DIRECTORATE OF WATER SUPPLY
DIRECTORATE GENERAL CIPTA KARYA
MINISTRY OF PUBLIC WORKS
REPUBLIC OF INDONESIA

DIRECTORATE GENERAL
INTERNATIONAL COOPERATION
MINISTRY OF FOREIGN AFFAIRS
KINGDOM OF THE NETHERLANDS

# MDP PRODUCTION TEAM

# TRAINING MATERIALS FOR WATER ENTERPRISES

## VOLUME 6A

| | | |
|---|---|---|
| | GUIDE FOR USERS OF TRAINING MATERIALS | |
| ● | TRAINING MODULES | |
| | | GENERAL |
| | | ORGANISATIONAL |
| | | Basic knowledge / skills |
| | | Processes/procedures |
| | | Equipment/materials |
| | ● | TECHNICAL |
| | | Basic knowledge/skills |
| | | Processes/procedures |
| | ● | withdrawal |
| | ● | treatment |
| | | distribution |
| | | consumption |
| | | Equipment/materials |
| | TAPE / SLIDE PROGRAMMES | |



MDP PRODUCTION TEAM

DHV - IWACO - TGI

DIRECTORATE OF WATER SUPPLY
DIRECTORATE GENERAL CIPTA KARYA
DEPARTMENT OF PUBLIC WORKS
GOVERNMENT OF INDONESIA

DIRECTORATE GENERAL
FOR INTERNATIONAL COOPERATION
MINISTRY OF FOREIGN AFFAIRS
GOVERNMENT OF THE NETHERLANDS

MDP PRODUCTION TEAM

# TRAINING MATERIALS FOR WATER ENTERPRISES



## VOLUME 6A
## TRAINING MODULES
## TECHNICAL (Withdrawal + Treatment)

DHV CONSULTING ENGINEERS
IWACO B.V.
T.G. INTERNATIONAL

JAKARTA
APRIL 1985

# P R E F A C E

This volume is part of the Final Report of the MDP Production Team which produced Training Materials for Water Enterprises as part of a project under the bilateral cooperation programme between the Government of the Republic of Indonesia and the Government of the Kingdom of the Netherlands.

This Final Report contains the following volumes:

| | | |
|---|---|---|
| Volume 1 | Guide for users of training materials | |
| Volume 2A | Training Modules, | GENERAL + ORGANIZATIONAL (basic knowledge/skills) |
| Volume 2B | Training Modules, | GENERAL + ORGANIZATIONAL (basic knowledge/skills) |
| Volume 3 | Training Modules, | ORGANIZATIONAL (processes/procedures; equipment/materials) |
| Volume 4 | Training Modules, | TECHNICAL (basic knowledge/skills) |
| Volume 5A | Training Modules, | TECHNICAL (processes/procedures) |
| Volume 5B | Training Modules, | TECHNICAL (processes/procedures) |
| Volume 6A | Training Modules, | TECHNICAL (Withdrawal + Treatment) |
| Volume 6B | Training Modules, | TECHNICAL (Withdrawal + Treatment) |
| Volume 7 | Training Modules, | TECHNICAL (Distribution + Consumption) |
| Volume 8 | Training Modules, | TECHNICAL (equipment/materials) |
| Volume 9 | Tape/slide programmes | |

## TABLE OF CONTENTS

### TRAINING MODULES

| | |
|---|---|
| Module : **THE WATER CYCLE** | Code : TWG 010 |
| | Edition : 21-09-1984 |
| Section 1 : I N F O R M A T I O N  S H E E T | Page : 01 of 01/04 |

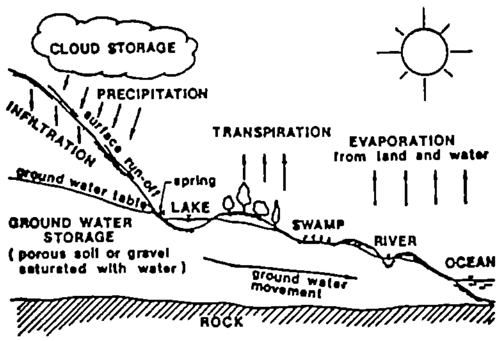
| | |
|---|---|
| Duration : | 45 minutes. |
| Training objectives : | After the session the trainees will be able to :<br>- list the basic principles of the water cycle. |
| Trainee selection : | - All jobholders. |
| Training aids : | - Viewfoils : TWG 010/V 1;<br>- Handout : TWG 010/H 1. |
| Special features : | - |
| Keywords : | Water cycle. |

