NETWORK FOR INDUSTRIAL ENVIRONMENTAL MANAGEMENT (NIEM)

PHASE I FINAL REPORT

Volume 1

MAIN REPORT

AUGUST 1989

SWEDISH INTERNATIONAL DEVELOPMENT AUTHORITY

UNITED NATIONS ENVIRONMENT PROGRAMME REGIONAL OFFICE FOR ASIA AND THE PACIFIC

BANGKOK, THAILAND

NETWORK FOR INDUSTRIAL
ENVIRONMENTAL MANAGEMENT (NIEM)

PHASE I FINAL REPORT

Volume 1

MAIN REPORT

AUGUST 1989

SWEDISH
INTERNATIONAL
DEVELOPMENT
AUTHORITY

UNITED NATIONS
ENVIRONMENT PROGRAMME
REGIONAL OFFICE FOR
ASIA AND THE PACIFIC

BANGKOK, THAILAND

The Report consists of three volumes. The Volume 1 is the "Main Report" which provides conclusions and recommendations about the NIEM Phase I programme as a whole. The Volume 2 includes the first six Annexes to the Report which are the "Manuals and Guidelines" produced during Phase I. The Volume 3 contains the Annexes 7-12 of the Report which include the six reports on the field studies carried out during Phase I. Additionally, a brief "Executive Summary" for the Phase I Report was also produced.

Contents

	Page
1. INTRODUCTION	1
2. MANUALS AND GUIDELINES	5
2.1. Manual on Discharge Characterization	5
2.2. Manual on Receiving Water Quality Evaluation	6
2.3. Manual on Receiving Land Quality Evaluation	7
2.4. Guide on Determination of Acute Lethal Toxicity of Pulp and Paper Mill Effluent to Freshwater Fish	7
2.5. Guide on Preliminary Assessment of Environmental Effects of Existing Small Pulp and Paper Mills	8
2.6. Guide on Conducting National Training Workshops	8
3. FIELD STUDIES	9
3.1. Field Study Descriptions	9
3.1.1. Bang Pa-In Paper Mill Field Study	9
3.1.2. Padalarang Pulp and Paper Mill Field Study	9
3.1.3. Hindustan Newsprint Mill Field Study	10
3.1.4. Pudumjee Pulp and Paper Mill Field Study	11
3.1.5. Neijiang Regional Mills Field Study	11
3.1.6. Huasheng Paper Mill Field Study	11
3.2. Field Study Results and Conclusions	12
3.2.1. Discharge Characterization	12
3.2.2. Receiving Water Quality	15
3.2.3. Receiving Land Quality	18
3.2.4. Acute Toxicity Testing of Freshwater Fish	21
4. NIEM TRAINING WORKSHOP	24
5. RECOMMENDATIONS	25
6. CONCLUSION	26

1. INTRODUCTION

The Network for Industrial Environmental Management (NIEM) has been established comprising of research institutions, laboratories, government agencies, and pulp and paper mills located in seven countries of the Asia and the Pacific region (China, India, Indonesia, Malaysia, Philippines, Sri Lanka and Thailand). The Network has catalyzed the participating institutions of the seven countries in cooperating and coordinating on information exchange regarding environmental management in small pulp and paper mills. It has also established a procedure for information exchange and collaborative research, which was previously non-existent among these institutions.

During the NIEM Phase I programme conducted between February 1987 and March 1989, Network members initially:

- agreed upon protocols for collaboration, coordination mechanisms, report formats, and monitoring procedures to facilitate exchange of information;

- prepared and disseminated a bibliography of publications related to environmental control in the pulp and paper industry held by member institutions; and

- began circulating a quarterly newsletter to inform regularly and systematically about Network activities. The newsletter contains articles contributed by Network members regarding their research activities and other news items related to the pulp and paper industry.

Using this established, information-sharing framework, Network members then collaborated in the major Phase I activities of:

- conducting and preparing reports on a series of six related field studies regarding:

    (1) mill discharge characterization;

    (2) evaluation of receiving media; namely, land and water;

    (3) assessment of environmental impacts of small existing pulp and paper mills;

    (4) reuse of pulp and paper mill effluents, specifically related in Phase I to the application of discharges to land for irrigation of crops;

- developing three manuals and three guidelines for use in conducting the field studies and to assist in dissemination of information. The manuals and guides include:

    (1) Manual on Discharge Characterization;

    (2) Manual on Receiving Water Quality Evaluation;

(3) Guide on Determination of Acute Lethal Toxicity of Pulp and Paper Mill Effluent to Freshwater Fish;

(4) Manual on Receiving Land Quality Evaluation;

(5) Guide on Preliminary Assessment of Environmental Effects of Existing Small Pulp and Paper Mills;

(6) Guide on Conducting National Training Workshops.

Finally, twenty-six personnel of Network institutions participated in a training workshop held at the end of Phase I. Phase I activities were reviewed and the plan of activity for Phase II was discussed.

A main achievement resulting from the above mentioned Phase I activities was the providing of techniques, methods and criteria to ensure that analytical results can be reproduced and compared. The manuals and guides cooperatively developed during Phase I (see Sec. "2. Manuals and Guidelines") recommend harmonized procedures for producing reliable and comparable data. Using these procedures, NIEM members can obtain basic information from their own studies about mill operation and environmental impacts, while also being able to compare their results with those obtained from the studies of other members. Thus, these harmonized procedures facilitate technical cooperation amongst member organizations and expand the information-base available to Network members now and in the future.

Focusing on the Asian and Pacific regional pulp and paper industry, NIEM activities address environmental management problems related to this area's particular conditions. These include small average mill size, common use of various non-wood raw materials and appropriate non-wood pulping processes, and aspects of the local tropical environment. Phase I research produced information pertinent to these regional conditions that, combined with members' existing expertise, helped to develop specific research methods and guidelines appropriate for analyzing environmental impact of pulp and paper mills in the region.

The research on discharge characterization helped develop knowledge of appropriate:

- pollution parameters to be examined in assessing environmental impact of non-wood pulping processes; and

- methods of flow rate measurement and sampling methods in small existing mills.

Conducting land and water quality evaluation research, NIEM members gained experience in, and developed guidelines for:

- monitoring the effects of mill wastewater irrigation on local crops;

- establishing priorities for investigated pollution parameters;

- monitoring local river waters, especially flow dispersion effects; and

- assessing wastewater salinity and alkalinity its potential impact on local soils, crops and groundwater.

In addition, to provide a procedure for complimenting discharge characterization and infer some potential environmental effects, a standard freshwater fish toxicity test was modified during Phase I for regional use in assessing the biological effects of mill effluents. These modifications include recommendations to:

- use local indigenous test species;

- use unpolluted parts of the receiving body at ambient temperatures as dilution water;

- aerate the test solution throughout the test period.

