OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

EIA models for UNIDPLAN

Arne Jernelöv and Ulf Wahlgren

18093

1. Introduction

An industrial project encompasses many development stages, from the initial prefeasibility efforts over the detailed planning and execution of the project to the final evaluation. The division within UNIDO which is primarily concerned with the initial planning efforts is IO/IIS/PLAN. Computer aided tool are acknowledged methods within IO/IIS/PLAN, and the mathematical models are collected in the UNIDPLAN toolkit. At the early planning stage it is clear that most of the work must be carried out mainly in the home office, and the data needed for the planning, including the modelling, must thus largely be available from open sources. In particular on-the-site data collection should be kept at a minimum. The awareness of the importance of addressing environmental impact problems has increased within UNIDO during the recent years, and activities in this direction are underway in several branches of the organization. In order to enhance the introduction of Environmental Impact Assessment (EIA) models into the regular UNIDPLAN toolkit the IO/IIS/PLAN division undertook the organization of a workshop in Kiev in oct, 1989, with the objective to define the problems and to recommend actions to be taken on the part of UNIDO. The emphasis of the workshop was on computer aided EIA tools. Based on the experiences from the Kiev meeting UNIDO has set as a goal that 3-4 EIA models should be developed and included in the regular UNIDPLAN toolkit during 1990.

In the following the discussion will be restricted to adverse effects of industrial discharges on the environment.

Environmental impact problems are very different depending on the substance emitted, the medium which it enters, and the local conditions such as climatological region. In order to meet UNIDO:s short term goal separate models must in general be developed for different impact problems in terms of substance, medium geographic scale etc. If too ambitious models are developed initially the effort needed to test and verify them may become quite severe and it is not likely that the time schedule can be kept. The ultimate goal is of course to develop models which covers a range of problems. If due attention is paid to this fact at the onset of the model development, nothing prevents several models to be included in one master model for all environmental problems connected with e.g. a given type of industry in the future A modular model development approach should thus be used, and this was also recommended by the Kiev workshop.

An EIA model will generally consist of two quite distinct parts: the transport/distribution, which also contains elements such as transformation of chemical substances between different forms, oxidation processes, precipitation etc., and the

effect problem. The transport problem is often rather well defined (i.e. it is determined by laws of physics and chemistry), while the effects usually are known only empirically, i.e. deduced from observations under similar conditions. Deterministic mathematical models of some generality, which can be used on the basis of generic data (i.e. data typical for the region) with due attention paid to local conditions such as geography etc., can be developed for many transport/distribution problems, but this is usually not the case for deterministic effect models which have a tendency to depend strongly on local data. This problem can be circumvented by developing EIA models in the form of computerized decision support systems which contain deterministic models for the transport/distribution problem but where effects related to the distribution of some chemical are given on a purely empirical basis.

It must be strongly emphasized that it is very important that the transport/distribution models should be used with easily available (e.g.generic) data. If this was not the case it would be very difficult for UNIDO to use the models for planning purposes. A consequence of this model structure is also that the data collection, the data treatment and the data storage are very important elements in the model development.

2. Priority industries in UNIDO environmental programme

In the Environmental programme as proposed by the Director General to the third general conference, the following subsectors of industry are mentioned as priority ones for control and mitigation of industrial pollution:

a. Metallurgic industries with metal emissions as dust to the atmosphere and in ionic forms to water.

b. Paper and pulp industries with emissions to water of dissolved organic matter (that cause oxygen depletion and discoloration of receiving bodies of water), fiber and boiling chemicals as well as byproducts from bleaching such as chlorinated hydrocarbons. In addition, reduced sulphur compounds emitted to the atmosphere cause problems with odour.

c. Cement industries release large quantities of lime-dust, frequently in highly alkaline forms, which strongly irritate the respiratory tract. Environmental problems with cement production also include formation of NOX at high temperature incineration as well as destruction in the carries.

d. Textile industry causing water pollution with high BOD content from fiber cleaning and pollution with metal (e.g. cadmium and lead), and persistent organic compounds from dying operations.

e. Tanneries, giving rise to water pollution from salt (used for preparation of hides), BOD and tannery chemicals (e.g. chromium).

f. Food-processing industries (in particular slaughter-houses, breweries and distilleries).

g. Chemical process industry (in particular paints, dyestuffs, petrochemicals, pesticides, fertilizers and fine chemicals) leading to water and air pollution problems of most kinds in addition to hazardous waste handling problems.

h. Low-grade coal power-plants resulting in air pollution with metal containing dust, sulphur dioxide and nitrogen oxides as well as PAH (polyaromatic hydrocarbons) or POM (polyorganic matter).

Based on criteria such as omnipresence in most countries and intensity of effects, as well as in-house capabilities within UNIDO for dealing with the problems, tanneries and cement industries have been proposed to be the priority sectors of industry.

3. Media

The different media which serve as recipients for industrial effluents can, from a modelling point of view, be (somewhat arbitrarily) divided into:

1. Air
2. Fresh surface water (rivers, lakes, reservoirs)
3. Ground water
4. Coastal regions (estuaries and the sea close to the shore)

The geographical scale which is relevant for a given substance will depend on the substance in question, the medium which receives the discharge and the effects considered. The following table can be used as an illustration of the particular problems and scales associated with the particular discharges:

TABLE 1. Media, discharges, Environmental problem and geographical scale.

