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

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POLLUTION CONTROL RESEARCH INSTITUTE HARDWAR (U.P.)

DP/IND/83/008

INDIA

Technical report: Findings and recommendations*

Prepared for the Government of India
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of Mr. Bernard Huriet, chemical engineer

Backstopping officer: S. P. Maltezou, Chemical Industries Branch

United Nations Industrial Development Organization
Vienna

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PREFACE

POLLUTION CONTROL RESEARCH INSTITUTE

(Hardwar - India)

This Institute is a project of Government of India financed through the Bharat Heavy Electricals Limited (BHEL) and the UNIDO acting as excecutive Agency.

The main purpose of the PCRI is to assist industrial firms in resolving the pollution problems (air, water, noise, solid wastes).

Pollution problems associated with human activities (domestic pollution) and from industrial activities in India are continuously growing and become an injure to the environment of local populations.

Rivers are more and more polluted, air is more and more smelling.

The environmental concerns involve four kinds of nuisances :

- Water pollution
- Air pollution and odors
- Disposal of solid wastes
- Noise pollution

It is not spoken of the radioactives pollution or contamination which constitutes a special field of research, development and implementation of industrial facilites to control the peril by nuclear power units.

P.C.R.I. intends to involve in its work areas (research, developement, technical implementation, monitoring, control,....) all the preceeding fields.

Among the duties assumed by the P.C.R.I. the most important one seems the water pollution control because the water used at first as drinking water for human people or animals is the primary vehicle of diseases or epidemics.

Drinking water is the source of life and it's a prevailing aim to protect it and to clean the natural resources more and more spoiled with the increasing industrial development.

I - FOREWORD

Originally the mission of the UNIDO consultant required in HARDWAR (Job description DP/IND/83/008/11-02/32.1) had several duties within the framework of setting up the Pollution Control Research Institute. All these duties were focused in the field of water pollution control.

In comparison with these aims, a new element has occured because the PCRI had alreay acquired a practical experience in the area of drinking and wastewaters analysis, thanks to a recent acquisition of analytical instrumentation.

A talk with Mr. Prof. MAHAJAN and Mr. GUPTA of PCRI has allowed to define by a mutual agreement the topics which could be approached during the mission and which could constitute the subjects of lectures or talks with the engineers of PCRI.

It is obvious that PCRI and his staff were very interested in practical aspects of informations which could be taught.

The practical aspects pointed out in Hardwar, proceeded from my own experience acquired in research laboratories, in biological treatment plants, in factories facing pollution problems.

it is a realistic purpose because PCRI intends to train experts or skilled people who will be in touch with actual problems arriving in industrial activities.

The following topics were displayed to engineers of PCRI :

- Biodegradability studies of effluents
- Design of wastewater treatment plants
- Sludge dewatering
- Incineration of sludge
- Effluents from pulp and paper industry
- Guidelines for best biological treatments

II - PROGRAMME OF MISSION

MONDAY 24 th NOVEMBER 1986

Arrival at New Delhi International Airport
Transportation to Ambassador Hotel by UNDP car
Afternoon : contact with UNDP Representatives in New Delhi and staff members
Introducing to Mr. HUSSEIN anf financial people

THUESDAY 25 th NOVEMBER 1986

Morning

Contact with Mr. PATHAK - regarding transportation to Hardwar

Afternoon

Travel by UNDP car between New-Delhi and Hardwar

WEDNESDAY 26 th NOVEMBER 1986

Preparation of the topics regarding the report

THURSDAY 27 th NOVEMBER 1986

Visit PCRI Labs and finalization of initial work plan
Lecture on biodegradability studies (aerobic)
- batch tests for sludge adaptation
- batch tests for biodegradability rate determination

FRIDAY 28 th NOVEMBER 1986

Lecture on biodegradability studies (aerobic)
Design regarding lab-scale pilot plants
Activated sludge
Trickling filter

Testing programme for investigations on pilot plant performances

MONDAY 1st DECEMBER 1986

Lecture on biodegradability studies
- aerated lagooning
- anaerobic treatments

Lab practicals on degradability tests
- aerobic adaptation of sludge

TUESDAY 2nd DECEMBER 1986

Lecture on design of industrial waste water treatment plants
- Background of design
- Sand and grit removal
- Effluent pumping
- Primary and secondary settling tanks

Lab practicals on degradability tests
- Anaerobic degradability test device

WEDNESDAY 3rd DECEMBER 1986

Compilation of the report
Lab practicals on degradability tests
- Setting up of anaerobic degradability testing devices
- Information in relationship with biological treatment : rotating biological contactors, anaerobic lagoons

THURSDAY 4th DECEMBER 1986

Lecture on design of industrial waste-waters treatment plant
- Flow patterns of aeration tanks
- Trickling filter
- Aerated lagoon

Lab practicals on degradability tests

FRIDAY 5th DECEMBER 1986

Lecture on sludge dewatering
- Types of dewatering facilities
- Flow sheet for sludge pumping station

MONDAY 8th DECEMBER 1986

Lecture on sludge incineration and disposal
Lab practicals on treatment plants design

TUESDAY 9th DECEMBER 1986

Lecture on pulp and paper mill wastewater treatment
Meeting with Mr. MAHAJAN, GUPTA, REITER (Austroplan)
Lab practicals on equipment and instrumentation

WEDNESDAY 10th DECEMBER 1986

Lecture on pulp and paper mill wastewater treatment

TUESDAY 11th DECEMBER 1986

Lecture on guidelines for biological treatment patterns
Trip Hardwar New Delhi

FRIDAY 12th DECEMBER 1986

UNDP Center in New Delhi for debriefing

III - INFORMATION REPORT

III.1 - INTRODUCTION

Teaching reported to PCRI people intended to accustome them with the implementation of methods or test procedures aiming at

- the determination of main parameters or characteristics to enable the size calculation of biological treatment plants supplied with biodegradable industrial wastewaters

- the accurate assessment (or enough accurate) regarding design, pattern, size of a full scale treatment plant including sludge dewatering, disposal and incineration

All detailed information delivered to the people attending the lectures has been gathered together in an attached report to which everybody may refer. (Part II - Technical Report - Detailed programme of training)

Teaching or training programme related to the following subjects.

- Test procedures for biological treatments (anaerobic and aerobic ways) :

    - Microorganisms adaptation methods to biodegradable effluents
    - Biodegradability kinetic determinations

- Designing of lab-scale pilot plants

    - Activated sludge plants
    - Trickling filter plants
    - Aerated lagooning plants
    - Anaerobic digestion plants

- Working project of lab-scale treatment plants

- Design criteria for the setting up of treatment plant works (full-scale)

  - Grease and sand removal
  - Settling tanks or clarifiers
  - Aeration tanks - Air flow
  - Trickling filters
  - Aerated lagooning
  - Sludge dewatering
  - Sludge disposal and incineration

- General information with reference to pulp and paper industry wastewaters

  - Types of pulp and paper making
  - Effluent biological treatments
  - Colour removal

- General information regarding the guide-lines for the selection of a biological treatment.

This teaching was given in order to provide to PCRI people practical means to carry out studies or researches related to :

- biodegradable industrial effluent treatments
- selection of the most economic way to implement a treatment plant (as far as investment and running costs are concerned)
- size determination of a full scale treatment plant to achieve an organic loading removal and to meet a discharge standard concentration

PCRI people will have working documents or first principles :

- to perform on its own biodegradability studies

- to give advices to industrial firms or factories facing with water pollution problems
- to give advices to treatment plants manufacturers
- to estimate the size of a plant
- to aid sanitary engineers

Lectures were completed with talks, discussions, practical advices given to some persons of PCRI in relationship with the training programme. The following topics were considered :

- Aerobic adaptation test carrying out
- Setting up of an anaerobic degradability studies device
- Technical equipments or instrumentation used for the implementation of lab-scale pilot plants and for the study of an industrial effluent problem
- Size calculation of the treatment plant works
- Reflexions on pulp and paper mills effluent biological treatment

To initiate a research and development programme regarding industrial effluent treatments, which leads to the design of treatment plant, PCRI has to make the necessary arrangements to get some basic equipments and instrumentations allowing :

- the determination of the organic loadings and their variations : flow measurements and BOD, COD, SS concentration analysis
- the setting up of lab-scale pilot plants enabling to establish the design criteria for treatment plant erection.

An attached listing gives the equipments, apparatuses, devices needed to carry out such studies (Appendix A).

PCRI has to acquire the missing equipments or appliances in relationship with the intended kinds of treatment implemented in laboratory scale.

It stands to reason that some appliances have priority. The equipments used to determine the effluent pollution loadings and the related variations are preemptive purchases, that is to say

- Automatic sampling apparatuses (24 flasks) (refrigerated if possible)
- Flow measurement devices : flow-meters, weirs,
- Flow velocity devices,
- Temperature and pH recorders,

Parameters as BOD, COD, SS concentrations in the effluents and flows (minimum, maximum, peak, average) are the basic criteria for the designing of a treatment plant.

III.2 - COMPLEMENTARY INFORMATION

PCRI would have wanted to get detailed and complete information regarding some particular subjects such as

- Electroplating wastewaters
- Coal distillation effluents (phenolic compounds degradation)
- Tannery wastewaters
- General considerations on anaerobic treatments
- Sugar industry
- Distillery wastewaters

In consideration of the varieties of

- the industrial activities
- the industrial processes
- the discharged effluents
- the effluent treatment means

environmental science and technology are very diversified.

One expert is qualified in a specific industrial area. Since I was not an expert in some topics for which PCRI would have wished to get information, and since I had no documents relevant with these subjects, it was agreed to send technical documentation or litterature to PCRI in the following scopes

- Distillery wastewaters anaerobic treatments
- Molasses anaerobic treatments
- List of water sampling apparatuses suppliers
- Design of a lab-scale rotating biological contactor (rotating disks)
- Basic principles of the UASB anaerobic treatment (Upflow Anaerobic Sludge Blanket Reactor)

In this way PCRI will have up to date information.

III.3 - BIBLIOGRAPHICAL REFERENCES

In an attached appendix, lists of periodical publications and books are given, about sujects interesting PCRI (Appendix B).

III.4 - ENGINEERS TRAINING

PCRI and IRCHA activities about environmental problems are the same (see Appendix D). IRCHA could receive through CERLAB, in its Research Center (40 km southern Paris) two or three PCRI engineers, during two or three months, thanks to an UNIDO financing for training.

Training programme would be discussed in accordance with UNIDO and PCRI staff.

It could be related to subjects such as :

- Anaerobic treatment of effluents (lab-scale pilot plants)
- Aerobic treatment of effluent (lab-scale pilot plants)
- Biology and ecotoxicology
- Biodegradability studies
- Air pollution
- Electroplating effluents treatment

PART II

TECHNICAL REPORT

DETAILED PROGRAMME OF TRAINING

I. - TREATABILITY STUDIES OF BIODEGRADABLE INDUSTRIAL EFFLUENTS

I.1. INTRODUCTION

The design criteria which determine the size and shape of biological treatment plants are well known for municipal waste waters.

These criteria are valid for any country if it is taken into account:

- the flow
- and the BOD concentration

since the loadings in terms of polluted organic substances (COD, BOD, SS) per capita and the consumption of water per capita are not the same according to countries and life conditions.

Industrial effluents containing organic and biodegradable matters are also identified by the value of BOD. However this paramater does not give enough available information about the rate or the kinetic with which organic effluents are degraded. Basically, BOD is a figure while sanitary consultants would like to obtain or to have at their disposal a curve of biodegradation of organic compounds in relationship with time, to design a treatment plant.

Another aspect of industrial wastewater problems is that effluents assumed not degradable by biological way, could be however degraded with microorganisms or sludge in aerobic or anaerobic conditions because that sludge could be adapted to these effluents.

This way is possible if it is sure that in this effluent, there are never toxic chemical products discharged in sewers which could stop or hindrance the biological process.

However, biodegradable industrial effluents, with and without adaptation of microorganisms have to be treated because if they are discharged in a river or in a lake, the living microorganisms in water degrade organic substances using D.O. in water.

If the re-aeration rate by the water surface is not sufficient, the concentration in D.O. (dissolved oxygen) reduces and could reach zero. Life in aerobic conditions which are the normal conditions in a river is impeded.

For industrial wastewaters which require adapted sludge to degrade their organic materials and which are discharged in a river without treatment, it is clear that in this river after a long time, microorganisms will be progressively adapted to these organic substances.

These microorganisms degrade them, utilize the dissolved oxygen from the river, the concentration of which is slowly decreasing, downstream the discharge location. The same process takes place as with easily degradable matters.

Three kinds of tests or experiments are used to get enough information regarding the aerobic biodegradability of industrial effluents :

- aerobic adaptation tests
- biodegradability rate tests
- lab scale pilot plants : activated sludge
  trickling filter
  aerated lagoon

I.2. AEROBIC ADAPTATION TESTS

Considering an industrial effluent, the ratio COD/BOD gives a good information about the possibility of biological degradation.

The smaller this ratio is, the more biodegradable an effluent is. When it is increasing, effluents are less and less biodegradable.

For example, municipal wastewaters have a ratio about 2.

Wastewaters from pulp and paper industry have a ratio of roughly 3. It is possible to abate more than 90 % of their BOD. But the kinetic of biological reaction is slower than with municipal waters and times of retention in treatment plants are longer.

In chemical industry if the ratio of COD/BOD is in excess of 3, after sludge adaptation it is possible to run biological treatment with good performances. On the other hand, detention times in aeration tanks are sometimes longer.

PCRI is able to perform simple tests which need only current laboratory equipments to grow up an activated sludge adapted to an industrial effluent. This one, of course, has to be exempt from toxic chemical products.

These above mentionned tests will be carried out in bechers or vessels with a capacity of ten liters (or less if there is no vessel available).

These vessels will be equipped with a mechanical agitation and with an air diffusion device.

In these containers, are mixed, 50/50 in volume (Appendix C1) :

1 - Sludge coming

either from a municipal wastewater
either from a biological treatment plant treating a similar type of the experimented effluent

2 - The experimented effluent for which it's necessary to adapt a sludge

In the mixture, N and P ($NH_4OH + H_3PO_4$) are added to achieve the balance BOD/N/P = 100/5/1 ; pH is adjusted to neutral conditions.

Aeration and agitation are started. Aeration is regulated by a valve to maintain 2 ppm D.O.

After 23 hours, aeration is stopped. The make up is made with distilled water to offset the evaporation if necessary and decantation takes place for 1 hour. After decantation the clear supernatant of the vessel is discarded and the same quantity of fresh tested effluent is replaced in the vessel.

In the fresh effluent, pH is checked, N and P are added and agitation and aeration are started again.

This process is daily renewed as far as after one hour of decantation, all the capacity of the vessel is full of sludge.

The level of decanted sludge slowly increases with the time of adaptation.

Duration for the adaptation phase is depending on the kind of effluent. Some days will be necessary with an effluent easily biodegradable and some weeks with an effluent not easily biodegradable.

The adaptation procedure needs few determinations :

- dissolved oxygen (daily in vessel)
- BOD of fresh effluent to adjust N and P
- pH before aeration/agitation phase

It allows :

- on the one hand to adapt a sludge and to determine the rate of adaptation by checking daily the sludge level after one hour of decantation,

- on the other hand, to provide a stock or a reserve of sludge in order to carry out tests of biodegradability rate (kinetic) versus the time according to the following procedure

1.3. BIODEGRADABILITY RATE TESTS

These tests use the same type of equipment than the previous one. From the above reactor it is taken a volume of mixed liquid phase which contains about 30 gr of sludge (in terms of dry solids).

The liquid phase and sludge are separated by filtration or centrifugation.

Sludge is poured into a vessel of ten liters with tested industrial effluent. N and P are added and pH is adjusted at 7. Agitation and aeration are started. D.O. is monitored and regulated at 2 ppm.

A sample is taken at the time 0 (departure) from the effluent - sludge mixture. It is poured into a graduate cylinder. After one hour of decantation BOD, COD and SS are determined on the clear supernatant (Appendix C 2).

This sample procedure is renewed every one or two hours according the degradability rate of the effluent in order to draw a curve giving the values of BOD, COD and SS versus time. This test which defines the effluent biodegradability rate, requires a few skillfulness. It is sometimes required to make it again one or two times.

For this purpose, it is good to keep the sludge settled in the different graduate cylinders in order to form again a stock of sludge and to make again the test as soon as possible.

This biodegradability test, using current laboratory equipments and standardized analysis gives information about degradation rate of industrial effluents.

This test is a step ahead the set-up of a lab scale biological treatment plant.

The lab scale pilot plant experiments could be easily carried out by PCRI :

- either in research laboratories
- either in factories

These pilot plants allow to define the needed main criteria in order to design a large scale industrial treatment plant (scaling up).

Experiments may last just two months. All these plants could be built with plastic (PVC) material. This one can be easily welded and sticked with a little practice and skill.

1.4. ACTIVATED SLUDGE PROCESS PILOT PLANT (LAB SCALE)

It can be operated at feeding flows ranging from 10 to 20 l/h but at steady flow. Every day a stock of tested feed effluent is got ready. Nitrogen (NH_4OH) and phosphorus (H_3PO_4) are added in order to meet the balance BOD/N/P = 100/5/1. The pH is adjusted to 7.

With flows less than 10 l/h, one can be fear the hazard that sludge adheres to the settling tank walls as the settling tank diameters are in relationship with the feeding flow. This sludge adherence on walls of small diameter settling tanks may disturb the decantation of suspended matters.

Primary and secondary settling tanks will be constructed with PVC pipes. According to the selected feed flow, the pipe diameter will be selected in order to have the following hydraulic loadings :

- primary = < 1.4 m3/m2/h
- secondary = < 1 m3/m2/h

Settling tanks will be equipped with valves for withdrawal of primary and secondary sludge.

The maximum residence time in the plant (aeration tank or vessel) will be calculated according to curves of determination of biodegradability rate (kinetic).

Residence time will be selected to achieve a BOD concentration meeting the standards required for discharge (degree of treatment).

Regarding the lay-out of activated sludge aeration tanks, two cases may happen (Appendix C 3 - 4).

- one vessel, the overflow level of which is adjustable in order to get the useful capacity modified

- two, three... or more vessels, of similar capacities and disposed in series.

These two fittings allow a better flexibility in the use of pilot plant instead of having one vessel with inchangeable capacity. As a matter of fact, experiments will be carried out at a selected steady flow for diameters of settling tanks are determined in relationship with the flow. The diameters of the settling tanks cannot be modified when the pilot plant is running.

The flexibility of the lab scale aeration tanks is used as follows.

For instance, if performances regarding BOD, COD and S.S. removals are wanted at shorter aeration detention times than the maximum available :

- in the first case, the volume of the aeration tank is reduced without changing the flow, by lowering of the overflow level,

- in the second case, samples are taken off at the outlet of the aeration vessels. The samples are settled in a graduate cylinder for one hour. BOD, COD and S.S. are determined on supernatant.

The aeration tanks will be provided with a mechanical agitator and an aeration device with air flow regulation.

The air flow will be 60 to 100 l air/gr of BOD applied into the treatment plant. From the bottom of the scondary clarifier the sludge will be recirculated ahead the aeration tanks to a pump with a flow similar or higher than that of the feed metering pump. This pump will be started and stopped by timer if its hourly flow is too high.

A programme for checking the performances of the pilot plant will be performed and will include BOD, COD, suspended solids (S.S.) determinations (Appendix C 5) :

- in fresh water before addition of N and P and before pH adjustment,
- at primary settling tank outlet
- at secondary settling tank outlet

In the aeration tanks, the dissolved oxygen (D.O.) concentration will be regulated between 1 and 2 ppm in reducing or increasing the air-flow, if necessary.

In order to obtain a high water treatment efficiency it is essential to maintain in the aeration tanks between 2 and 4 g/l of activated sludge (dry solids). This is possible in withdrawing more or less sludge from the secondary clarifier.

Volumes and dry solids concentrations of sludge withdrawn from the both (I.II) settling tanks will be monitored daily.

If there is foam in aeration tanks it could be necessary to add not toxic and biodegradable antifoam.

The experiments will last from 4 to 6 weeks according to the kind of effluent (starting phase completed).

Measures of BOD, COD, S.S. will be carried out only weekly during the starting phase, before the activated sludge concentration reaches 3-4 g/l in aeration tanks.

During the running phase, the frequency of determination BOD, COD, S.S., will be daily.

Within one month, if there are no shut-downs of the plant or disturbances in the process (pH $\approx$ 7), enough information could be obtained in order to design a large scale treatment plant and to get main criteria :

- BOD, COD, S.S. removals
- quantity of primary sludge withdrawn
- quantity of secondary excess sludge withdrawn
- residence time in aeration tanks
- settlability of the sludge (I and II)

Treatment plants using activated sludge are running at BOD loadings varying from 0.5 to 2 kg/m3 aeration tank/day.

The BOD removals are 90-95 % according to the kind of effluent and the BOD loadings.

The more BOD loading is low, the more efficiency or degree of treatment is high.

I.5. <u>TRICKLING FILTER</u>

Another type of pilot plant that PCRI could set up is the trickling filter process.

The trickling filters with stones as biofilm media or support are only used for municipal wastewaters treatment. They are not reliable for industrial effluents. The BOD loadings are generally too high and cloggings happen.

For more than twenty years, plastic materials have been used in trickling filters treating industrial effluents. They avoid the clogging specially with primary effluent containing high S.S. concentration.

These trickling filters could be run at loadings in terms of BOD from 3 to 6 kg/m3 filter bed/d, sometimes higher, depending on the biodegradability rate of the effluent.

PCRI could manufacture plastic pilot plants. They should be fed with flows ranging from 10 to 20 l/h.

Regarding the settling tanks design criteria (diameter or hydraulic loading) the same rules as in lab scale activated sludge pilot plants, are suitable for lab scale trickling filter pilot plants (Appendix C 3).

A lab scale trickling filter with plastic media packing will be 2 meters high.

An effluent recirculation will be provided from the basin or sump collecting the effluent flowing downwards through the filter. This flow is pumped on the top of the filter in order to maintain an hydraulic loading of 3-4 m3/m2/h.

This flow is essential, for a good watering of every part of the plastic support. A rotating device will be used to distribute the effluent at the upper level of the trickling filter.

In addition this high hydraulic loading creates a washing out of the support preventing the clogging.

For example (Appendix C 6), considering an effluent BOD of about 1 g/l and if the feed flow to the plant is 10 l/h, the trickling filter will be 0.225 meters in cross-section diameter (2 m high).

Flow of effluent recirculation pump at the top of the trickling filter will be 160 l/h to achieve an hydraulic loading of 4 m3/m2/d.
As the activated sludge pilot plants, trickling filter pilot plants will be fitted with primary and secondary settling tanks (diameters in accordance with the feed flow).

It is often advantageous in this kind of treatment plant using trickling filter to recirculate the secondary sludge from the bottom of the secondary clarifier to the sump beneath the filter.

The checking analysis programme to investigate the plant performances will be similar to that one of activated sludge plant (Appendix C 5) :

- in fresh waste water
- outlet of primary settling tank
- outlet of secondary settling tank

The following parameters will be measured daily:

- BOD
- COD
- S.S.
- Volume and concentration of primary and secondary sludge

Pilot scale experiments using trickling filter may last longer than activated sludge ones because more time is required to get a sufficient development of the biofilm on the plastic media. This time depends on the roughness of the material.

Analysis programme may start just when the media is wholly covered with biofilm.

I.6. <u>AERATED LAGOON</u>

The third kind of pilot plant that could be carried out by PCRI is the aerated lagoon process. This kind of aerobic treatment is well appropriate in countries with hot temperature.

The pilot plant will be made of a vessel, 200 liters capacity, equipped with mechanical agitation and air diffusion device like activated sludge aeration tanks.

In aerated lagoon process, detention time is varying from 3 to 6 days according to the BOD concentration of the effluent. For example for municipal waste (BOD = 300 ppm) detention time is 5 days.

The running of an aerated lagoon pilot plant is very simple and easy. Every day, a part of the content of the vessel is taken off. The volume of the sample is one third of the to al volume if the detention time is three days, one ,uarter for four days detention time and so one.

The same volume of fresh effluent is added in the pilot plant. As for activated sludge and trickling filter, in fresh effluent, N and P are brought (BOD/N/P = 100/5/1) and pH is adjusted to 7.

Measurements of COD, BOD and S.S. in fresh effluent and in daily discarded samples enables to calculate the efficiency of the system in relationship with the selected detention time.

In large scale aerated lagoon treatment, there is a primary settling tank but no secondary settling tank.

Practically in lab scale plants, regarding the S.S. separation the best way consists of the settling of the fresh effluent for one hour. The aerated lagoon is supplied with the selected volume of supernatant in accordance with the detention time.

1.7. **ANAEROBIC BIODEGRADABILITY**

Some kinds of industrial effluents are very concentrated in terms of biodegradable organic matter and consequently in BOD and COD.

Aerobic treatments are not reliable for these kinds of effluents because the aeration devices have a limited capacity. With high strength biodegradable effluents the oxygen uptake rate by the biomass is faster than the dissolving rate of oxygen with current aeration devices except pure oxygen.

For these reasons, keeping 1-2 ppm of dissolved oxygen in an aeration basin fed with high concentrated biodegradable effluents is not possible and a reactor is continuouly in alternate aerobic/anaerobic conditions.

Strictly anaerobic biological treatments are a mean to reduce the pollution loadings of effluents dosing in excess of 1 to 2 g BOD/l.

Anaerobic treatments are less expensive in running cost than the aerobic ones. They allow with very high concentrated effluents to recover methane (biogas) produced by fermentation. This methane is used :

- to heat the anaerobic reactor
- to supply boiler in the factory as additional fuel

However, anaerobic processes have a slower kinetic of biodegration than the aerobic ones.

They require the heating of the anaerobic reactors at 35-40°C in order to quicken the biochemical reactions and to achieve short residence times consistent with expected BOD and COD removals. As the kinetic is slow, the more the biomass will be concentrated, the more the efficiency of the reactor will be high.

Therefore, it is desirable to increase the biomass concentration in the reactor.

This is possible by putting in the reactors, inert supports on which the biomass is growing.

A lot of kinds of supports are available : stones, pieces of plastic, textile fibers, polyurethane foam, Berl saddles, pieces of tube, etc..

The appropriate support for an industrial effluent may arise from laboratory tests and depends on the local material available (supply, cost...).

The degree of treatment depends on the type of support and the organic loading applied to the anaerobic reactor.

For studying of anaerobic biological treatment and designing a large scale plant three steps are required :

Step 1 : adaptation of a biomass
Step 2 : choice of a support
Step 3: running of a lab scale pilot plant

The two first steps may be carried out in the same type of reactor.

I.8. <u>**BIOMASS ADAPTATION**</u>

These kinds of biotests could be performed by PCRI in airtight vessels with 3-5 litres capacity (Appendix C 7) made of plastic material.

The vessel will be kept at determined temperature (37-38°C) thanks to a water jacket supplied with warm water heated in a water bath.

A circulation of the content of the digestor in order to avoid clogging of the support will be provided owing to a pump (500 l/h) continuously working.

Seed will be carried out with sludge or biomass withdrawn from an existing anaerobic treatment plant or from a municipal treatment plant.

Gas production will be measured with gas-meter or graduate cylinder.

Every day the fresh effluent will be introduced into the anaerobic reactor through a pump.

This fresh effluent will be balanced regarding COD, nitrogen and phosphorus in order to meet the ratio

COD/N/P = 100/5/0.1

The feed flow depends on the COD concentration in the tested effluent and the anaerobic degradability rate of this effluent. The basic criteria to consider is the COD loading kg/m3 reactor/day (or COD g/l reactor/d).

For testing an effluent, regarding the adaptation of anaerobic microorganisms, it is conservative to start the experiments with a low loading in terms of kg COD/m3 reactor/day (for example 2-5 kg COD/m3/d).

Following parameters will be monitored daily

- COD inlet and outlet
- Gas volume
- pH in the reactor
- Feed flow

If necessary pH will be adjusted to 7 in the reactor. Progressively when the gas production increases the COD loading will be increased in checking the pH value in the reactor. For the understanding of the tests it is desirable to plot some curves as :

- Applied COD loading kg/m3/d versus time
- Produced gas volume m3/m3 reactor/d versus time
- Produced gas volume m3/m3 reactor/d versus COD loading kg/m3 reactor/d
- COD removal % versus time
- COD removal % versus COD loading kg/m3 reactor/d

The experiments may last between 75 and 100 days or more according to the biodegradability kinetics of the effluents.

They will be stopped when the slope of the curve giving the produced gas m3/m3 reactor/d versus COD loading kg/m3 reactor/d is less steep or when the gas production in terms of m3/m3 reactor/d versus COD loading kg/m3/reactor/d is constant.

Theses experiments allow to adapt a biomass to an industrial effluent and to get information on the capacity of a reactor supplied with these effluents.

They will be carried out at 37-38° C as far as possible.

I.9. SELECTION OF SUPPORTS

The same reactors will be utilized to select the best fitted support to an industrial effluent.

Several reactors, fed with the same effluent, will be run in parallel in the same loading and temperature conditions.

The supports will be different in the reactors.

The preceding curves plotted for each reactor enable to identify the best support in accordance with the required performances :COD removal, gas production, maximum COD loadings...

I.10. LAB SCALE ANAEROBIC PILOT PLANTS

These pilot plants are the last step for the studies of anaerobic treatability of an industrial effluent.

The data collected from the experiments set up the design criteria for scaling up a large scale anaerobic treatment plant.