Finally, in attempting to develop a guide on preliminary assessment of environmental effects of the region's existing small mills, Phase I research produced a simplified method for calculating effluent parameters when only the raw materials and processes used in a mill are known. This methodology will be further tested during Phase II studies.

Much of the information used to develop the methodologies described was obtained through experience gained from the six separate Phase I field studies. Additionally, results obtained from these studies, though not yet comprehensive, produced several conclusions (see Sec. "3. Field Studies") about the specific nature of the regional mill effluents and their environmental effects. These conclusions give direction to member countries in organizing future pollutant monitoring and control programmes.

NIEM members recognize the importance of improving environmental management through both the expanded training of and increased cooperative efforts between mill and government personnel who are responsible for pollutant monitoring and control measures. Particularly important and fruitful in conducting Phase I activities was the direct participation of industry personnel. Industry personnel's first-hand knowledge of mill physical plant and process peculiarities combined with government and research institutions' resources proved an effective combination in completeing the research activities and preparing the manuals and guides.

This multi-institutional cooperation catalyzed by the Network during Phase I also resulted in establishing contacts, nationally and regionally, that can be built on to facilitate future regional environmental management activities and to improve each individual NIEM member's effectiveness. Whether future activities are organized locally or regionally, members now have:

- experience in coordinating research with harmonized procedures;

- trained personnel from the regional training workshop with established contacts with other Network members within their countries and the region; and

- reference documents from Phase I and personnel familiar with them and their use.

The NIEM Phase I programme was conducted over 25 months, from February 1987 to March 1989, experiencing a short, unexpected delay in final outputs caused by delayed completion of one field study due to technical difficulties. Total cost of Phase I was over US$355,000, of which approximately 43 per cent was provided by SIDA and the rest by NIEM cooperating institutions in the seven Asian countries. From preliminary estimates, national counterpart contribution by NIEM cooperating institutions was US$203,000, of which US$105,800 was allocated to the sub-projects with the remaining for other indirect expenses.

The financial contribution by SIDA to the Network served two important goals:

(1) It catalyzed and enabled the mills to cooperate in this network, which are usually financially constrained with a lack of such foreign funds to conduct extensive pollution monitoring and control measures on their own; and

(2) By encouraging their participation in the projects, ensuring the success of the Network's final objective, which is better environmental management in all regional pulp and paper mills.

The success of NIEM Phase I programme can be illustrated by attainment of the expected goals, and shows the viability of cooperative regional efforts in environmental management. Through the enthusiastic participation in research studies and information exchange, as well as, in-kind contributions, financial and technical, by the NIEM members, effective institutional arrangements were set up to complete Phase I activities and the resulting outputs. This established Network coordination, the resulting data base, and members' willingness to participate in a Phase II programme provides a good foundation for continuing NIEM activities and success.

2. MANUALS AND GUIDELINES

The manuals and guidelines included with this report as Annexes 1-6 were first drafted by Resource Persons and then edited to reflect comments provided by NIEM members through a cooperative exchange of information, experience and the findings of the field studies. At the training workshop, comments were consolidated and the documents finalized. The manuals and guidelines produced during Phase I are summarized below.

2.1. Manual on Discharge Characterization

The primary objective of the manual (see Annex 1) is to outline the appropriate methods for NIEM members to characterize mill effluents before these are discharged to any receiving media. The manual is aimed at assisting mill managers, researchers, and government regulatory personnel in their day-to-day work.

The manual outlines methods for characterizing mill discharges with reference to:

- the characterization concept;
- check point location;
- direct and indirect flow measurement methodology;
- sampling methodology;
- selection of parameters for characterization;
- analysis of parameters;
- presentation of results;
- cross checks on the reliability of results.

Also included in the manual are several Appendices with reference to:

- design, construction and installation of various flow measuring devices and flow calculation methods for these devices, with the most specific information for weirs and Parshall flumes;

- specific methodology for the analysis of suspended solids in wastewater and sodium content in wet pulp;

- an environmental control form for presenting experimental and evaluated results in a common, easily understood form;

- examples of expected values, mass balances and technical data used for cross checking the reliability of study results, with specific reference to considerations for non-wood pulping.

Since the regional pulp and paper industry consists of comparably small mills with limited facilities for process and discharge control, emphasis is placed on simple, low-cost techniques giving acceptable and comparable results, while more precise and elaborate techniques have been omitted.

The general objective of this and the other manuals and guides is to help the NIEM members to harmonize procedures and provide reliable data, thus obtaining better basic information about mill operation and environmental impact from their own and other members' experience. This information should serve to identify areas where savings in raw material, water and energy useage could be made, in order to obtain more even and economic mill operation, resulting in better rentability and less environmental impact.

2.2. Manual on Receiving Water Quality Evaluation

The objective of the manual (see Annex 2) is to provide guidance to those individuals charged with the complicated task of monitoring the environmental quality of pulp and paper mill receiving waters. The approach produces comparable data which can be used:

- to determine the overall quality of the receiving water and its ability to sustain various beneficial uses;

- to plan the extent of pollution control measures to be taken;

- as part of the environmental impact assessment studies and other research activities.

Because of the high cost of even routine sampling and analysis, it is important to carefully plan all aspects of the monitoring programme before the field work begins. The manual is designed to meet this objective by giving a step-by-step approach to conducting a receiving water quality monitoring programme for use by the various NIEM research teams. This approach to receiving water quality evaluation is outlined in the manual with reference to:

- background information collection; specifically regarding review of existing information on factors influencing the quality of the receiving water body, benificial uses of the receiving body, dispersion characteristics of the receiving body, etc;
- selection of sampling points;
- sampling frequency;
- sampling procedure; including comments on sample preservation and identification, manual, automatic and composite sampling, etc;
- analytical methods;
- presentation of results.

Attached as Appendices is information on:

- biological assessment of water quality following a methodology for sampling benthic macro-invertebrates;

- a standard NIEM receiving water quality data form;

- problems associated with sodium in irrigation waters.

2.3. Manual on Receiving Land Quality Evaluation

This manual (see Annex 3) addresses the assessment of the quality of lands irrigated with industrial wastewaters, particularly pulp and paper mill wastewaters. Its objective is to provide concise information and guidance to environmental scientists and engineers engaged in monitoring the impacts of wastewater application on land. The focus is on assessing and evaluating positive and negative impacts on soils; in other words, of both the enhanced productivity and the deterioration of land and soil which may occur when effluents are used to irrigate crops.