Medium	Discharge	Problem	Scale[a]
Air	particles	health	local
-"-	metals	health	local[b]
-"-	NOX+hydroc.	effects on forests	regional
-"-	SO_2+NOX	health	local
-"-	SO_2+NOX	Acidification	regional
Fresh water	Org. matter	oxygen depletion	local
-"-	fertilizers	eutrophication	local
-"-	Org.mat.+fert.	health	local
-"-	Org.tox.chem.	health	local-regional
-"-	-"-	effects on biota	local-regional
-"-	metals	health	local[b]
-"-	-"-	effects on biota	local-regional
-"-	other tox.chem.	health	local-regional
-"-	-"-	effects on biota	local-regional
-"-	mercury	health	local-regional
-"-	salt	irrigation	local
Ground water	salt	irrigation	local
-"-	-"-	domestic water	local
-"-	pers.tox.chem.[c]	health	local
Coastal regions[d]	Org. matter	oxygen depletion	local
-"-	fertilizers	eutrophication	regional
-"-	metals	effects on biota	local
-"-	Org.tox.chem.	effects on biota	local-regional
-"-	other tox.chem.	effects on biota	local-regional

[a]local means a radius of appr. 100 km from the source

[b]in the case of Cd the scale is actually local-regional

[c]a common problem in this context is metal leaching from deposits

[d]in coastal regions the main problem is usually adverse effects on the reproduction of important species.

Models on different levels of complexity exist for the transport/distribution on the local scale for all media and discharges listed in table 1. Plume models which describe airborne transport processes are available both from IIASA and from the Glushkov Institute in Kiev. For discharges to rivers there are many operational

transport models available, e.g. the WQRRS model which includes also reservoirs. As a particular case one may also mention the common BOD/DO models, which are used to calculate the oxygen concentration in rivers subjected to discharges of organic material. Similarly ground water transport models are available from e.g. IIASA. Water exchange models applicable to estuarine problems are often more elaborate but simplified such models may also be available. Air transport models applicable on a regional scale are also available e.g. at IIASA, and probably also at the Glushkov Institute of Cybernetics, but such models are more data dependent than the local models. There are also 2 and 3-dimensional hydraulic models which can be used to trace substances over a large body of water, but these models are invariably very complex and data demanding. A review of existing EIA models has been written for UNIDO by K.Fedra of IIASA.

In general environmental problems on a regional scale are more difficult to address than local problems, for several reasons. As mentioned in the previous paragraph the data need and the complexity of large scale models is often high. In addition environmental effects on a regional scale are often not well established, as exemplified by the acidification problem where it is well known that sulphur and often nitrogen are important factors for forest damage but where dose-response relationships are unknown. In view of the goals set by UNIDO it is thus reasonable to restrict the present effort to local problems. A particular problem which arises in this case is that on the local scale dilution is a common method to decrease ambient concentrations. Examples of this is high chimneys for discharges to air and long diffusion tubes for discharges to water. Such solutions may be acceptable in special situations, but in general they should be avoided since many effluents do have adverse effects also on the regional scale (see table 1), and dilution solutions should thus not in general be recommended by the models.

EIA models useful to the IO/IIS/PLAN division should be of the screening type. This means that the models should not be used to generate a detailed account of all the environmental or health effects connected with a given industry but rather give effect estimates, possible techniques to decrease or eliminate the effects, and associated costs. The effect the models should be developed as decision support systems the answers should be in terms of worded advice and values should be given in ranges, not specific numbers (i.e. the output from the models should be qualitative). In cases where the effects are judged potentially serious (by the model) the advice should be to investigate the problem in more detail.

4. Characterization of the environmental problems of the industries on UNIDO:s priority list

The industrial pollutants from the industries on UNIDO:s priority list are characterized in table 2:

TABLE 2. Environmental effects from the industries on UNIDO:s priority list.

Industrial subsector	Important pollutant	Medium	Geographical scale[a]
Metallurgic industries	Metal containing dust	air	local
	metal ions to water	water	local
Paper and pulp industries	organic material (BOD)	water	local
	fibre	water	local
	boiling liquids	water	local-regional
	reduced sulphur	air	local
Cement industries	dust containing CaO	air	local
	NOX	air	regional
textile industries	BOD	water	local
	metal and organic pigments	water	local
Tanneries	BOD	water	local
	chromium	water	local
	salt	water	local-regional
Food-processing industries	BOD	water	local
	nutrients	water	local-regional
Chemical process industry	most types of pollutants	all	every
Low grade coal power plants	SO_2	air	local-regional
	NOX	air	local-regional
	metal containing dust	air	local
	PAH(POM)	air	local-regional

[a]local means a radius of appr. 100 km from the source

5. UNIDO's requirements and wishes

A number of requirements and wishes on the part of UNIDO were formulated for the Kiev workshop:

-Industrial application
-Easy-to-obtain input data
-User-friendly
-Easily adaptable to different computer systems including PC's (AT's)
-Limited expert need
-Easily adaptable to different conditions (e.g. geographical, climatological) or economical
-Step-by-step development of comprehensible EIA models.