A lab scale pilot plant is a vessel or reactor similar to the preceding ones. On the other hand, the capacity is 70-100 liters according to the available vessel.

A lay-out of a reactor is given in the appendix (Appendix C 8). One of the best material is similar to the one for the lab scale aerobic treatment plants, (PVC). The vessel is full of the support selected in the second step of experiments. A recirculating loop, supplied with a 2000 l/h pump is running temporarely to avoid clogging of the support.

The water bath is set up at the wanted temperature.

The main parameter governing the experiments is the COD loading applied to the reactor (kg COD/m3/d) and the inlet flow is adjusted according to the COD concentration in the effluent and the selected loading.

Progressively the loading is increased in order to establish performances (COD removal, gas production, CH_4 percentage, maximum loading...) in relationship with the loading.

The monitored parameters are :

- Days from the start
- COD concentration inlet : mg/l or g/l
- COD concentration outlet : mg/l or g/l
- Hydraulic residence time : hours
- COD loading : kg COD/m3/d (applied)
- COD removal : %
- Methane production : l CH_4/kg COD applied

- Temperature reactor (as a rule steady)
- Gas production m3/m3 reactor/day
- Methane production m3/m3 reactor/day
- Ratio CH_4/biogas %

These parameters will be measured daily.
Some curves have to be plotted in order to check up the running of the lab pilot plant and to draw a conclusion from the experiments for the scaling-up of a treatment plant. These curves are :

COD loading kg/m3/d versus time
CH_4 volume m3/m3/d versus time
COD removal % versus COD loading kg /m3/d
CH_4 volume m3/m3/d versus COD loading kg/m3/d

According to the kind of effluent experiments may last between 100 and 200 days.

The collected information at the end of the experiments are enough to scale up a large anaerobic treatment plant.

The general performances of anaerobic treatment are very dependent on the effluents, the running parameters and the type of support. It is not possible to give overall rules concerning the degree of treatment.

COD removals may range from 50 to 75 % - 80 %
With some supports made appropriate to some effluents COD loading about 80 kg/m3/d could be achieved (sometimes more). Regarding the gas and methane productions the following figures are common in pilot plants:

Gas : 10 - 20 m3/m3/d
CH_4 : 7 - 10 m3/m3/d
CH_4 : 300 - 400 l/kg COD removed

II - DESIGN ASPECTS OF INDUSTRIAL WASTE WATER BIOLOGICAL TREATMENT PLANTS

II.1. FOREWORD

The design of wastewater treatment plants is based on some criteria which allow to determine the main sizes and shapes of the different units forming the treatment plant.

It has been useful to give information topics to the PCRI people regarding the main design criteria applied to biological treatments.

II.2. BASIC CONSIDERATIONS

A treatment plant is characterized according to

- effluent flow
- BOD loading

The hydraulic flow will determine the size of the settling tanks and the diameter of the connection pipes. These criteria will be calculated not from the hourly average flow discharged at the outlet of the factory but from the maximum flow which will be expected according to the industrial processes (washings of apparatus or equipments, factory shut-downs, accidents, leakages).

New outputs which are planned and the output increases will be taken in consideration for the calculation of the future flow. If possible, the non pollutant cooling waters will be separated from the overall effluent and directly discharged in the river without treatment or recirculated in the process.

In order to know the effluent flow to be treated it is advisable to set up flow measurement devices and to monitor the level variations ahead these devices.

The organic loading will be determined from measures of BOD and COD carried out on samples coming from the sewer.

The average concentration will be calculated. For reliability considerations, it is advantageous to take an extra loading of + 20 %. Increases of production and new outputs will be taken in account in order to get the organic loading in the future if necessary.

Suspended solids concentration in the effluent will be also determined because their abatement is about 60-70 % in the primary settling tank. Daily, the weight of primary sludge to withdraw has to be known as it forms, with the excess secondary sludge the overall quantity of sludge to be dewatered in a fitted facility. Of course, pH variations will be monitored in order to know if a pH adjustment device is required.

Inquiries in the factory will give information regarding the possible discharging of toxic substances and heavy metals. These compounds will be removed or reduced to acceptable limits at their source.

II.3. SCREENING

Sometimes, this treatment is necessary ahead effluent pumping when large pieces of wood, plastic, clothes are contained in the effluent in order to avoid a clogging of the pumps. The maximum size of the openings in any screen is dependent upon the size of the largest particles which may be allowed to pass.

Common screen openings are :

Type of screen	Opening in cm
- Bar screen ahead of raw sewage pumps and grit chambers	5 to 15
- Bar screen ahead of other devices or processes	1.5 to 5
- Communiting devices	0.6 to 1.5
- Fine screen	0.2 to 0.4

II.4. PUMPING STATION

The pumping station is indispensable as generally sewers are located below the ground level and effluents have to be lifted to gain sufficient head for it to flow through the treatment works.

The following types of pumping are used

- vertical pumps
- horizontal pumps
- screw devices

The last type will be prefered when the effluent contains abrasive matters which could damage the impellers of centrifugal pumps. In any case a stand by pump will be provided for.

II.5. SAND AND GRIT REMOVAL

Sometimes in factories where earth or sand and grit are mixed with raw materials, they may clog pipes and withdraw pumps transporting the primary sludge from the settling tank. Sand and grit removal is advantageous in some cases.

Differential sedimentation together with the scouring of settled particles is a fundamental action involved in the operation of all grit chambers.

The basic data required for grit chamber designing include:

- data relative to effluent flow (average and peak flow)
- data relative to quantity and quality of grit

In most cases, the rational design of grit chambers is based upon removal particles over and above 0.20 mm or 0.25 mm in size.

In actual practice, designs are generally calculated using the control of the flow velocity (peak flow) within the range of 0.22 m/s-0.35 m/s and as close to 0.30 m/s.

II.6. GREASE REMOVAL

This pre-treatment is justified in the case of effluents containing greases which could choke transfering pipes in becoming solids.

The best system is to operate by air flotation

II.7. SEDIMENTATION

Ahead biological treatment, the primary settling tanks allow to separate the suspended materials. In secondary treatment, the settling tanks, remove the activated sludge which is recirculated to the aeration tanks in order to continuously seed the biological reactor (aeration tank or filter bed).

Two types of settling tanks are used in effluent treatment (Appendix C 9) :

- rectangular shape : the maximum length is 90 meters and the maximum width 6 meters. For high effluent flows, several settling tanks are used.

A conveyor chain device collects the sludge in a hopper. From there the sludge is withdrawn by a pump. The velocity of the sludge collecting device is 0.8 - 0.9 m/min.

At the upper liquid level a scraping device removes the scum and the floating matters.

- circular shape : the diameters can reach between 4 and 60 m. Beyond 60 m, several settling tanks are used, running in parallel.

Small settling tanks (diameter < 6 m) don't have in general sludge collecting device. Every big size settling tank is provided with mechanical device for pushing the sludge towards a central hopper. It is supported on beams attached to a rotating bridge.

The racking device includes several blades sweeping the bottom of the settling tank.

The velocity of rotating bridge is 1 m/minute maximum at the peripherical end in order to avoid a disturbance of suspended solids sedimentation.

Also, there is an elimination scum device on the upper level of settling tank to remove the floating matters.

The detention time in a settling tank is from 90 to 120 minutes.

The solids loading is calculated from 12 to 14 kg SS/m2/h.

In primary settling tanks, hydraulic loading is about of 1.4 m3/m2/h ; in secondary one only 1 m3/m2/h (or less), both calculated in relationship with the peak flow.

These figures are only examples. They vary according to types of effluents and sedimentation characteristics of suspended materials and activated sludge (sludge volume index).

Circular settling tanks require more space than rectangular ones. Rectangular settling tanks need more maintenance costs for collecting sludge devices than circular ones.

II.8. <u>FLOTATION</u>

Flotation is a good step to separate small suspended materials and grease and solids, the density of which is similar to that of the effluent : the solids cannot settle or settle only slowly.

In this last case, a very low hydraulic loading is necessary for their separation by sedimentation devices and large settling tanks are required.

Flotation has to be considered as a pre-treatment or as a complete primary treatment, as well, if the S.S. removal through the flotation unit is high.

There are 3 types of flotation units :

- Aeration type units : air is pumped by a blower or compressor in the bottom of a tank. Small bubbles are formed through an appropriate device ; they adhere to solids and lift them at the surface. They are not very efficient.

- Pressure type units : the wastewater is pressurized with air at one or three atmospheres and then released to atmospheric pressure in a suitable tank. When the pressure on the liquid is reduced the dissolved gas is also released in extremely fine bubbles.

The bubbles adhere to the suspended solids and lift them.

The units are from 1,2 to 3 m deep

The current overflow rates are 4 - 10 m3/m2/h.

- Vacuum type units : the wastewater is satured with air in an aeration tank or the air is permitted to enter on the suction side of the effluent pump.

Then a partiel vacuum is applied. Under partial vacuum (22 cm Hg) solubility of gas in liquid decreases, and air is released as minute bubbles.

Solids rise at the upper level of the tank with the bubbles adhering to them.

The air requirement is 0.2 - 0.4 m3/m3 effluent.

Using this system it can be expected 35-50 % solids removal at hydraulic loadings of 10-20 m3/m2/h.

Every flotation unit is equipped with scum collecting device.

The flotation units have the followings advantages and desadvantages:

Advantages

- grease, light solids, grit and heavy solids removed in the same unit
- high overflow rates
- less space requirements

Desadvantages

- high operating costs
- suspended solids removal not as high as in sedimentation tanks
- high power requirements for pressure type units
- expensive airtight structure for vacuum type units

II.9. BIOLOGICAL STAGE

- Activated sludge

Generally, aeration tanks are 4 to 4.5 m deep
Several patterns of aeration basins are used (Appendix C 10)

- Total mixing : primary effluent and recycled activated sludge after mixing are poured into the aeration tank in several places alongside the longest side. The outlets are disposed at the opposite side. Every aeration device has the same capacity.

The treatment plant can be compared to several small independant units working in parallel. This pattern enables a better withstanding to the shock loadings.

- Step aeration : primary effluent is poured into the tank in some places alongside the longest side of the aeration tank. The circulated secondary sludge is introduced along the short side. Outlet is at the opposite short side.
The oxygen requirements gradually level out to a fairly uniform rate.
This process has the advantage to aerate the sludge before contact with the treated effluent.

- Plug flow : sludge and primary effluent are put together into the tank at the short side of aeration tanks and the outlet is at the opposite side. The oxygen requirements are very high in the first part of the tank and decrease quickly.

The degree of treatment with this pattern is very high.

- Sludge re-aeration

Before mixing with primary effluent, the activated sludge withdrawn from secondary settling tank is aerated in a separate tank. There the organic matters adsorbed on the sludge are degraded.

This kind of pattern allows to reduce the size of the aeration tank for effluents and induces a saving regarding the investment cost.

Every type of aeration device has its advantages and desadvantages. The best type is in relationship with kind of effluent, organic loading variations, BOD removal to achieve, economical conditions, cost of energy, possibility of maintenance, etc...

Regarding the aeration devices for activated sludge aeration tanks the main types are as follows (Appendix C 11) :

- Porous diffusers

Generally, they are disposed on the bottom of tanks, on the side. With an air blower, fine bubbles (diameter < 3 mm) are provided and induce a circulation or agitation of the mixture effluent/activated sludge.

These diffusers clog very easily when there are shut-downs of the blowers. It is necessary to clean them periodically or to change them.
Air blowers are provided with air cleaning equipments.
Efficiency of aeration is about 15-20 %.

- <u>Non porous diffusers</u>

They diffuse air by pipes plunging into aeration basins. Medium size bubbles (diameter = 5-6 mm) are supplied in the tank. Aeration induces also a whirling effect in tanks which maintains activated sludge in suspension and instigates agitation.

The devices do not clog. However, they are less efficient than porous diffusers regarding the oxygenation capacity. The average oxygenation yield ranges from 5 to 10 % according to the diameter of the the bubbles.

- <u>Surface aerators</u>

They are widely utilized in industrial wastewater treatment plants.

Two kinds of aeration are marketed :

- low speed (peripherical speed of the aerator = 4-6 m/s)
- high speed (750-1800 rev/min)

They are put at the upper liquid level of the aeration tanks.

Rotation of aerators induces a throwing of effluent in air and oxygen dissolves itself in it. There is also agitation of the mixture effluent /sludge. Surface aerators or mechanical aerators are supported on beams at the top of aeration tanks or equipped with pontoons and put on the water level.

These aeration devices are advantageous especially in effluents which contain solid materials risking to clog air-diffusers.

The powers range from some Kw to 75 KW according to the suppliers.

Their oxygenation capacities are from 1.5 to 2 kg O_2/KW in specific conditions.

- Combined aerators

In some plants air diffusion and mechanical agitation are combined.

The diffuser is a medium size bubbles device located beneath a mechanical agitation, breaking the bubbles in small bubbles and inducing agitation. This device does not clog.

The air requirements in large scale biological treatment plants depend on :

- type of effluent
- D.O. saturation in effluent
- aeration capacity of aerators
- type of aeration pattern
- performances of treatment
- applied organic loading
- effluent temperature
- activated sludge concentration (MLSS) in aeration tanks

With porous diffusers

- 35-45 m3 air/kg BOD removed are required at applied loading 1 kg BOD/m3/d.

With less efficient aerators, the air requirements range from 60 to 100 m3 air/kg BOD removed.

With surface aerators 1.5 - 1.2 kWh/kg BOD removed, according to the type of effluents and performances, are needed.

Current organic loadings in activated sludge treatments range from 0.5 to 2 kg BOD/m3/d or 0.2 - 0.7 kg BOD/kg MLSS/d for industrial effluents.

- Trickling filter

Trickling filters with plastic media are a very common mean to treat industrial wastewaters. They do not clog and the energy consumption per kg BOD is less than in activated sludge processes.

Filters are between 2 m and 6 m high.

One of the main design criteria is the hydraulic loading at the upper level of the filter bed. This flow has to be high enough to water all the parts of the support. Simultaneously the hydraulic load induces a washing out of the biofilm adhering to the support, thus avoiding the clogging.

In addition, through the filter beds in plastic media ventilation is suitable and an artificial ventilation is not justified.

Hydraulic loadings ranges from 3 to 4 m3/m2 cross section/h. This flow rate is achieved by recycling the effluent filter through the filter itself. A sprinkler or distributor is used for adequate flow distribution on the upper level of the filter bed.

In some cases of trickling filters, using plastic media, a re-circulation of secondary activated sludge from the secondary settling tank is provided.

Thanks to the suitable aeration when effluent flows down through the bed filter, a concentration of D.O. in excess of 1 ppm can be maintained.

Treatment efficiencies of plants are thus increased.

Plastic media trickling filters are working with organic loading from 1 to 6 kg BOD/m3 plastic media/d, sometimes higher.

BOD removals are not very high ranging from 50 to 70 % according to the type of effluent et BOD loadings.

In order to increase BOD removal, some flow diagrams use filtration in two stages with intermediate settling tank.

Plastic bed filters are often classified as roughing filters and they just achieve only a partial treatment. In order to get high BOD removals a second stage of biological treatment has to be considered : activated sludge, aerated lagoon.

Plastic media trickling filters are applied to industrial wastewaters with high BOD concentrations (> 1000 mg/l) especially when kinetics of biodegradability are very fast.

For example :

- food industry, pharmaceutical processes
- dairy wastes, fermentation industries
- meat industries

The power consumption in a one stage filter pattern is less than 1 kWh/kg BOD removed.

The plastic media trickling filters are very sensitive to temperature and are sometimes used as cooling towers ahead biological treatment supplied with hot industrial effluents.

- Aerated lagooning

This type of treatment is very simple, inexpensive regarding the construction cost but requires a lot of space.

Generally, it is used for effluents which contain a BOD concentration less than 1000 mg/l.

Effluents are stored for 3-6 days in basins which are 3 to 4 m deep digged in the ground.

Aeration is supplied by surface aerators (high or low speed) supported by beams or pontoons on the water level.

Applied organic loadings are about 0.05 kg BOD/m^3 aerated lagoon/day or from 1 500 to 1 800 kg BOD/hectare/day according to the basin depth.

The specific power of aerators is about 1.5 - 1.8 kWh/kg BOD applied according to the organic loading.

For a good mixing of any part of the lagoon it is recommanded to provide an aeration power in excess of 3 watts/m3 lagoon capacity.

At the outlet of an aerated lagoon, concentration in suspended materials is not high. It is often unnecessary to provide a secondary settling tank because suspended solids don't settle quickly.

Between surface aerators, there are tranquilization zones where suspended solids settle and then a slow anaerobic decomposition takes place.

Suspended solids in the agitated zones are well oxidized materials as the detention time in a lagoon is very long. Their oxygen uptake rate is low and they can be discharged at the lagoon outlet in the receiving water without drawback.

Sometimes at the outlet part of an aerated lagoon a tranquilization zone is arranged where the heaviest suspended solids settle. This zone has to be dredged periodically with appropriate pumping system according to the sludge accumulation.

A tight plastic film is often put on the bottom of the lagoons to avoid ground water contamination by effluent infiltration.

Beneath aerators a concrete floor is sometimes fitted up in order to restrict erosion of the lagoon bottom or the plastic film.

- Connecting pipes

The velocity of flow in effluent piping is generally from 1.2 to 1.8 m/s, less than 3 m/s at maximum flow to avoid excessive head losses, and greater than 0.6 m/s at minimum flow to avoid deposition of solids in horizontal runs.

Sludge withdrawal piping generally has a minimum diameter of 15-20 cm either for gravity withdrawal or for lines connected to pumping station. The slugde velocity in pipes will be less than 1 m/s. Beyond this velocity the head losses with heavy sludge increase dramatically.

III - SLUDGE DEWATERING

III.1. BACKGROUND CRITERIA

Quantities of primary and secondary sludge to be dewatered can be determined in lab scale treatment plants.

They depend on :

- efficiency of primary settling tank and S.S. concentration at the inlet
- excess sludge withdrawn (0.3 - 0.6 kg dry solids/kg BOD removed) according to the type of biological treatment.

Primary sludge is removed from settling tanks at roughly 3 % solids consistency. It is easily dewatered whithout addition of chemical floculating agents.

Secondary sludge is withdrawn at maximum 1 % solids concentration. It does not dewater easily.

In large scale plants, excess secondary sludge is pumped to the primary settling tank and the mixture of combined primary and secondary sludge is dewatered.

From the primary settling tank, sludge is withdrawn at maximum 3 % solids concentration and pumped towards the dewatering facility.

III.2. THICKENING

Sludge thickening is a mean to reduce the cost of sludge handling and to increase the solids capacity of dewatering device. Ahead the dewatering device is provided a mechanical thickener.

A mechanical thickener is similar to a circular settling tank.

Conventional sludge collecting equipment with vertical pickets and blades is used in thickening. Sludge is withdrawn from a central hopper by pump (Appendix C12).

Sludge residence time in a thickener is several hours, sometimes more than one day in order to increase the sludge concentration to 7-8 %.

Superficial hydraulic loading is 15-30 m3/m2/h and the current solids loading is 40-60 kg/m3/d.

When residence time is long, acid fermentation happens in the bottom of thickener and sludge can go up with gas bubbles and float in supernatant. To hinder the phenomen, lime is added at the inlet of the thickener in order to keep the pH near 7.

Lime addition improves the dewaterability of sludge.

III.3. <u>SLUDGE CONDITIONING</u>

Mixtures of primary and secondary sludge have to be conditioned before feeding of the filtration devices. Chemical conditioning is a process of adding certain inorganic or organic chemicals to coalesce particles in sludge in order to facilitate the extraction of moisture by filtration.

The following chemicals in common use are :

- ferric chloride
- ferric sulfate
- lime and ferric chloride
- aluminium sulfate
- polymers : cationic, anionic, non-ionic

The chemicals are dissolved in tanks and fed in coagulation tanks ahead dewatering facility by pumps.

The dosage of coagulation agents for conditioning is determined by laboratory tests. For example, typical dosages are presented hereafter :

- $FeCl_2$:1-2 % of dry sludge solids
- CaO :6-8 % of dry sludge solids
- CaO :10-20 % of dry sludge solids
- Polymer : 1-3 kg/t dry solids (cationic or anionic)

III.4. VACUUM FILTER

A vacuum filter consists of a cylindrical drum which rotates partly submerged in a pan of sludge (Appendix C13).

A vacuum is applied between the drum deck and the filter media forcing the water to be extracted.

The sludge is retained on the filter cloth and dewaters slowly when the drum rotates.

The filter clothes are now made with plastic. The solid filter rate is 20-30 kg dry solids/m2 filter/hr depending on the type of sludge and the primary/secondary ratio.

Cakes can be obtained at 22-25 % dryness after conditioning.

Vacuum filters do not require maintenance, only a temporary supervision.

But they are expensive in energy as a vacuum pump is used to extract the water from the sludge.

A washing device is generally provided for the filter cloth cleaning.

III.5. PRESSURE BELT FILTERS

Two filter clothes (one upper, the other lower) move slowly horizontally imprisoning the sludge. (Appendix C14).

In the first part of the filter, dewatering takes place only by gravitary drainage through the lower filtercloth.

Then pressure rollers squeeze the sludge and force the water to be extracted.

The velocity of the filter clothes ranges from 0.5 to 5 m/minute depending on the solids capacity.

The pressure rollers are settled in line or in S. In this last case on account of the waving of the filter cloth their wear is very fast if the sludge contains fine abrasive materials not removed in sand removal stage.

The capacity of the pressure belt filters is about 500 kg dry solids h/m width of the filter, depending on the type of sludge.

Cake dryness is 28-30 % according to the kind of sludge and the dosage of conditioning chemicals.

Belt filters require few maintenance and are inexpensive in energy consumption (5-20 kWh/t dry solids).

III.6. DRYING BEDS

Drying beds are the most commonly device used for sludge dewatering.

They are useful in warm climates and can be covered if the rainfall is excessive in some countries.

Drying beds are very appropriate for small quantities of sludge.

A drying bed is designed as follows :

- embakment - 30-35 cm heigh - wooden planks or concrete plates
- sand : 30 cm heigh (diameter 0.3 - 0.75 mm)
- gravel : 7.5 cm heigh - diamter 2-3 cm
- underdrain (ø 10 cm)with backfilling with gravel to avoid disturbing the lines of underdrain

The solids capacity of drying beds is about 90-100 kg dry solids/m2/year (more with covered drying beds). Conditioning with organic (polymer) or inorganic chemicals is recommanded for better and quicker dewatering prior pouring.

Liquid sludge is poured on a depth of 20 cm.

III.7. SLUDGE PUMPING STATION

It is sometimes difficult to increase the dry solids content of sludge withdrawn from a primary settling tank by increasing the sludge average residence time in the tank because one can fear a blocking and stoppage of the sludge collecting device if the sludge concentration is too high.

From primary settling tank to thickener it is wise to operate the sludge pumping continuously without stopping the pumps in order to avoid deposits in the pipes. These deposits are difficult to remove when the pumps are running again.

To regulate the sludge flow, a device with open overflow weirs, easy to clean with water is advantageous. Such a system, consumes energy for continuous pumping but does not clog (Appendix C15).

It is careful to provide into the sludge pipes devices with compressed air and clean water for cleaning, if necessary.

To convey the sludge from the thickener towards the dewatering facility, a good system consists in a loop continuously supplied with sludge by pumping ,connecting the bottom (central hopper) of the thickener and the inlet of the thickener.

As a matter of fact the sludge pump transporting sludge with high consistency (6-8 % dryness) never has to be stopped except a few minutes.

At a bent of the loop, a valve, automatically regulated by the sludge level in the storage tank ahead the dewatering device, is opened more or less in relationship with the sludge level in the storage tank.

The valve has to be positioned as close as possible to the loop pipe in order to shorten the "dead" distance in which sludge could settle and clog the sludge supplying.

The loop and the valve will be equipped with air and water inlets for clearing (Appendix C15).

In a sludge dewatering facility and sludge pumping station, recommandations were given regarding the designing and the running to avoid the clogging of pipes (air and water clearing, continuously working of pumps) and to reduce the maintenance and shut-down times.

It will be advisable in the construction of the dewatering plants to have horizontal runs of pipes as short as possible and to give a slope to the connecting pipes in order to facilitate the cleaning with air and water under pressure.

IV - SLUDGE INCINERATION

IV.1. SLUDGE DISPOSAL

Mixture of primary and secondary sludge, coming from biological treatment plants in which it is sure that there are no toxic chemical products or no heavy metals, or no toxic metals, may contain sometimes, high ratio in secondary sludge.

The organic matter associated with secondary sludge is a good fertilizer after some weeks of aerobic fermentation (composting).

The composting of sludge, combined with biodegradable garbage and solid wastes, is an efficient and economic way to get rid of the sludge coming from biological treatment.

This mean will be considered when the potentiality of land application as fertilizer is possible. Some kinds of I + II sludge, conditioned with lime, may be used also as land application, in acid soils in order to increase the pH.

IV.2. BASES OF DESIGN

For the designing of an incineration facility, some design criteria have to be known namely:

- quantity of dry solids per day and peak values (the data are obtained from lab scale treatment plants)
- characteristics of the sludge at the outlet of the dewatering facility
- cake dryness
- volatile solids concentration
- BTU of the sludge (heat - capacity)
- kind of fuel available
- timetable of the operation of the incinerator (24 h/day or 1 or 2 shifts)

Between the dewatering facility and the incinerator the sludge lines using sludge conveyors have to be as short as possible.

It is easier and less expensive to transport liquid sludge (even at 7 %) than sludge cakes.

It's a prevailing factor in the location of the incinerator.

The sludge conveyors with belts, buckets or blades are the most common ones.

The pneumatic conveyors are more expensive and clog sometimes when the sludge dryness is not steady.

IV.3. MULTIPLE-HEARTH INCINERATOR

A circular multiple-hearth incinerator consists of a circular steel furnace with several hearths fed at the top with a centershaft and arms acting as an agitator to move the sludge downwards from hearth to hearth, and through which combustion air is supplied (Appendix C16).

Sludge burning starts at the top of the furnace ; ashes are collected at the lower hearth.

Some types of sludge may develop odor when they burn. In certain incineration plants exhaust gas are burnt with a post-combustion system supplied with appropriate fuel in order to increase the gas temperature to 800-820° C.

Flying ashes are removed by scrubber.

IV.4. FLUIDIZED BED INCINERATION

A subfloor of a furnace supports a layer of calibrated sand (Appendix C16).

Through the subfloor and the sand is supplied a high air flow raising the sand (fluidization). Air is pre-heated with exhaust gas in a heat exchanger at 400-450°C.

The sludge cakes are introduced by screw conveyors in the fluidized sand and burn within few seconds increasing the temperature in the furnace at 800-850° C. Additional fuel is injected at the same level in the sand. Ashes are removed by scrubber.

With sludge containing high ratio in secondary sludge (volatile solids > 85 %) and having a dryness of more than 29 % a fluidized be incinerator can work without additional fuel.

The prevailing factor is to get a good exchange in the heat-exchanger in order to increase the fluidization air temperature at 400-450° C. Sometimes, with ashes escaping from the furnace when they are sticky, they can adhere to the exchange device and reduce its exchange capacity.

Consequently fuel has to be added for sludge burning.

The exhaust gas kept at this temperature doesn't smell and it is not necessary to add a post combustion device to abate the odors.

For the running of a fluidized bed incinerator for safety considerations, instruments and controls are associated namely :

- weightometer for dewatered sludge from dewatering device
- fluidized air flow recorder
- temperature recorders at the controlling points in the combustion process and in the air heating exchanger
- additional fuel flow meter
- pressure recorders at the controlling points

The main drawback in running fluidized bed is the clogging of the air/gas heat-exchanger. Appropriate devices have to be provided (steam sweeping or cleaning) for clearing of the equipment in order to keep the heat exchange capacity at its nominal level and to restrict the additional fuel consumption.

A boiler using the exhaust gas downwards the heat exchanger can be fitted if necessary.

IV.5. COMMENTS

Sludge incinerators are not of common use and are set up in large treatment plants. They are appropriate for high quantities of sludge (several tons/day) when the additional fuel is not too expensive and when there is no land available for disposal.

For small units, the best way for sludge disposal, when the sludge does not contain toxic materials is to use it as fertilizer in the vicinity of the plants.

In addition incinerators require a skilled labour for running and maintenance.

V - PULP AND PAPER MILL WASTEWATERS

V.1. INTRODUCTION

Pulp making and paper making have to be separated for assesment of the pollution loadings.

Paper making proceeds in two steps.

The first step is to manufacture pulp (unbleached or bleached) with appropriate fibrous materials (wood, straw, bagasse...)

According to the wood species and fibrous materials and the types of pulp making, the pulps have different characteristics in terms of physical properties.

In the second step, different kinds of pulp are mixed and paper is produced.

The physical properties of the produced paper or paper board are determined by the composition of the pulp mixture in which are added filling or chemicals in order to provide to the ultimate paper product some specific characteristics regarding printability, tearing strength, elongation, porosity, etc..

V.2. PULP MAKING

The aim of the pulping process is to liberate the fibers and prepare them in a form suitable for paper making.

In the mechanical pulping the fibers are liberated by mechanical action only, while in chemi-mechanical pulping the bonding between the fibers is softened by a chemical treatment. The fibers liberation is then achieved by mechanical action.

In semi-chemical process a cooking liquor containing a chemical is used to separate the fibers.

In chemical pulping a cooking liquor is also used but the pulp yield (ratio dry weight of raw pulp produced/ dry weight of fibrous material) is less than in semi-chemical process.