| Module : THE WATER CYCLE | Code : TWG 010 |
|---|---|
| | Edition : 21-09-1984 |
| Section 2 : S E S S I O N   N O T E S | Page : 01 of 01 |

| | |
|---|---|
| **1. Introduction** | |
| - The water cycle is a complete natural cycle in which water is conserved in one way or another;<br>- Water Enterprise, to supply drinking water, interrupts this water cycle. | Show V 1 |
| **2. Rainfall** | |
| - Some clouds are rain bearing;<br>- Precipitation (rain) occurs when warm moist clouds are cooled (e.g. over hills);<br>- Rain falls to the ground. | |
| **3. Surface Water** | |
| - Most rain runs off the surface into streams, rivers and lakes;<br>- Some rain percolates through the soil;<br>- There it is stored in porous soil or rock. | |
| **4. Water Losses** | |
| - Evaporation losses from rivers, streams and lakes;<br>- Ground water in porous rock can flow to the sea;<br>- Large evaporation losses from the sea. | |
| **5. Cloud Formation** | |
| - Evaporation losses are in the form of warm moisture which rises.<br>- Clouds are cooled at higher altitudes.<br>- Cloud formation starts the water cycle all over again. | |
| **6. Summary** | Give H 1 |

| Module : THE WATER CYCLE | Code : TWG 010 |
|---|---|
| | Edition : 21-09-1984 |
| Section 3 : T R A I N I N G   A I D S | Page : 01 of 01 |

The water cycle TWG 010/V 1




THE WATER CYCLE

The water cycle TWG 010/H 1

The water cycle is a continuous natural process and water is conserved in one form or another throughout the entire process.

Rain bearing clouds are formed which are essentially moist warm water vapour. When these clouds are cooled, usually when rising over hills or mountains, the water vapour precipitates in the form of rain.
The rain falls to the ground and either drains off as surface water through streams, rivers and lakes towards the sea or percolates through porous soil and rock to be stored underground. The water is lost either by the stored groundwater flowing to the sea or, more normally, by evaporation from the streams, rivers and lakes or the sea.

Most evaporation losses occur through the sea.
The evaporated water in the form of vapour rises to form clouds and the whole water cycle starts again.