These points were elaborated and commented during the workshop, and UNIDO was recommended to develop a library of Environmental Impact Assessment (EIA) models accordingly. The most important comments were that the models should be developed in the form of decision support systems (points 3 and 4), that both qualitative and quantitative models should be developed where the former should be usable on the basis of incomplete or generic data (point 2), and that the models should be developed in a modular fashion (point 7).

In view of what has been said in the previous paragraphs and the expressed goal that 3-4 working EIA models should be developed before the end of 1990 the following short-term criteria for the model development can be formulated:

1. The models should not depend on detailed "on-the-site" data. This requirement means that the models should be used primarily on the basis of generic data assembled for typical regions from e.g. WMO or local sources for metrological data, and similarly for other types of data (e.g. geological).

2. Deterministic models should initially only be developed for the transport/distribution problem. Effects should at this stage be included as simple rules based on ambient concentrations only. The complete models (transport/distribution + effect) should be developed in the form of computerized decision support systems (or similarly).

3. The models should in general be dedicated for a specific problem such as the emission of a particular substance to a particular medium. The models should be simple, primarily qualitative (see point 1) and applicable on small computers (AT's)/par

4. The output from the models should be given in a qualitative form indicating the extent of the problem and technical solutions. Costs should be given in monetary terms wherever possible. The system should recommend expert intervention and detailed studies whenever the problem is deemed potentially serious.

5. It should be foreseen in the model development work that a future goal is to merge several models into a master model applicable e.g. for a whole industrial sector

6. The models should initially be designed for local problems only (it should be emphasized that a "local" problem may cover a fairly large area if several sources are to be handled simultaneously). Solutions such as high chimneys or long infiltration tubes (dilution solutions) should in general not be recommended (in many cases a dilution will create new problems on a larger geographical scale). The system should instead recommend different technical solutions to reduce the discharges.

7. The models should be developed in accordance with the general availability of data in the regions of interest (UNIDO:S target countries). The data collection should be regarded as a part of the model development.

Criteria 1-5 cover largely the "requirements and wishes" listed above.

6. A suggestion on activities for 1990

The model development effort for 1990 should be undertaken in accordance with the priorities set by UNIDO for industrial development projects, following the criteria listed in the preceeding chapter. The highest priority in UNIDO:s list is given to cement industries and tanneries. The discharges from cement industries are primarily to air. the major substances emitted are dust and NOX and the main problem associated with both substances is health on a local scale (dust being the most hazardous component). For tanneries the discharges are primarily to water, the substances are BOD, salt and chromium. The effects associated with BOD are health problems due to bacterial growth and deoxygenation of the water. The discharges of salt present a potential problem for irrigation downstream the tannery and the chromium is a health problem locally (see table in chapter 4).

a. The cement industry

In the case of cement industries two models describing transport/distribution of dust and NOX are needed. The appropriate scales for these two substances are

somewhat different (dust is a very local problem while NOX is a problem on a slightly larger scale), but the methodologies will be quite similar and it may be possible to develop one single model covering both substances. The model development work will cover the following items:

- Plume models should be used to estimate the transport/distribution of dust and NOX (one model may suffice for both compounds). The NOX model should include a description of atmospheric transformations of NOX and it should be able to handle multiple sources.

- The plume models should be elements of substance specific decision support systems (if only one plume model is needed it might be convenient to merge the decision support systems). These decision support systems should contain data bases with known health effects and environmental effects associated with different concentrations of dust and NOX. Expert assistance is necessary for the development of these databases. The output from the decision support systems should be given in qualitative form (see the preceeding chapters).

- Metrological data should be collected from a limited number of regions (maybe 3-5) typical for UNIDO's target countries. The data should cover substantial time periods (10-20 years) and be treated by means of statistical methods such that it can be put in the form required by the plume models.

- The models (decision support systems including plume models) should be structured in such a way that it is open ended (it should be possible to add new rules easily).

- The model structure should be such that it can be included in a more comprehensive decision support system in the future.

b. Tanneries

Several different models should be developed for the environmental effects of tanneries:

- A BOD/DO model for the oxygen depletion problem connected with the discharges of organic substances. The BOD/DO model should be usable on the basis of simple data and general information from maps etc. The model should be part of a decision support system which should present technical solutions to reduce the deoxygenation. The system should include informations such as the increased risk for bilharzia if open lagoons are used for the oxidation of the organic matter.

- A model which estimate the salt concentration downstream the tannery. The

decision support system should in this case give information on expected increased salinity of irrigated soils from the salt concentration in the irrigation water, soil data etc., and give estimates of the resulting decrease in agricultural production (for the actual crops).

- A model to estimate the concentrations of Cr in the recipient (special emphasis should be put on Cr in highly reduced states). The decision support system should give information on the resulting health hazards based on e.g. WHO:s recommendations. The system should take the demographic situation into consideration.

All the decision support systems should give estimated costs in monetary terms both for the effects (if possible) and for the technical solutions.