The manual concentrates on detailing harmonized methods for conducting a soil sampling and evaluation study with regards to:

- collection of background data on general cultivation practices, extent of irrigation, types of local soils and rock, ground water depth, etc;
- planning of the sampling programme; including selection of, sampling points, sampling frequency and sampling apparatus;
- execution of sampling; involving removal of samples, preparation of composite samples and sample labeling, handling and storage;
- methods of analysis;
- interpretaion of results and remedial action.

Much of the manual's specific information on soil analysis procedures and methods to determine impact on crops and groundwater is contained in annexes and tables. These items include information on:

- crop sampling procedures;
- tolerance of various crops to exchangable sodium;
- reclamation of alkaline soils;
- analytical methods for grains and consumable plant parts;
- determination of soil infiltration rate, permeability, etc;
- measurement of soil pH; etc.

2.4. Guide on Determination of Acute Lethal Toxicity of Pulp and Paper Mill Effluent to Freshwater Fish

The guide on toxicity determination (see Annex 4) is aimed to provide NIEM members with a procedure for complimenting the physical and chemical characterization of pulp and paper mill effluents. This procedure provides a biological test having relevance for a first assessment of the biological effects caused by mill discharges.

The guide provides a slightly modified version of the International Standard ISO 7346/2-1984, "Water quality - Determination of the acute lethal toxicity of substances to a freshwater fish - Part 2: Semi-static Method". The included modifications were developed based on evaluations and experience gained by Network members during Phase I. The guide

includes this standard test as an appendix but also provides details on:

- test species selection;
- test condition modifications;
- reporting of results.

2.5. Guide on Preliminary Assessment of Environmental Effects of Existing Small Pulp and Paper Mills

The objective of the guide (see Annex 5) is to give an outline of a basic procedure for undertaking a study environmental effects of existing small pulp and paper mills. Since many regional mills have insufficient resources to conduct a complete discharge characterization programme or receiving media quality study, this guide gives advice on simplified methods for a first, basic assessment of environmental effects of wastewater discharges from small existing mills.

The simplified procedures to assess environmental effects proposed in the guide are:

- provide background information on the mill;
- determine pollution load from the mill;
- identify and evaluate the effects of mill discharge on receiving waters and land;
- determine permissible discharge levels to maintain acceptable water quality standards;
- identify abatement and resource saving measures to achieve stipulated discharge levels.

The guide was prepared based on experience and results obtained from Phase I study of discharge characterization and receiving media quality evaluation. Further Phase II study data is needed to compliment the information in the guide and test it further under operating conditions.

2.6. Guide on Conducting National Training Workshops

The guideline (see Annex 6) briefly outlines methods and procedures to be considered for organizing and conducting training workshops at national and regional levels. The workshops will aim to train a large number of regional industry and government personnel to monitor mill process discharges and use the collected data in process control efforts. These workshops will utilize the manuals, guidelines and other NIEM outputs.

3. FIELD STUDIES

Six field studies were conducted in four different countries during NIEM Phase I. The mills investigated included:

- four mills discharging to freshwater streams;
- one mill discharging to both freshwater and onto land; and
- one mill discharging onto land only.

The six mills use various wood and non-wood raw materials; such as, rice straw, wheat straw, bagasse, grasses and purchased pulp, employ several different chemical and chemi-mechanical processing methods for pulping, and have various levels of wastewater and chemical recovery/recycling capacity. The exact research methods used and scope of investigation at each mill was different. However, efforts were made to compile the study reports in a standard form.

3.1. Field Study Descriptions

3.1.1. Bang Pa-In Paper Mill Field Study

Bang Pa-In Paper Mill located in Bang Pa-In District, Ayuthaya Province, Thailand (about 60 km north of Bangkok) is an integrated pulp and paper mill, producing 40 tons/day of writing paper from pulp of which 18-20% is imported softwood pulp and the rest produced from rice straw using the sulphite process. Wastewaters, except spent liquor and some portion of the bleaching wastewaters, are discharged without treatment into the Chao Phraya River at a point about 30 km upstream of a water intake point for the Bangkok water supply system. The combined major portion of spent liquor and bleaching wastewater is discharged into a series of four holding ponds before final discharge. There is no wastewater recycling system used.

The mill study (see Annex 7) included:

- discharge characterization of the mill effluents;
- a receiving water quality evaluation, including biological observations of plankton, coliform and benthic communities;
- toxicity tests on the untreated final discharge and the influent to and effluent from the treatment ponds.

3.1.2. Padalarang Pulp and Paper Mill Field Study

Located 20 km west of Bandung, Indonesia, Padalarang Paper Mill is a small, integrated pulp and paper mill with a combined production capacity of 24 tons/day of cigarette, malina carton, drawing, writing, cyclostyle and specialty papers. A large portion of the mill's pulp is imported, while a small percent is produced at the mill. The mill's major raw material for pulping is rice straw, though the hard wood Albizzia falcataria has been used more lately as rice straw is in short supply. The soda process is used to cook the rice straw, while the

soda-anthraquinone process is chosen for wood processing. Small amounts of chemicals and wastewater are recovered in the process, including a small portion of white water and some portion of black liquor. The untreated mill effluent is discharged directly into an irrigation channel, and this water, also contaminated by domestic wastewater, is then used solely for irrigation.

The study (see Annex 8) dealt with:

- characterization of effluents;
- evaluations on receiving media (ie. paddy fields) with respect to:
  (1) soil;
  (2) paddy planting;
  (3) population of micro-organisms;
  (4) macrozoobenthos;
  (5) two sets of toxicity tests on local fish using the final effluent discharge from first a mostly non-wood and then a mostly wood pulping-paper making process.

3.1.3. Hindustan Newsprint Mill Field Study

Hindustan Newsprint Mill is located about 30 km south of Cochin in the state of Kerala, India. It is an integrated mill producing up to 250 tons/day of newsprint using 70-75% chemo-mechanical pulp (CMP) produced from eucalyptus wood and 25-30% chemical pulp (kraft) produced from reed and bamboo. Spent liquor from both pulp mills is concentrated in multiple effect evaporators and then processed in the chemical recovery plant, consisting of a recovery furnace and causticiser, for the recovery of chemicals which are re-used in the pulping process.

The effluents from the different sections of the mill are segregated and collected in three different sewers as high solids, low solids and clear streams. Effluent treatment consists of a primary clarifier, settling ponds, an aeration pond, and a polishing pond. Colour removal from the effluents is carried out by addition of alum at the primary treatment stage. The low and high solids effluents are treated in the aeration stabalization basin after removal of colour and suspended solids. The quality of the final treated effluents discharged into the Muvattupuzha River remains within the desired limits of pH: 5.5 to 9.0, BOD: 30 mg/l, SS: 100 mg/l, COD: 250 mg/l, and Colour: 100 + river water colour in Pt-Co units.