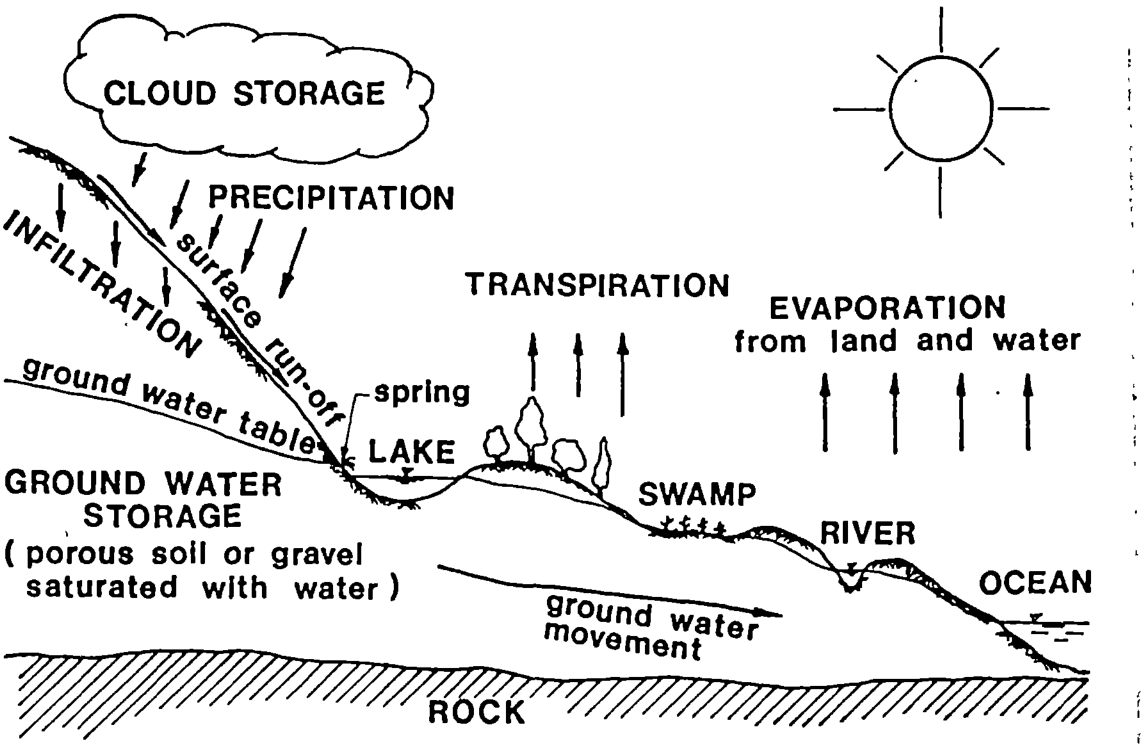
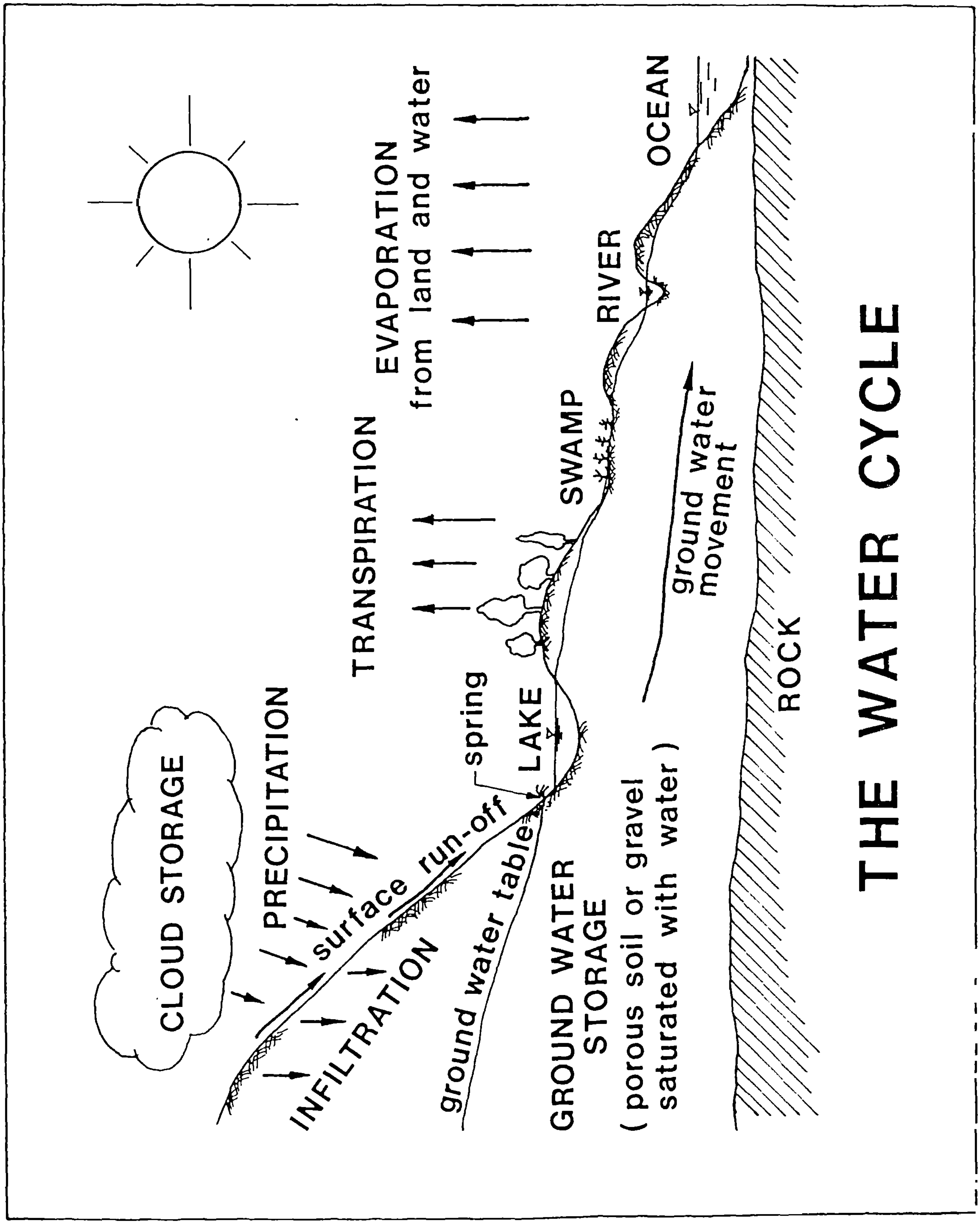



