprise personnel with management experience in each of the above three media. A team leader, with adequate managerial experience, as well as a broader understanding of the environmental management issues involved, should be designated and assigned overall responsibility.

The study team, depending on the complexity of the situation and the range of experience of the available personnel, may consist as few as two or three persons, including the project manager who may also participate in the analysis of one or more media, but probably not more than ten persons so as not to loose its coherence and flexibility. A model team for a complex study area will probably comprise seven persons working in very close cooperation, two per media and the project manager.

In addition to the study team personnel, several outside experts are likely to be invited to provide substantial input. Their involvement however, will depend on the analysis requirements, as various needs arise, and will be limited to the solution of the particular problems that emerge. For example, meteorologists from the local weather station may be requested to provide meteorological data and have them processed in a form that facilitates their subsequent use,(see section 8.2.2.1). Hydrogeologists from the ministry of mining and minerals may have to be requested to provide input in the selection of suitable landfill sites.

The study team should be selected from local or national environmental health staff, since the purpose of the study, in addition to assessing the pollution and waste sources and related problems, and developing an appropriate control strategy, is to strengthen national and local proficiency in environmental management methodology. Also, since environmental management programmes are an on-going activity, it is important that national staff should be involved from the start. Thus, outside experts could be engaged only to give on-the-job training to local study personnel, who will later have the responsibility to take whatever follow-up action is necessary.

Proper authorization for access to data and information and for securing the technical input from outside experts should be obtained from all relevant government departments and industries. Such authorization could be obtained on the basis of existing government policy of allowing data collection and inter-departmental cooperation for environmental management issues.

Development of a spirit of cooperation between the survey team and those providing the data (government offices, industries, business groups, trade unions, etc) should be encouraged. Such cooperation will facilitate data collection, improve the completeness and accuracy of the study, and lay the ground work for future development of pollution control activities at national level.

Finally, administrative support, including transport, office space, telephone, fax, personal computers with appropriate software packages, photocopier, typing or printing facilities and a secretary will be required.

6.1.2 Time Requirements

Environmental management studies should normally take only a couple of months to complete in areas where the problems are uncomplicated, and not much more than six months in the most complex metropolitan areas. If the time allocated is too short, it may not be possible to obtain all the required data and to complete the problem analysis and strategy synthesis phases. The end product under these circumstances cannot provide reliable guidance for the follow-up feasibility and detailed design studies. If on the other hand the time spent is too long, the chances are that the study has crossed the preliminary design limits and entered into the detailed analysis of particular measures. The latter however, should be deferred until the entire strategy has been formulated and clear targets have been set.

6.2 Definition of the Study and Sub-Study Areas

6.2.1 Definition of the Study Area

For national or regional environmental management studies the first step is to determine the number, types, and sizes of the study areas. Often the definition of the study area is influenced by prevalent pollution or public health problems in the region or country. However, it is advisable to consider the existing legal, institutional, or economic systems in the country in selecting boundaries. Usually the country or region is already divided into several districts that have particular socio-economic features: e.g. urban, industrial, rural, agricultural, mining, etc. These serve as a good basis for the definition of the study areas.

The major concern, however, is the selection of the appropriate boundaries. Sometimes there may be many possible choices of boundaries, but usually they fall into one or more of the following categories:

Physical boundaries, such as drainage basins (surface or sewered), ridge-lines, rivers, coastlines, escarpments, express-ways, railroads, canals, etc.

Political/legal boundaries, such as country, state or provincial borders, city limits, public health districts, census districts, air quality control regions, flood control/drainage districts, etc.

Economic boundaries, such as industrial zones, mining districts, economic development areas, water/sewerage/refuse collection districts, etc.

Each category has its merits. Natural features usually facilitate the evaluation of the impact of pollution on air or water quality; political or legal boundaries facilitate data collection because the desired information, as well as the knowledgeable support staff are generally available in the corresponding government office in or near the study area; and, economic boundaries facilitate the assessment of the environmental impact of future growth. Thus, the person responsible for rapid pollution inventory studies must consider each of these categories in relation to other factors, such as known pollution or public health problems and available staff, in making the final decision on the definition of the study areas. A metropolitan city area along with the adjacent zones is a typical example of a suitable study area.