The study (see Annex 9) involved:

- discharge characterization;
- receiving water quality evaluation, including observations on coliform and benthic macro-invertebrates;

- extensive toxicity testing of the effluents from each process section and for each different raw material.

3.1.4. Pudumjee Pulp and Paper Mill Field Study

Pudumjee Pulp and Paper Mills is located in Pune District, the State of Maharashtra, India about 12 km from Pune City. The mill is a partially integrated operation producing 30 to 35 tons/day of soda pulp from bagasse and combining with purchased pulp and waste paper makes about 60 tons/day of a variety of specialty papers, e.g. grease-proof, glassine, teleprinter, tracing, kraft and cultural. No chemical recovery is adopted, but much of the paper machine wastewater is recycled.

The mill has a wastewater treatment system consisting of two primary clarifiers for seperately treating pulp mill and paper machine wastewater, and two aeration basins with seperate clarifiers. The entire volume of the wastewater from the treatment plant is disposed of on land for crop irrigation.

The study (see Annex 10) included:

- discharge characterization;
- a receiving media quality evaluation involving monitoring effects on:
  (1) the River Pawana adjacent to the mill;
  (2) groundwater quality;
  (3) soil irrigated with effluent;
  (4) crops grown with wastewater irrigation.

3.1.5. Neijiang Regional Mills Field Study

The mills studied are located in the Neijiang Region in Sichuan Province, the People's Republic of China and primarily discharge into the Toujiang (Tou River). The Neijiang mills include seven integrated pulp and paper mills using bagasse as their raw material. Using either the sulphate or ammonium sulphite process, from 10 to 15 metric tons/day of machine glazed, letterpress, writing, copy, or poster paper is produced at each mill. Chemical recovery and effluent treatment is not developed or non-existant at these mills.

The study (see Annex 11) included a general survey of the environmental impacts created by the mills and confirmed data from an earlier study. An involved case study of one mill is proposed for further research.

3.1.6. Huasheng Paper Mill Field Study

Huasheng Paper Mill is located in eastern China in the suburb of Suzhou, Jiangsu Province. The mill produces 25 ton/day of soda pulp using wheat straw and in turn produces 22,000 metric tons of paper and paperboard annually. Operational treatment facilities include white

water recovery, preliminary sedimentation pond, and pulp recovery equipment. These facilities remove pollutants from the effluent before their discharge to the Grand Canal water system and recover wastewater for reuse.

The study (see Annex 12) included:

- wastewater characterization;

- acute toxicity testing of the final effluent.

3.2. Field Study Results and Conclusions

It is difficult to draw many generalized conclusions about the nature of the Network's pulp and paper mills' environmental effects from the above studies because of the many differences in the scope of each individual study and the nature of each mill operation. However, there are several common conclusions of potential interest that can be drawn from the different study focus areas. These observations will help guide future studies as NIEM research becomes more specific and detailed.

3.2.1. Discharge Charaterization

Each mill's effluent characteristics vary depending on the use of different raw materials, processes and reuse/recycling methods. The difficulty experienced by several mills in flow measurement variously effected each mill's discharge data during Phase I study. These difficulties stemmed from irregularities in mill drainage systems, frequent variation in production output, changes in the mixture of raw materials used, in-plant spills, and mill equipment failures ie. pumps to treatment facilities etc. Despite these differences in mill operation and difficulties in collecting totally reliable and representative data from each mill, several general observations can be made.

In Table 1 below is a representation of the percentage of pollution load from different process sections in the reporting mills. From the information in this table, the following can be observed:

- Pulping units using both non-wood and non-wood/wood mixture raw materials are the highest process contributor to pollution loads in most mills, especially in contribution to dissolved solids, COD and colour. The pulping unit in the Padalarang study is also noted as the highest contributor to increased conductivity;

- The bleaching process is generally a smaller contributor to most pollution parameters, but certain amounts of chloro-organic compounds were noted in the Huanshang and Hindustan reports which may increase toxicity;

- Paper machines are also a low pollution load contributor except for suspended solids, especially when certain papers are being produced, such as newsprint at the Hindustan mill. However, paper machines generally consume and then discharge the highest percentage of total flow. This can be easily observed at the mills which do not recycle any wastewater from this section; namely, Padalarang and Bang Pa-In. Also

Table 1: Process Section Effluent Pollution Loads as a Percentage of the Combined Effluent Load

Mill	Huasheng			Pudumjee			Padalarang						Bang Pa-In		Hindustan		
Section / Parameter	(1)	(2)	(3)	(1)	(2)	(3)	(1)		(2)		(3)		(1) (2) Combined	(3)	(1)	(2)	(3)
							I	II	I	II	I	II					
flow	35%	15%	25	35	38	27	20	14	15	21	65	65	54	40	17	33	29
COD	64%	15	10	85	13	2	89	92	4	4	7	4	79	21	38	28	29
SS	44	17	30	81	9	9	20	14	14	19	66	67	36	63	18	20	48
colour	90	low	low	-	-	-	high		low		-	-	60	-	90	4	-
DS	-	-	-	88	10	2	71	77	14	11	15	12	-	-	-	-	-

(1) Fibre line
(2) Bleaching
(3) Paper Making
other:
soda recovery
utilities
paper board

Pulping
Raw Material:
100% non-wood

(1) Pulping
(2) Bleaching
(3) Paper Making

Pulping
Raw Material:
100% non-wood

(1) Pulping
(2) Bleaching
(3) Paper machine I - III

Pulping Raw Material:
I - 56% non-wood
44% wood
II - 19% non-wood
81% wood

(1) Pulping:
-Raw material
-Black liquor
-Thickener
screen
-Cowan filter
(2) Bleaching
(3) Paper
making
other:
chemical plant

Pulping
Raw Material:
100% non-wood

(1) Raw material
Fibre line
(2) Bleaching
Chemical Prep
(3) Paper making
other:
chemical recovery
utilities

Pulping
Raw Material:
28% non-wood
72% wood

reported was that if no recycling of white water was done at the Pudumjee mill, the flow from this section would be about 59% of the total discharge.

Though the bulk of raw materials used for pulping at mills studied under Phase I was non-wood, two mills used substantial amounts of wood as well. During the time data was collected, the Hindustan mill combined pulp from one non-wood process and one wood process to produce paper. While at the Padalarang mill, one set of observations was made during the use of a primarily non-wood pulp mixture and another set during the use of a mostly wood-based pulp. The discharge data from the pulping and bleaching sections of both mills and for the final effluent of the Padalarang mill is presented in Table 2.