The following groups of pulp are identified :

Pulp group	Pulp yield %	Kind of chemical
Mechanical	90-97	None
Chemimechanical	85-95	Buffered sodium sulphite
Semi-chemical	60-85	Sodium neutral sulphite
Chemical	30-60	Kraft : sodium hydroxyde + sodium sulphite Acid : calcium) magnesium) Sulphite sodium) ammonium)

Mechanical pulping

Regarding mechanical pulp, in the stone groundwood process logs are fed to the grinders and are forced hydraulically against the rotating grindstone, specifically designed for the purpose.

The grinding occurs in the presence of a large quantity of water which acts both as a coolant and a carrier to sluice the pulp from the grinder.

Chemical pulping (Appendix C17 - 18)

In the chemical pulping (kraft pulping - acid pulping - dissolving pulp) fibrous material, cut in small pieces (wooden chips) is cooked in a digester with a cooking liquor (white liquor) containing appropriate chemicals according to the kind of pulp.

The cooking time is between 7 and 12 hours at 150-170° C.

At the end of the cooking time in the digester there are two mixed phases :

- solid phase : pulp fibers (raw pulp - unbleached)
- liquid phase : cooking liquor containing the dissolved lignine bounding the fibers and the chemical. This liquid phase is called spent liquor.

The further step in chemical pulping is to separate the pulp (fibers) and the spent liquor in a washing plant.

The separation is more or less complete depending on the efficiency of the washing equipment used.

The spent liquor contains dissolved wood substance and most of the added cooking chemicals.

It is colored and contains organic oxygen consuming matter, sulphides, sulphites and high concentrations of other substances potentially harmful to environment.

Before further treatment the pulp should be washed as thoroughly as possible this requirement is consistent with the need for efficient chemical recovery and for a low emission of environmental pollutants.

Washing

The pulp washing (chemical pulp) is performed in a number of different types of apparatus of both continuous and discontinous types :

- Batch diffusers
- Vacuum filters (the most common devices)
- Pressure filters

In vacuum filters, washing takes place by repeated dilution dewatering and displacement on series connected drum filters-usually four in number.

Clean hot water is used for washing and added in the last filter of the series, the filtrate from which serves as the wash for the previous filter. The flow is thus counter-current to pulp from one filter to another.

After washing the two phases are separated :

- pulp at consistency between 10 and 15 % removed from the last filter (unbleached pulp)

- spent liquor containing dissolved organic materials (lignin) and the chemicals

Liquor evaporation

The spent liquor recovered in the washing plant is sent to evaporation plant in order to evaporate most of the water.

This is accomplished in several stages the usual system being based on the use of five apparatuses units operating at reduced pressure with live steam as heating agent.

The dry solids content of the spent liquor through the evaporation plant increases from roughly 15-20 % to 60-65 %. This thick liquor is pumped to the recovery unit for burning. The condensates coming from the evaporators are in part used in washing plant.

Liquor burning

In chemical pulping, the evaporated liquor (spent liquor) is burnt in a recovery boiler, the chemicals then being recovered and the heat from the organic solid is used for producing steam.

The recovered chemicals are utilized for preparing a new cooking liquor mixed with fibrous material (chips) and sent to the digester.

Except spent liquor losses, spent liquor leakages, accidental spillages, the pollution load coming from the unbleached pulp manufacturing is not high since the organic material resulting from the cooking and dissolved in the liquor is burnt.

The water pollution discharges from chemical pulp are as follow:

	Water consumption	B.O.D. kg/t	S.S. kg/t	
Unbleached Kraft pulp	50 -250	28 - 40	20 -35	Old mill
	40 -60	6,5 - 16	10 -20	Modern mill
Acid pulp (Mg, Na)	150 -200	35 - 105	30 -40	

The main sources of pollution are caused by wastewaters from debarking, foul condensates from cooling and evaporation.

Semi-chemical (Appendix C19)

In the semi-chemical cooking and chemi-mechanical cooking, the yield of the pulp is higher than in chemical pulping and thereby the quantity of organic matter dissolved in the spent liquor is less high.

For economical reasons, it is not advantageous after washing and separation of the two phases raw pulp/liquor to concentrate the spent liquor by evaporation and to burn it in a boiler, with minerals recovery.

The organic solids content of the spent liquor ranges from 10 to 50 gr/l (dry-solids). These figures depend on the process conditions (type of process, temperature, pulp, concentration chemicals added).

When they are compared with dry solids concentrations in chemical pulping spent liquors, it can be noticed that there is more water to evaporate and it is understandable that this operation is not profit earning.

The discharge loadings from semi-chemical and chemi-mechanical pulping range from 10 to 30 kg BOD/t pulp and the BOD concentrations of the spent liquors are in excess of 1 g/l.

Generally, semi-chemical and chemi mechanical pulping units are small, producing some about tens of pulp tons per day.

When these units are associated to chemical pulp mills, spent liquors are sometimes evaporated together with the spent liquor extracted from the washing plant of the chemical pulping.

When semi-chemical ou chemi-mechanical units are lonely, spent liquors are discharged in the receiving water.

The investment cost and the running cost of an evaporation plant are too expensive to justify evaporators setting up.

V.3. SCREENING

The step ahead pulp bleaching is the screening in order to remove impurities, e.g. knots and fiber bundles.

V.4. BLEACHING

The bleaching is defined as a process that is intended to raise the brightness of the pulp. Dark and coloured substances are removed from the pulp or their colour is reduced in intensity. Among these substances there are lignin and its degradation products, resins and flecks of various kinds.

The main purpose of bleaching is to render the paper made from the pulp more suitable for printing and to increase the readability, but also to improve the visual impression of tissue paper for example.

Another object of bleaching is to remove lignin and hemicellulose from the pulp so as to obtain pure cellulose (dissolving pulp, in acid process, for the manufacture of rayon for example).

In chemical pulping, bleaching is performed in a number of stages with chlorine, hypochlorite and chlorine dioxide, the object of which is to decompose the lignin in the pulp.

Between these stages the pulp is treated with alkali to dissolve the lignin degradation products.

The two first stages of a bleaching sequence (chlorine and caustic extract) are the most polluted and coloured ones.

The effluents extracted from these stages cannot be pumped to the evaporation plant because they are too diluted and they contain chlorine which is a corrosive chemical for the recovery boiler.

Both effluents (chlorine and caustic extract) are discharged in the sewers.

They are the principal sources of BOD, colour and sometimes toxicity in chemical pulping.

The organic loading from a bleaching plant is between 15 and 20 kg BOD/t pulp.

Regarding the color, the specific loading can reach 200-300 kg Pt (color units)/ton of pulp.

For semi-chemical and chemi-mechanical pulp bleaching agents are peroxides or hydrosulphites.

The approximate loadings are as follow :

Bleaching process	BOD kg/t	Colour kg/t
Hydrosulphite	16	
Peroxide	25	40

The whole material dissolved in peroxide or hydrosulphite is not discharged with the effluent. A part of the dissolved material follows the pulp to drying or to the paper mill.

V.5. PAPER MAKING

In the paper mill the pulp is converted to paper. An integrated paper mill is situated near a pulp mill and receives the pulp as a slurry directly from the pulp mill. The non-integrated paper mill normally obtains the pulp in dried and baled form and then the first operation is to desintegrate the pulp in water (Appendix C 20).

The first stage of the paper making operation is the stock preparation. The fiber types to be included in the stock are beaten and mixed chemicals and fillers are also added.

The stock is pumped to the paper machine system where it is screened and then brought to the paper machine itself.

The sheet is dewatered on a fine mesh wire, pressed in several roll presses and dried in a steam heated dryer section. After drying the sheet may be surface treated in a calender or coated before it is wound up on shafts to large reels.

The paper is then finished according to the customer's requirements including rewinding, cutting to sheets and off machine coating.

A great variety of paper qualities can be fabricated each requiring its own special manufacturing procedure.

The water pollution from paper making is mainly caused by suspended solids (fibers, fillers) and dissolved substances (dissolved wood components, additives, etc...).

Water consumption and material losses depend to a great extent on the paper grade produced, age and size of the mill and the degree of white water system closure.

The following table shows typical water consumption and pollution loads in modern paper and board mills :

	Water consumption m3/t	Suspended solids kg/t	BOD kg/t
Newsprint	20 - 30	8 - 20	2 - 4
Magazine paper	20 - 30	10 - 20	2 - 4
Wood free printing paper	10 - 20	12 - 25	3 - 6
Kraft paper	10 - 20	8 - 15	1 - 3
Folding boxboard	20 - 30	2 - 8	2 - 5
Food board	20 - 40	2 - 8	2 - 5
Corrugated medium	10 - 20	10 - 25	1 - 3

During the papermaking process the effluent is discharged from :

- save-all (excess white water)
- press section
- cleaning system (rejects)
- vacuum pumps
- cooling and sealing

The amount of dissolved substances discharged is influenced by the purity of pulp used, various additive required in paper making, coating agents, etc...

V.6. EXTERNAL EFFLUENT TREATMENT METHODS

The combination of internal and external pollution control measures usually gives the most economical alternative for reducing discharges from pulp and paper mills.

Typical examples are modern paper mills, which are designed for a fresh water consumption of 10 - 30 m3/t or even less. The reduced flows can then be treated in primary and secondary stages to abate pollution discharges.

The treatment plant usually consists of the following stages :

- pre-treatment
- primary treatment (removal of suspended solids)
- secondary treatment (removal of dissolved material by different biological treatment methods)
- sludge treatment

Some effluent streams can be discharged directly to the river without treatment. In some mills bleach plant effluent is treated separately and the purified effluent is pumped to the secondary treatment plant.

Primary treatment.

Sedimentation is the most common method for removing suspended solids from pulp and paper mill effluents. It is normally carried out in circular or rectangular clarifiers. Large earthen basins are still used in many old mills.

Primary treatment without the addition of chemicals removes about 50-90 % of suspended solids, which corresponds to a removal of between 80 - 95 % of settleable solids, the treated effluent having a concentration of suspended solids between 20 and 200 mg/l.

If chemicals are added, a higher removal efficiency of suspended solids is achieved. Effluent BOD is also lowered by 30 - 50 %. The greatest disadvantages of this method are the cost of chemicals and high sludge production ; therefore, chemically assisted clarification is seldom used for concentrated wastewaters. In paper mills, on the other hand, small amounts of chemicals (e.g., aluminium sulphate, polyelectrolytes) are often used in order to get more efficient treatment results.

Secondary treatments.

Their aim is to reduce the organic pollution load (BOD)

Efficient toxicity removal is usually achieved in the same process.

The following biological treatment processes are normaly used :

- stabilization ponds
- aerated lagoons (or aerated stabilization ponds)
- activated sludge process
- trickling filter

In stabilization ponds the hydraulic retention times are of ten days or more in some instance even of weeks. Aeration takes place by natural means from air.

Aerated stabilization ponds or aerated lagoons are units with hydraulic retention times between 5 and 10 days. Aeration is accomplished with mechanical aerators floating on the surface or by diffusers or mixers located on the bottom of the lagoon. Air is supplied by compressors through a piping system.

With activated process the main design parameters used are :

- biosludge concentration (MLSS) : 1.5 - 3 g/l in aeration tanks
- hydraulic retention time : 2 - 10 hours
- sludge loading : 0.2 - 0.5 kg BOD/kg MLSS/d (F/M ratio)
- volumetric loading : 0.7 - 3 kg BOD/m3/d

BOD removals can achieve 80 - 95 % according to the running parameters and the kind of effluent.

Volumetric loadings in trickling filters using plastic media range from 1 to 5 kg BOD/m3/d. But the BOD removal efficiency of a trickling filter is usually less than 80 % and therefore, an additional biological treatment unit (e.g., activated sludge or aerated lagoon plant) is required for higher BOD removal efficiencies.

Anaerobic treatments originally used for the treatment of municipal waste water sludges and concentrated industrial effluents for example, in the food industry, are now used for some kinds of effluents containing high BOD concentrations as :

- caustic extract effluents
- spent liquor from semi-chemical or chemi-mechanical pulping
- evaporation condensates, etc..

These treatments are often partial treatments integrated in the mill in order to reduce the BOD loading applied to a biological treatment plant supplied with the general effluent. Some full-scale plants are already in operation.

A comparison of different technical and economical parameters of the following treatments used in pulp and paper industry :

- stabilization pond
- aerated lagoon
- trickling filter
- activated sludge
- chemical floculation

is given in Appendix C 21.

V.7. COLOUR REMOVAL

Effluents from pulp industry (and sometimes from paper industry for coloured paper) are very coloured. This colour originates from the lignin dissolved durin the cooking in the digesters and from the lignin dissolved in bleach plant (major source of discharged colour).

Biological treatments are very efficient regarding BOD removal but less effective regarding COD and colour removals.

For example, an activated sludge treatment plant achieving 90-95 % BOD removal of kraft pulp mill effluents, reduces only the COD by 50-60 % and the colour by 45-50 % in these effluents.

The colour content (and COD) in secondary effluent is owed to the residual lignin content for lignin is not easily biodegradable by biological treatments.

There are different methods used to reduce the colour loading from a pulp mill.

Oxygen bleaching

This stage of bleaching takes place between the pulp cooking and conventional bleaching sequences and can be considered as a delignification prolongation.

Oxygen bleaching is carried out at 110 to 120° C in a reactor for 30 to 45 minutes. Pulp at 25 % consistency is introduced at the top of the reactor, falls down through the reactor and is withdrawn at the bottom. Pulp is then washed before introduction to chlorine bleaching. Wash water chlorinefree may be used for stock washing and then eventually burnt, after evaporation, in recovery boiler.

Color loading abatement of the bleaching plant is roughly 50 %.

Precipitation with lime

This process is identified as a chemical rather than a physical process.

There are two methods using lime

massive lime method
minimum lime method

The massive lime treatment uses the total circulating quantity of the kraft mill for the precipitation of strongly coloured effluent particularly that one from the first extraction stage in bleaching plant. The sludge therefore contains a considerable amount of free $Ca(OH)_2$ which makes sludge easier to dewater.

The dewatered sludge is used for causticizing, and then precipitated organic material is redissolved and transferred to the cooking liquor (white liquor).

A reduction of coloured matter of 90-97 % is achieved when treating caustic extract effluent from bleaching.

The minimum lime method involves a precipitation of coloured material with lime added as milk of lime.

The lime sludge is removed by sedimentation and is further dewatered after being mixed with dewatered lime mud which is transferred to the lime kilm for recovery of lime . Colour removal ranges from 80 to 95 %.

Ultrafiltration and reverse osmosis

The purpose is to concentrate the coloured polluting components before destruction (e.g. burning in recovery boiler) takes place.

The effluent to be concentrated enters a membrane module through the feed pump which also controls the pressure in the module. As the effluent passes by a semi-permeable membrane, water, ions and small molecules may penetrate the membrane and form the permeate stream. The remaining effluent leaves the module as the concentrated stream.

A R.O. process uses very tight membrane to allow almost nothing but water to penetrate. The R.O. process operates at pressures of 3-8 MPa. Commercially available membranes are made of cellulose acetate which make them sensitives for extreme pH values and temperatures.

Ultrafilitration uses less tight membranes. The UF processes operate at a pressure of up to 1.5 MPa. The UF membranes are usually made of some polymeric material, e.g., polysulfones and some of them can stand temperatures up to 80 % and pH 0-14 according to the supplier.

For high coloured bleaching effluents, colour removal can achieve 60-70 %.

<u>Ion exchange technique</u>

This process is a combination of ion exchange and adsorption and can be characterized as a cyclic adsorption process in which alkali and acid are consumed.

The method was developed for the treatment of the first caustic extraction stage effluent but has since been developed further for treatment of both the chlorination and extraction stage effluent.

The adsorbent is a weak anionic resin of the phenol formaldehyde type. The adsorption is optimal at pH 3-4. When the resin is saturated it is eluated with alkali and the organic materials are desorbed and transferred to the eluate which is burnt in the recovery boiler.

The reductions in terms of colour are 90 % for caustic extract effluent and 65 % for chlorination effluent.

V.8. REFERENCES

Environmental problems in pulp and paper industries regarding especially air and water pollution are very intricate and complicated.

They are depending on many factors as :

- types of tree species used (hardwoods, softwoods)
- types of cooking (kraft, acid, dissolving, semi-chemical, etc...
- types of bleaching sequences
- types of final product (market pulp, paper, board)
- decay of the mills
- size of the mills

It is not possible in a short report to claim tc give all information regarding the multiple aspects of the pollution problems and the associated treatments.

There are numerous publications regarding these subjects (periodicals, books, booklets, monographs, etc..)

In order to get a comprehensive view on the pollution problems in pulp and paper industry, PCRI people could obtain the publications listed in Appendix B (Selected publications dealing with water pollution control. Books and Monographs).

VI - GUIDE LINES FOR SELECTING A BIOLOGICAL TREATMENT PLANT

VI.1. INTRODUCTION

Every biological treatment

- aerated lagoon
- activated sludge
- anaerobic digestion
- etc.

is available for pollution loading abatement of biodegradable industrial effluents.

However according to :

- Degree of treatment
- Kind of effluents
- BOD concentration (and COD)
- Space available
- Energy cost
- Investment cost
- Discharge regulation
- Effluent temperature etc... etc...

biological treatments are more or less appropriate to a determined effluent if an optimization of the treatment is sought.

Some information regarding the best types of treatments to implement in order to achieve a certain BOD removal is given further (Appendix C 22).

The basic criteria used for selecting a link of process is the BOD concentration in the effluent.

VI.2. **BOD > 5 000 mg/l**

The best way is to implement an anaerobic treatment (in 2 on 3 stages if necessary) with biogas recovery and utilization for effluent heating or in a boiler in the factory.

This step enables to reduce the BOD concentraiton to 1000 - 2000 mg/l.

The second step is to apply a trickling filter system, cheaper in energy running cost to abate 50 - 70 % of the BOD concentration.

The last step is :

- aerated lagoon if some space is available
- activated sludge - more expensive in investment and running costs.

VI.3. **1 000 mg/l < BOD < 5 000 mg/l**

Two ways have to be considered

- trickling filter applied as first step if the effluents are quickly biodegradable and then aerated lagoon or activated sludge.

- anaerobic treatment in one stage followed by trickling filter process and eventually activated sludge.

The choice depends on the eventuality to recover biogas or methane.

VI.4. **500 mg/l < BOD < 1 000**

A trickling filter as first step of treatment is an economic way to reduce the BOD without excessive running cost.

The treatment has to be up-graded wih aerated lagoon or activated sludge.

Another way is to use activated sludge treatment lonely in one or two stages if the inlet effluent BOD concentration is too high.

VI.5.**BOD < 500 mg/l**

Trickling filter with plastic media does not allow to meet in one step the BOD standard regulations (30 mg/l).

It is wise to implement an efficient treatment capable to abate more than 80 % of the BOD.

Therefore, aerated lagoon or activated sludge processes are the best suitable treatments.

VI.6. **REMARKS**

The suggested patterns are only given for information.

Theref-)*/ are no general rules regarding the types of treatment to implement.

In the :ntroduction it was said that the selection of a treatment pattern depends on many factors.

Effluent BOD concentration is one of the parameters which can be taken in account for guide lines in designing a treatment plant.

Of course, all the above mentionned parameters have to be considered in the ultimate decision to select the best treatment and the less expensive in investment and running costs.

APPENDIX A

EQUIPMENTS FOR TREATABILITY STUDIES

- Flow mesurement devices (Weirs)
- Water level recorder
- Samplers (24 bottles of 2 liters) refrigerated if possible
- pH meters with recorders
- Temperature recorders
- Quick COD, BOD determination equipments
- Vacuum device for S.S. or sludge concentration determinations
- Metering pumps (10 - 20 l/h)
- Pumps (10 - 20 l/h or more working with timer) for secondary sludge recirculation
- Pump 100 - 300 l/h for effluent recirculation for trickling filter
- Valves for air diffusion
- Valves for sludge withdrawal
- Air compressor
- Mechanical agitators
- Water bath for anaerobic tests
- Plastic tube ø 30 mm for effluent and sludge connections
- Plastic tube ø 10 mm for air connections
- Plastic tube ø 95-160 mm for settling tank building
- Plastic vessel (50 - 100 l) for aeration tanks or anaerobic reactors
- Plastic vessel (100 - 200 l) for aeration tank or aerated lagoon
- Plastic media for trickling filter
- Pump (2 m3/h) for anaerobic pilot plants
- Pump (500 l/h) for anaerobic test devices
- Gas flow meters
- Gas Chromatograph Apparatus

These equipments constitute the basic equipments to undertake biodegradability studies and to carry out lab scale pilot plants experimentations in order to get the design criteria for preliminary design of a large scale treatment plant.

PCRI has to get the missing equipment required for the experiments it intends to perform.

APPENDIX B

SELECTED PUBLICATIONS DEALING WITH WATER POLLUTION CONTROL

I - PERIODICAL ISSUES

- American Water Works Association Journal
  6666 W. Quincy Avenue Denver, Co 80 235 (U.S.A.)

- Aqualine Abstracts W.R.C. Information
  Pergamon Journal Ltd., Headington Hill Hall, Oxford OX 3 OBW (U.K.)

- Biotechnology
  65 Bleeker Street - New York (U.S.A.)

- Biotechnology and Bioengineering
  John Wiley and Sons, Inc., 605 Third Avenue, New-York, NY 10 158 (U.S.A.)

- Bulletin of Environmental Contamination and Toxicology
  Springer Verlag, Heidelberg Platz 3, D 1000, Berlin 33 (Germany)

- Current contents
  Agriculture, Biology and Environmental Sciences
  Universal Subscription Agency Pvt, Ldt,
  18-19 Community Center Post Bag n° 8
  Malviya Nagar Extn. (Saket)
  New Delhi 110 017 (India)

- Effluent and Water Treatment Journal
  Thunderbid Enterprises Ltd Omega Lodge
  Troutstream Way, Rickmansworth, Herts, WD 3 4 JN, (U.K.)

- Industry and Environment
  Published by the United Nations Environment Programme UNEP,
  17, rue Marguerite 74017 - PARIS (France)

- Environmental Pollution A and B
  Ecoloby - Biology
  Monks Wood Experimental Station, Abbots Ripton, Huntingdon,
  PE 17 - 2 LS (U.K.)

- Environmental Science and Technology (E.S.T.)
  American chemical society, 1155 - 16 th Street, N.W.
  Wsahington D.C. 20 036 (U.S.A.)

- EPA Publications Bibliography Quaterly Abstracts Bulletin NTIS-US
  Department of Commerce - National Technical Information Service - Springfield, Virginia 22 161 (U.S.A.)

- Filtration and Separation
  Uplands Press Ltd, 38 Mount Pleasant, London, WC1 X 0AP (U.K.)

- Journal of Applied Bacteriology
  Society for Applied Bacteriology Balckwell Scientific
  Publications, Osney Mead, Oxford, OX 2 - 0EL (U.K.)

- National Technical Information Service (NTIS)
  Environmental Pollution Contol. Abstracts Newsletter
  5285 Port Royal Road, Springfield, VA 22 161 (U.S.A.)

- Pollution Abstracts and Index
  Cambridge Scientific Abstracts, 5161 River Road,
  Bethesda, Md, 20 816 (U.S.A.)

- Science of Total Environment
  Elsevier Science Publishes B.V., Journal Department,
  P.O. Box 211, 1000 AE, Amsterdam (The Netherlands)

- Water, Air and Soil Pollution
  190 Old Derby Street, Hingham, MA 02043 (U.S.A)

- Journal of Water Pollution Control Federation
601 Wythe Street, Alexandria, VA 22 314-1994 (U.S.A.)

- Water Pollution Control
Lesdon House, 53 London Road, Maidstone, Kent,
ME 168 JH, Maidstone (0622) 62034 (U.K.)

- Water Research
Journals Production Unit, Pergamon Journal Ltd,
Hennock Road, Marsh Barton, Exeter, Devon, EX 28 NE (U.K.)

- Water and Waste Treatment Journal
DR Publications Ltd, Faversham House, 111 St Jame's
Road, Croydon, CR 92 TH (U.K.)

- Water Engineering and Management
Scranton Gilette Communications Inc, 380 Northwest
Highway, Des Plaines, IL, 60016 (U.S.A.)

II - BOOKS AND MONOGRAPHS

- Anaerobic Treatment of Wastewater in Fixed Film Reactors IAWPR Specialised Seminar, June 16-18 1982 - Department of Sanitary Engineering Technical University of Denmark, in collaboration with the Danish IAWPR - Committee - Copenhagen Denmark

- Anaerobic Digestion Second International Symposium. Travemünde Germany - 6 -11 Sept. 1981 D.A. STAFFORD, B.J. WHEATLEY, D.E. HUGHES, Elsevier Biomedical Press.

- Anaerobic Digestion 1985 - Fourth International Symposium - 11 -15 Nov. 1985 - GUANGZHOU CHINA

- Anaerobic Treatment - A Grown-up Technology - Aquatech 86 - 15 - 19 September 1986 - Amsterdam. industrial Presentation-'s Gravelandseweg 284 - 296 - 3125 BK - Schiedam - The Netherlands.

- Advances in Water Pollution Research. Proceedings of the 4 th International Conference - Prague 1969 - Edit. S.H. JENKINS, Pergamon Press

- Anaerobic Treatment of Forest Industry Wastewaters - Proceedings of the First IAWPRC Symposium on Forest Industry Wastewaters - Tampere, Finland, 11 - 15 Junes 1984 Edit. P. RANTALA and A. LUONSI Pergamon Press.

- Anaerobic Treatment of Sewage - Proceeding of the Seminar/Workshop. 27-28 Junes 1985. University of Massachusetts at Amherst - Edit. M.S. SWITZENBAUM U.S. National Science Foundation.

- Biological Monitoring of Heavy Metal Pollution : Land and Air. M.H. MARTIN, P.J. COUGHTREY Edit. Applied Science Publishers London.

- Dynamic Exposure and Hazard Assessment of Toxic Chemicals in the Environment B. HAQUE U.S. E.P.A. Washington D.C., U.S.A.

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- Membrane Separation Processes - 1978 - Report n° 5 -78, by JAMES, CRITSER, EXINGTON, Data Box 371 Ashland. M.A., 01721 (U.S.A.)

- Membrane and Ultrafiltration Technology. Recent Advances - 1981. Chemical Technology Review n° 226 - Noyes Data.

- Organic Compounds in Aquatic Environment, S.D. FAUST and J.V. HUMTER - Marcel Dekker Inc. (1971) New York.

- Pollution Control and Chemical Recovery in the Pulp and Paper Industry - H.R. JONES. Pollution Technology Review n° 3 Noyes Data Corporation (1973)

- Advances in Environmental Sciences and Technology. Ed. J.N. PITTS and R.L. METCALF Wiley Interscience

- Aquatic Toxicology and Hazard Assessment Edit. CARDWELL, PURDLY, BAHNER - ASTIM Publication. Code Number 04-85-4000 - 16 - 1916 Race Street, Philadelphia, Pa, 19103 - U.S.A.

- Measurement of Dissolved Oxygen - M.L. HITCHMAN - John Wiley and Sons

- Modeling the Fate of Chemicals in the Aquatic Environment. Edit. K.L. DICKSON, A.W. MAKI, J. CAIRNS - Ann. Arbor Science The Butterworth Group.

- Pesticide Manual - British CRAP - Protection Council Edit. C.R. WORTHING. Glasshouse Crops Research Institue 6 th Edition 1979.

- Water Recycling and Pollution Control Handbook. A.V. BRIDGEWATER and C.J. MUMFORD Edit. C.G. GODWIN Limited (U.K.)

- Water Use and Effluent Treatment Practice for the Manufacture of the 26 Priority Drugs in the UNIDO Clustrative List. UNIDO.

- Water and Wastewaters Engineering Systems. D. BARNES, P.J. BLISS, B.W. GOULD, H.R. VALLENTINE, PITTMAN Books Limited London.

- Water Pollution Control with Toxicity Avoidance Test 1983. HADUINICOLAOU, IVANNIS - Ph. D. MEGILL University (Canada)

- Phosphate Removal in Biological Treatment Processes - Edit. H.N.S. WIECHERS Pergamon Press

- Handbook of Water Resources and Pollution Control. Edit.. by H.W. GEHM and J.I. BREGMAN. Van Nostrand Reinhold Company.

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- Conference on Nitrogen as a Water Pollutant 18-20 August 1975 - IAWPR Specialized Conference - Copenhagen Denmark.

- Proceedings of the International Conference - Management Strategies for Phosphorus in the Environment. Lisbon 1-4 July 1985 - Edit. J.N. LESTER and P.W.W. KIRK Selper Ltd London.

- Nutrient Control Manual of Practice FD 7 - Facilities Design. Water Pollution Control Federation 1983 - 2626 Pennsylvania Avenue N.W. Washington D.C. 20037 (U.S.A.)

- Directory of Pollution Control Equipment Companies - Edit. R. WHITESIDE and H.C.H. WHITESIDE, M.A. GRAHAM, Trotman Dudley Publishers Limited 1974.

- Resource Recovery and Recycling Handbook of Industrial Wastes. M. SITTING, Environmental Technology Handbook n° 3 Noyes Data Corporation.

- Selected Techniques for Environmental Management. Training Manuel World Health Organization Geneva 1983.