The study team should have the flexibility to modify the boundaries of the study area during the course of the study if the collected data indicate that this will enhance the completeness of the inventory, facilitate the assessment of emission impacts, or help in the formulation of better pollution and waste control strategies.

Finally, all of the study areas in a country or region should be ranked in order of priority. Among other factors, the severity of the pollution problems and the existence of any previous inventory studies could serve as the basis for setting such priorities.

6.2.2 Definition of the Sub-study Areas

During the initial stages the study team, using area maps and other information obtained from the planning department or from other sources, should form a general idea about the geography or the area, the current and projected land usage, the location of industries and population centres, the boundaries of existing and planned sewerage systems, the prevailing meteorological and hydrological conditions, the various liquid waste receivers, the solid waste collection and disposal system, as well as the major pollution and public health problems and the existing pollution control authorities and legislation.

On the basis of this general information, the study team may find it desirable to subdivide the study area into smaller zones. It is useful to decide at an early stage whether or not the study area is to be subdivided, since this will affect the collection and organization of data. Generally, the complexity of the survey work increases with the number of subdivisions since separate pollution source activity data are required for each subregion. Experience so far indicates that the added difficulties are usually not so great as to preclude subdivision, but that the decision to subdivide should only be made when there are definite reasons for doing so.

With regard to air pollution, it is normally desirable to make separate assessments of the emissions from all major point sources, as well as separate inventories for the area sources (space heating and traffic) of each major population centre, since inventory data in this form are required as inputs to the air quality models for the analysis of the air pollution situation and the formulation of control strategies (see Chapter 8).

With regard to liquid wastes, area subdivisions that allow separate assessments to be made of effluent discharges into different receiving water bodies are often desirable. Such subdivisions facilitate the evaluation of the impact of discharges on receiving water bodies and help in the formulation of water pollution control strategies (see Sections 9.1 and Section 9.2). Also, subdivisions may be made in order to determine the type and capacity of pollution control facilities for the waste volumes and pollution loads discharged into the existing, planned, or proposed sewerage system.

With regard to solid wastes, area subdivisions sometimes have to be made along economic boundaries on the basis of the existing organization of waste collection and disposal systems.

Although separate reasons are given above for subdividing the study areas with regard to water, air, or land pollution problems, in practice all the above reasons have to be considered simultaneously so as to have the study area separated into a meaningful number of sub-areas in line with the overall analysis requirements.

6.3 Data Acquisition

Most of the input data required for the study are normally available in various government departments. In fact, the study procedure was designed with a view to making maximum use of existing information. To facilitate the organization of the survey data, the U.N. classification of industries and services is used (see Section 2.2 and Appendix II). This system should also facilitate the acquisition of data from government and industry since these commonly utilize the same or similar systems.

6.3.1 Authority for Data Access

In the course of the survey work the study team will have to contact many government agencies, local authorities, industrial associations, other institutions, as well as individual industries.

Written authorization to obtain access to both published and unpublished data is desirable, as it will enable government officials to disclose information without fearing any possible consequences. Industrial concerns may also demand such government authorization before they will disclose process and production data, or even permit site visits. The authorization should include references to the appropriate statutes and regulations and be issued by the appropriate minister or an equivalent high-level governmental official.

However, authorization alone may not be enough, since the most important element in this type of work is the establishment of a spirit of true cooperation between the study team and the agencies and industries involved. In places where competition exists among various government agencies for authority over pollution control work, it may be desirable to assign the inventory task to a team not directly associated with any of them, or to involve all the competing agencies in order to ensure cooperation between them.

6.3.2 General Description of Information

Before starting data collection, it is advisable to look up and list the type of data that is required for each of the industries identified in the study area . This can be done through the air, water and solid waste inventory models provided in Sections 3.2, 4.2, and 5.2 and the formulation of relevant survey questionnaires as discussed in Sections 3.2.4, 4.2.4 and 5.2.4.