Results from this data are far from conclusive, but a few trends can be observed for situations where wood was used as the raw material for pulping rather than non-wood, including:

- Effluent flow decreased for all process sections and the final effluent at Padalarang, except for the bleaching section at Padalarang;

- Suspended solids decreased, except for the bleaching section at Hindustan and final discharge at Padalarang;

- COD and colour increased, at times significantly, except for COD in the pulping section at Padalarang and the bleaching section at the Hindustan mill.

Table 2: Pollution Loads of Effluent Using Non-wood vs. Wood Raw Materials in Mean Value per Ton Product

Mill		Hindustan				Padalarang					
Process		Fibre line		Bleaching		Pulping		Bleaching		Final	
Parameter / Units		I	II	I	II	I	II	I	II	I	II
		per ton pulp				per ton pulp				per ton paper	
flow	m^3	41	15	81	45	764	546	540	628	579	572
SS	kg	26	16	21	27	142	113	91	87	89	104
COD	kg	42	62	53	55	2018	1811	53	58	113	249
colour	kg*	29	216	19	7	3959	9852	6	34	90	822

*based on 1 Pt. Co unit equivalent to 1 kg Pt.

Note:

Hindustan: I - Effluent from the production of chemical pulp from reed and bamboo by the kraft process.
28% of total pulp

II - Effluent from production of chemimechanical pulp from eucalyptus wood.
72% of total pulp

Padalarang: I - Combined effluent from the production of pulp from:
56% rice straw using the soda process
44% wood (Albizzia falcatarin) using the soda anthraninone process

II - Combined effluent from the production of pulp from:
19% rice straw
81% wood
-Up to 80% of total pulp for paper production purchased from outside.

Another observation from several studies is that by the use of efficient recycling practices wastewater volume generation can be reduced considerably. For the mills operating with wastewater recovery systems, which include the Pudumjee, Hindustan and Huasheng mills, total effluent discharge was between 72-178 m^3 per ton of paper produced, while the mills not recovering wastewaters discharged between 576 m^3/ton and 593 m^3/ton. These savings primarily come from recycling of white water from the paper mills.

Also noted was the feasiblity of significantly reducing pollution loads from the final effluent if proper treatment systems are used, as is the case at the Hindustan, Huasheng and Pumudjee mills. The treatment efficiency of the Hindustan system is over 90% with respect to suspended solids, BOD and colour removal and 89% and 64% for COD and dissolved solids respectively. The Huasheng mill meanwhile claims a 80-85% reduction in pollution parameters with only certain components of their treatment system active.

3.2.2. Receiving Water Quality

Three mills conducted studies of river waters affected by their mill discharges; including, the Hindustan, Bang Pa-In and Pudumjee mills. However, each mill and the river system it affects are significantly different.

At the Hindustan mill, the mill discharges its well-treated effluents directly into the Muvattpuzha River which flows at an average rate of 120 m^3/sec during the wet season and can fall to a minimum of 40m^3/sec during the dry season. There are no major industries on the river but a number of villages are situated on the banks of the river. As the mill's average discharge is 0.423 m^3/s, the dilution ratio is 1/280 during the average high flow rate and reaches a minimum of 1/95.

The Bang Pa-In mill discharges its only partially treated effluents directly into the Chao Praya River. The river flows recorded in the mill study varied from 993 m^3/s during the wet season to 290 m^3/s during the dry season. The river passes through a district town about 5 km upstream of the mill and is also well-populated on both river banks downstream of the mill. With the mill discharging about 0.232 m^3/s year round, the dilution ratio of the effluent to the river flow is 1/4200 during the wet season and 1/1200 during the dry season.

The Pudumjee mill takes water from the River Pawana whose flow is regulated by a large dam and weir control system. This flow is largely dependent on the demand from irrigation with large fluctuations. The volume of the river flow is not specifically mentioned in the mill report. The river area is generally well-populated with the Pudumjee mill situated on the river's right bank at one point and a complex of industrial establishments on the opposite bank in the same area. The mill discharges no effluents directly into the river, but only percolates from the wastewater irrigated cropland and occasionally a small quantity of unused wastewater from the mill join a nullah which confluences with the river.

The water quality studies conducted at each mill varied slightly in the methods and scope of study and in the manner results were reported.

The most significant difference was the locating of river water sampling stations along the river in relation to the mill effluent discharge point. The locations used at the three mills are as follows:

Hindustan	Bang Pa-In	Pudumjee
I-0.60 km upstream of discharge	1-5.0 km upstream of discharge	1-3.1 km upstream of were nullah joins the river
II-0.05 km downstream	2-2.0 km downstream	2-2.6 " , above weir which holds water used in mill
III-1.05 "	3-in side-stream (up 1 km), stream 3 km down from mill	3-2.5 km upstream
IV-2.05 "	4-8.0 km downstream	4-2.1 "
V-2.25 km downstream, in Ithipuzha Branch	5-16.0 "	5-1.6 "
VI-3.25 "	6-30.0 "	6-0.1 "
VII-2.25 km downstream, in Murinjapuzha Branch		7-0.1 km downstream
VIII-3.25 "		8-2.1 "
		9-3.4 "
		10-5.4 "

Similar pollution parameter levels were analyzed for each study's samples and the results of this analysis for representative samples upstream and downstream of each mill's discharge point are presented in Table 3. At each of the three mills, river water temperatures and pH levels were in normal, acceptable ranges only varying slightly and so are not shown in Table 3, but several other listed parameters were of significant magnitude and varied considerably.

On p. 13-14 of Annex 5 of this report, suggested water quality standards for NIEM members' use are included. These standards include the classification of three levels of pollution content in relation to several pollution parameters and the corresponding safe usages for these different levels of effected river water. Five parameters are used which were also analyzed during the Phase I studies; including, DO, BOD, DS, SS, and coliform count. "Standard 1" river waters are classified for use as a source of domestic water supply provided they receive adequate treatment and are the least polluted class of waters. The suggested parameter levels include:

DO - $\geq$ 6 mg/1;
BOD - $<$ 4 mg/1;
DS - $<$ 500 mg/1;
SS - $<$ 100 mg/1;
Coliform count - $<$ 500/100 mg.