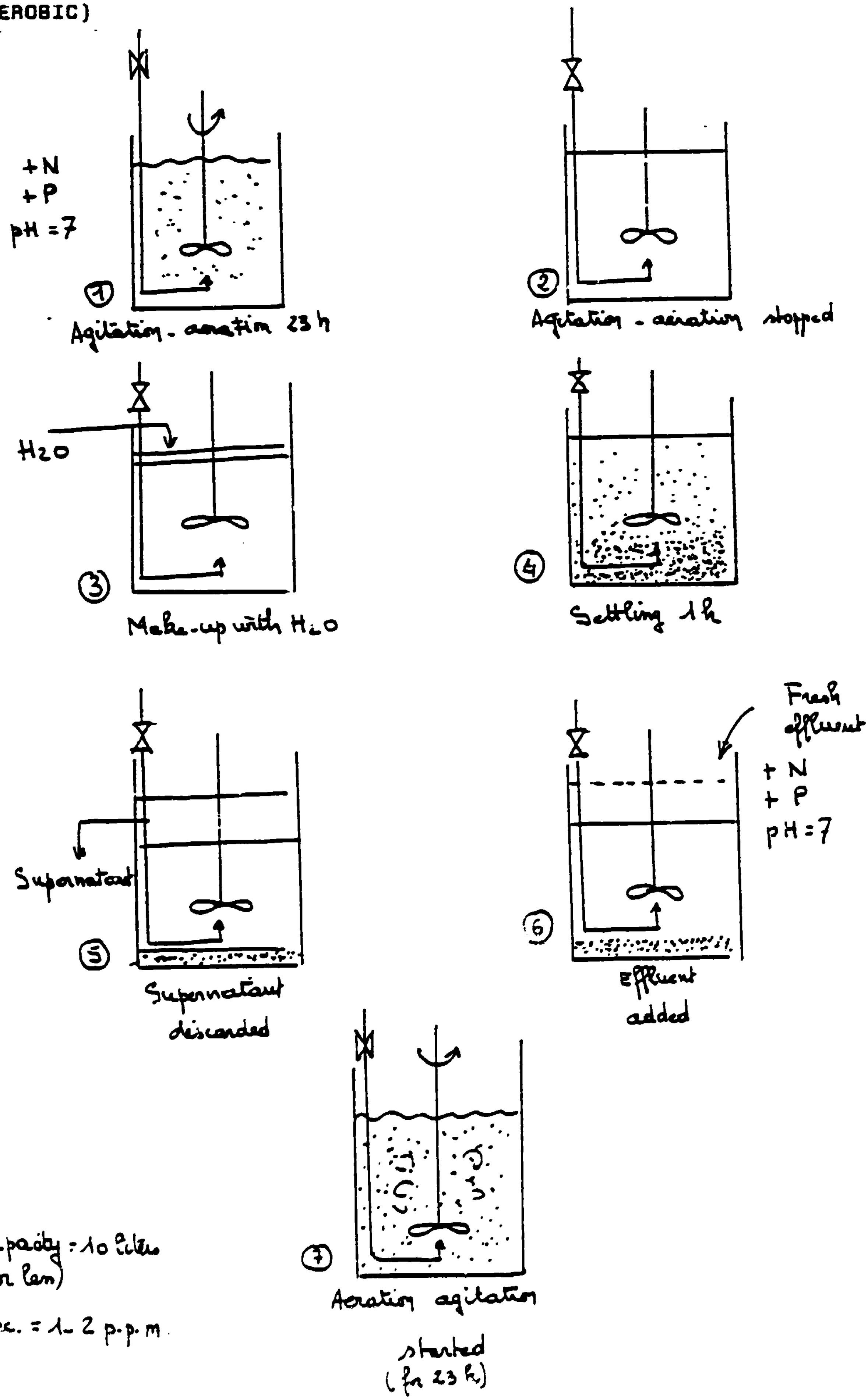
- Sewage Treatment Plant Design American Society of Civil Engineers and Wate-Pollution Control Federation 601 Wythe Street, Alexandrie, V.A. 22 314 1994 U.S.A.

- Environmental management in the pulp and paper industry (Vol. 1 and 2) UNEP - Industry and Environment Manual Series - United Nations Environment Programme (1981) Reference ISBN 92-807-1037-0

- Pollution Abatement and Control Technology (PACT) Publication for the Pulp and Paper Industry - Industry Environment Office in Collaboration with Infoterra/PAC United Nation Environment Programme.

APPENDIX C - 1

SLUDGE ADAPTATION
(AEROBIC)

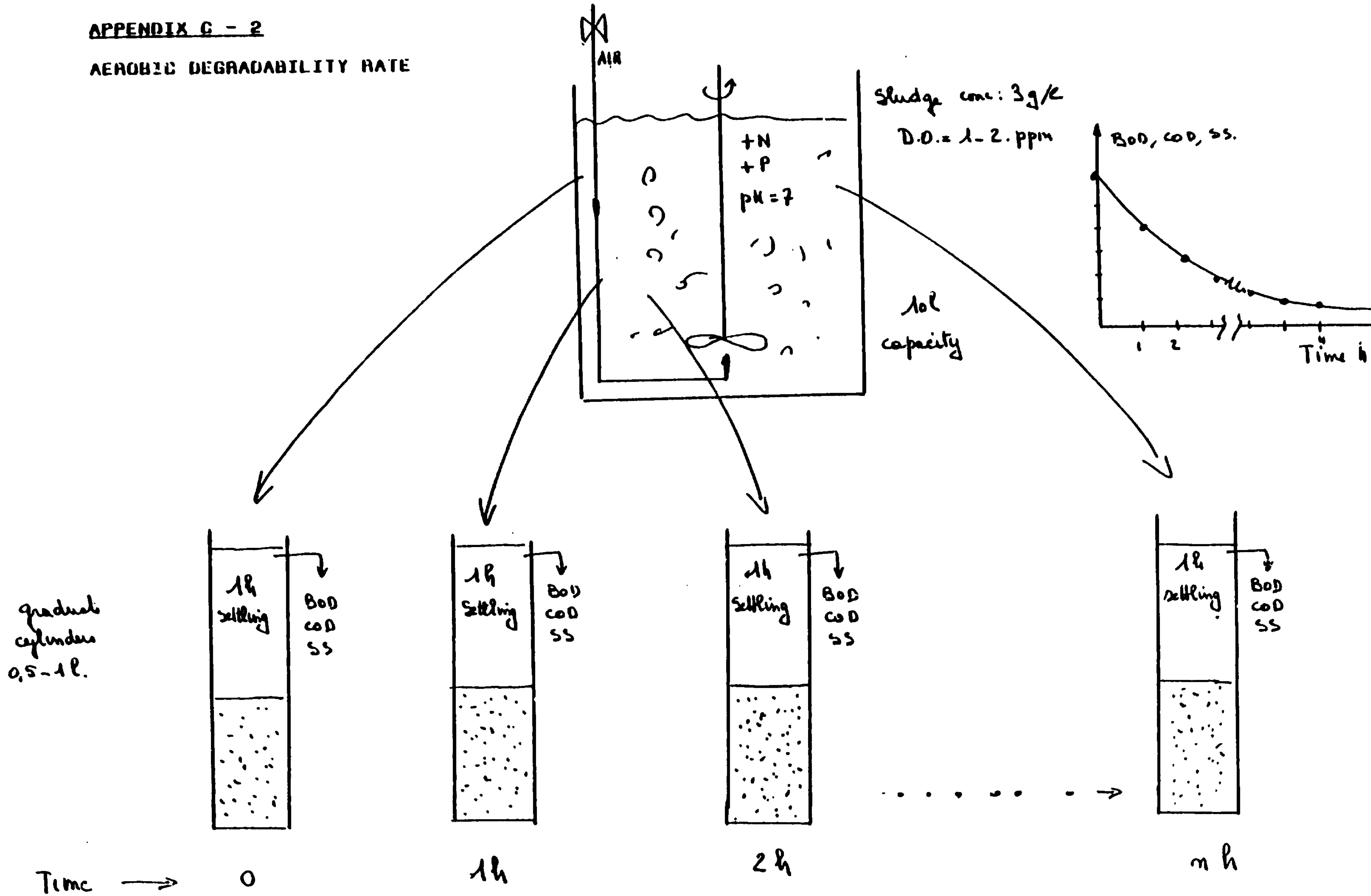


Vessel capacity = 10 liters
(or less)

D.O. conc. = 1 - 2 p.p.m.

APPENDIX C - 2

AEROBIC DEGRADABILITY RATE

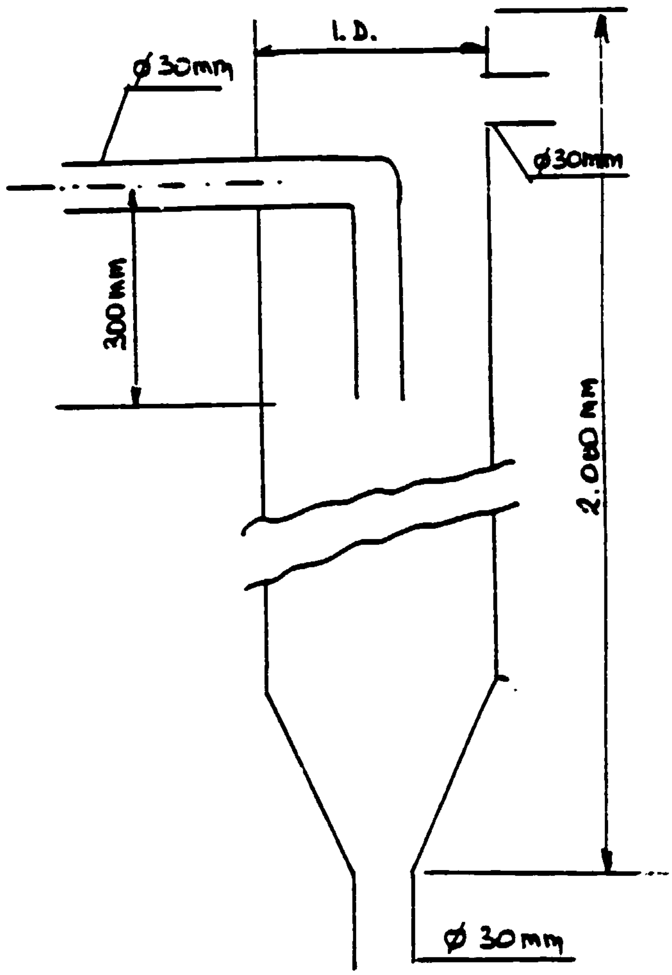


APPENDIX C - 3

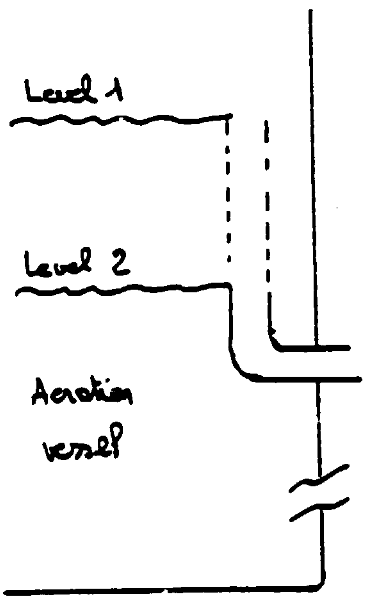
LAB SCALE PILOT PLANT (ACTIVATED SLUDGE)

Settling tank diameter

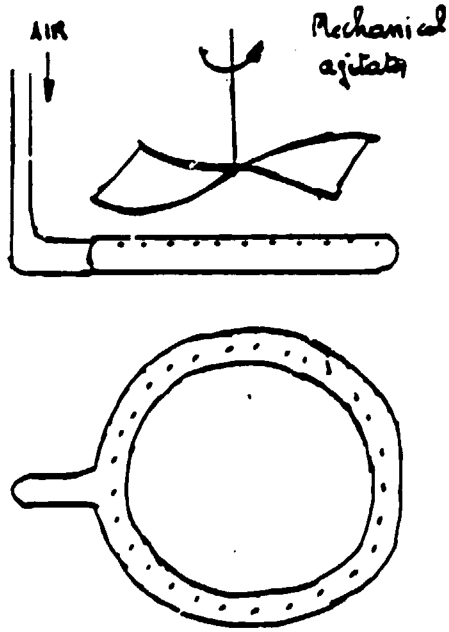
Flow l/h	Ist mm	IInd mm
10	95	110
15	120	140
20	140	160
overflow rate $m^3/m^2/h$	1.4	1



Settling tank



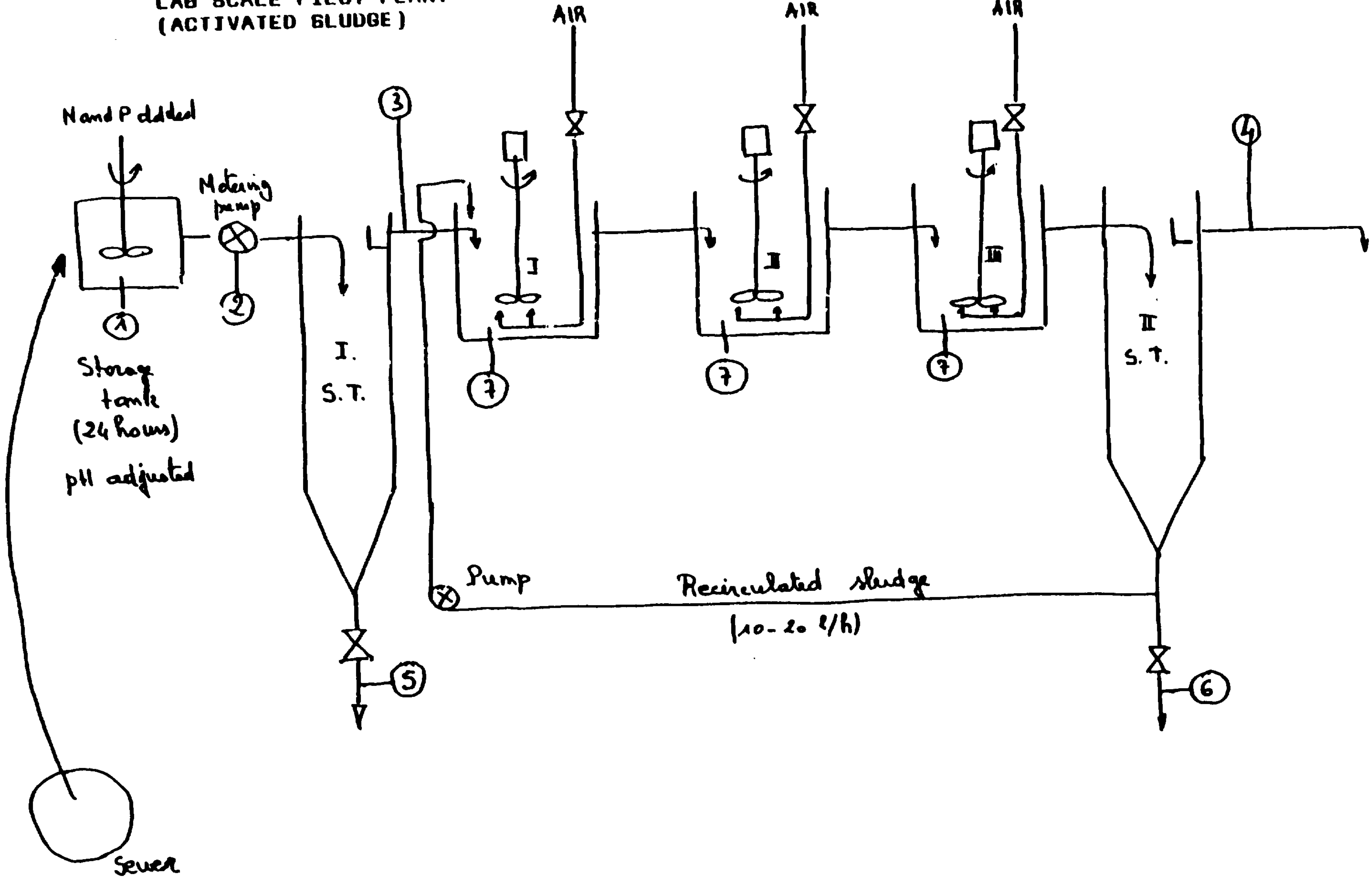
Adjustable capacity



Aeration device

APPENDIX C - 4

LAB SCALE PILOT PLANT
(ACTIVATED SLUDGE)



LAB SCALE PILOT PLANTS

Check list of monitoring

1) Storage tank
   - BOD
   - COD
   - S.S.
   - Add N (NH_4OH) + P (PO_4H_3) [BOD/N/P = 100/5/1]
   - pH adjustment (7)

2) Metering pump
   - Flow (10 - 20 l/h)

3) Primary effluent
   - BOD
   - COD
   - S.S.

4) Secondary effluent
   - BOD
   - COD
   - S.S.

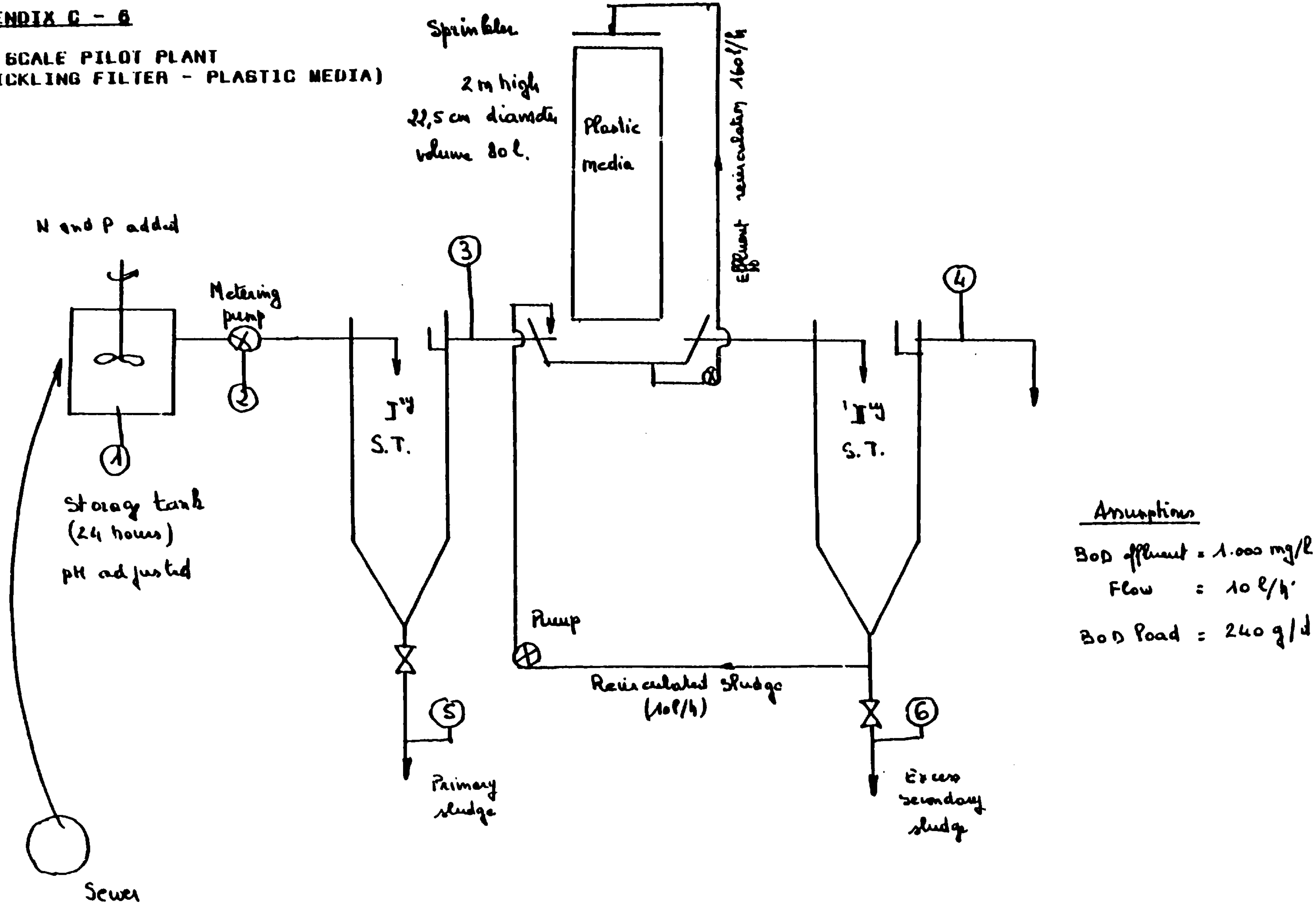
5) Primary sludge
   - Extracted volume
   - Concentration (dry solids)

6) Secondary sludge (excess)
   - Extracted volume
   - Concentration (dry solids)
   - Sludge volume index (30' and 60' sedimentation)

7) Aeration tank
   - Dissolved oxygen (1 - 2 p.p.m)
   - Sludge concentration (2-4 g/l dry solids)

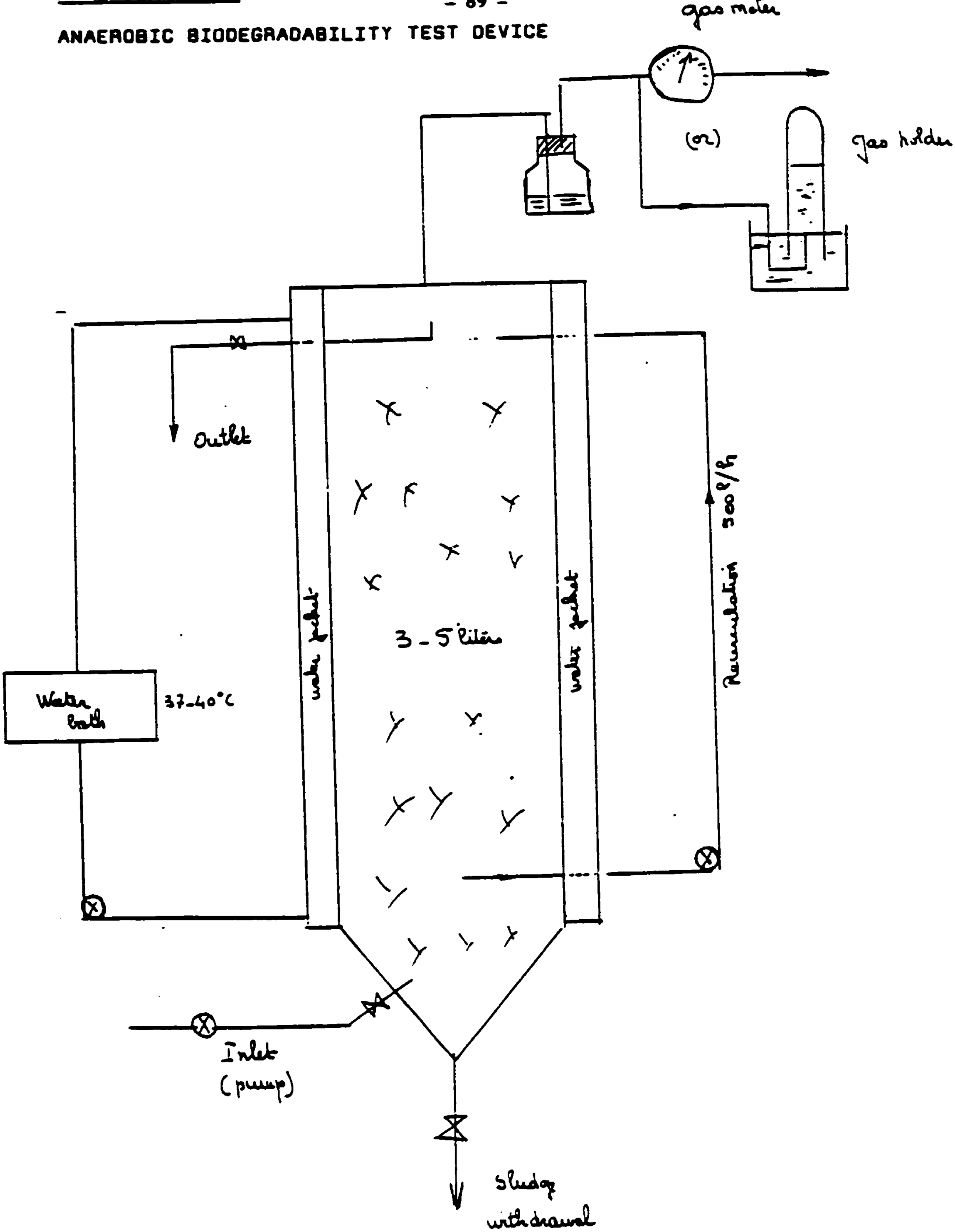
APPENDIX C - 6

LAB SCALE PILOT PLANT
(TRICKLING FILTER - PLASTIC MEDIA)



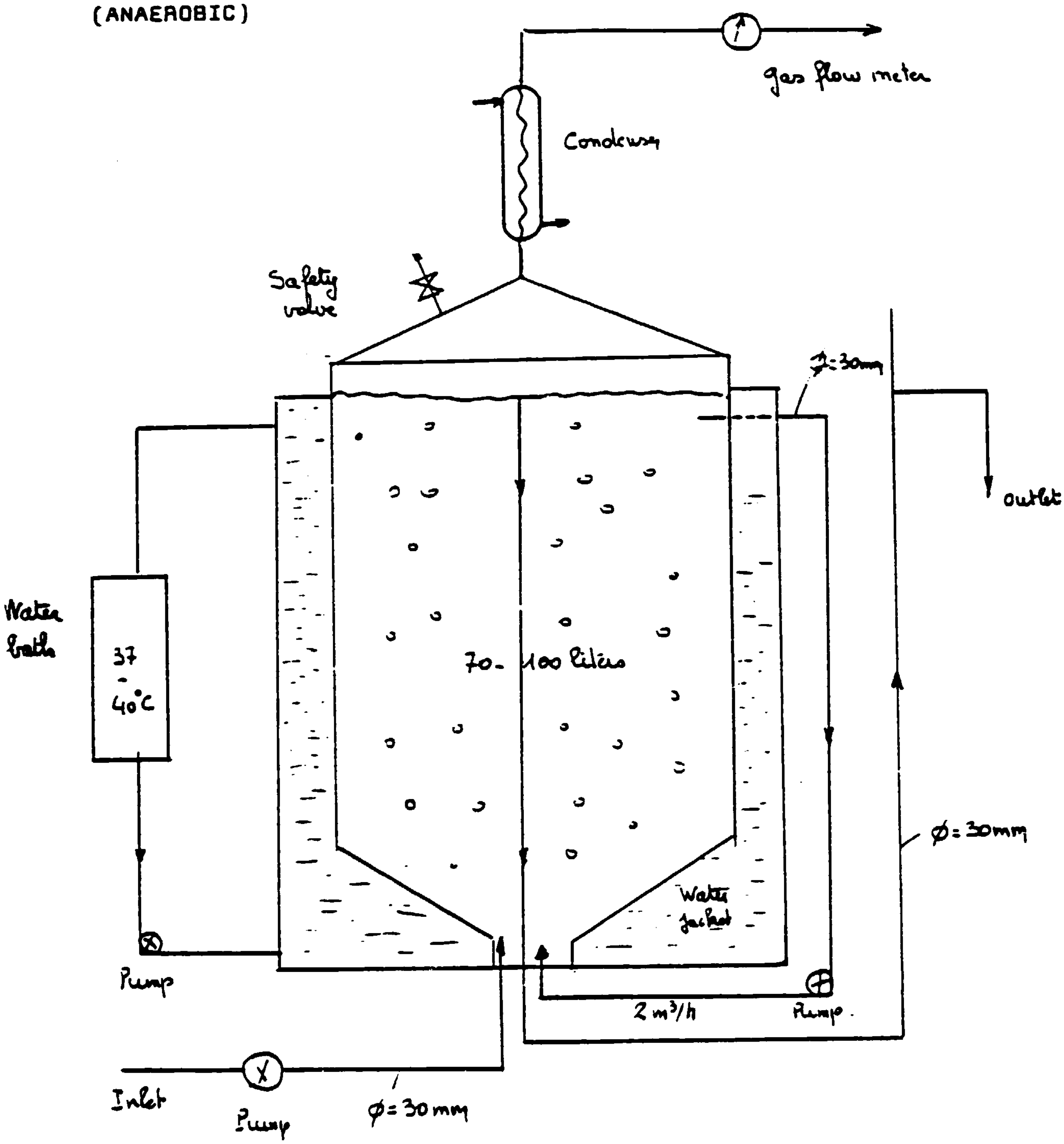
APPENDIX C - 7

ANAEROBIC BIODEGRADABILITY TEST DEVICE



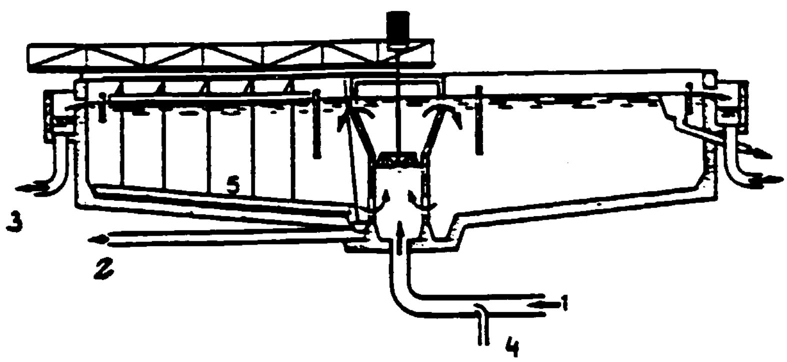
APPENDIX C - 8

LAB SCALE PILOT PLANT
(ANAEROBIC)