In most cases important information can be found in government publications, such as statistical year books, industrial activity reports, master plans, or environmental impact statements. Useful data can also be obtained from publications of international organizations such as UNDP, UNEP, UNIDO, WHO, and from any studies being undertaken in the area by United Nations Regional Economic Commissions or other Regional Intergovernmental Organizations. Also, reports produced by local authorities or industrial associations, trade unions, social security agencies, etc., may contain valuable information.

A sizeable portion of the required information available from various government agencies is often unpublished. These data are usually kept in a raw form and are not classified. Therefore, some effort has to be made to have the useful information extracted, processed, and classified. Examples of unclassified data include annual questionnaires completed by industries for government production statistics or economic studies and individual census forms.

The major difficulties with unpublished information are determining which data are required. Often there is a danger of leaving out important information if the screening is not done carefully, and, on the other hand, the complexity and the resource requirements increase considerably if relatively unimportant data are retrieved and processed. Previous experience in data collation will certainly be most helpful here in minimizing work, while ensuring the accuracy of the final results. If the study team has only limited experience of data handling, it is advisable to put in additional work in order to reduce the danger of major omissions.

During the inventory process all data collected have to be organized, critically assessed, and, whenever possible, cross-checked. This procedure will help identify areas for which data are lacking so that more emphasis can be placed on them. Clearly, not all of the data required can be obtained from government departments. Therefore, additional information will have to be sought either through experienced government employees or through direct contact with industry. Again this process is time-consuming and a balance has to be struck between the need for particular data and the effort required in obtaining them. Experience again helps to reduce the volume of this work without sacrificing much accuracy. Typical examples of additional information that can be obtained though industry surveys include detailed information on the processes, the air and water pollution control systems employed, the stack dimensions, the liquid waste receivers and the solid waste in-house storage and recycling/processing facilities. Section 2.3 provides guidance on how best to balance the information obtained from government and the detailed one from source survey visits.

The sources of all the data collected should be fully documented. For easy access during the survey, it is also recommended that files be set up in a systematic manner. Such a system would also be valuable when and if, at a later date, further verification and upgrading is carried out.

6.3.3 List of Possible Data Sources

A major task of the study team is to locate all major government information sources and to extract the required data from them. In order to facilitate this task, a list summarizing the most important types of information required and likely places from which such information can be obtained is provided in Table 6.3.3-1. The list is by no means exhaustive since data sources will vary in different countries depending upon the structure of government services.

6.3.4 Verification of Data Reliability

Background information on population, industrial establishments, and commercial facilities is most often available through national agencies dealing with population censuses, manufacturing and commerce. The accuracy of these data may vary considerably and, where data are likely to be less reliable, efforts should be made to verify and cross-check them to the maximum extent possible with information from other sources.

Cross-checking the data with information from other sources is often possible and highly desirable, since it is the best way of measuring the accuracy of the results. If important data from various sources of information are in significant disagreement, investigation of their original derivation often provides a good basis for the formulation of the most reasonable assumptions and provides guidance as how to proceed with the data collection so as to fill the gap. In any event, the reliability of the data along with major data deficiencies and disagreements should be clearly indicated in the final report. This will allow an overall assessment to be made of the accuracy of the results and the validity of the conclusions derived.

As an example of data cross-checking consider the case where for the inventory of traffic emissions the study team collects data about the total gasoline consumption in the study area from the ministry of energy and data about the number of gasoline powered cars, their age distribution and mean annual milage from the ministry of transport. From the latter through the model in Section 3.3 the anticipated gasoline consumption can be estimated and this can be compared with the actual gasoline consumption data from the ministry of energy. Obviously, major discrepancies will have to be carefully investigated.

