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

05647

[illegible]
[illegible] 1974
[illegible]

United Nations Industrial Development Organization

Expert Group Meeting on Minimizing Pollution
from Fertilizer Plants

Helsinki, Finland, 2[illegible] - 31 August 1974

THE INFLUENCE OF EFFLUENT STANDARDS ON THE ECONOMICS OF ALTERNATIVE WASTEWATER TREATMENT DESIGNS 1/

F. de Lora* and A. Masiá**

---

* Head of Ecology Department, Técnicas Reunidas, S.A., Madrid, Spain.

** Technological Promotion Director, Técnicas Reunidas, S.A., Madrid, Spain.

1/ The views and opinions expressed in this paper are those of the authors and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

id.74-5026

CONTENTS

INTRODUCTION

An existing fertilizer production complex has been studied to design adequate facilities for wastewater treatment and disposal. The complex includes plants for the production of ammonia, sulphuric acid, nitric acid, ammonium sulphate, superphosphate, ammonium nitrate and NPK formulations. Main pollutants are suspended solids, free acidity, heavy metals (As, Cu, Fe, Zn), nitrogen (ammonium and nitrate ions) and fluoride.

Two alternative designs for the wastewater treatment have been considered:

(a) to meet stream standards taking advantage of dilution in the river receiving the treated effluent, and

(b) to meet those standards without dilution.

Investment requirements for both alternates are included.

I. WASTEWATER EVALUATION

The drainage system of the Complex is divided into three sewers. Sewer I collects the wastewater from the ammonia plant, sewer II the wastewater from the sulphuric plant, and sewer III the wastewater from the fertilizer facilities. The drainage system is shown on Figure I, including the design flowrates used in the study. The wastewaters collected in each sewer flow separately by gravity to three pits and are subsequently pumped to the river by submersible centrifugal pumps. A portion of the flow in sewer III is diverted into sewer II in order to dilute the heavy solids concentration of acidic effluent to pumping requirements.

The compositions of the wastewaters are summarized in Table 1; stream standards are shown as well. Only significant parameters are included.

II. EFFLUENT REQUIREMENTS

Spanish legislation on wastewater disposal into rivers is extensive and dates from 1879. Since that time some 30 laws and orders have been enacted. Most deal with administrative procedure and, as is the case in many other countries, problems of legal interpretation can arise.

Table 1. Composition of wastewater and stream standards (in ppm)

Parameter	Stream Standard	Sewer I		Sewer II		Sewer III	
		Average value	Peak value	Average value	Peak value	Average value	Peak value
pH	5.3-9.0	8.0	8.5	1.5	1.2	7.0	8.5
Suspended solids	60	1800	2000	3000	9000	100	120
N as NH_4^+	1	20	30	30	70	120	200
N as NO_3^-	200	50	75	150	300	800	1800
F^-	10	7	8	70	120	170	180
As	4	Neg.	Neg.	15	20	Neg.	Neg.
Cu	3	Neg.	Neg.	15	20	Neg.	Neg.
Fe	5	Neg.	Neg.	60	70	Neg.	Neg.
Zn	15	Neg.	Neg.	20	30	Neg.	Neg.

This situation is now fully recognized and new updated texts are under preparation. It is expected that all previous legal documents will be combined into a single text.

In Spain it can be said that river disposal is governed by the so called stream standards. Natural continental waters are divided into four categories according to the water utilisation (namely for drinking, irrigation, power, and industrial uses, respectively).

The procedures to be followed in particular cases can be obtained by reference to three main sources as follows:

(a) Order of September 4th 1959. Published in the official gazette dated Sept. 10th 1959. This document deals with the classification of rivers and the administrative procedures for waste water disposal therein.

(b) Order of March 23rd 1960. Published in the official gazette dated April 2nd 1960. This document lists the parameters to be considered in establishing stream water quality.

(c) Directive of Ministry of Public Works. June 21st.1960. This document lists allowable concentrations of various contaminants.