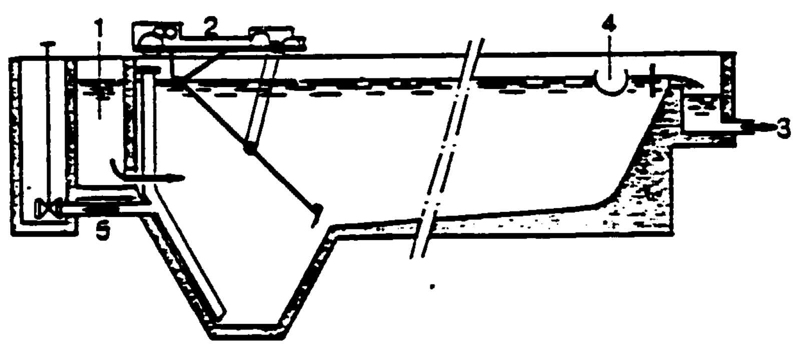
APPENDIX C - 9

Circular primary settling tank



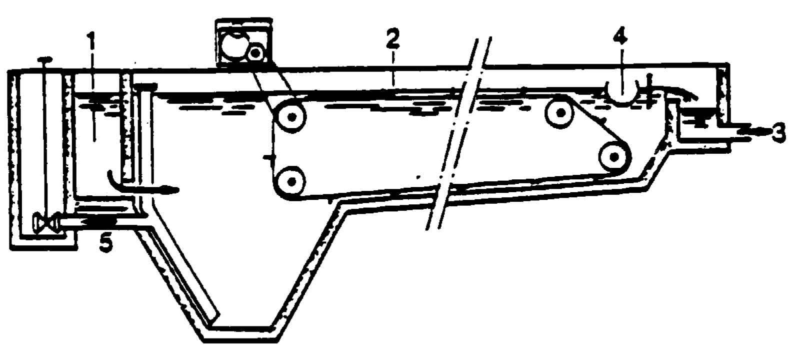
1 Inlet
2 Sludge withdrawal
3 Outlet
4 Flocculating chemicals
5 Sludge collecting device

Rectangular primary settling tank



1 Inlet
2 Moving bridge
3 outlet
4 Scum
5 Sludge withdrawal

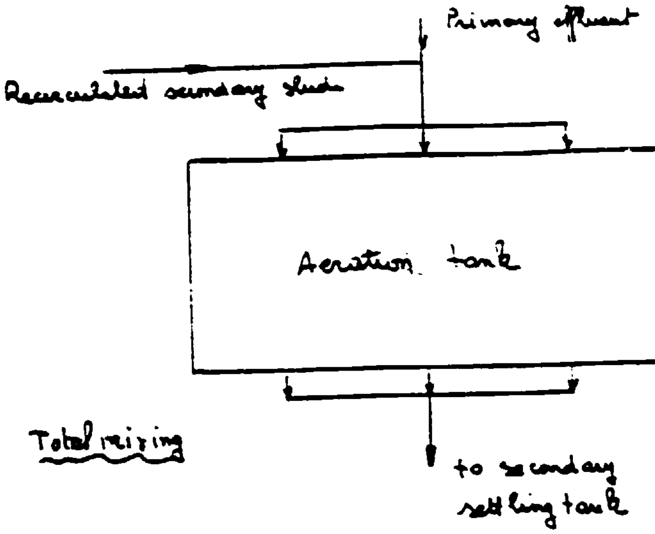
Rectangular primary settling tank



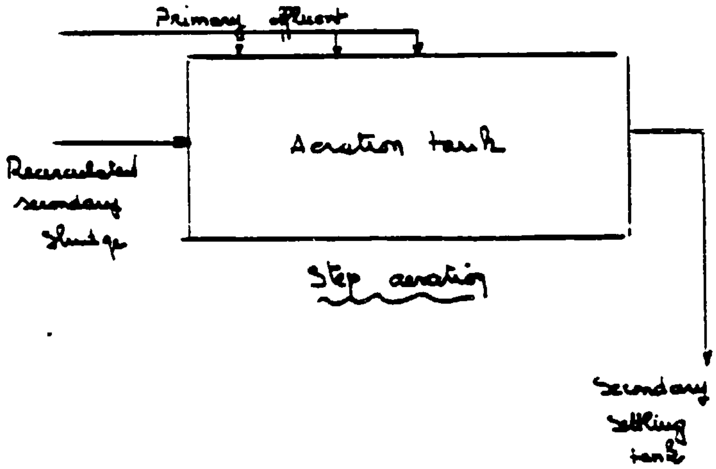
1 Inlet
2 Sludge collecting device
3 Outlet
4 Scum
5 Sludge withdrawal

APPENDIX C - 10

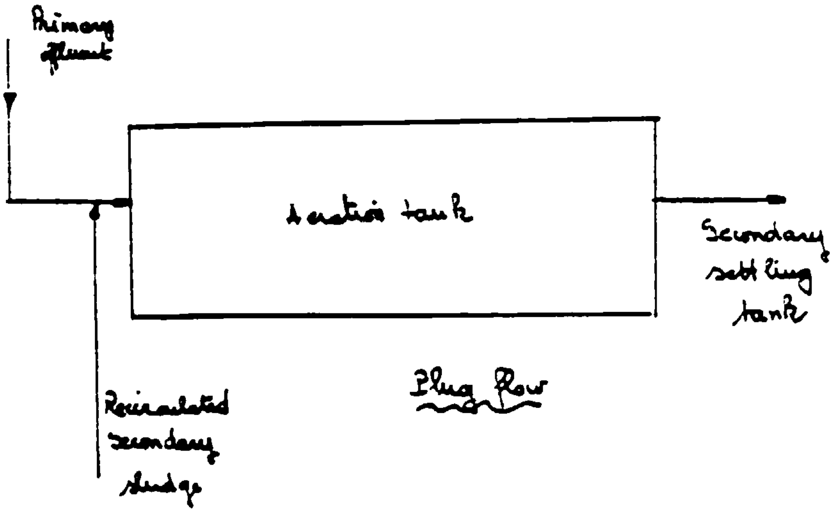
AERATION TANK FLOW PATTERNS



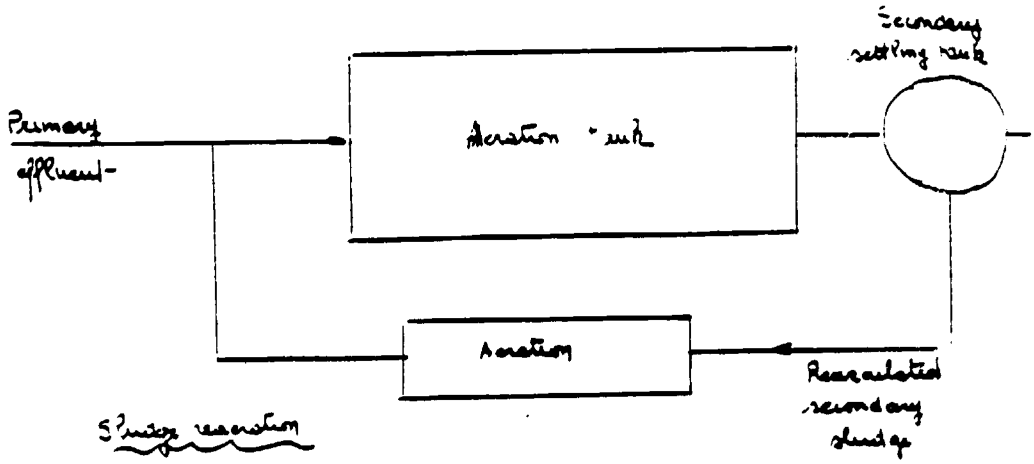
Total mixing



Step aeration



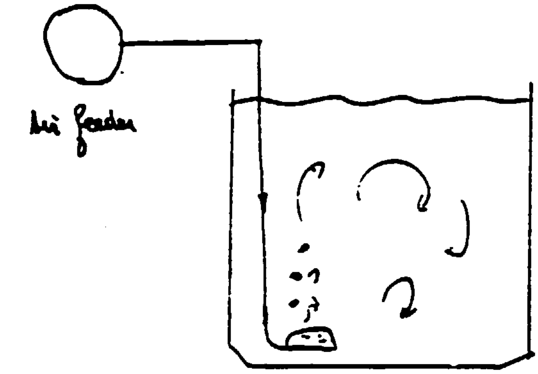
Plug flow



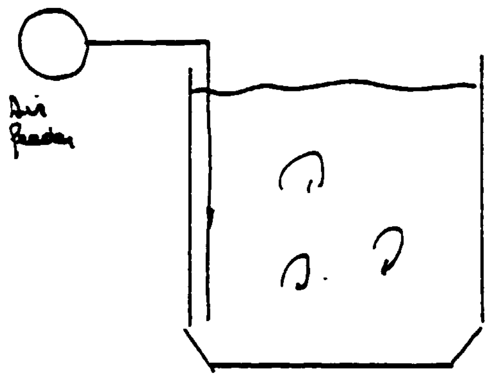
Sludge reaeration

APPENDIX C - 11

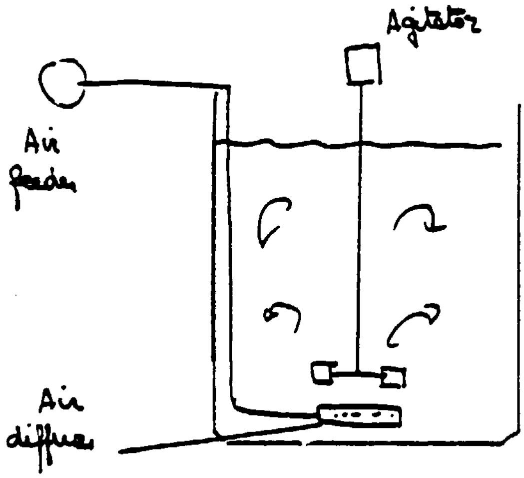
AERATION DEVICES
(ACTIVITED SLUDGE TREATMENT PLANTS)