Table 6.3.3-1 List of Data Often Required in Environmental Management Studies, and Likely Sources for them (page 1 of 2)

Type of Data	Possible Source
Population	Statistical year-books Census reports Master plan studies National planning or development agencies
Health, mortality and morbidity data	Ministry of public health Local health services
Meteorological data	Meteorological services Airport authorities Universities
Hydrological data	Hydrological services River authorities Municipalities Water company
Agricultural activity	Ministry of agriculture National planning or economic development agencies Local governments
Mining Activity	Ministry of mining and energy National planning or economic development agencies Local governments Internal revenue agencies
Industrial activity	Ministry of industry and commerce National planning or economic development agencies Local governments Electric energy ministry, authority or company Internal revenue agencies Industry associations Ministry of animal production Air and water pollution control authorities
Road traffic	Ministry of transport
Length of streets, roads and highways	Ministry of public works Ministry of transport Municipalities

Table 6.3.3-1 Continued (page 2 of 2)

Type of Data	Possible Source
Airport activity	Airport authorities Ministry of transport
Port activity data	Port authorities Ministry of transport
Fuel consumption	Ministry of energy Ministry of industry Internal revenue agencies Refineries or oil distribution companies
Fuel quality	Refineries or oil distribution companies Ministry of energy Air pollution control authorities
Water supply	Ministry of public works Ministry of health Water company Municipalities
Sewage collection and disposal	Ministry of public works Ministry of health Sewerage organizations Municipalities
Solid waste	Local authorities Ministry of environment Private refuse disposal companies Area planning and development companies
Water quality and effluent loads	Oceanographic institute Ministry of health River authorities Water pollution control authorities Ministry of fisheries Area planning agencies Local health departments Universities
Air quality and air emissions	Ministry of environment Ministry of health Air pollution control authorities Universities

6.4 Presentation of a Pollution Management Report

The following is a recommended outline, with brief description of the key elements for a report of an environmental management study.

Introduction

The introduction should include the reasons for undertaking the study, its major objectives, a brief review of the methodology followed, some guidance on how the report material is organized, and a short statement about the uses and the limitations of the study results.

Conclusions and Recommendations

The results from the source inventory work, the analysis of the existing pollution situation and the synthesis of a rational strategy should be briefly described for air, water and solid wastes separately. The highest priority measures and their anticipated impact should be separated from the rest so as to define a highly effective short term action programme. Follow-up activities must be defined, and the government departments responsible should be mentioned.

General background

A description of the study area including a map should be provided. The geographical limits of the study area, prominent geographical and hydrological features and key characteristics of the area meteorology should be defined. For the urban regions within the study area some basic information about the population, and population trends, numbers of motor vehicles in use, fuel and water usage, as well as a brief description of the existing sewage collection, treatment and disposal, the refuse collection and disposal, and the nature and dimensions of the industrial activity should be presented. For industrial zones information such as, the zone size and location, the type of industrial establishments, the fuel and water supplies, the effluent treatment and receivers, should be given.

Air Pollution

For each major point source in the study area the computed air emission loads and the critical impact analysis results (maximum credible concentrations on the critical and selected sensitive receivers) should be listed, see Table 8.1.2.2.2-2. Appropriate mitigation options (e.g. stack height modifications, fuel quality improvements, or control requirements) should also be included.

For each important type of area source (traffic emissions from passenger cars, taxis, buses, trucks, etc, space heating emission, etc) the computed emission loads and the long-term air quality impact analysis results (centre-maximum and spatial-average concentrations) should be listed. The air quality monitoring data that may exist should be summarized and the air quality model predictions should be calibrated. The highest pollution contributors, as they emerge from the above analysis, should be clearly identified. The formulated air pollution control strategy in relation to area sources and its anticipated impact in the air emission loads and on the air urban air quality should be presented. The proposed measures should be screened and those with the highest priority (highest cost effectiveness, simplest implementation) identified, so as to formulate a high-priority action programme. The impact of the latter on the emissions and on the air quality should be assessed.

The longer term prospects in terms of population and urban growth, increase in traffic, fuel consumption, industrial production etc, should be analysed and the likely air quality problems, if no corrective action is taken, should be assessed. Alternative strategies for the solutions to these longer term problems should be defined.

Water Pollution

Population and population trend data should be displayed. Existing sewage disposal systems (e.g. use of septic tanks, septage collection, treatment and disposal, or sewage collection, treatment and disposal systems) should be described in sufficient detail. Relevant computed waste volumes and loads and their distribution among the various receivers should be given.