*Fig. 1. The water cycle.*

| TITLE : | CODE : |
|---|---|
| 1. The water cycle | TWG 010/V 1 |


THE WATER CYCLE
CLOUD STORAGE
PRECIPITATION
surface run-off
INFILTRATION
ground water table
spring
LAKE
TRANSPIRATION
EVAPORATION
from land and water
SWAMP
RIVER
OCEAN
GROUND WATER STORAGE
( porous soil or gravel
saturated with water )
ground water
movement
ROCK

| | |
|---|---|
| Module : **SURFACE WATER ABSTRACTION METHODS** | Code : TWG 023 |
| | Edition : 19-03-1985 |
| Section 1 : **I N F O R M A T I O N   S H E E T** | Page : 01 of 01/13 |

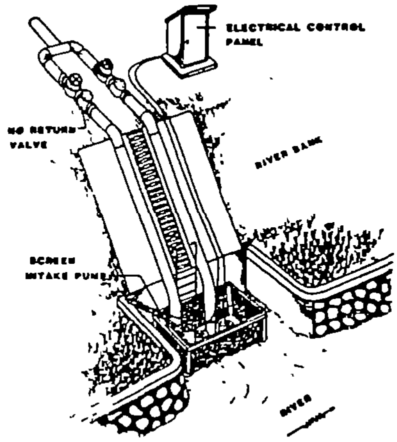
| | |
|---|---|
| Duration : | 45 minutes. |
| Training objectives : | After this session the trainees will be able to:<br>- describe principles of raw water supply;<br>- recognize the various types of intakes. |
| Trainee selection : | - Head of Section Production;<br>- Head of Sub Section Water Treatment;<br>- Water Treatment Plant Operat...<br>- Intake Attendant. |
| Training aids : | - Viewfoils : TWG 023/V 1-6;<br>- Handout : TWG 023/H 1. |
| Special features : | - |
| Keywords : | Surface water abstraction/water intake/screen/ pump compartment/rotameter. |

| | |
|---|---|
| **1. Raw water supply** | |
| - Raw water abstraction comprises the elements:<br>. raw water source (river or lake);<br>. intake;<br>. flow measuring and control;<br>. piping. | Use whiteboard |
| **2. Aims of raw water supply** | |
| - The aims of raw water supply are:<br>. to supply raw water to the purification plant.<br>. to control the amount of water stored in the clear water reservoir.<br>. to elevate the water to a level from which it can flow by gravity through the purification plant. | |
| **3. Intake** | |
| - Location: at or very close to the source. | |
| - The intake is constructed of:<br>. concrete;<br>. batu kali (cement bounded river strokes);<br>. wood;<br>. steel. | Give V 1-3 |
| - The elements of the intake are:<br>. inlet to pump compartment;<br>. screen;<br>. 2 or more pumps;<br>. check valves;<br>. gate valves;<br>. flow control valve;<br>. air release valve;<br>. control panel;<br>. piping with fittings. | |

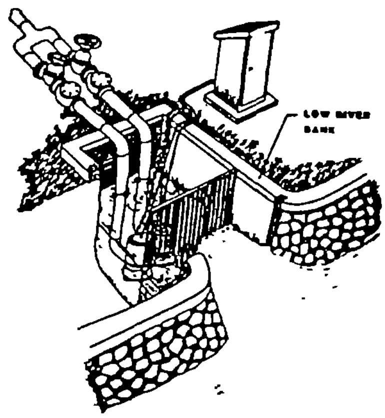
| | |
|---|---|
| **4. Principle of intake** | |
| - Principles of raw water intake are:<br>. abstraction of raw water;<br>. retaining coarse floating matter;<br>. supplying a sufficient quantity of raw water to purification plant. | |
| - Water level in river/lake is changing due to meteorological influences. | |
| - Coarse floating matter has to be retained by means of a screen. | |
| - More intake pumps are needed for a continuous supply. | |
| - Sand and mud settles in pump compartment so regular cleaning is necessary. | |
| - River water flow is known by measuring the water level. | |
| - Pumped water flow is measured. | |
| **5. Types of intakes** | |
| - The four most common types of intakes are:<br>. for shallow rivers;<br>. for middle deep rivers;<br>. for rivers with high and steep banks;<br>. for flooded banks/crossing dykes. | Show V 1-4 |
| **6. Raw water flow control** | Show V 5-6 |
| - The raw water flow can be measured by:<br>. rotameter;<br>. stilling well with V-notch;<br>and controlled by:<br>. flow control valve. | Write keywords on whiteboard |
| **7. Summary** | Give H 1 |

| Module : SURFACE WATER ABSTRACTION METHODS | Code : TWG 023 |
| --- | --- |
| | Edition : 19-03-1985 |
| Section 3 : T R A I N I N G   A I D S | Page : 01 of 02 |