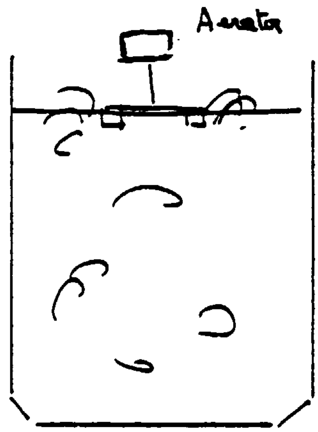
Porous diffuser



Non porous diffuser



Combined aerator

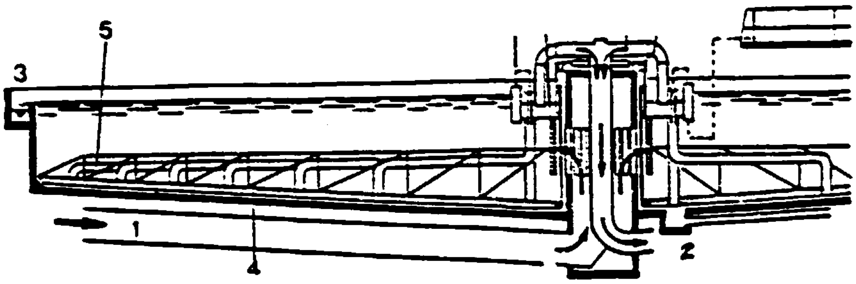


Surface aerator

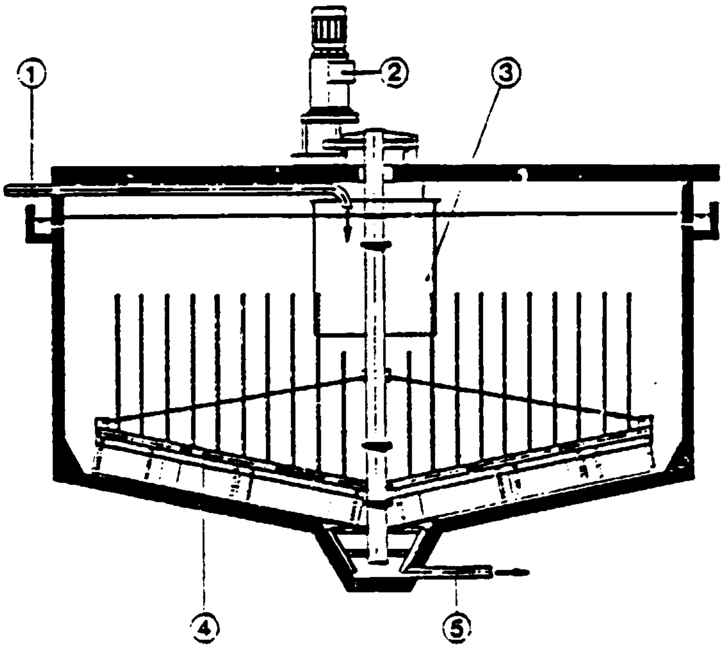
APPENDIX C - 12

CIRCULAR SECONDARY SETTLING TANK

1 Inlet
2 Sludge withdrawal
3 Outlet
4 Blades
5 Beams

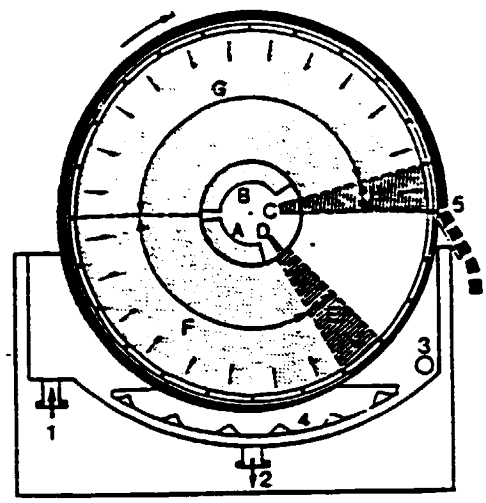


Mechanical thickener

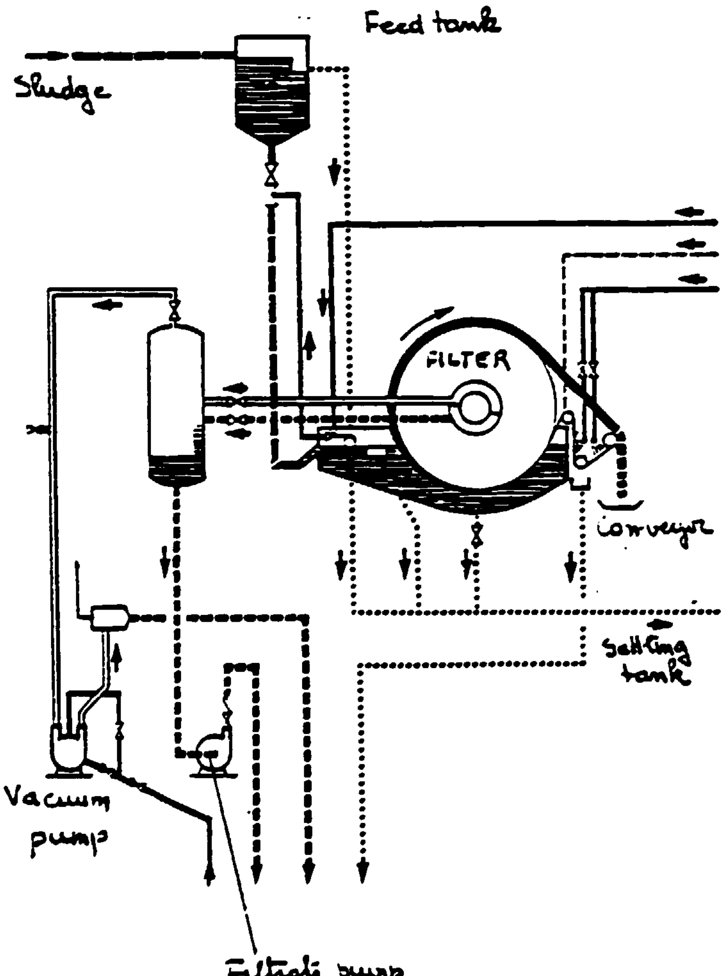


1 Inlet
2 Drive
3 Diffuser
4 Sludge collecting device
5 Sludge withdrawal

VACUUM FILTER



1 Feed
2 Withdraw
3 Overflow
4 Agitator
5 Cake

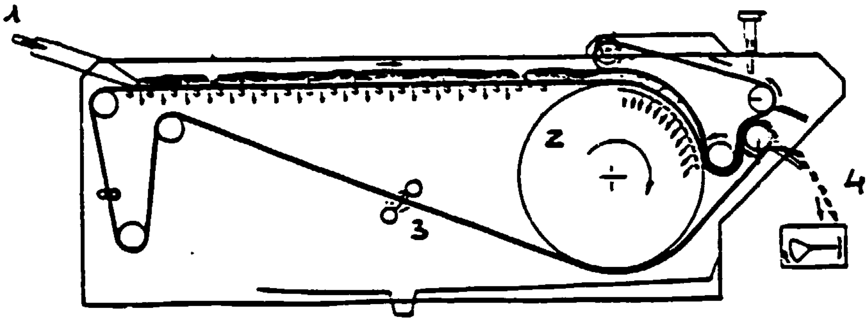


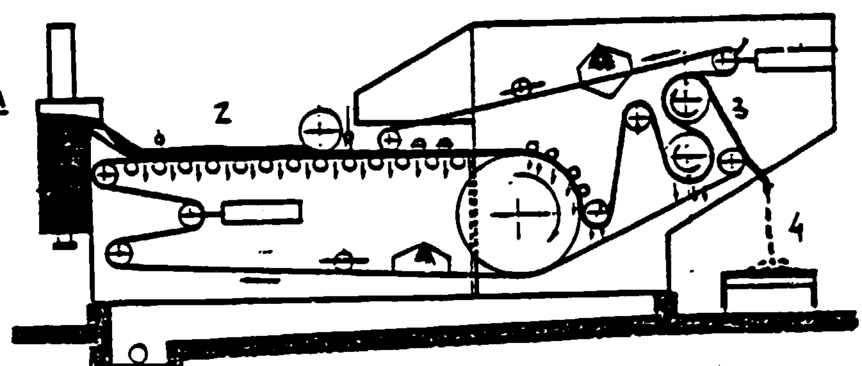
Vacuum filter flow sheet

APPENDIX C - 14

TYPES OF PRESS BELT FILTERS

1 Sludge
2 Press roller
3 Washers
4 Cakes

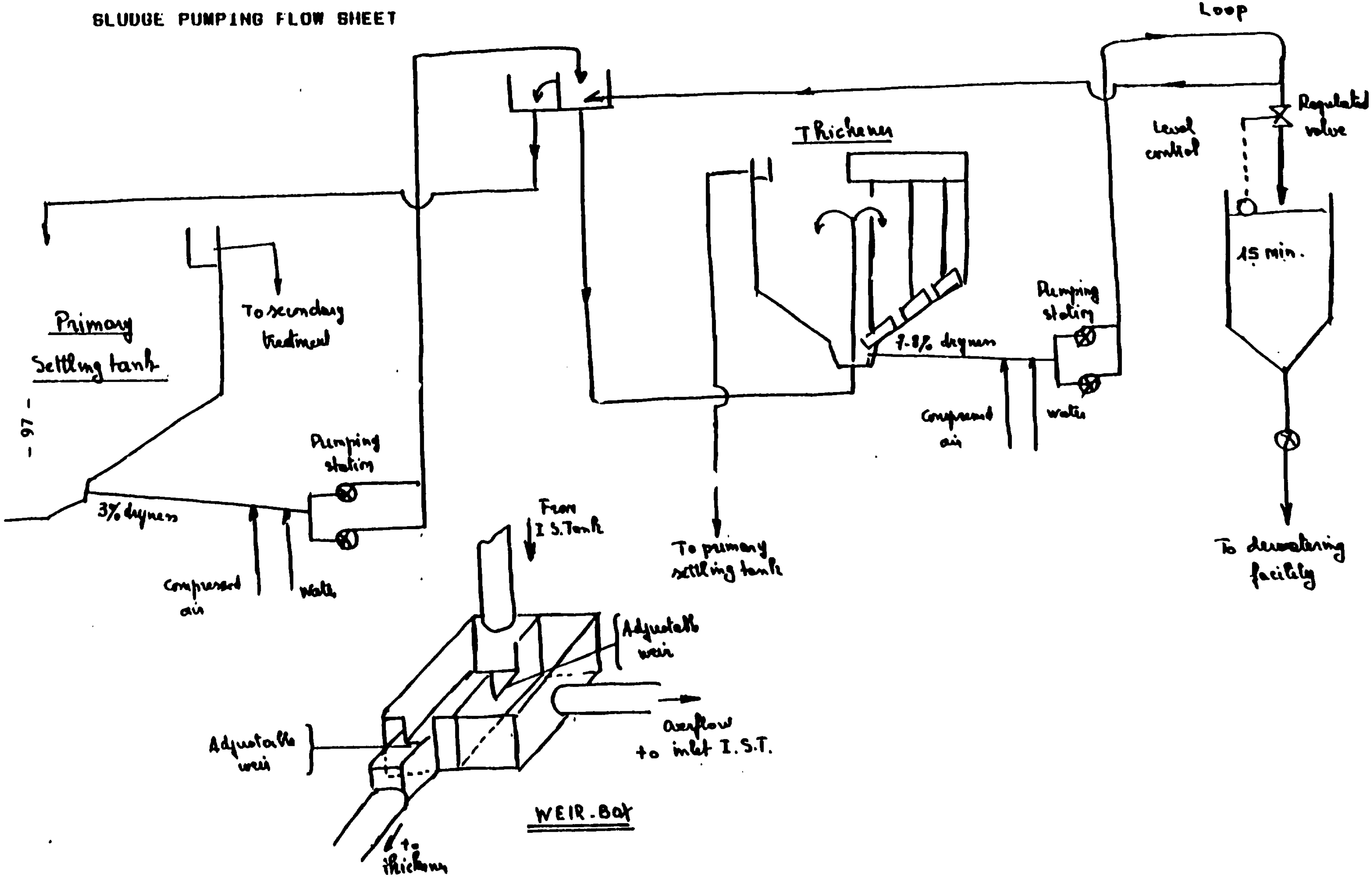




1 Sludge feed
2 Drainage zone
3 Press zone
4 Cakes

APPENDIX C - 15

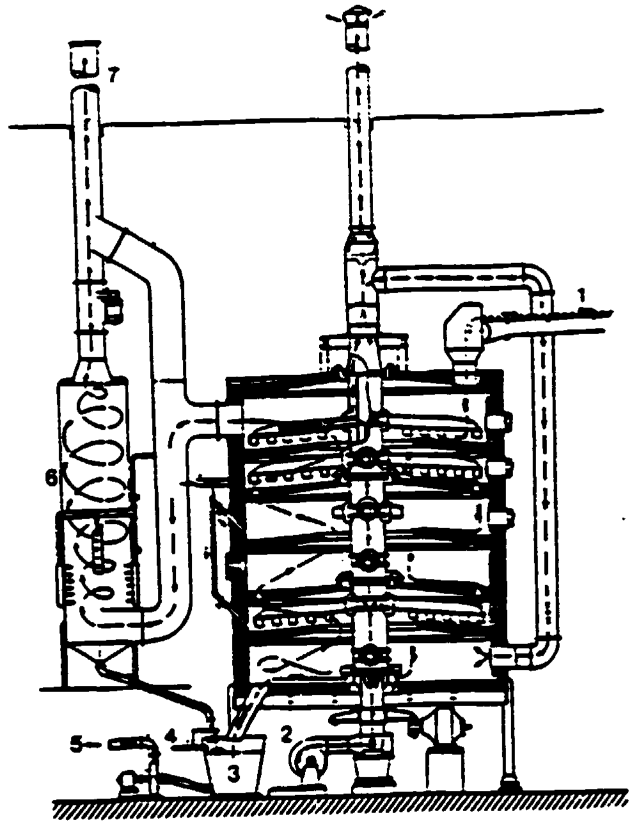
SLUDGE PUMPING FLOW SHEET



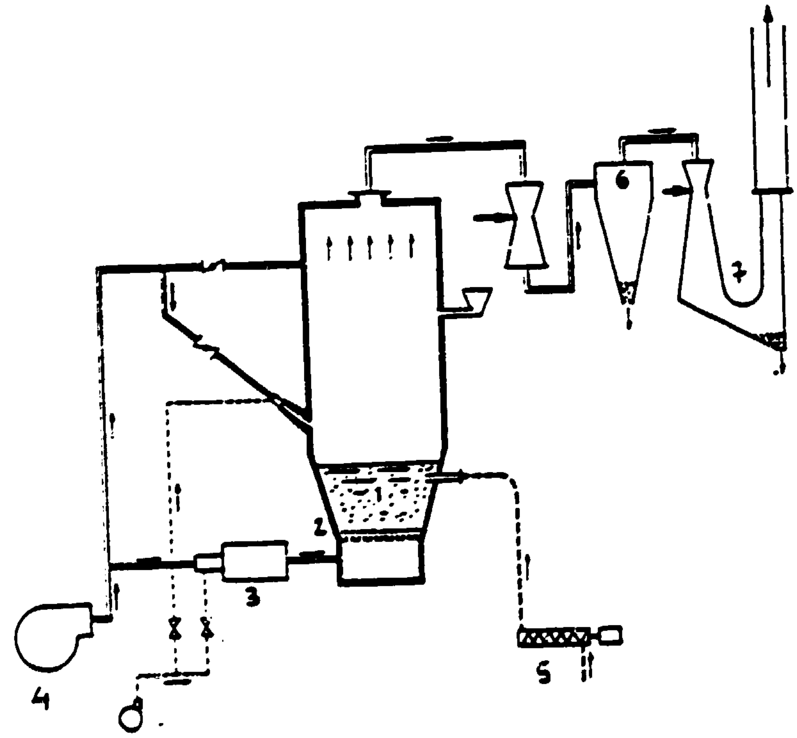
APPENDIX C - 16

INCINERATORS

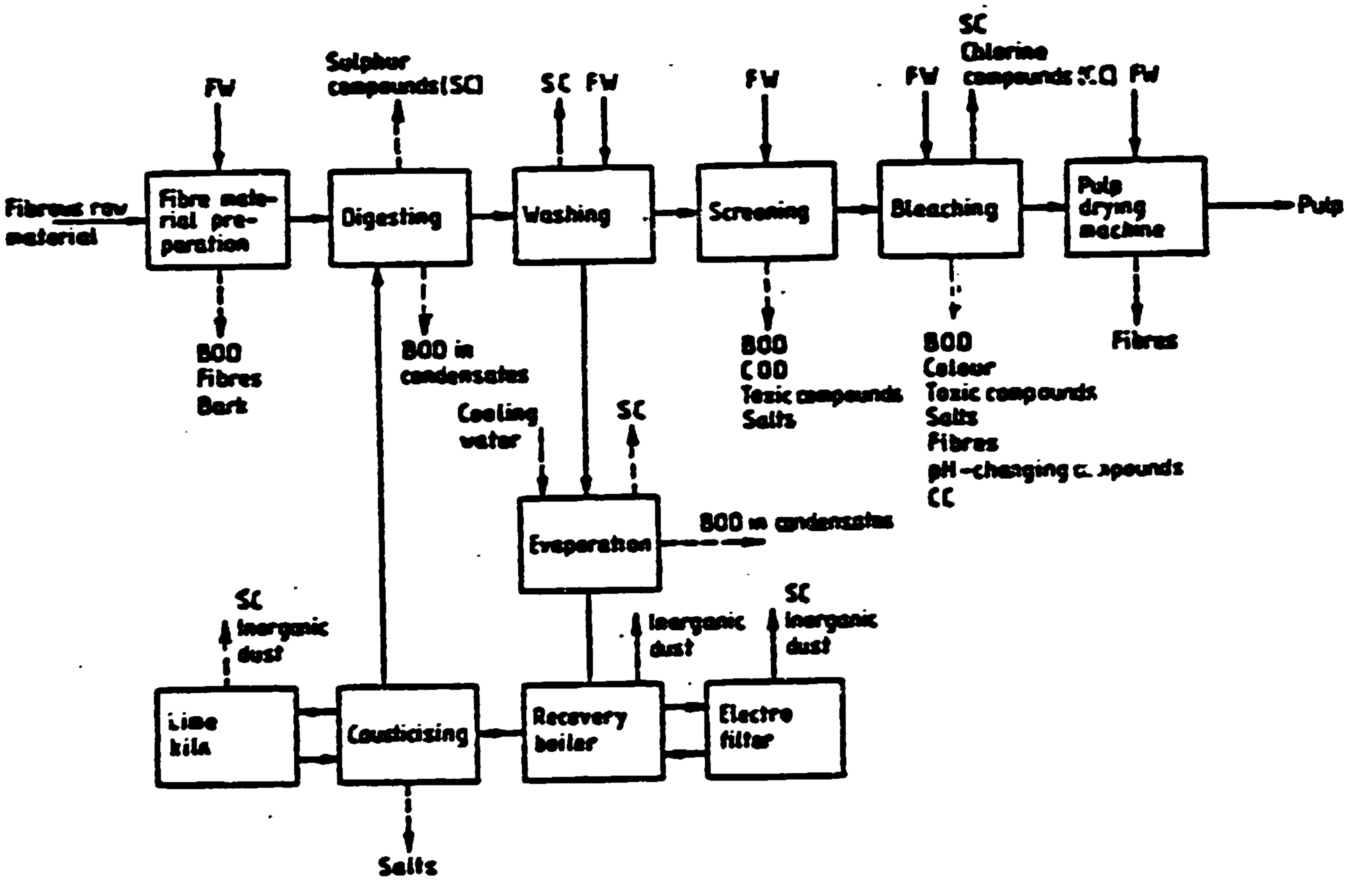
Multiple-hearth incinerator



Fluidized bed incinerator



APPENDIX C - 17

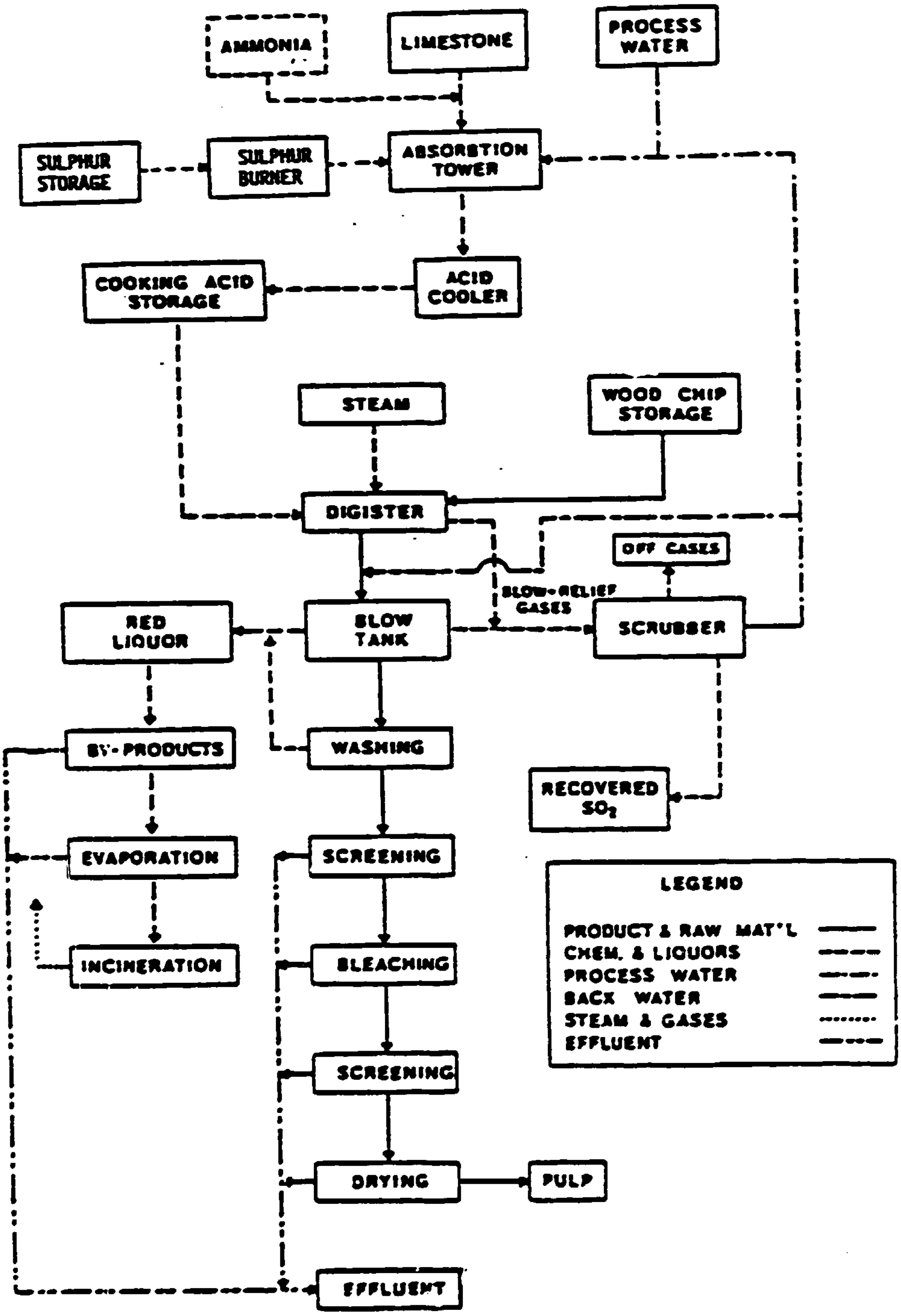


Sulphate pulping process

SC= sulphur compounds

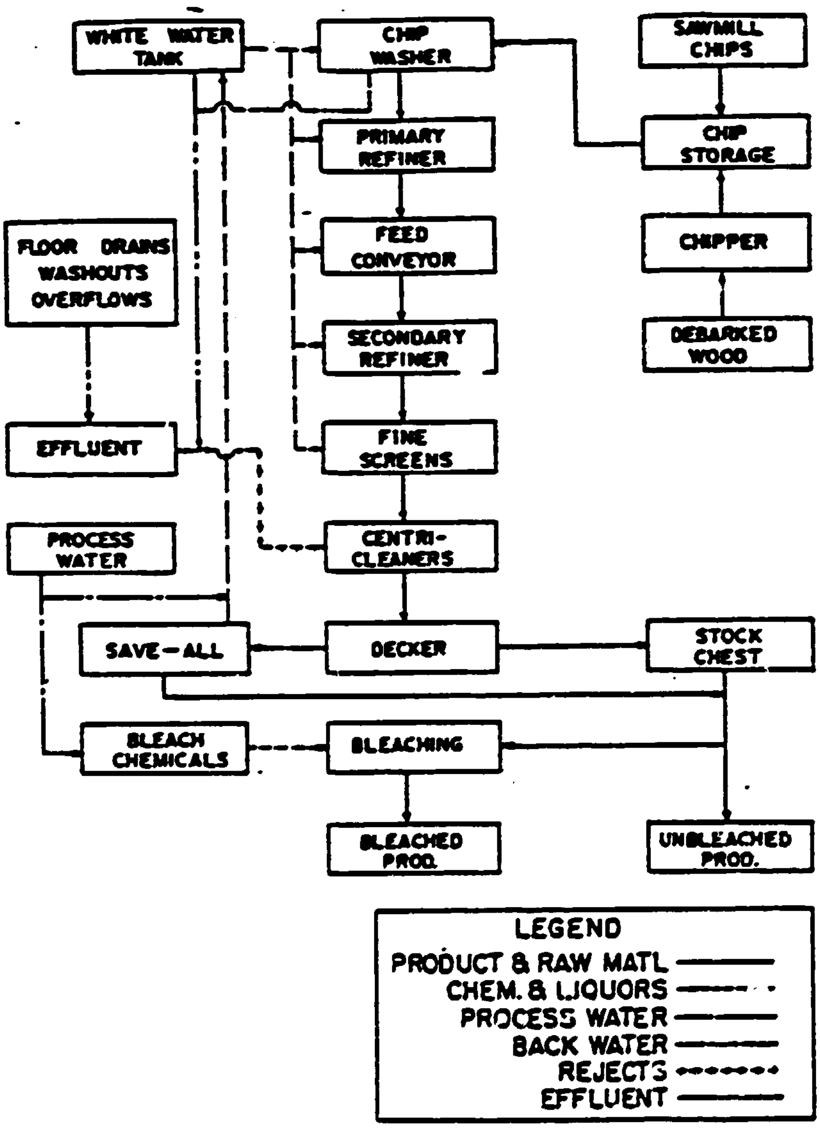
CC= chlorine compounds

FW= fresh water



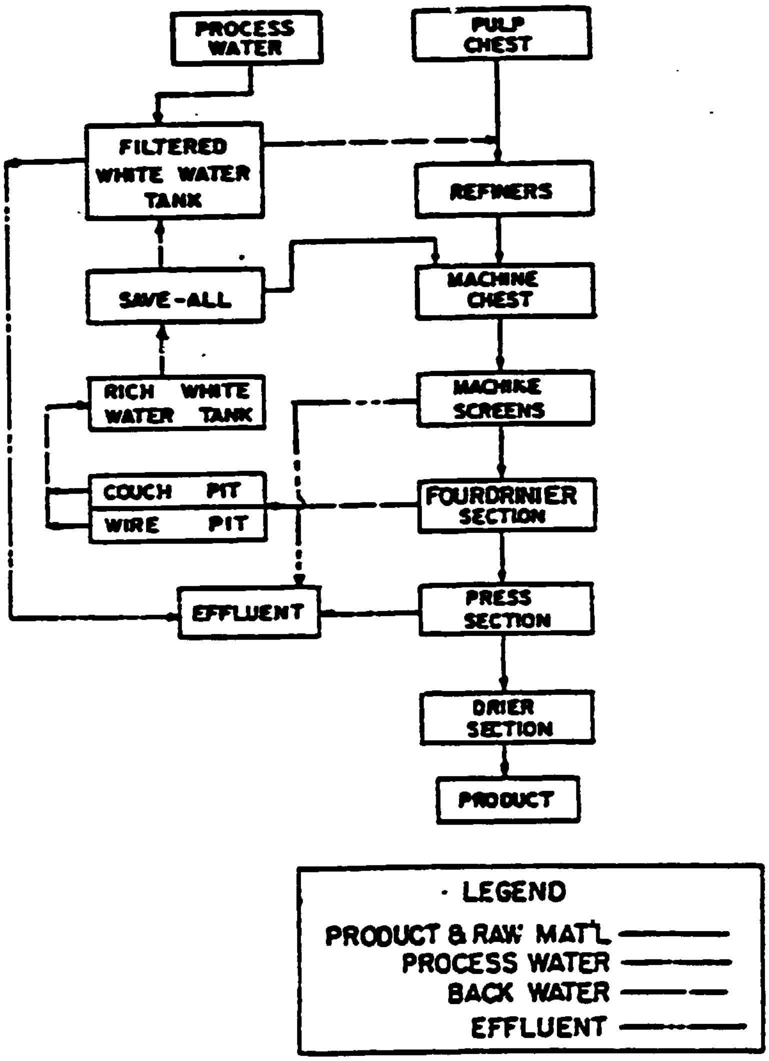
Sulphite pulping process

APPENDIX C - 19



Thermo-mechanical pulping process

APPENDIX C - 20



Papermaking process

APPENDIX C - 21

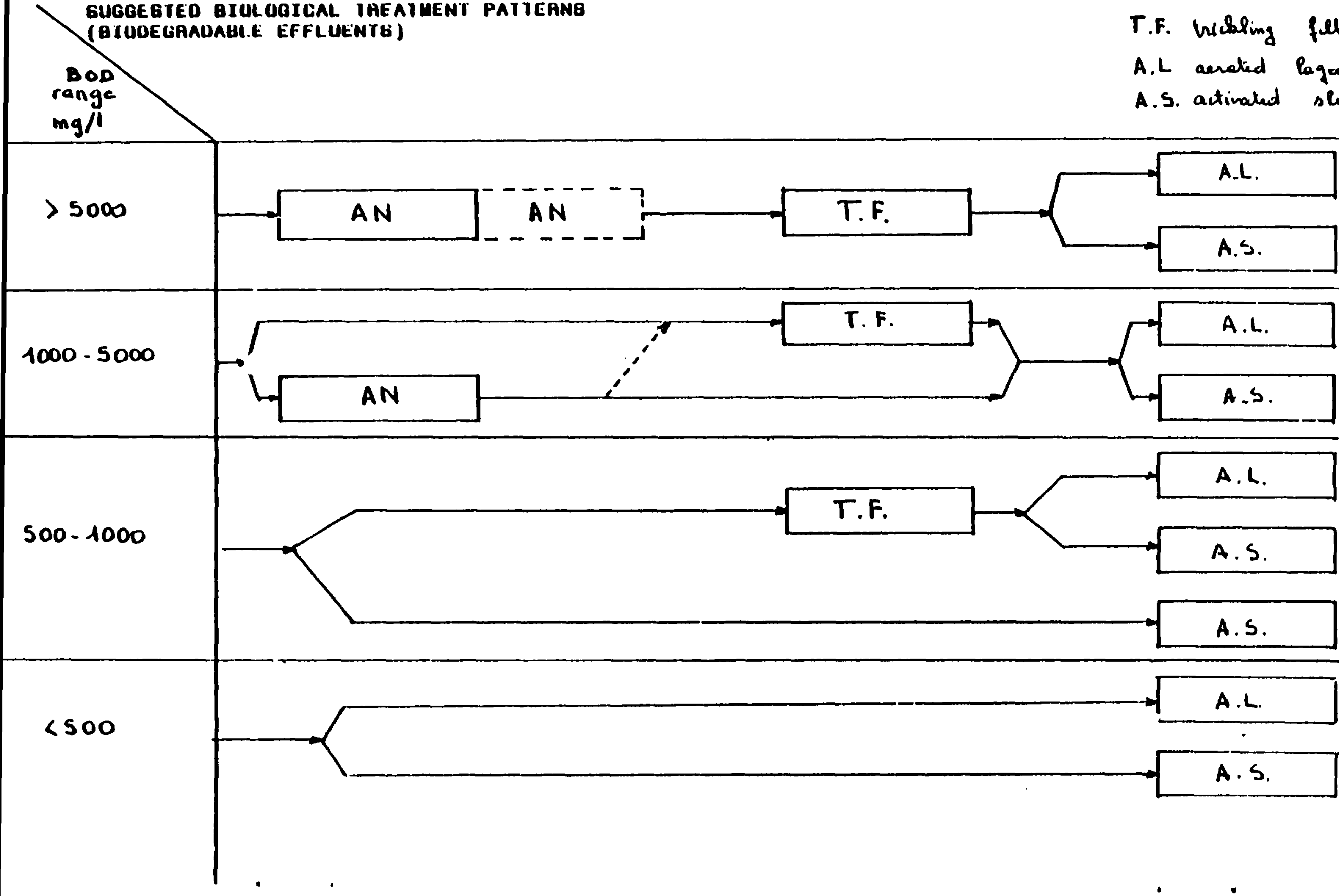
COMPARISON BETWEEN DIFFERENT SECONDARY TREATMENT METHODS

PARAMETER	STABILIZATION POND	AERATED LAGOON	TRICKLING FILTER	ACTIVATED SLUDGE	CHEMICAL FLOCULATION
Area requirement	very large	large	small	small	small
Loading range kg BOD/M3/d	0.005 - 0.01	0.04 - 0.2	2 - 5	1 - 4	high
BOD reduction %	50 - 80	50 - 90	40 - 75	70 - 95	20 - 40
Equalization requirement	none	none	small	large	none
Equalization capacity	very large	very large	small	small	small
Shock resistance	very high	very high	high	limited	high
Flow variation resistance	high	high	high	rather high	high
Loading variation resistance	very high	very high	high	rather high	high
Effluent quality change resistance	very high	high	high	small	rather small
pH range	wide	wide	small	small	small
Resistance to close down period	good	good	rather good	small	good
Sensitivity to low air temperature	very high	rather high	rather small	small	small
Nutrient requirement (N and P)	small	small	rather small	high	-
Sludge production	very small	small	rather large	large	large
Sludge settleability	poor	poor	good	good	rather good
Maintenance requirement	very small	small	small	large	rather small
Dirigibility	small	small	small	large	rather small
Energy demand	small	high	rather high	high	low
Installation costs	low - high	high	rather high	high	low
Operation costs	very low	rather high	rather high	high	high

<u>APPENDIX C - 22</u>

SUGGESTED BIOLOGICAL TREATMENT PATTERNS
(BIODEGRADABLE EFFLUENTS)

AN: anaerobic treatment
T.F. trickling filter
A.L aerated lagoon
A.S. activated sludge



I.R.CH.A.

IRCHA* (National Institute of Applied Chemical Research) is a public state establishment with an industrial and commercial charter and of incorporated status, financially independent, sponsored by the ministry in charge of the chemical industry.

Its work force is about 300 persons. It has major laboratories and pilot units at Vert-le-Petit, with over 15,000 square meters devoted to research and development, Corbeil-Evry, Lille-Villeneuve d'Ascq, Toulouse (CEPICA) and Marseille (PACA).

Research is conducted under contract on behalf of :

1 - Private firms, French and foreing, and international bodies
2 - Public establishments
3 - Directorate of the Chemical, Textile and Miscellaneous Industries under the Ministry of Industry.

IRCHA has also founded the following "economic interest groups" in collaboration with industry :

- The Research and Predevelopment Center on Organic Materials for Advanced Techniques (CEMOTA) in Solaize.

- The IRDAL, a manufacturing and marketing body for high performance varnishes

- The CERLAB, Centre Interlaboratoires d'Etudes et de Réalisations (Interlaboratory Center for Studies and Realizations)

* Institut National de Recherche Chimique Appliquée
Centre de Recherche - B.P. N° 1 - 91710 - VERT-LE-PETIT
Tél. : (1) 64.93.24.75 - Télex 660820 F Télécopie 64.93.43.32

Aside from which IRCHA has taken an active part in the operation of NOREX which is devoted to the technical assistance to french exporters.

Research and Development activities are bent to chemistry and environment.

The main fields in environmental Science and Technology are :

BIOLOGY

Miscellaneous biological research and tests, isolating strains, effectiveness tests on antiseptics and disinfectants, biological water monitoring, Ames mutagenesis tests.

ECOTOXICOLOGY

The Ecotoxicological Laboratory, accredited by the French National Testing Network (RNE), conducts analyses on Proper Practice of Laboratories laid down by the OECD.

Miscellaneous aquatic and terrestrial ecotoxicological analysis, development of test methods, standardization, ecotoxicology of chemical effluents and products, biodegradability of detergents, etc..

WATER POLLUTION

- Detection and estimation of pollution levels ; developing and refining methods of measuring and identifying pollutants and their metabolites.

- Biological purification ; physico-chemical purification ; research on pilot scale industrial sites ; development of improved technologies tailored to concrete problems.

- Local action : water sampling and analysis on behalf of the public authorities, financial and industrial agencies ; technical consultation and assistance to sewage plants.

AIR POLLUTION

- Coordinating of research conducted in France, in liaison with appropriate European Laboratories, on evaluating and refining specific methods and instrumentation for pollution (dust, vapor, gas, odors).

- Methodology of pollution surveillance and alarm in industrial areas ; comprehensive local campaigns on atmospheric pollution ; mathematical models of forecasting and alarm.

- Environmental impact surveys

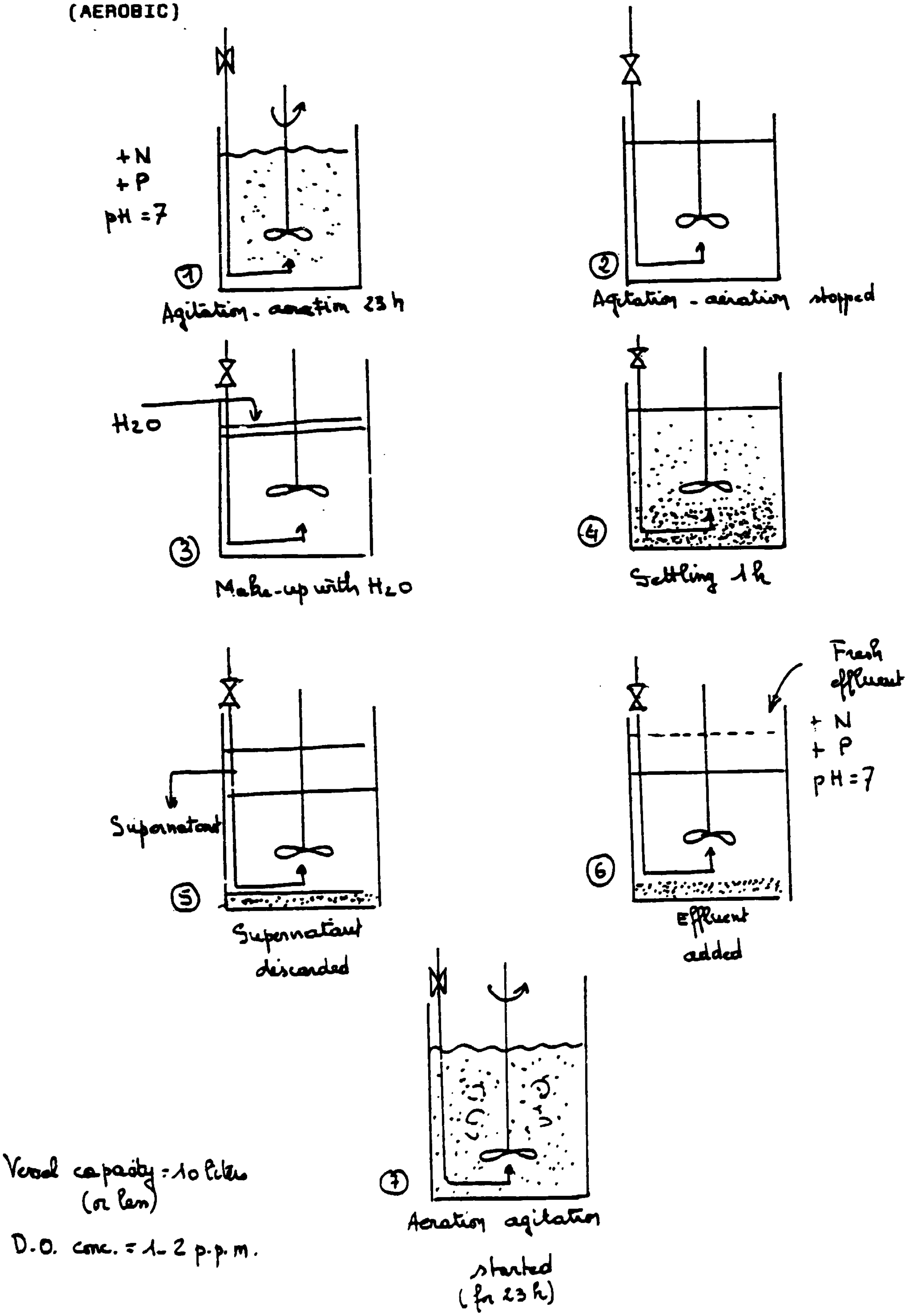
INSTRUMENTATION

- Developing and refining measuring and testing instrument for water and air pollution.

To conduct the above tasks, the Institute's Divisions call on the Analysis Service, which also works for outside agencies, to perform biological analysis, chemical analysis (conventional and specialized), physico-chemical analysis (UV, IR, ICP, GCMS, chromatography, polarography, electron microscope, etc...).

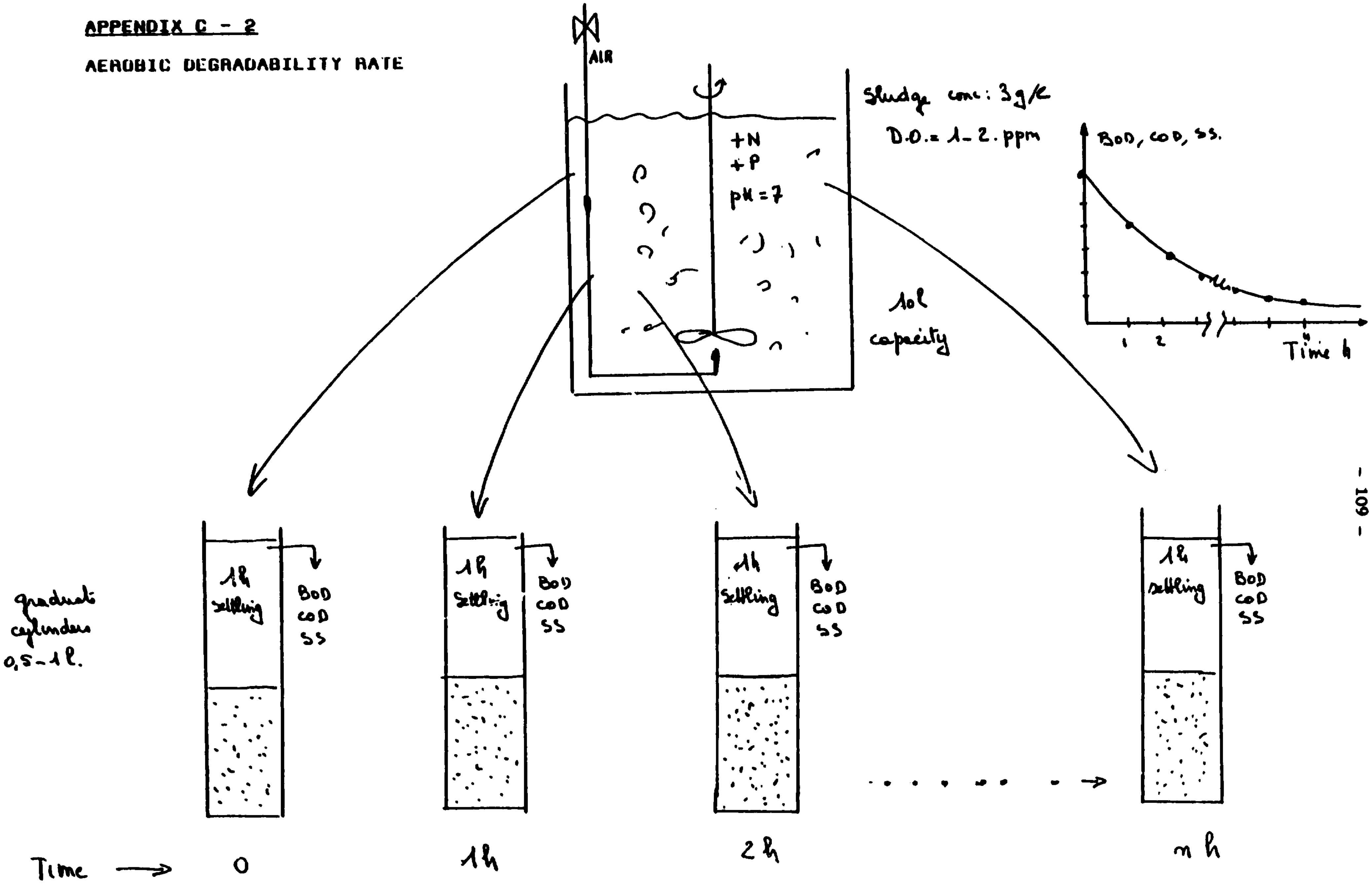
APPENDIX C - 1

SLUDGE ADAPTATION
(AEROBIC)



APPENDIX C - 2

AEROBIC DEGRADABILITY RATE



APPENDIX C - 3

LAB SCALE PILOT PLANT
(ACTIVATED SLUDGE)

Settling tank diameter

Flow l/h	I^y mm	II^y mm
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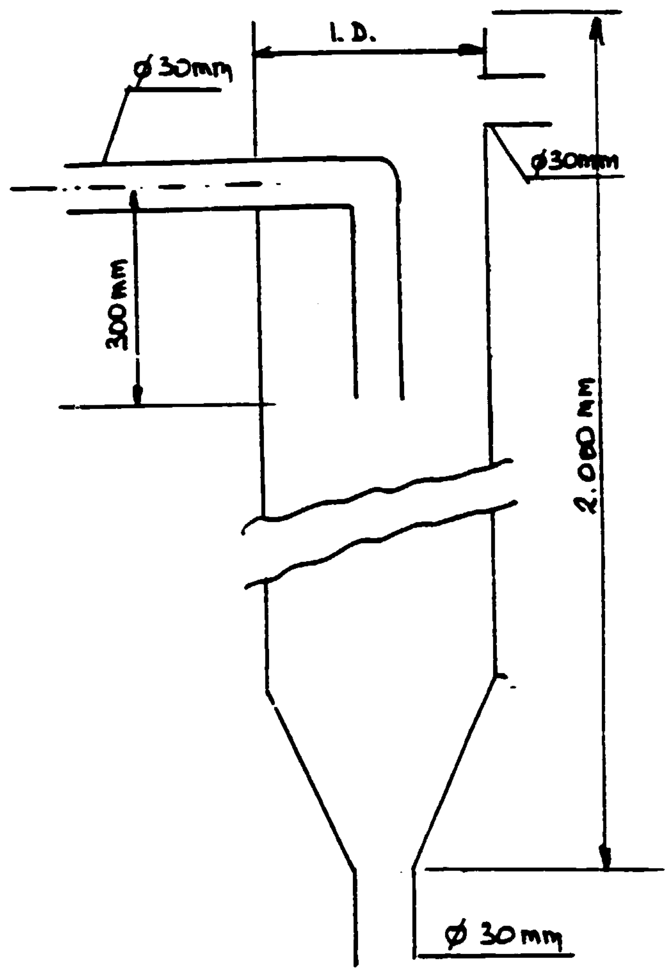
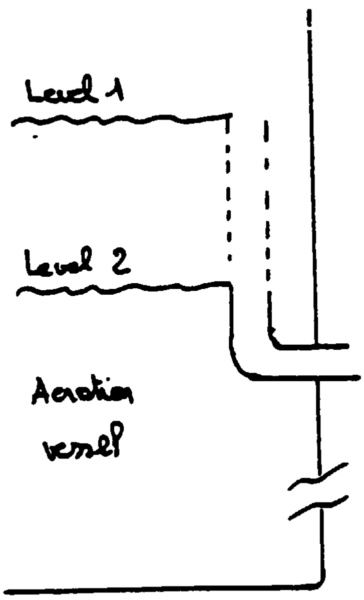
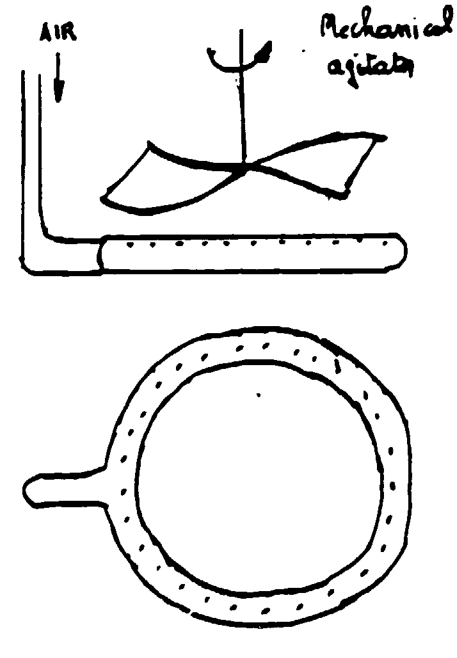