The computed effluent volumes and loads from industrial sources, grouped and sub-totalled separately according to effluent receivers, should be listed. Separate lists of industries with toxic effluents should be provided and industries should be classified according to their type, size and their toxic waste problem.

The characteristics of the water bodies receiving the industrial and the domestic wastes should be provided, the critical parameters that define the controlling impact on such receivers should be identified, and the water pollution problems, as computed through the use of water quality models, should be defined.

The formulated water pollution control strategy should be described and the expected improvement after its implementation, defined. The proposed measures should be screened and those with the highest priority (highest cost effectiveness, simplest implementation) should be identified, so as to formulate a high-priority action programme. The impact of the latter on the effluent loads and on the water quality should be assessed.

The longer term prospects in terms of population and urban growth, increases in water consumption and in the industrial production etc, should be analysed and the likely water quality problems, if no corrective action is taken, should be assessed. Alternative strategies for the solutions to these longer term problems should be defined.

Land Pollution

Current municipal waste management practices (recycling at the source, collection, transportation, processing and disposal) should be described and their effectiveness in terms of the level of service offered, cost, and protection of the environment should be defined. Formulated strategies in relation to the medium and longer term prospects should be described, and the associated capital investment requirements along with the economic and environmental merits should be defined. Intermediate, high priority, measures should be identified and their economic and operational impacts should be discussed. The implementation aspects, and especially the transition from the existing to the proposed system, should be adequately addressed.

The hazardous waste inventory results should be listed and the current management practices reviewed and assessed. The formulated relevant strategies in relation to the medium and longer term prospects should be described, and the associated economic and environmental merits should be defined. Intermediate, high priority measures, should be identified and their economic and operational impacts discussed.

Acknowledgements should be made where they are due, while detailed calculations and any additional information should be annexed.

Finally, the report should make frequent use of maps, photographs and graphic displays to support the text. In addition to tables, pie-, bar-, or line-charts should be used as they can provide a quick and clear understanding of relative load distributions and trends.

6.5 Bibliography

1. Economopoulos, A.P., (1989). Management and Control of the Environment, ed. H. W. de Koning. WHO/PEP/89.1. World Health Organization. Geneva.

2. World Health Organization, (1982). Rapid Assessment of Air, Water and Land Pollution Sources, Publication No. 62. Geneva.

APPENDIX II

UN CLASSIFICATION OF INDUSTRIES AND SERVICES

APPENDIX OUTLINE

II.1 Classification Table for Industries and Services

0 Activities not Adequately Defined

1 Agriculture, Hunting, Forestry and Fishing

11 *Agriculture and Hunting*
111 Agriculture and Livestock Production
112 Agricultural Services
113 Hunting, Trapping and Game Propagation

12 *Forestry and Logging*
121 Forestry
122 Logging
130 Fishing

2 Mining and Quarrying

21 *Coal Mining*

22 *Crude Petroleum and Natural Gas Production*

23 *Metal Ore Mining*

29 *Other Mining*

3 Manufacturing

31 *Manufacture of Food, Beverages and Tobacco*
311 Food Manufacturing
313 Beverage Industries
314 Tobacco Manufacturing

32 *Textile, Wearing Apparel and Leather Industries*
321 Manufacture of Textiles
322 Manufacture of Wearing Apparel, Except Footwear
323 Manufacture of Leather and Products of Leather
324 Manufacture of Footwear

33 *Manufacture of Wood and Wood Products, Including Furniture*
331 Manufacture of Wood & Wood Products, Except Furniture
332 Manufacture of Furniture and Fixtures

34 *Manufacture of Paper and Paper Products, Printing & Publishing*
341 Manufacture of Paper and Paper Products
342 Printing Publishing and Allied Industries

35 *Manufacture of Chemicals, and Chemical, Petroleum, Coal, Rubber and Plastic Products*
351 Manufacture of Industrial Chemicals
352 Manufacture of Other Chemical Products
353 Petroleum Refineries
354 Manufacture of Misc. Products of Petroleum and Coal