A great deal of controverty exists internationally as to whether stream or effluent standards should be used as the basis. Recently[1], Wolman (1) has discussed the uselfulness of stream standards and the criteria that should be imposed for water conservation in the US. Some of his ideas are applicable to the situation discussed in this paper.

"... In some countries that have adopted high standards of environmental quality, there is a significan disparity between the realities existing in the environment and the published standards".

"A consistent policy does not require absolute uniformity".

---

1 Numbers in parenthesis refer to the corresponding numbers in the reference list at the end of the paper.

"The words stream standards seem momentarily anachronistic. Emphasis on effluent requirements in the Water Pollution Control Act Amendments of 1972 and a general feeling that stream standards do not work have driven the concept into hidding. The assumption is made that the effluent standards that specify the quality of the discharge must automatically supplant stream standards specifying the characteristics of the water bodies themselves".

This is true of the case history studie in this paper when the authorities imposed on the fertilizer Complex, effluent standards equal to stream standards.

As conclusion it could be stated, following Wolman (1), that:

(a) "... determining standards for water quality requires the weighing of varied water use objetives of society and the translation of these objetives into reasonable guides appropiate to administrative action".

(b) "... if standards are to have meaning, these must be attainable goals designed to achieve specified objetives".

III. WASTEWATER TREATMENT

Wastewater treatment design for the Complex was prepared for two cases, i.e. both to meet stream standards taking advantage of dilution, and to meet these standards in the outfall. The two designs are named simplified and complete design, respectively.

A. Simplified design.

Wastewater from Sewer I (see Table 1) is polluted mainly with suspended solids (free carbon), and corresponds to the soot water produced in the quench-scrubber section of a partial oxidation process.

The carbon particles are very small in size and consequently difficult to settle. Coagulation with conventional reagents proved to be unsuccesful.

Soot aglomeration can be accomplished by fuel-oil addition. Laboratory test results indicated that with 3% v/v fuel-oil and 3 ppm of polyelectrolyte the soot water is settled after 1 hr to a clarified effluent of 10-15 mg/l of suspended solids.

A modification of the typical coagulation process (2) has been envisaged. This comprises the utilization of a mixer-settler for the carbon-fuel oil agglomerate separation. This agglomerate can be disposed of by burning in the plant boilers.

Wastewater from Sewer II must be treated to remove heavy metals, suspended solids and acidity. This can be carried out by lime addition up to pH 9.0 followed by settling, thickening and vacuum filtration. Stream requirements can easily be achieved.

Problems from Sewer III wastewaters arise from nitrogen (both ammonium and nitrate ions) and fluoride contents. Present technology for nitrogen reduction in this type of wastewater poses quite a number of problems, as discussed later. However, in this particular case, an available dilution factor of 200 could solve the problem.

Consequently, with the process described for the three effluents, after mixing and dilution in the river, the diluted outfall composition shown in Table 2 can be expected.

B. Complete Design

In order to meet stream standards at the plant outfall it is necessary to reduce the nitrogen and fluoride concentrations contained in all three sewers. Sewers I and II will therefore be initially treated as described in the simplified design, will then be combined with sewer III prior to nitrogen and fluoride reduction. The composition of this mixed effluent is stated in Table 3 and it can be seen that 520 m^3/hr need to be treated for nitrogen and fluoride reduction.

Present technology for nitrogen decontamination includes the following processes (3):

(a) Biological nitrification;
(b) Biological denitrification;
(c) Air stripping of ammonia;
(d) Recovery of ammonium nitrate solution by ion exchange;
(e) Reverse osmosis.

Table 2. Diluted outfall composition for simplified design (in ppm)

pH	7,5
Suspended solids	~60 [1]
N (NH_3)	0,5
N (NO_3^-)	3
F^-	~ 0,6
As	Neg.
Cu	Neg.
Fe	Neg.
Zn	Neg.