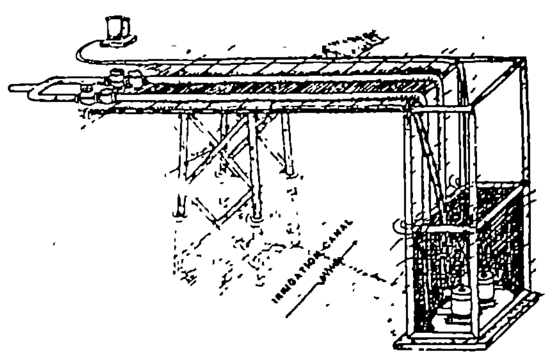
**Intake I** — TWG 023/V 1



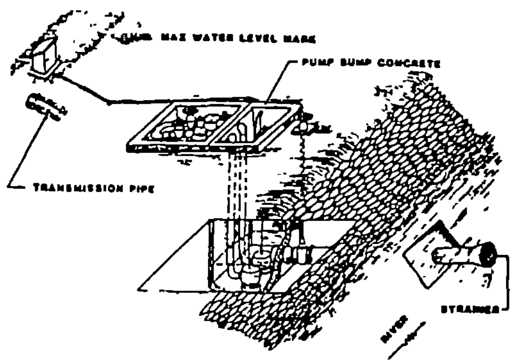

**Intake II** — TWG 023/V 2



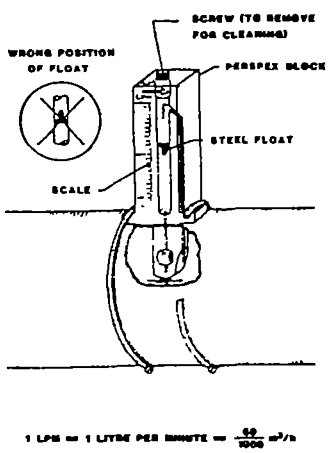

**Intake at irrigation canal** — TWG 023/V 3



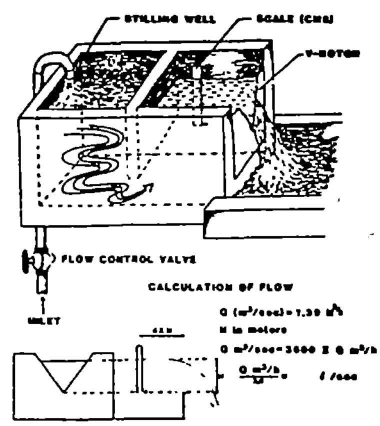

**Intake at flooded bank** — TWG 023/V 4




**Rota/pitot meter** — TWG 023/V 5




**Stilling well and V-notch** — TWG 023/V 6



| | |
|---|---|
| | |
| | |
| | Surface water abstraction methods TWG 023/H 1 |

## 1. INTRODUCTION

Raw water abstraction comprises the following elements:
- Raw water source (lake or river).
- Intake.
- Flow measuring and control.
- Piping.

## 2. OBJECTIVES OF RAW WATER ABSTRACTION

Purposes are:
- To supply raw water to the water purification plant(s).
- To control the amount of water delivered, which should comply with the water demand.
- To raise the raw water to a level, from wich it can flow by gravity through the purification plant into the ground reservoir.

## 3. INTAKE

The intake consists of a structure, containing intake pumps and screens for the abstraction of water from the river or lake.
The amount of water taken in must be enough to provide the purification plant with sufficient raw water under all circumstances.

The purposes of the intake are:
- To abstract water from the river at an amount which covers the water demand.
- To retain coarse and floating matter, thus preventing damage to pumps, piping and ancillaries.
- To supply raw water to the water purification plant during 24 hours a day.

## 4. PRINCIPLES OF INTAKE

A natural river always has a varying flow of water.

The water level frequently changes, because of meterological influences (rainy and dry seasons) or artificial river flow control (e.g. weirs, sluices).

When the water level is above a certain minimum, the river water will flow into the pumping compartment of the intake, where it reaches the inlet of the pumps.