355 Manufacture of Rubber Products
356 Manufacture of Plastic Products not Elsewhere Classified

36 *Manufacture of Non-metallic Mineral Products, Except Products of Petroleum and Coal*
361 Manufacture of Pottery, China and Earthenware
362 Manufacture of Glass and Glass Products
369 Manufacture of Other Non-Metallic Mineral Products

37 *Basic Metal Industries*
371 Iron and Steel Basic Industries
372 Non-ferrous Metal Basic Industries

38 *Manufacture of Fabricated Metal Products, Machinery and Equipment*
381 Manufacture of Fabricated Metal Products, Except Machinery
382 Manufacture of Machinery Except Electrical
383 Manufacture of Electrical Machinery Apparatus & Appliances
384 Manufacture of Transport Equipment
385 Manufacture of ... Photographic and Optical Goods

39 *Other Manufacturing Industries*

4 **Electricity Gas and Water**

41 Electricity, Gas and Steam

42 Water Works and Supply

5 **Construction**

6 **Wholesale and Retail Trade**

61 *Wholesale Trade*

62 *Retail Trade*

63 *Restaurants and Hotels*
631 Restaurants, Cafes, and other Eating & Drinking
632 Hotels, Rooming Houses, Camps and Other Lodging

7 **Transport, Storage and Communication**

71 *Transport and Storage*
711 Land Transport
712 Water Transport
713 Air Transport
719 Services Allied to Transport

72 *Communication*

8 **Financing, Insurance, Real Estate and Business Services**

9 **Community, Social and Personal Services**

91 *Public Administration and Defence*

92 *Sanitary and Similar Services*

93 *Social and Related Community Services*
931 Educational Services
932 Research and Scientific Institutes
933 Medical, Dental, Other Health & Veterinary
934 Welfare Institutions

94 *Recreational and Cultural Services*
941 Motion Pictures and Other Entertainment Services

95 *Personal and Household Services*
951 Repair Services not Elsewhere Classified
952 Laundries, Laundry Services and Cleaning
953 Domestic Services
959 Miscellaneous Personal Services

II.2 Bibliography

1. United Nations (1980). Year-book of Industrial Statistics. Department of Economic and Social Affairs, Statistical Office of the United Nations. New York.

2. United Nations, (1989). Industrial Statistics Year-book. UN publication, Sales No. E/F.91.XVII.14.

APPENDIX III

CONVERSION FACTORS AND SELECTED MATERIAL PROPERTIES

APPENDIX OUTLINE

III.1 Conversion Factors

TO CONVERT	INTO	MULTIPLY BY
Gaseous Pollutant Concentrations[a]		
O_3, ppm volume	O_3, μg/m³	1960.
NO_2, ppm volume	NO_2, μg/m³	1880.
SO_2, ppm volume	SO_2, μg/m³	2610.
H_2S, ppm volume	H_2S, μg/m³	1390.
CO, ppm volume	CO, μg/m³	1140.
HC (as CH_4), ppm volume	HC (as CH_4), μg/m³	654.
Mobile Sources		
Fuel cons, mile/(US gal)	Fuel cons, km/lt	0.426
Emission, gr/mile	Emission, gr/km	0.6214
Length		
Millimeter (mm)	Inch (in)	0.0394
Centimeter (cm)	Inch (in)	0.3937
Meter (m)	Foot (ft)	3.2808
Kilometer (km)	Mile	0.6214
Inch (in)	Millimeter (mm)	2.54
Foot (ft)	Meter (m)	0.3048
Mile	Kilometer (km)	1.6093
Yard (yd)	Meter (m)	0.9144
Area		
Square centimeter (cm^2)	Square inch (in^2)	0.1550
Square meter (m^2)	Square foot (ft^2)	10.7639
acre	Square meter (m^2)	4046.8
acre	Hectare (ha)	0.405
Hectare (ha)	Square meter (m^2)	10000.
Hectare (ha)	acre	2.471
1000 m^2	acre	0.2471
Square kilometer (km^2)	Square mile	0.3861
Square inch (in^2)	Square centimeter (cm^2)	6.4516
Square foot (ft^2)	Square meter (m^2)	0.0929
Square mile	Square kilometer (km^2)	2.5900
Square yard (yd^2)	Square meter (m^2)	0.8361