1 Assuming 60 ppm in the river.

Table 3. Composition of mixed effluent (in ppm)

pH	7,5
Suspended solids	70
$N(NH_3)$	90
$N(NO_3^-)$	560
F^-	120
As	0,2
Cu	Neg.
Fe	0,2
Zn	Neg.

Processes (a) and (b) together provide nitrogen gas as final product. They are technically feasible but are both difficult and expensive (4). In addition, as is well known, biological nitrification and denitrification requires long cell residence times for specific bacteria (Nitrosomonas and Nitrobacter) due to low growth rates; therefore long retention periods of the wastewater and large installations are necessary. Further the fluoride problem is not solved by this method.

Process (c) is not a satisfactory solution because it changes a water pollution problem to an air pollution problem (4).

At this point, it becomes clear that the only possible solutions are either ion exchange or reserve osmosis, even though both have the serious desadvantage of obtaining the pollutants in concentrated form and therefore of their disposal elsewhere.

Reverse osmosis must be discarded at this stage of the development of the technology, because of efficiency and cost; in particular high power consumptions are required.

Therefore an ion exchange system was designed to treat 520 m^3/hr of mixed effluent up to stream requirements as follows:

(a) NH_3	1 ppm
(b) NO_3	200 ppm
(c) F^-	10 ppm

Obviously, ammonium concentration is the significant parameter for design. Both strong and weak cationic and anionic resins are required. Regeneration of cationic resins could be carried out with nitric acid, and ammonia could be used for regeneration of anionic resins. Therefore ammonium nitrate solution would be the combined eluates. To dispose of the eluates in this case it was decided to use an evaporating process, followed by final concentration up to salts. In this situation the final products of the complete design are:

(a) Demineralized water for reuse.

(b) Carbon-F.O. agglomerate for burning;

(c) Pyrite ashes, calcium sulphate and metal hydroxides, for dumping as wet sludge, and

(d) Salts for dumping from the ion-exchange system, mainly ammonium nitrate form.

Complete design, therefore, leads to the water reuse concept, and a small discharge to the river should be expected.

Conceptual process diagram for the simplified and complete design is shown in Figure II.

IV. ECONOMIC COMPARISON AND CONCLUSION

Table 4 gives figures for the total installed cost (TIC) of wastewater treatment facilities corresponding to the simplified and complete designs mentioned. These costs include equipment, erection, civil works, piping and engineering and are based on spanish prices at the end of 1973.

Table 4. Economic comparison
(In million pesetas 1973)

Design Case		T.I.C.
Simplified	....	63
Complete	....	165

As can be seen there is a factor of 2.6 between the two designs. In this particular case the difference was not compensate for by the value of recovered ammonium nitrate and demineralized water which are available from the complete design and can be reused.

This case history is a clear example of the considerable economical burden which can be placed on plant operators as a result of choice of standards. Both designs normally produce a mixed effluent which is identical as for as stream standards are concerned. Clearly however, the river is cleaner by using the complete design. There is therefore a need for uniformity, in the criteria to be applied, not only within individual countries, but also worldwide. Otherwise some manufacturers will have unfair competitive advantages over others. Since protection of the environment and therefore of mankind is involved such criteria must be laid down by competent and monetarily unbiased authorities.