Settling tank



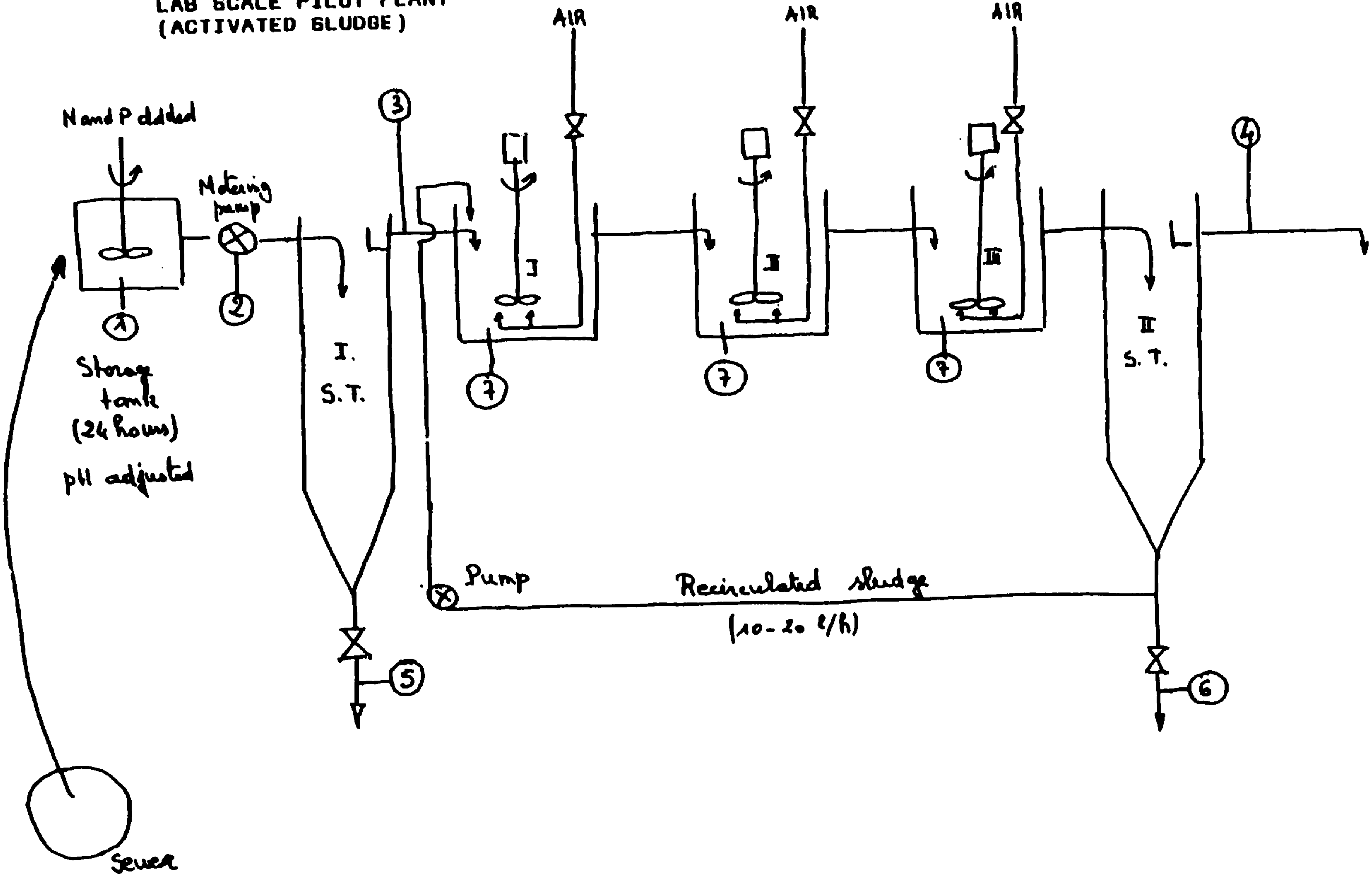
Adjustable capacity



Aeration device

APPENDIX C - 4

LAB SCALE PILOT PLANT
(ACTIVATED SLUDGE)



Check list of monitoring

1) Storage tank
   - BOD
   - COD
   - S.S.
   - Add N (NH_4OH) + P (PO_4H_3) [BOD/N/P = 100/5/1]
   - pH adjustment (7)

2) Metering pump.
   - Flow (10 - 20 l/h)

3) Primary effluent
   - BOD
   - COD
   - S.S.

4) Secondary effluent
   - BOD
   - COD
   - S.S.

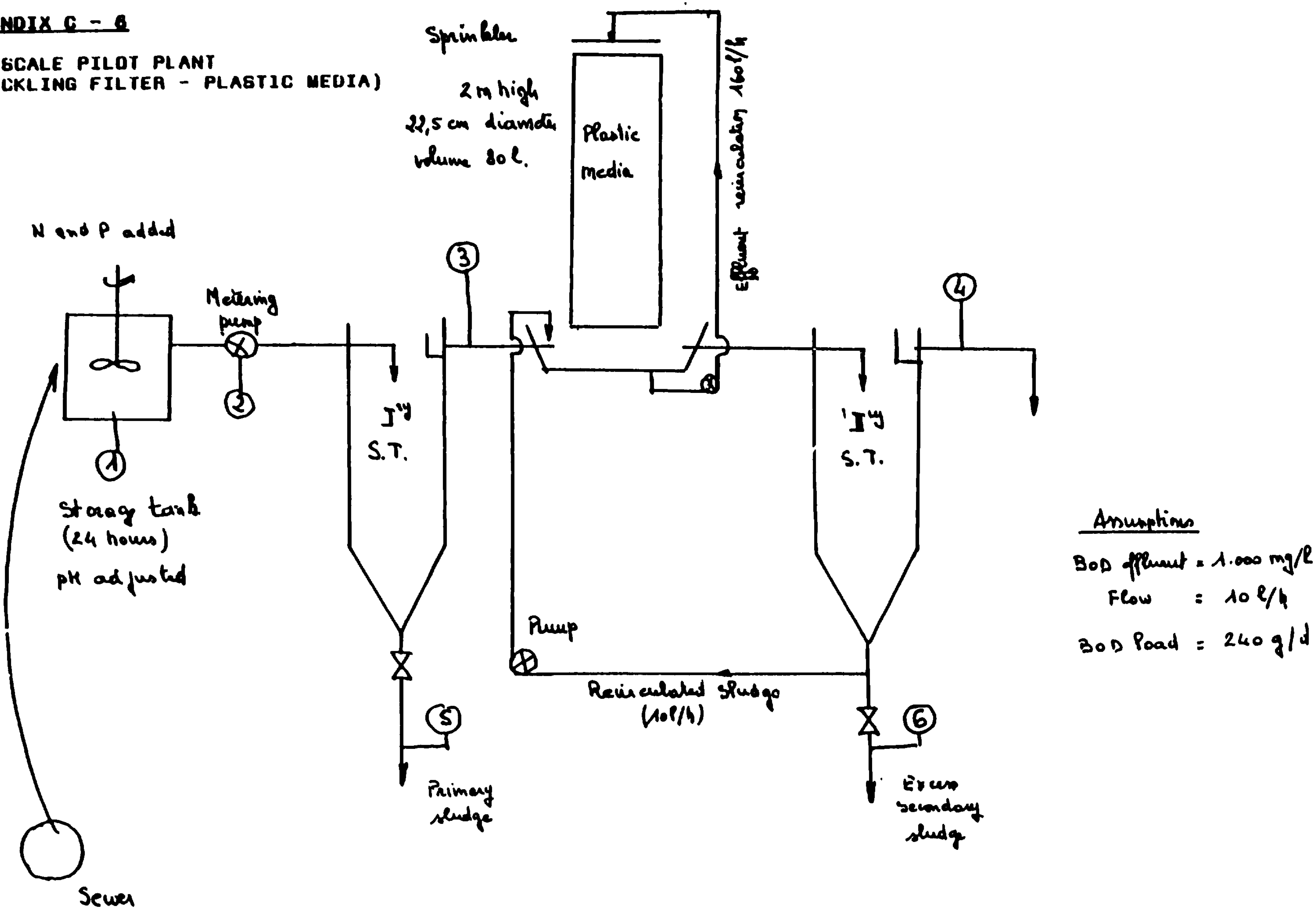
5) Primary sludge
   - Extracted volume
   - Concentration (dry solids)

6) Secondary sludge (excess)
   - Extracted volume
   - Concentration (dry solids)
   - Sludge volume index (30' and 60' sedimentation)

7) Aeration tank
   - Dissolved oxygen (1 - 2 p.p.m)
   - Sludge concentration (2 - 4 g/l dry solids)

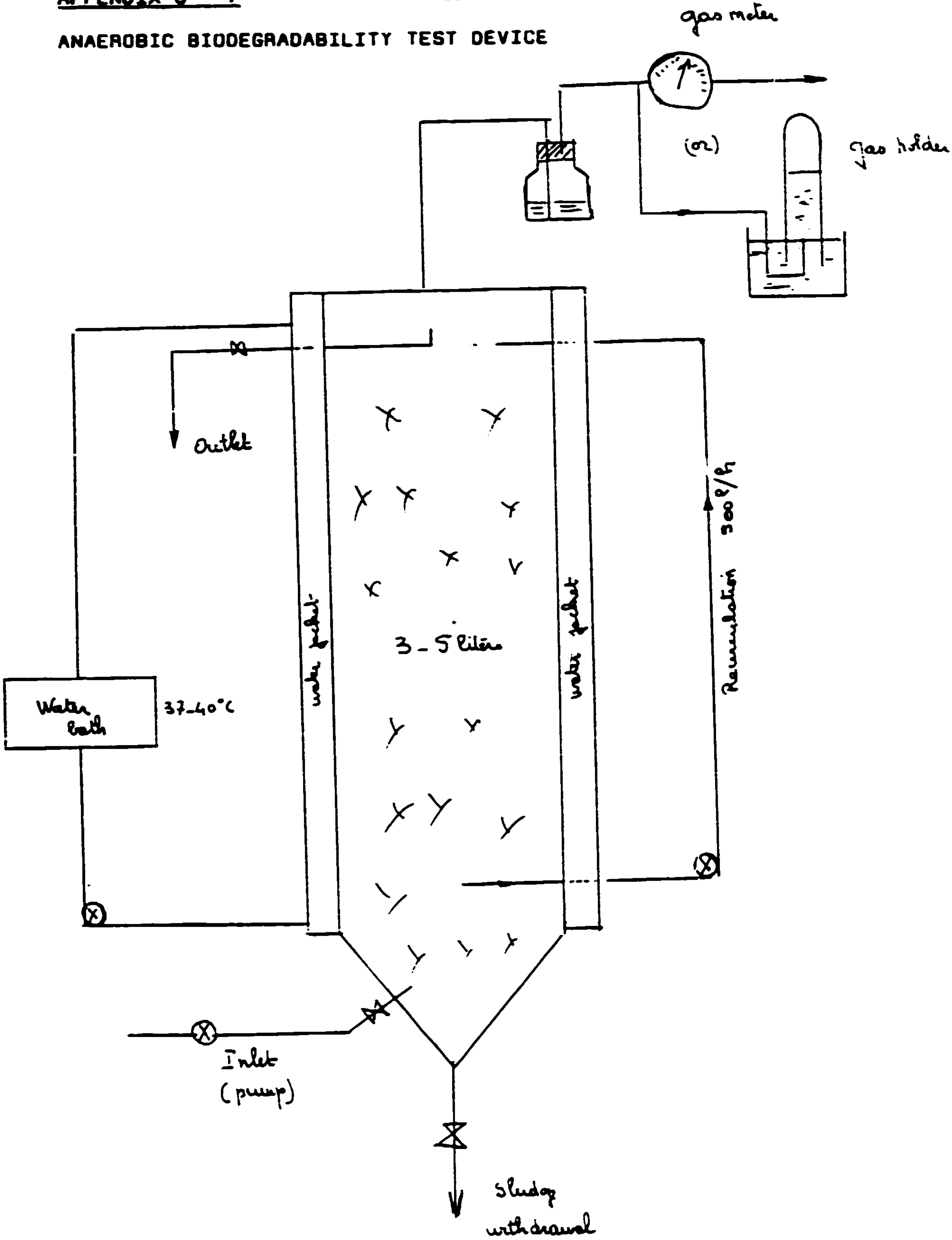
APPENDIX C - 6

LAB SCALE PILOT PLANT
(TRICKLING FILTER - PLASTIC MEDIA)



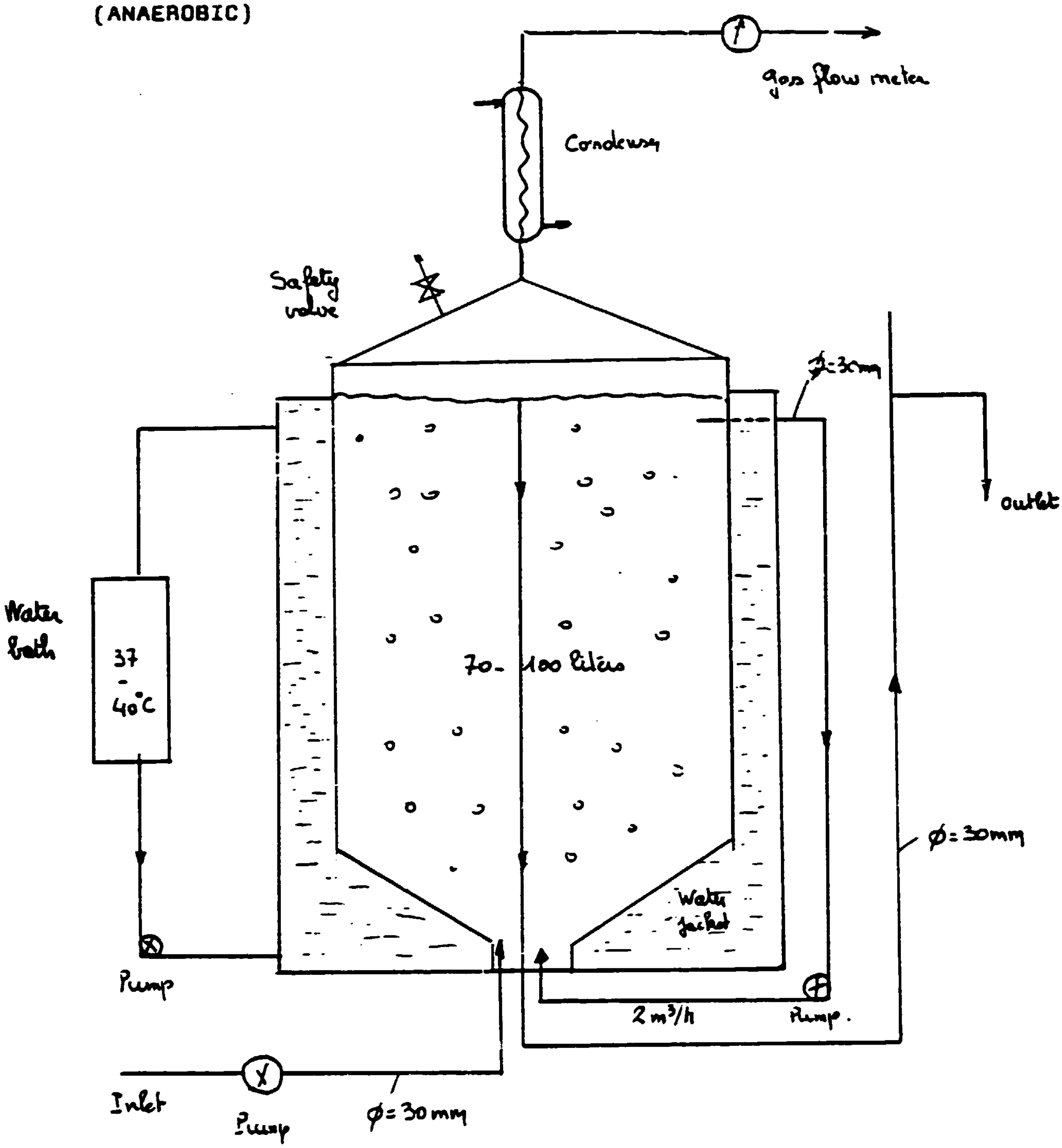
APPENDIX C - 7

ANAEROBIC BIODEGRADABILITY TEST DEVICE



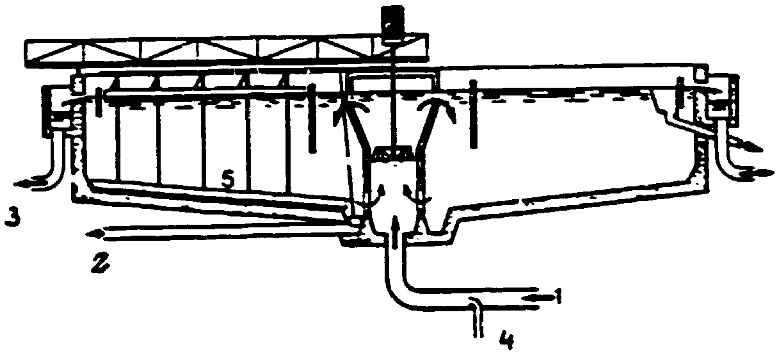
APPENDIX C - 8

LAB SCALE PILOT PLANT
(ANAEROBIC)



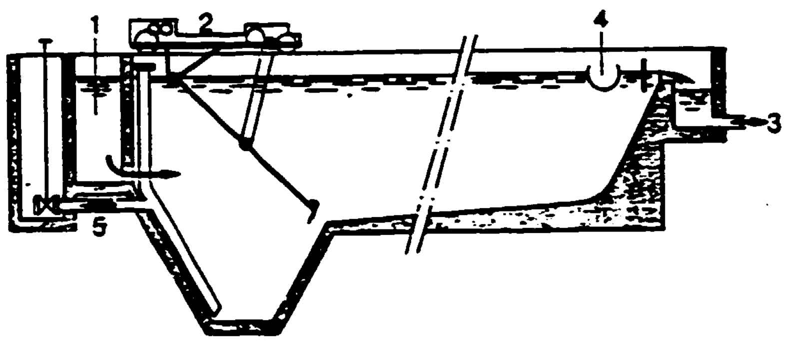
APPENDIX C - 9

Circular primary settling tank



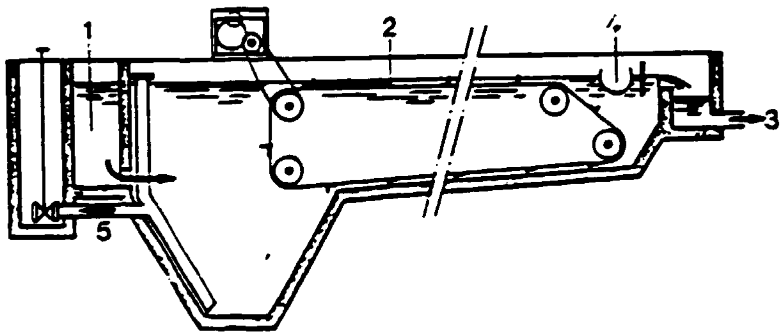
1 Inlet
2 Sludge withdrawal
3 Outlet
4 Flocculating chemicals
5 Sludge collecting device

Rectangular primary settling tank



1 Inlet
2 Moving bridge
3 outlet
4 Scum
5 Sludge withdrawal

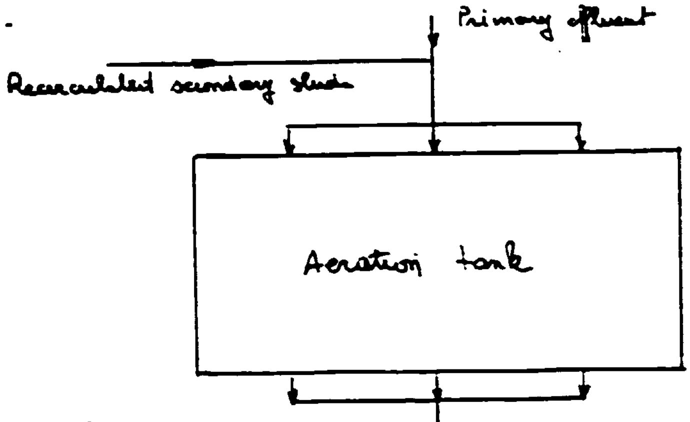
Rectangular primary settling tank



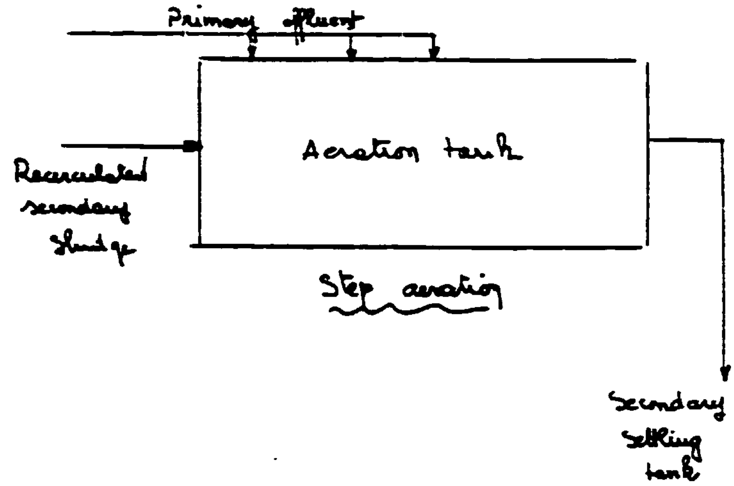
1 Inlet
2 Sludge collecting device
3 Outlet
4 Scum
5 Sludge withdrawal

APPENDIX C - 10

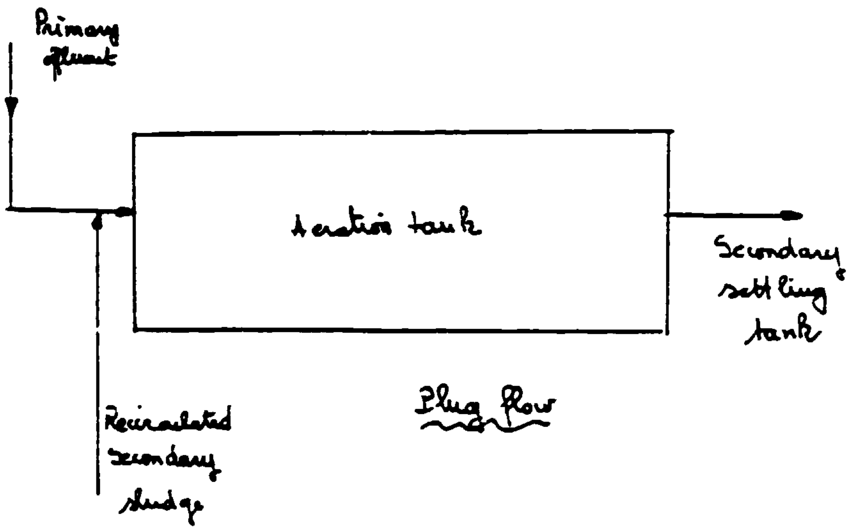
AERATION TANK FLOW PATTERNS



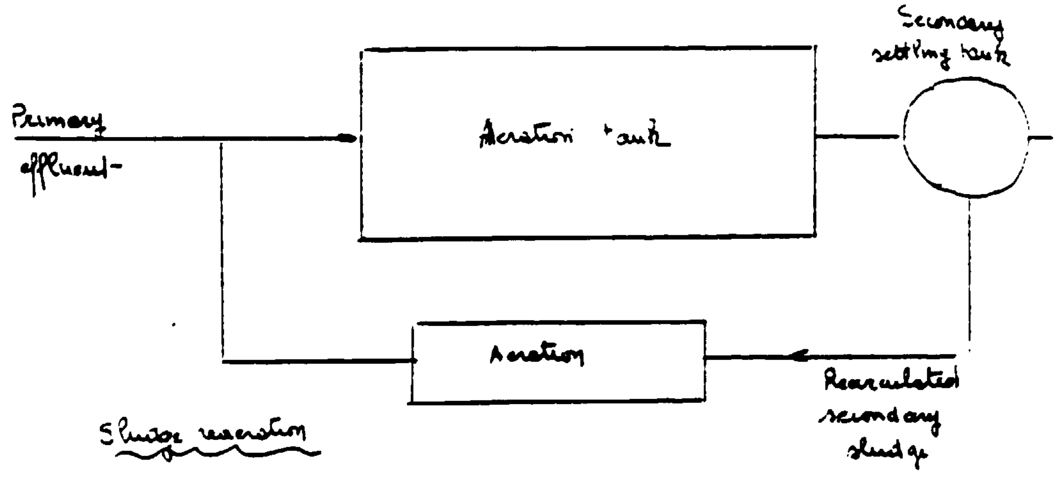
Total mixing



Step aeration



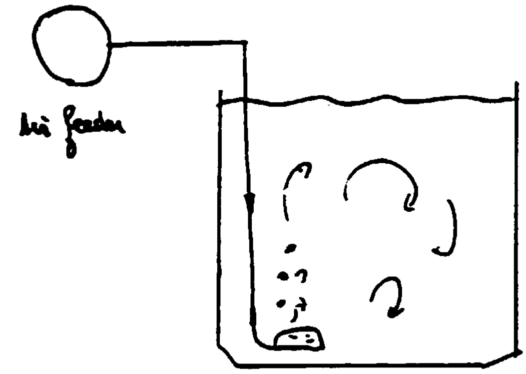
Plug flow



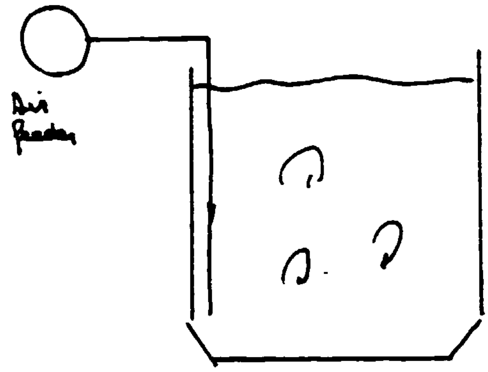
Sludge reaeration

APPENDIX C - 11

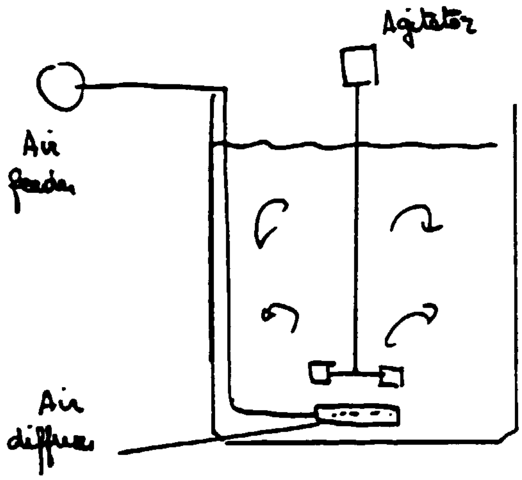
AERATION DEVICES
(ACTIVITED SLUDGE TREATMENT PLANTS)