TO CONVERT	INTO	MULTIPLY BY
Volume		
Liter	Cubic foot (ft^3)	0.03531
Cubic centimeter (cm^3)	Cubic inch (in^3)	0.06102
Cubic meter (m^3)	Cubic foot (ft^3)	35.31
Cubic foot (ft^3)	Liter (lt^3)	28.317
Cubic foot (ft^3)	Cubic meter (m^3)	0.0283
Bushel (bu)	Liters (lt)	35.24
Bushel (bu)	Cubic foot (ft^3)	1.2445
Barrel (US, dry)	Cubic inches (in^3)	7056.
Cubic Yard (yd^3)	Cubic meter (m^3)	0.7646
Liquid Capacity		
Liter (lt)	Quart (US)	1.0567
Liter (lt)	Gallon (US) (US gal)	0.2642
Liter (lt)	Quart (UK)	0.8799
Liter (lt)	Gallon (UK) (Imp. gal)	0.2200
Quart (US)	Liter (lt)	0.9464
Gallon (US) (US gal)	Liter (lt)	3.7854
Quart (UK)	Liter (lt)	1.1365
Gallon (UK) (Imp. gal)	Liter (lt)	4.5461
Barrel	Liter (lt)	158.984
Barrel	Gallon (UK) (Imp. gal)	34.9726
Barrel	Gallon (US) (US gal)	42.00
Pint	Liter (lt)	0.4732
Weight		
Gram (g or gr)	Grain	15.4323
Kilogram (kg)	Pound (lb)	2.2046
Metric ton (t or tn)	Short ton (US)	1.1023
Grain	Gram (g or gr)	0.0648
Once (oz)	Gram (g or gr)	28.3495
Once troy	Gram (g or gr)	31.1035
Pound (lb)	Kilogram (kg)	0.4536
Short ton (US)	Kilogram (kg)	907.2
Short ton (US)	Pounds (lb)	2000.
Agricultural Products		
Corn, bu	Corn, kg	25.4
Corn, bu	Corn, lb	56.
Milo, bu	Milo, kg	25.4
Milo, bu	Milo, lb	56.
Oats, bu	Oats, kg	14.5
Oats, bu	Oats, lb	32.
Barley, bu	Barley, kg	21.8
Barley, bu	Barley, lb	48.
Wheat, bu	Wheat, kg	27.2
Wheat, bu	Wheat, lb	60.

TO CONVERT	INTO	MULTIPLY BY
Agricultural Products (cont'd)		
Cotton, bale	Cotton, kg	226.
Cotton, bale	Cotton, lb	500.
Miscellaneous Liquids		
Beer, bbl	Beer, US gal	31.5
Paint, US gal	Paint, kg	4.5-6.8
Paint, US gal	Paint, lb	10.0-15.
Varnish, US gal	Varnish, kg	3.18
Varnish, US gal	Varnish, lb	7.0
Whiskey, bbl	Whiskey, lt	190.
Whiskey, bbl	Whiskey, US gal	50.2
Water, US gal	Water, kg	3.81
Water, US gal	Water, lb	8.3
Mineral Products		
Cement, bbl	Cement, kg	170.
Cement, bbl	Cement, lb	375.
Cement, yd^3	Cement, kg	1130.
Cement, yd^3	Cement, lb	2500.
Concrete, yd^3	Concrete, kg	1820.
Concrete, yd^3	Concrete, lb	4000.

[a] The conversion from ppm (volume) to $\mu g/m^3$ is based on the following Equation, which can be used for substances not listed in the table:

$$(C,\ \mu g/m^3) = (C,\ \text{ppm volume})*40.87*(MW),$$

where:

C, $\mu g/m^3$ = Concentration expressed in $\mu g/m^3$
C, ppm = Concentration expressed in ppm volume
MW = Molecular Weight (Use 16 for Hydrocarbons)