REFERENCES

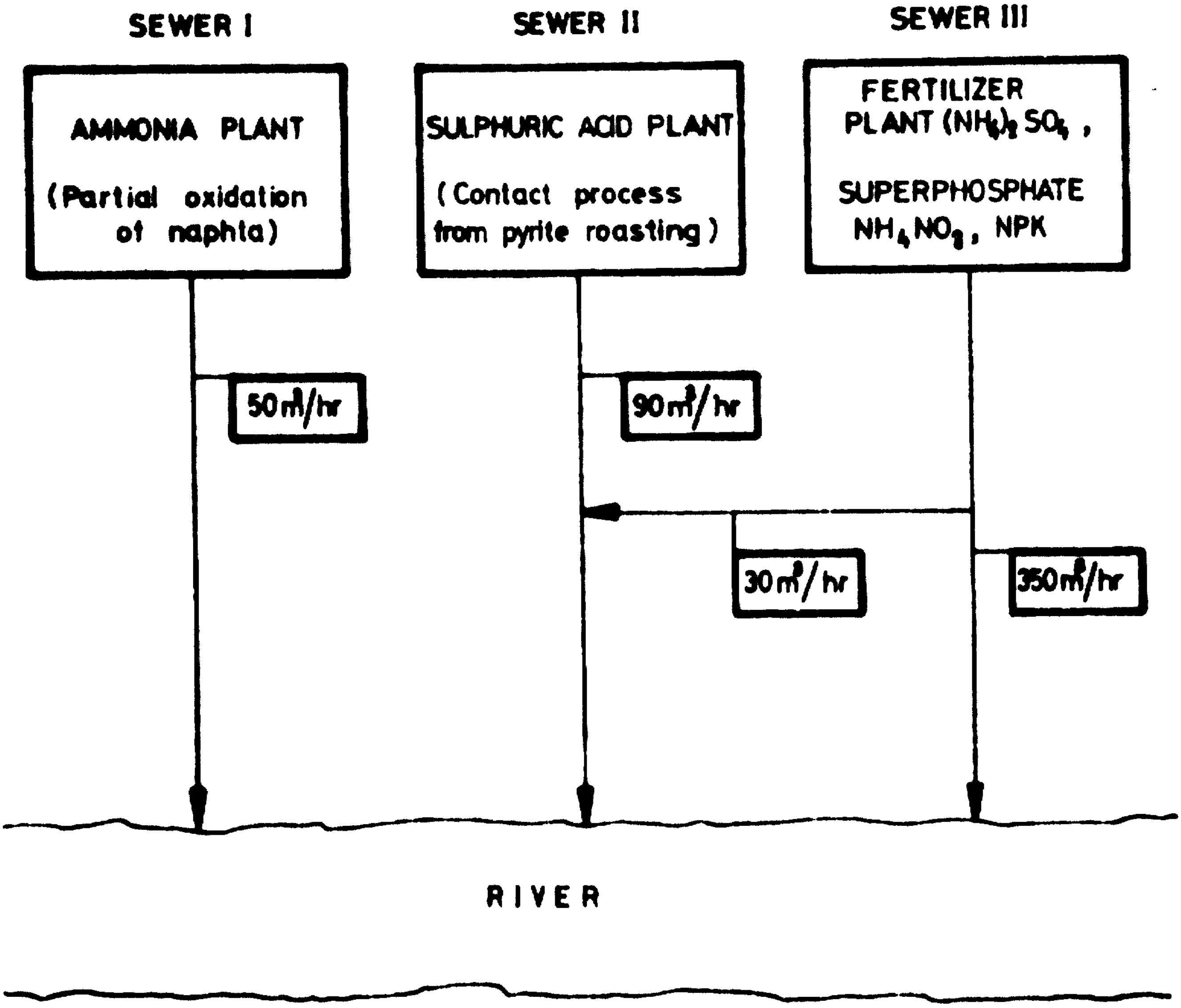
(1) WOLMAN, M.G.; Stream standards: Dead or hiding?; J. WPCF, 46, 3, 431-7 (1974).

(2) V. HAL, L.A.; Dispose of Soot by Recycle, Hydrocarbon Processing, 48, 12, 111-2 (1969).

(3) BINGHAM, E.C.; Water and Air Pollution Problems at a Nitrogen Fertiliser Plant, in Industrial Process Design for Pollution Control, AIChe, Vol. 4, New York (1972), pages 36-49.

(4) CECIL, L.K.; Difficult Pollution Control Problems, in Industrial Process Design for Pollution Control, AIChe, Vol. 3, New York (1971), page 100.