The Muvattpuzha River at the Hindustan mill is the least polluted of the rivers studied and can be classified a Standard 1 river at all locations except for a high BOD level at Station II (0.05 km from the discharge point) and in terms of coliform counts at all locations. Although indicating slightly higher levels of some pollution parameters, the Chao Praya River at Bang Pa-In is also a generally "clean" Standard 1 river except at some locations in terms of disolved oxygen and coliform count, especially during the dry season. The River Pawana however is a grossly polluted river system and at all times does not satisfy the Standard 1 requirements because of DO, BOD and coliform levels. This river would be classified as a Standard 2 river suitable for casual fishing, boating, irrigation and limited industrial use after pretreatment.

Table 3: Physico-chemical Characteristics of Receiving Water Quality
Upstream and Downstream of Mill Discharge Point

Mill		Hindustan				Bang Pa-In					Pudumjee			
Sampling Period		Full Year				Wet Season			Dry Season		Full Year			
Sampling Station / Parameter		Up	Down			Up	Down		Up	Down	Up		Down	
		I	II	III	IV	(1)	(2)	(4)	(2)	(1)	(5)	(6)	(7)	(8)
colour	Pt-Co	19	32	24	24	60	80	60	30	30	clear	clear	clear	clear
SS	mg/l	9.4	19.2	23.4	8.1	78.5	79.0	74.5	20.5	39.5	-	-	-	-
DS	"	69.4	170.5	124.3	83.4	167.5	155.0	150.5	173	162	-	-	-	-
DO	"	6.5	6.0	6.0	6.2	5.7	6.0	5.9	3.4	5.5	2.2	3.5	2.1	3.7
BOD	"	1.1	6.3	2.7	1.6	1.3	1.5	1.5	2.3	1.8	37.0	28.5	33.0	12.5
COD	"	4.7	20.0	14.1	10.2	13.4	13.4	12.1	11.0	6.6	92.0	73.0	92.0	39.5
Na	"	4.1	13.3	7.4	7.8	10.4	8.2	6.9	20.1	21.5	20.1	12.4	26.9	14.3
Ca	"	9.2	28.6	13.3	9.3	16.2	13.5	10.4	25.6	24.9	combined Ca+Mg comparable levels			
Mg	"	2.2	2.5	3.4	2.4	4.9	6.3	4.4	6.7	6.5				
SAR	-	0.52	0.81	0.56	0.64	0.6	0.5	0.5	0.9	1.0	0.91	0.56	0.65	0.66
chloride	"	4.8	35.2	22.0	12.3	6.0	5.8	4.3	16	17	-	-	-	-
Total Coliform, Colonies/100ml		1205	1144	1154	742	100	100	500	100	700	1600	1600	1600	1600

Sample Station in Relation to Discharge Point:

I - 0.60 km upstream
II - 0.05 km downstream
III - 1.05 km "
IV - 2.05 km "

(1) - 5.0 km upstream
(2) - 2.0 km downstream
(4) - 8.0 km "

(5) - 1.7 km upstream
(6) - 0.1 km "
(7) - 0.1 km downstream
(8) - 2.1 km "

Note: - The parameter value from each sample location for the Hindustan mill is the highest value recorded for the 6 different cross-sectional samples taken at the station, while for the Bang Pa-In and Pudumjee mills, values given above are the mean averages of the several cross-sectional samples at each station.
- At the Bang Pa-In mill during the dry season, the river was flowing inland because of tidal effects. Therefore, Station 2 which is downstream of the discharge point in normal flow conditions is listed as "Up" in the chart for this period, as the mill effluent should be having less effect on water quality at the station under these flow conditions.

Observing the increase in pollution parameter levels downstream of the mill discharge points is a simple way to judge effects of the effluent discharge on the river water quality. By looking at Table 3 again some of these effects can be observed.

At the Hindustan mill, all pollution parameters, except for the coliform count, intensify at short distances from the mill discharge point. However, the parameters return close to upstream levels after only about 2 km. Futhermore, the higher pollution parameter levels were observed at only the left bank of the river at 0.5 km downstream of the discharge and then only moderately high levels were noted at the middle and left bank at 1.5 km downstream. This pattern was also visually observed when the color of the effluents was particularly noticable.

These results suggest the importance of effluent dispersion into river waters when attempting to observe effects to water quality. This observation seems to be confirmed by the fact that little significant variation in parameters was observed in the Bang Pa-In study, as the sample points were located so far from the discharge point and such high river water/effluent ratios prevailed. Also from results of the Pudumjee study, an increase in all pollution parameters can be observed when comparing the two sample locations close to the mouth of the nullah. However, the increase would be unnoticed if compared to other highly polluted sections of the river; such as, Location 5, only 1.7 km away but obviously effected by other pollution sources.

In addition to the observations of river water quality mentioned above, benthic macro-invertebrates from the river bottoms were observed in the Hindustan and Bang Pa-In studies. These observations indicated no serious negative response to mill discharges except the precence of more pollution tolerant species at the station 0.05 km away from the discharge point at the Hindustan mill. In addition, observations on plankton at Bang Pa-In indicated some relationship between phyto-plankton occurences and factors including SS and DO levels and temperature, but these factors appear more related to seasonal variations than to mill discharges.

3.2.3. Receiving Land Quality

Two field studies included analysis of the quality of land receiving mill wastewater for the irrigation of crops; namely, the Padalarang and Pudumjee mill studies.

The Padalarang mill discharges its effluents to irrigation canals which irrigate 250 hectares of rice paddies. Four varieties of rice are grown three times a year on this land. From the table on p. 64 of the Padalarang report (Annex 8), it can be noted that the irrigation water analyzed in this mill's study is of low sodium hazard and medium to high salinity hazard considering observations of SAR and conductivity levels. The mill's effluent have been used for irrigation for about 60 years.

The Pudumjee mill has been using it's effluent for 16 years on 120 hectares of land; including, 50 hectares of paddy crop, 25 hectares of other cereals, 25 hectares of sugarcane and other misc. The mill effluent used for irrigation is of low to medium sodium hazard and high to very high salinity hazard according to the Annex 8 table.

Apart from the pollution potential of the effluents used for irrigation (see p. 14-18 Annex 8), environmental factors, such as rainfall and soil composition, determine the impact of the effluents on the irrigated land. As examining all of these environmental factors is difficult, analysis of different effects on the land irrigated was taken up in the Phase I studies.

Both studies examined the physico-chemical characteristics of the soil irrigated by the mill discharges and soil from areas not irrigated by these discharges. The two studies varied most in their sampling methods. The Padalarang study used four (one unirrigated, three irrigated), 4x4 m plots as sample areas, while the Pudumjee study chose 20 (5 unirrigated, 15 irrigated) spot sample points. Neither study appeared to take soil type into consideration in the selection of sample locations.