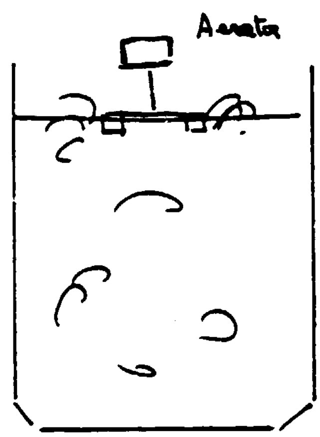
Porous diffuser



Non porous diffuser



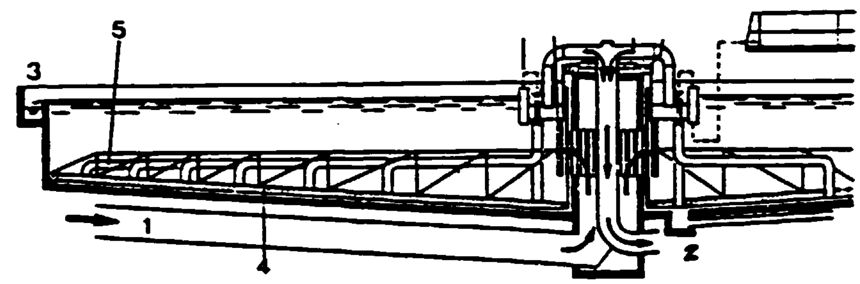
Combined aerator



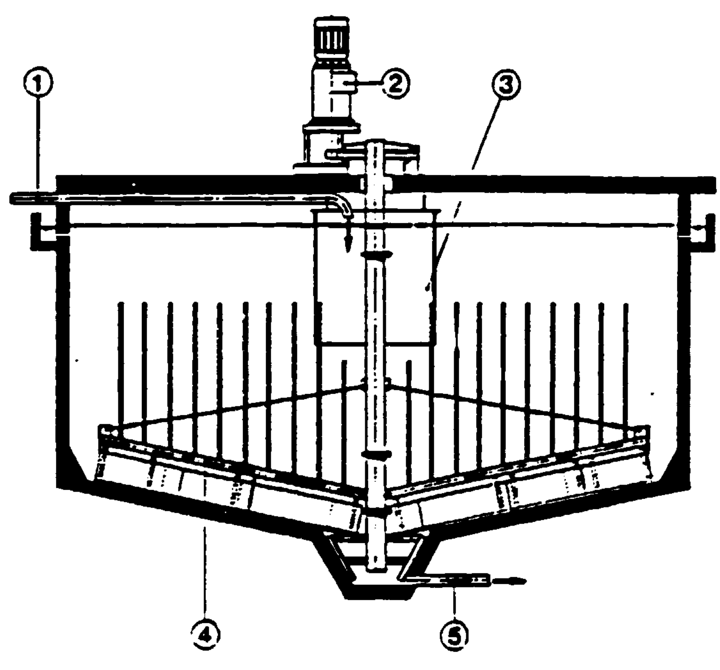
Surface aerator

CIRCULAR SECONDARY SETTLING TANK

1 Inlet
2 Sludge withdrawal
3 Outlet
4 Blades
5 Beams

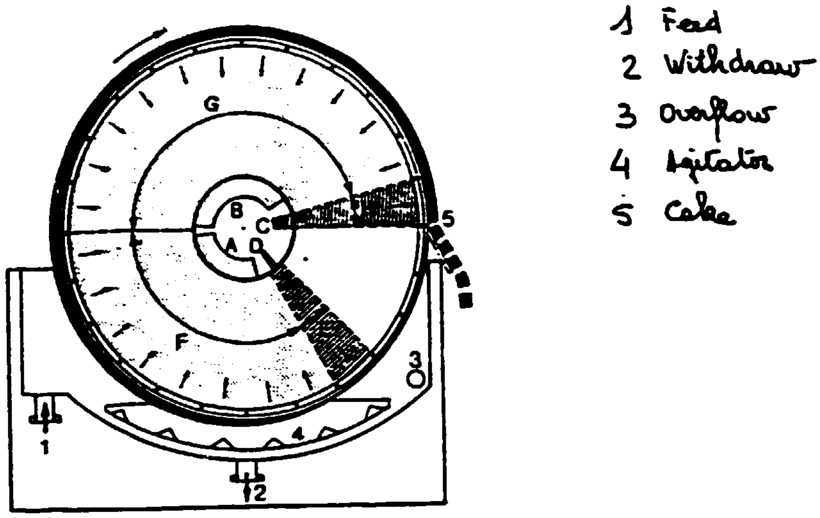


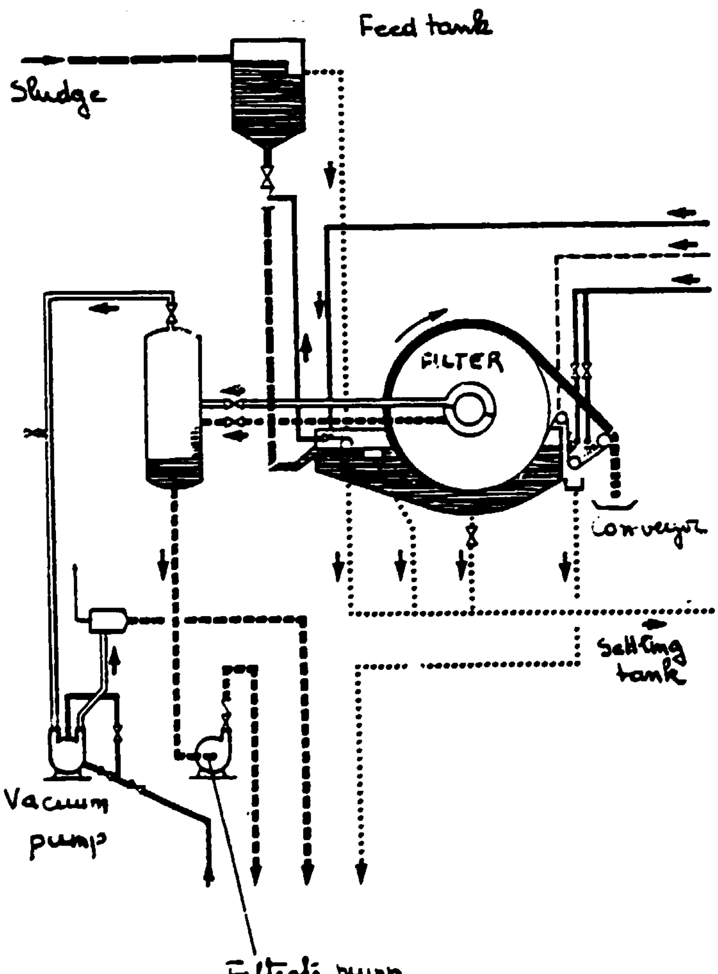
Mechanical thickener



1 Inlet
2 Drive
3 Diffuser
4 Sludge collecting device
5 Sludge withdrawal

VACUUM FILTER

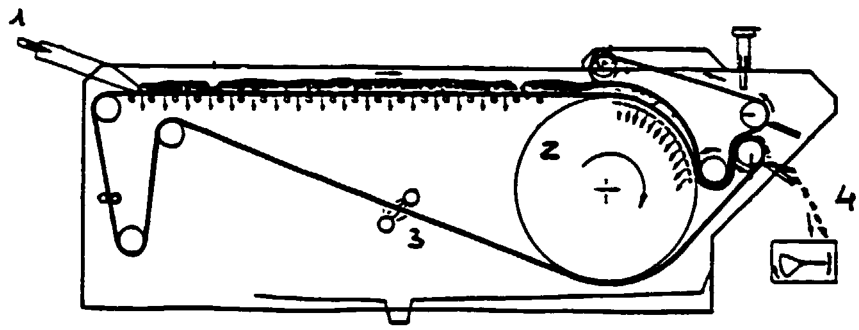


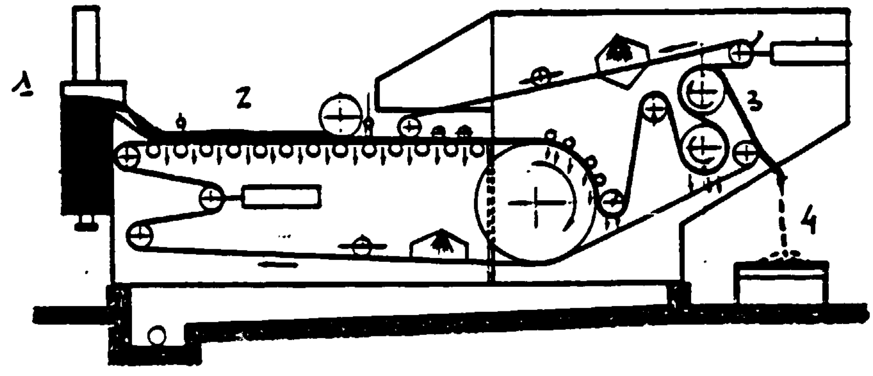


Vacuum filter flow sheet

TYPES OF PRESS BELT FILTERS

1 Sludge
2 Press roller
3 Washers
4 Cakes

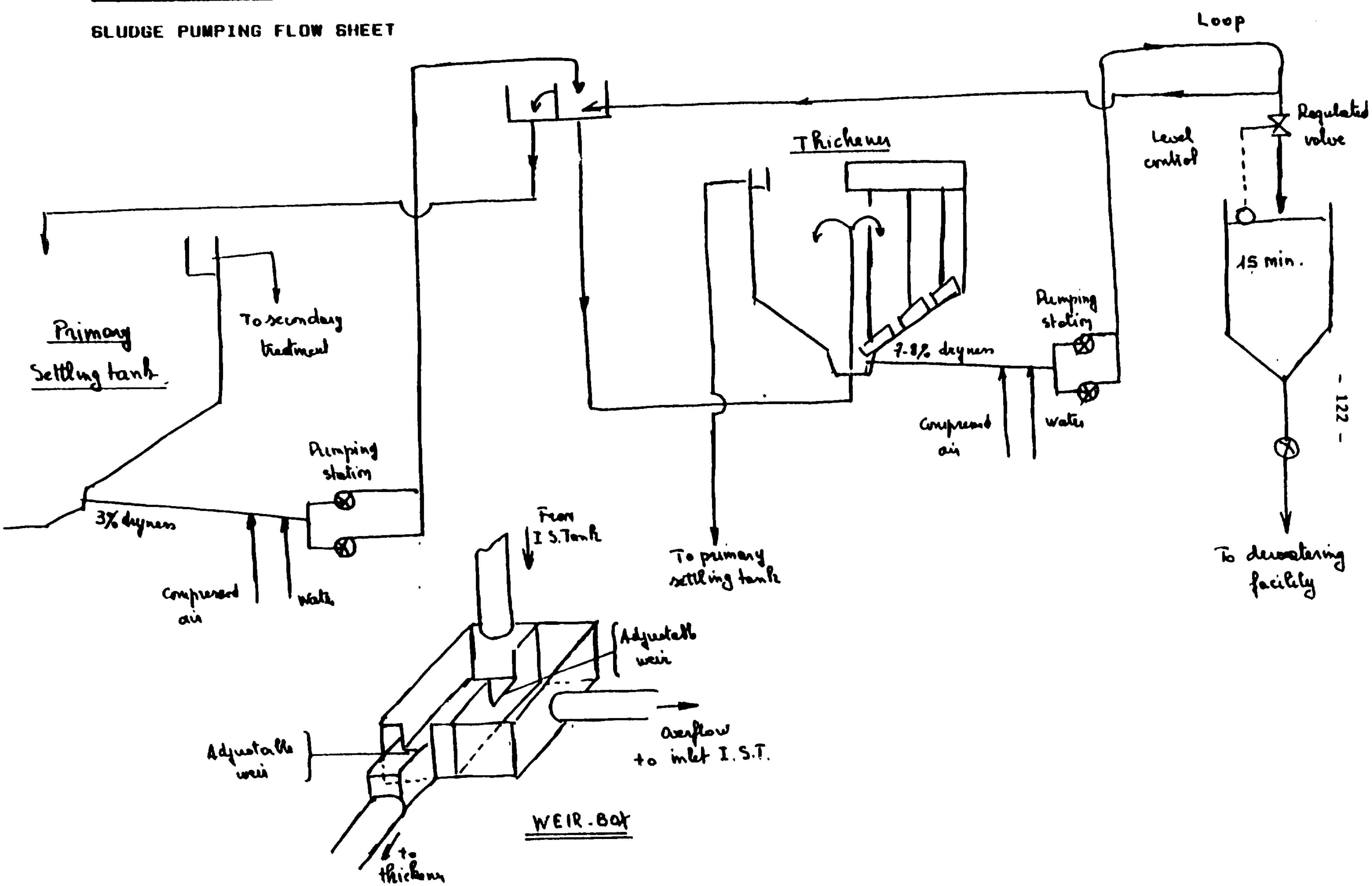




1 Sludge feed
2 Drainage zone
3 Press zone
4 Cakes

APPENDIX C - 15

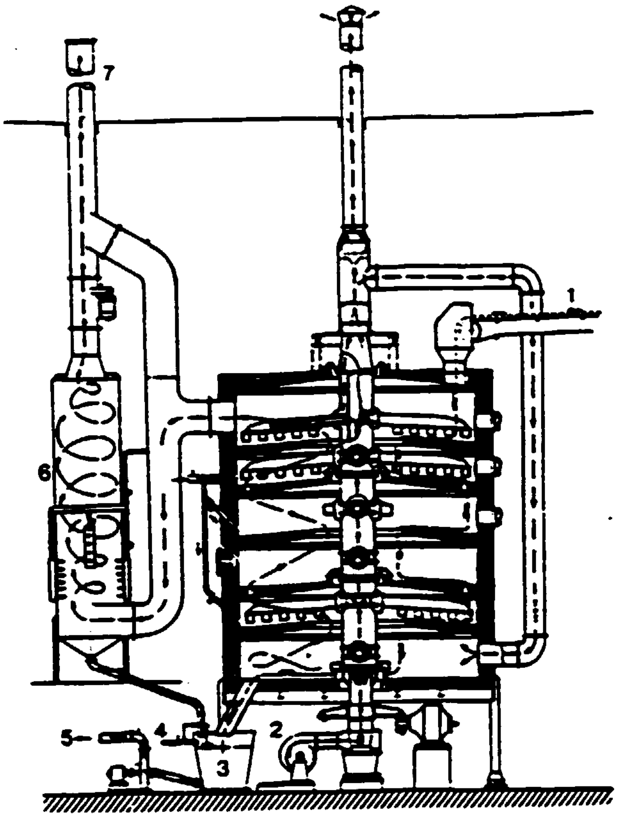
SLUDGE PUMPING FLOW SHEET



APPENDIX C - 16

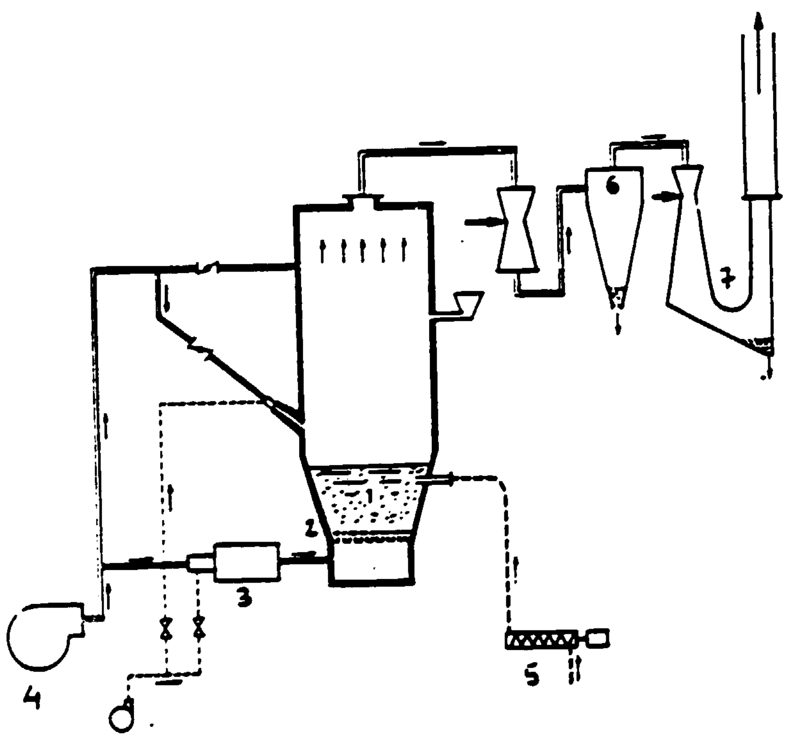
INCINERATORS

Multiple-hearth incinerator



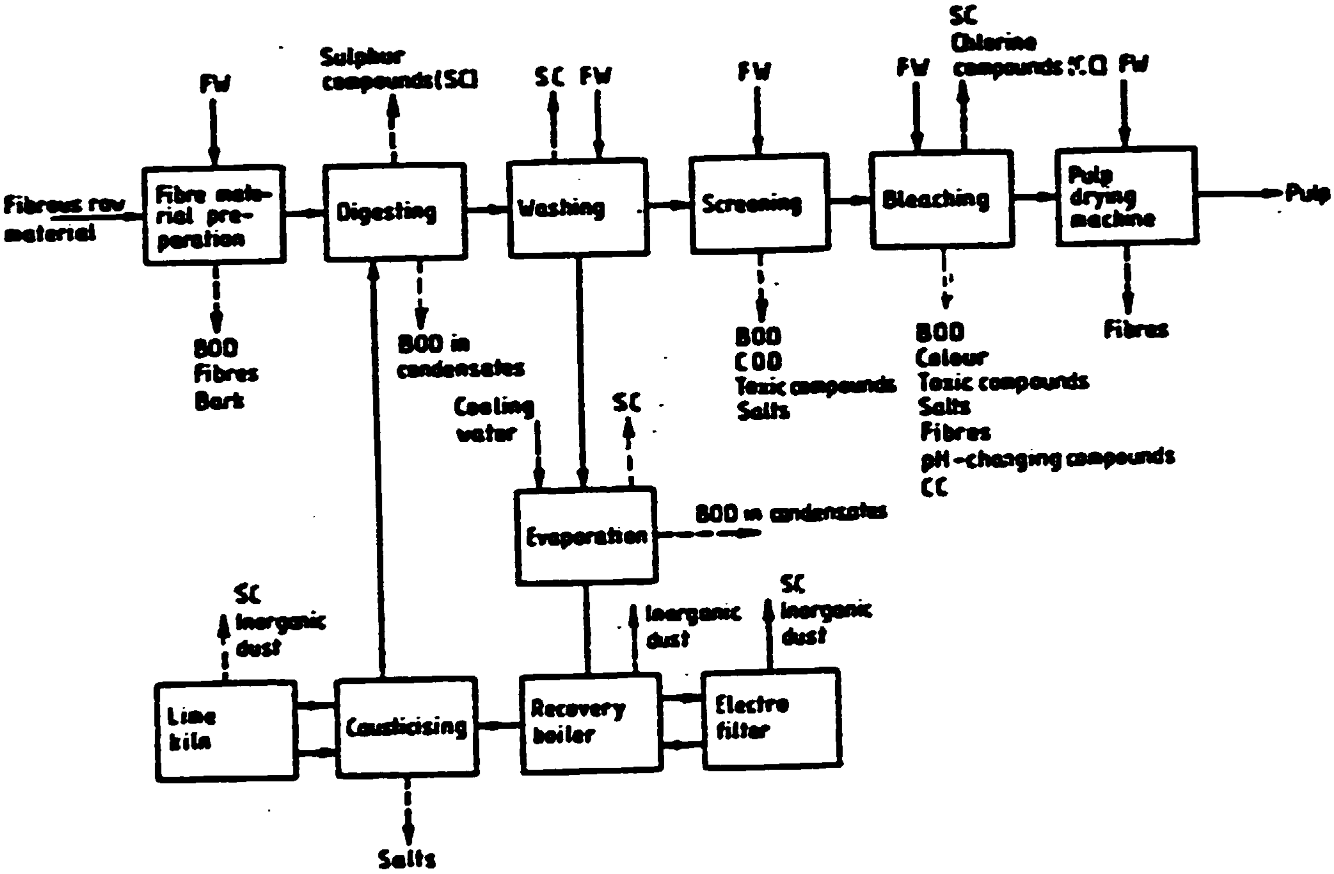
1 Sludge
2 Cooling air
3 Ashes
4 Water make-up
5 Disposal
6 Scrubber
7 Stack

Fluidized bed incinerator



1 Sand
2 Subfloor
3 Heat exchanger
4 Blower
5 Conveyor
6 Cyclone
7 Scrubber

APPENDIX C - 17



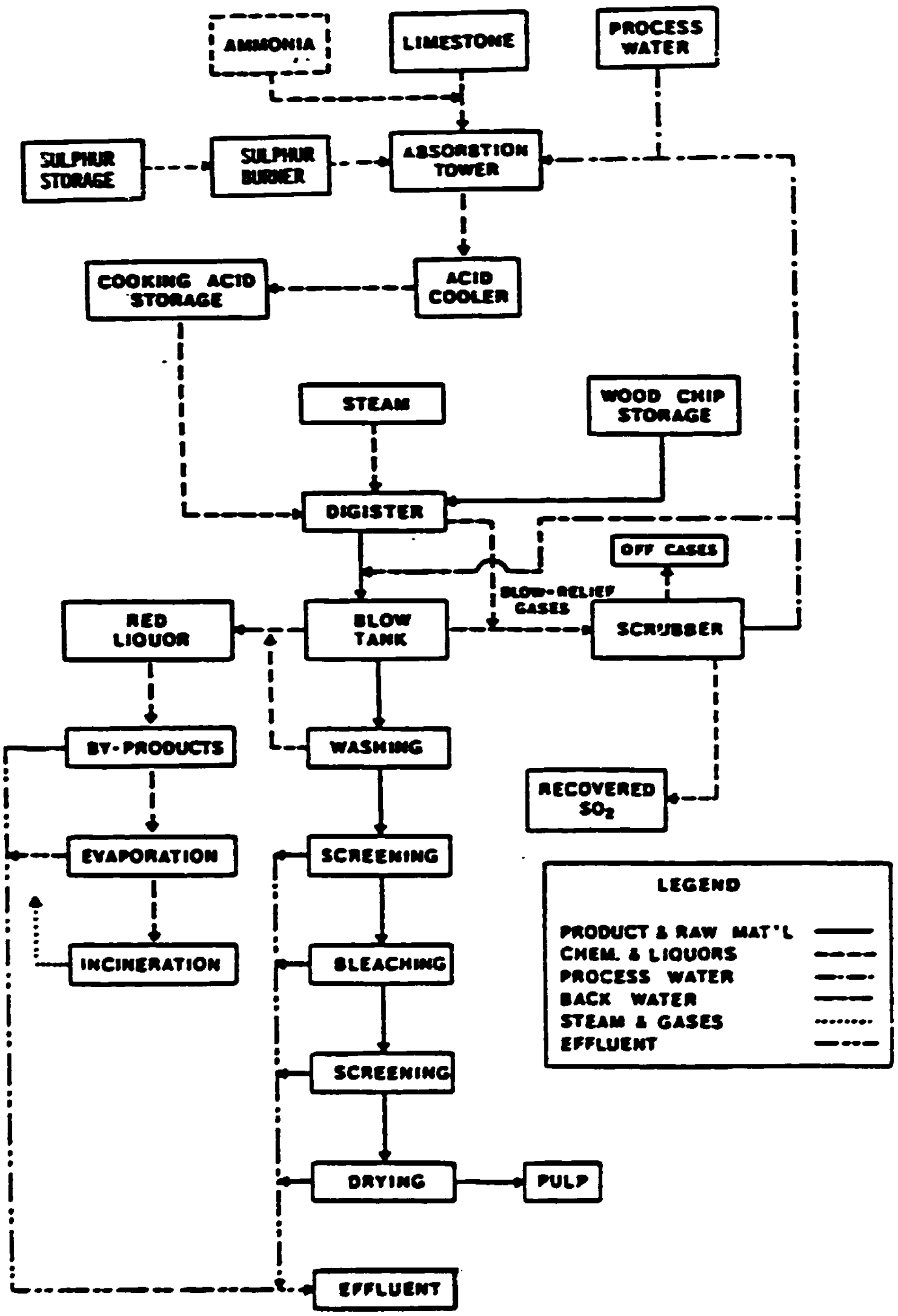
Sulphate pulping process

SC= sulphur compounds

CC= chlorine compounds

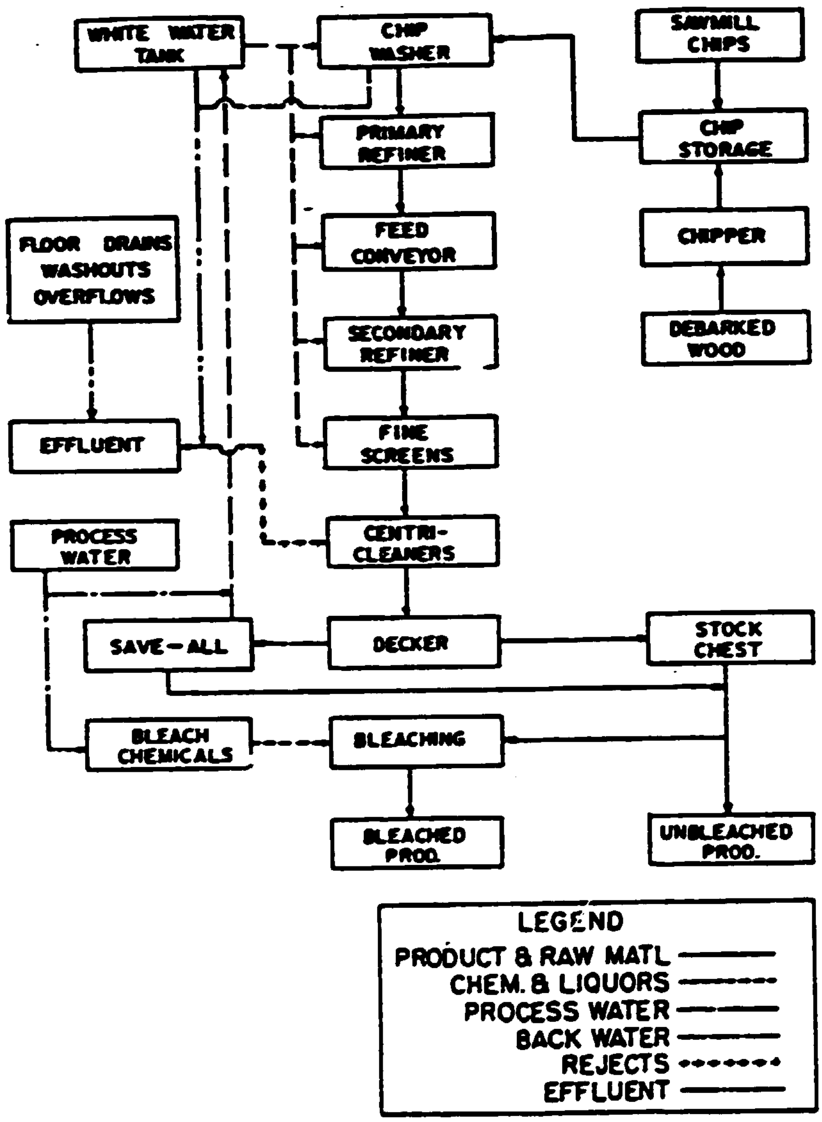
FW= fresh water

APPENDIX C - 18



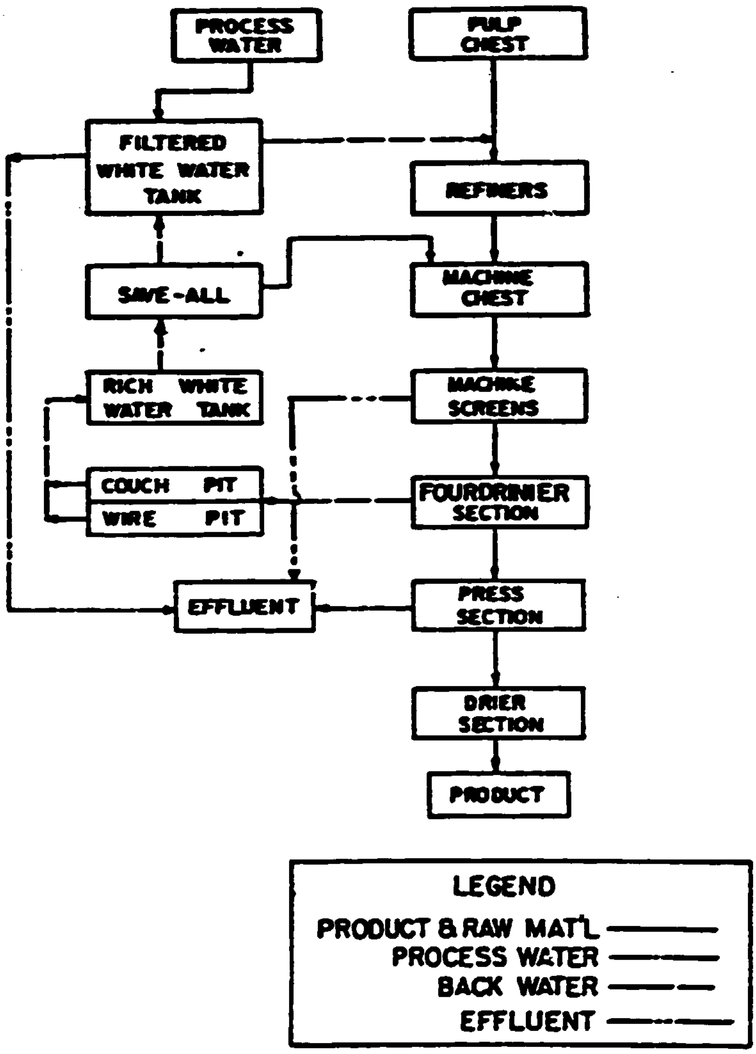
Sulphite pulping process

APPENDIX C - 19



Thermo-mechanical pulping process

APPENDIX C - 20



Papermaking process

APPENDIX C - 21

COMPARISON BETWEEN DIFFERENT SECONDARY TREATMENT METHODS

PARAMETER	STABILIZATION POND	AERATED LAGOON	TRICKLING FILTER	ACTIVATED SLUDGE	CHEMICAL FLOCULATION
Area requirement	very large	large	small	small	small
Loading range kg BOD/M3/d	0.005 - 0.01	0.04 - 0.2	2 - 5	1 - 4	high
BOD reduction %	50 - 80	50 - 90	40 - 75	70 - 95	20 - 40
Equalization requirement	none	none	small	large	none
Equalization capacity	very large	very large	small	small	small
Shock resistance	very high	very high	high	limited	high
Flow variation resistance	high	high	high	rather high	high
Loading variation resistance	very high	very high	high	rather high	high
Effluent quality change resistance	very high	high	high	small	rather small
pH range	wide	wide	small	small	small
Resistance to close down period	good	good	rather good	small	good
Sensitivity to low air temperature	very high	rather high	rather small	small	small
Nutrient requirement (N and P)	small	small	rather small	high	
Sludge production	very small	small	rather large	large	large
Sludge settlability	poor	poor	good	good	rather good
Maintenance requirement	very small	small	small	large	rather small
Dirigibility	small	small	small	large	rather small
Energy demand	small	high	rather high	high	low
Installation costs	low - high	high	rather high	high	low
Operation costs	very low	rather high	rather high	high	high

APPENDIX C - 22

SUGGESTED BIOLOGICAL TREATMENT PATTERNS
(BIODEGRADABLE EFFLUENTS)

AN: anaerobic treatment
T.F. trickling filter
A.L aerated lagoon
A.S. activated sludge