Figure 1 - Drainage system of the fertilizer complex



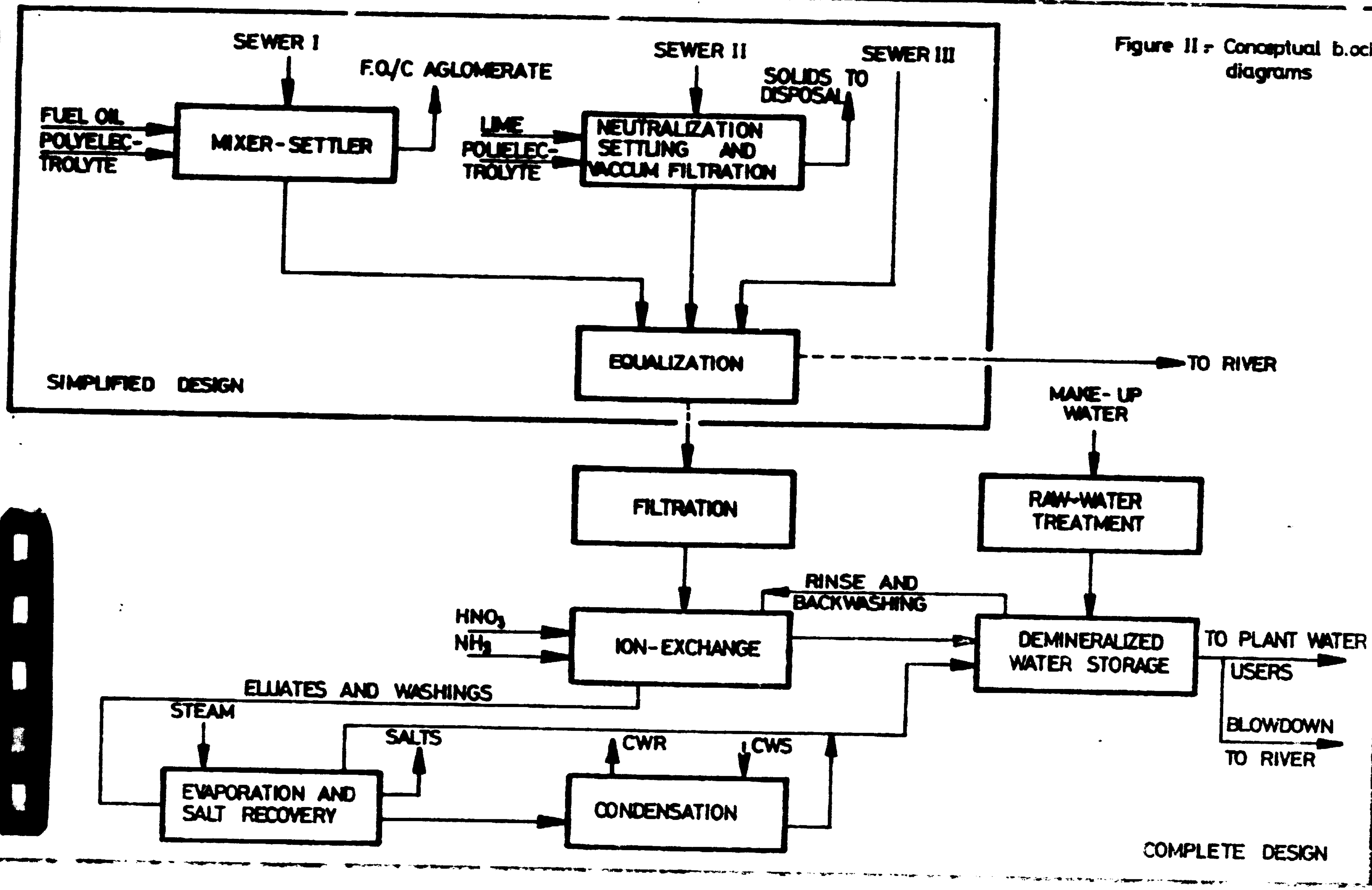


Figure II – Conceptual block diagrams

74.10.1