Summarized results of the soil analysis is presented in Table 4 below. In both studies, levels of pH, electrical conductivity (EC), Ca, K, and Na ions, exchangable sodium percent (ESP), and CEC all increase, while Mg ions levels decrease. Organic matter percentages decrease slightly for Padalarang soils while they increase at the Pudumjee site.

Table 4: Physico-chemical Characteristics of Soils Unirrigated & Irrigated with Pulp and Paper Mill Wastewater

Mill		Padalarang		Pudumjee	
Parameters \ Area		Un-irrigated	Irrigated	Un-irrigated	Irrigated
pH		6.0	6.8	7.11	7.22
EC	mmhos/cm	0.228	0.317	0.81	2.47
Ca	meq/100g	14.2	23.7	26 18	27.02
Mg	"	3.8	2.7	6.20	6.08
Na	"	1.5	2.1	1.05	8.05
K	"	1.0	1.4	1.72	2.02
CEC	"	20.5	30.0	35.23	43.15
ESP	(%)	6.66	7.12	2.97	18.48
Organic Matter	"	2.84	2.73	0.948	1.968

Note: - Figures above for the Padalarang mill represent the mean average values of one sample area at three different periods for the area unirrigated by wastewaters, while the irrigated values are the average of three sample areas receiving different combinations of mill discharges at the same three periods.
- For the Pudumjee figures, 9 sample values at different depths at 5 points were averaged for the unirrigated area, and 38 or 41 sample values from 15 or 16 points were averaged for the irrigated area.

The increases in soil EC and ESP (ie. salinity and alkalinity) was most severe at the Pudumjee mill site. Whereas unirrigated soils at both mills are considered normal, the average irrigated soil sample from the Pudumjee study is considered moderately saline and slightly alkaline, while the Padalarang irrigated soils are still considered just normal. This classification is done according to the scales on p. 17 and 19 of the Pudumjee report (Annex 10). These results offer confirmation of the predicted higher salinity and alkalinity hazard of the wastewaters from the Pudumjee mill, and also indicate that continuous application of pulp and paper effluents pose potential salinity and alkalinity hazards.

The interactions involved in these changes in the soils' chemical composition is hypothizied on p. 18-20 of Annex 8 and p. 15-18 of Annex 10. These comments include the explanation that Mg ion levels decrease as Mg is replaced by sodium or reacts with residual bicarbonate ions.

Biological characteristics of the soils at the Padalarang mill were also examined for that study. Populations of various microorganisms; including, heterotrophic bacteria, actinomycetes and cellulose decomposing bacteria, showed positive effect from irrigation with the mill effluent in both field and green house studies. This was attributed to the organic waste contributed by the effluent. In addition, though some aspects of the analysis was not completed, observation of macrozoobenthos communities based on the diversity index generally showed a tendency to recover from a polluted state during flooding to slightly polluted state toward the drainage period.

Study on the effects of irrigation with mill effluents on groundwater was completed during the Pudumjee study. Groundwater, which is at a depth of 15 to 18 m in the study area, was collected from 9 dug wells (10-20 m deep) and 4 tube wells (30-50 m deep). Physico-chemical characteristics for several representative wells along with data on the irrigation water and average values for percolate samples are presented in Table 5 below.

All dug wells, like Dug Well 6 in the table, were found to be contaminated by the effluent. Tube Wells 1 & 3 somewhat away from the irrigated land were not contaminated, whereas Tube Wells 2 & 4 in soils of coarse texture and a basalt rock formation in the irrigated area were contaminated. Comparing data on the wastewater used for irrigation and percolates collected from the irrigated fields indicates that the soil effectively removes organic pollutants and retains these colour causing organics even over prolonged periods of application. However, dissolved inorganics pass into the percolate and effect groundwater quality over a period of time. These conclusions are supported by comparing data on the contaminated tube and dug wells with that for the uncontaminated wells.

Additionally, both the Padalarang and Pudumjee studies included analysis of effects on crops grown with wastewater irrigation. The Pudumjee study reported 30-33% higher yield per hectare for paddy growth and 20-30% higher return for sugarcane on land irrigated by mill wastewater compared to rainfed land. No significant increase was observed for other crops. The increase was attributed to the possibility of year-round cultivation with wastewater irrigation. Crops were also analyzed for heavy metals, eg. Ni, Cd, Cr, Pd, which are toxic to animals and humans. The content of these substances in crops grown with wastewater irrigation compared well with the control crops.

Table 5: Physico-chemical Characteristics of Mill Wastewater Used for Irrigation, Well Water form Different Areas, and Percolate from Irrigated Areas at the Pudumjee Mill

Sample Location / Parameter		Treated Wastewater Used for Irrigation min. - max.	Tube Well (1)	Tube Well (4)	Dug Well (6)	Percolate
pH		7.06 - 7.65	7.96	7.80	8.28	7.63
EC	mmhos/cm	1.536 - 2.395	0.569	1.920	4.552	2.524
Ca	mg/l	88.18 - 153.31	60.12	236.47	204.41	162.92
Mg	"	19.46 - 25.90	26.75	56.15	109.44	47.79
Na	"	251.74 - 335.65	17.47	65.52	565.55	287.38
SAR		6.257 - 6.636	0.47	0.99	7.81	5.12
BOD	mg/l	105 - 142	-	-	-	-
COD	"	980 - 1370	8.0	16.0	79.5	38.8
DO	"	- -	5.2	4.3	3.1	4.34
colour		light brown	clear	clear	light brown	clear

Note: - Tube Well 1 is in an area not contaminated by wastewater irrigation, while Tube Well 4 and Dug Well 6 are in an irrigated area.
- Percolate parameter levels shown are the mean average of values reported form eight sample locations in the irrigated area.

The Padalarang study included field studies and green house studies of crops grown with mill discharge irrigation. The field study showed that after 2 months of growth the height of the rice plants was not significantly effected, and in fact, the quantity of buds and full grain yield in experimental plots showed a positive effect from effluent irrigation compared to crops not irrigated by the effluent. Green house studies also showed positive effects producing almost twice the full grain yield as the control.

3.2.4. Acute Toxicity Testing of Freshwater Fish

During Phase I, four of the mill studies included acute toxicity tests using freshwater fish. However, as each study used different species for testing, the results are not highly comparable. In addition to the difference in test specimens, test methodology also varied. These variations included:

- length of test duration from 48 to 96 hours;
- static vs. semistatic test conditions, semistatic referring to the renewal of the test solution every 24 hours;
- aeration or no aeration of test solution;
- different effluents tested (section, final, etc.);
- different dilution waters used.