III.2 Selected Material Properties

Table III.2-1 Typical Densities of Selected Fuels, Woods and Mineral Products

	Density gr/lt
Liquid and Gaseous Fuels	
Asphalt	1030.
Butane (liquid at 15^{o}C)	579.
Crude Oil	850-874.
Distillate Oil	845.
Gasoline	739.
Liquefied Natural Gas (LNG)	673.
Liquefied Petroleum Gas (LPG)[a]	521.
Natural Gas (at 15^{o}C)	0.78
Propane (liquid at 15^{o}C)	507.
Residual oil[b]	944.
Wood (Air dried)	
Elm	561.
Hemlock	465.
Hickory	769.
Maple, sugar	689.
Maple, white	529.
Oak, red	673.
Oak, white	769.
Pine	641.
Mineral Products	
Cement	1483.
Concrete	2373.
Glass, common	2595.
Gravel, dry packed	1600-1920.
Gravel, wet	2020.
Gypsum, calcined	880-960.
Lime, pebble	850-1025.
Sand, Gravel (dry, loose)	1440-1680.

[a] 20% Butane, 80% Propane

[b] Typical densities for residual oil #4, #5, and #6 are 904, 933 and 966 g/lt respectively.

Table III.2-2 Typical Properties of Various Fuels

Type of Fuel	Heating Value kcal	Sulfur % by wt	Ash % by wt
Solid Fuels			
Bituminous coal	7,200/kg	0.6-5.4	4-20
Anthracite coal	6,810/kg	0.5-1.0	7-16
Lignite (@ 35% moisture)	3,990/kg	0.5	6.2
Wood (@ 40% moisture)	2,880/kg	negl	1.0-3.0
Bagasse (@ 50% moisture)	2,220/kg	negl	1.0-2.0
Bark (@ 50% moisture)	2,492/kg	negl	1.0-3.0
Coke by-product	7,380/kg	0.5-1.0	0.5-5.0
Liquid Fuels			
Residual oil	9,980/lt	0.5-4.0	0.05-0.1
Distillate oil	9,300/lt	0.2-1.0	negl
Diesel oil	9,120/lt	0.2-0.8	negl
Gasoline	8,620/lt	0.03-0.04[a]	negl
Kerosene	8,320/lt	0.02-0.05	negl
Liquid Petroleum Gas (LPG)	6,250/lt	neg	negl
Gaseous Fuels			
Natural Gas	9,341/Nm^3	negl	
Coke Oven Gas	5,249/Nm^3	0.5-2.0	
Blast Furnace Gas	890/Nm^3	negl	

[a]Fuel specifications often allow up to 0.1% and sometimes up to 0.15%

APPENDIX IV

LIST OF ABBREVIATIONS

APPENDIX OUTLINE

IV.1 List of Abbreviations

AH	Ampere-Hour
bbl	Barrel
BOD	Biochemical Oxygen Demand
BOD_5	5-day Biochemical Oxygen Demand
BOD_u	Ultimate Biochemical Oxygen Demand
bu	Bushel
COD	Chemical Oxygen Demand
Conc	Concentration
d	day
ESP	Electrostatic Precipitator
FF	Fabric Filter (Baghouse)
g or gr	Gram
gal	US gallon
h or hr	Hour
HC	Hydrocarbons
l or lt	Liter
km	Kilometer
LDGP	Light Duty Gasoline Powered
LWK	Live Weight of animals Killed
m	Meter
mg	Milligram (10^{-3} grams)
MWH	Megawatt-Hour
Negl	Negligible
ng	Nanogram (10^{-9} grams)
NM VOC	Non-methane Volatile Organic Compounds
NTIS	US National Technical Information Service

This document was prepared for the WHO Global Environmental Technology Network (GETNET).

This Network of pollution control technology specialists was established in 1990 as a means for the World Health Organization to strengthen education, training, research and practice in the field of environmental control technology.

The Network aims as improved communication and collaboration between institutions and individuals in this field in developed and developing countries. A series of documents with information of value for training and research development is prepared for the Network and lists of Network members are distributed on a regular basis. Training and research promotion workshops are organized in collaboration with national and international agencies.

For further information write to:

Environmental Technology, EHE/PEP
Division of Environmental Health
World Health Organization
1211 Geneva 27, Switzerland
Fax:(+41) (22) 791 07 46