The Bang Pa-In toxicity study conducted two tests. Test One used Brachydanio sp. (zebra fish), prepared dilution water, semistatic renewal, no aeration and studied both the treated and untreated effluent. Test Two used Tilapia nilotica L., upstream river dilution water and other methods similar to Test One.

The Padalarang study used the local fish Cyprinus carpio L. as the test specimen and procedures from Standard Methods for the Examination of Water and Wastewater for 96-hour LC50 testing. Analysis of two samples of irrigation water was conducted. One sample received effluent from the mill during mainly rice straw pulping and the other sample received effluent from mainly wood pulping.

The Hindustan tests examined all the mill's different section effluents and the final discharge. The tests used Tilapia mossambica as test specimen, and were conducted under static and non-aerated conditions as well as semistatic and aerated conditions. Results were similar for testing under both conditions.

The Huasheng study included a test on toxicity of the final effluent to Carassius auratus (golden fish) under semistatic-aerated conditions. The dilution water was untreated well water.

The test resuts are summarized as follows:

Mill	Sample	Duration	LC50
Bang Pa-In	Test One-		
	Influent to Treatment Pond	48h	22%
	Effluent from Treatment Pond	24h	55%
	"	48h	55%
	Final Effluent	24h	50%
		48h	55%
	Test Two-		
	Influent to Treatment Pond	24h	12%
	"	48h	12%
	Effluent from Treatment Pond	72h	30%
	Final Effluent	48h	44%
Padalarang	Water with Rice Straw Effluent	96h	75-100%
	Water with Wood Pulping Effluent	"	95%
Hindustan	Wood Chip Wash	96h	12.5%
	Chemical (non-wood) Pulp Section	"	68.75%
	Chemical Pulp Bleaching Section	"	6.25%
	Combined High Solids	"	91.25%
	-Other sections and final effluent non-toxic-		
Huasheng	Final Effluent	24h	60%
	"	48h	36%
	"	72h	27%
	"	96h	21%

Several causes for the toxicity were forwarded in the studies. The Padalarang study stated that suspended solids in high concentrations appeared to cause toxicity by clogging gills of the fish, while the

Hindustan study sited wood extractives (tanins and resins) in the wood chip wash, chloro-organic compounds in the bleach section, and high pH and alkalinity in the recovery section as probable causes of toxicicty. Several of the studies also observed that the high concentrations required to make the final effluents toxic combined with the high dilution ratios of river water to effluents caused little concern for adverse impacts on effluent receiving river water.

As mentioned earlier in Section 2.4, the Phase I toxicicty studies contributed to the development of harmonized acute toxicity testing procedures for use by Network members. With these procedures now available as a guideline for member use, the toxicity testing planned for Phase II and future testing of effluent toxicity by NIEM members should produce more comparable and valuable results.

4. NIEM TRAINING WORKSHOP

As a final activity of NIEM Phase I, the first NIEM Training Workshop was conducted in Bangkok, Thailand during 27 June to 1 July 1988. A total of 26 mill personnel, representatives from the 7 NIEM countries and resource persons attended the workshop. The central purpose of the Workshop was to exchange information through informal discussion and presentations of the field studies of Phase I, discuss the applicability of the manuals and guidelines, assess the progress of the Network, and plan for Phase II of the NIEM programme.

Valuable information and experiences were exchanged among the participants on field studies, and constructive comments and recommendations were received from participants regarding modifications and improvements of manuals and guidelines.

This workshop provided a unique forum for the regional mill personnel to exchange ideas and obtain a better understanding of each other's views and experiences.

5. RECOMMENDATIONS

The Phase I study of the pulp and paper mills in NIEM countries has revealed the major problems encountered by mills in improving environmental management. Keeping in mind that most mills in developing countries have small production capabilities, use non-wood raw materials, and are not equipped with chemical recovery systems, much work remains to be done in promoting better environmental management in the mills. The following measures are recommended for future study and implementation.

- To improve environmental management, there should be more training of personnel at national and regional workshops particularly using the information and experiences gained in the field studies. In its future activities, the Network's training component has to be strengthened in different target areas in order to facilitate the effective and more productive dissemination of information at national and regional levels.

- As data available from the Phase I studies is limited to only some raw materials and processes, further data should be collected on discharge characterization for the mills using raw materials and processing methods other than those investigated in Phase I.

- Studies have to be carried out to relate process data to pollution parameters in order to prepare a manual to be used by government agencies and mill personnel to improve house-keeping measures.

- Study on feasible methodologies for chemical recovery in small mills, including use of spent liquors for various environmentally sound applications outside the mills.

- Further study is needed regarding the reuse of mill wastes, particularly raw effluents and treated wastewater in agriculture. Emphasis will be on protection of soils from excessive salt accumulation, groundwater contamination and effects on crops.

- Study to assess how mill pollution affects, changes and threatens tropical aquatic ecosystems, by conducting in-depth study on ecological impacts on receiving waters. Based on this study a manual on assessment of ecological impacts of pulp and paper mill effluents should be prepared to guide qualified scientists in modern methodologies to be used in conducting a comprehensive ecological assessment of the impacts mills have on tropical waters.

- Methodologies for color removal in pulp and paper mill effluents need to be assessed with particular emphasis on cost efficiencies.

These recommendations are now included in the Phase II work.

6. CONCLUSION

The NIEM Phase I programme was successful in establishing the Network as a viable mechanism of cooperation in regional efforts to improve environmental management in the pulp and paper industry. The Network members successfully established a procedure for information-sharing through agreement on protocols for collaboration and coordination mechanisms, disseminating a bibliography of publications related to the industry, and circulating a quarterly newsletter. This procedure was used as a foundation for collaboration in conducting and preparing reports on six field studies, as well as, developing six manuals and guidelines regarding discharge characterization, receiving media quality evaluation, assessment of environmental impacts of the mills, and reuse of mill effluents.

These programme activities achieved several short-term goals, including:

- establishing harmonized procedures for conducting field studies;
- developing appropriate research methodologies to deal with particular regional mill conditions;
- the training of a number of regional personnel in the use of the developed procedures and methodologies;
- encouraging and facilitating collaborative activities.

This achievement of NIEM's short-term goals, involving facilitation of technical cooperation, information exchange and training among Network members, was a neccesary step toward achieving the Network's long-term goal of enhancing environmental management capabilities of environmental agencies and industry in the Region. Network members' environmental management capabilities have been enhanced, in terms of improved understanding of sustainability, saving of resources and improved economy of mill operations, as a result of better knowledge, developed during Phase I, about details of water and material flows though and out of pulp and paper mills. Using the information-sharing network established during Phase I, this knowledge will continue to be developed in future NIEM activities furthering the long-term goals of the Network.