On its way, the water passes a screen, retaining coarse solid matter, which might damage and clog pumps, pipes and valves.

Normally more than one intake pump is installed to make sure that river water can be pumped to the treatment facilities when one of the pumps is out of order. Normally, one pump is stand-by, the other pump(s) transport(s) the raw water with the full capacity from the intake to the treatment plant.

The raw water contains sand and mud, which will settle in the pumping compartment of the intake. If the accumulation of sand and mud is voluminous, it might clog the inlet of the pumps.
Therefore, provisions should be made to remove accumulated sand and mud regularly, either mechanically or manually.

To calculate the flow of the river, by measuring the water level in the river, a reading scale must be installed.
For measurement the amount of water pumped by the intake pumps, flow measuring equipment must be installed.
Such equipment can be a Thompson V-notch or a rotameter.

## 5. TYPES OF INTAKE

The four most common types of intakes are intakes for:
- a steep river bank;
- a low stable river bank;
- an irrigation channel;
- a flooded bank.

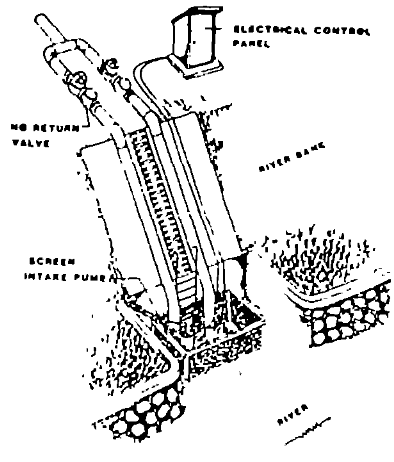



*Fig. 1. Intake on steep river bank.*

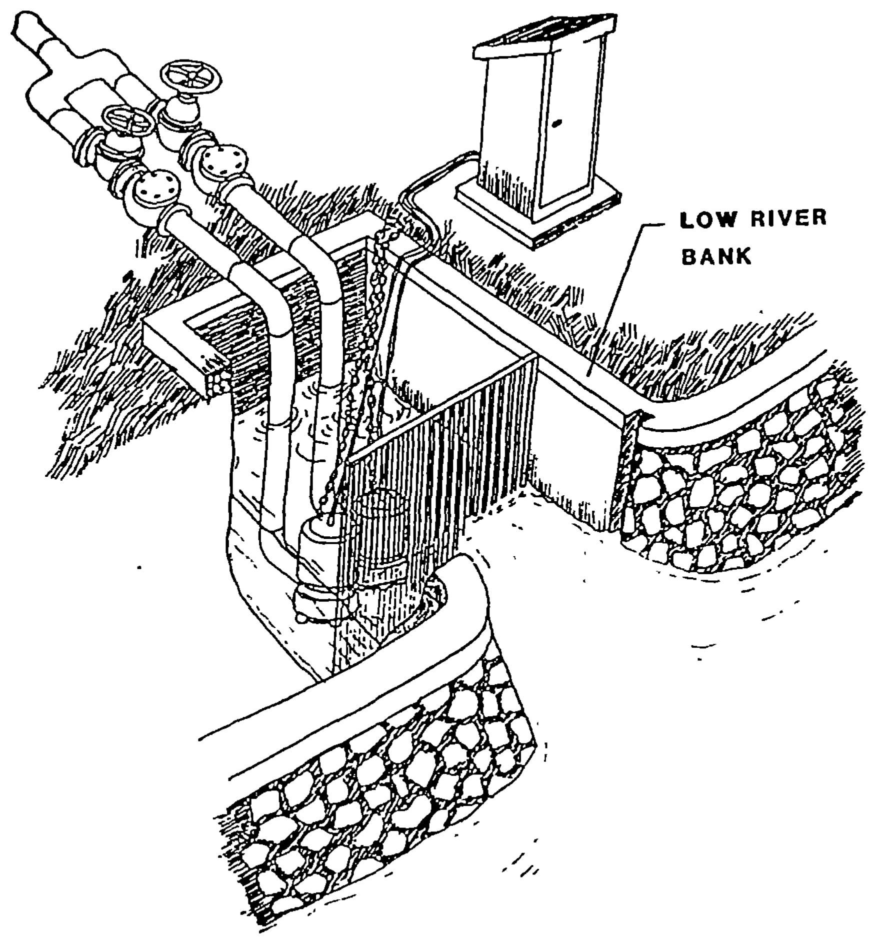



*Fig. 2. Intake on low, stable river bank.*

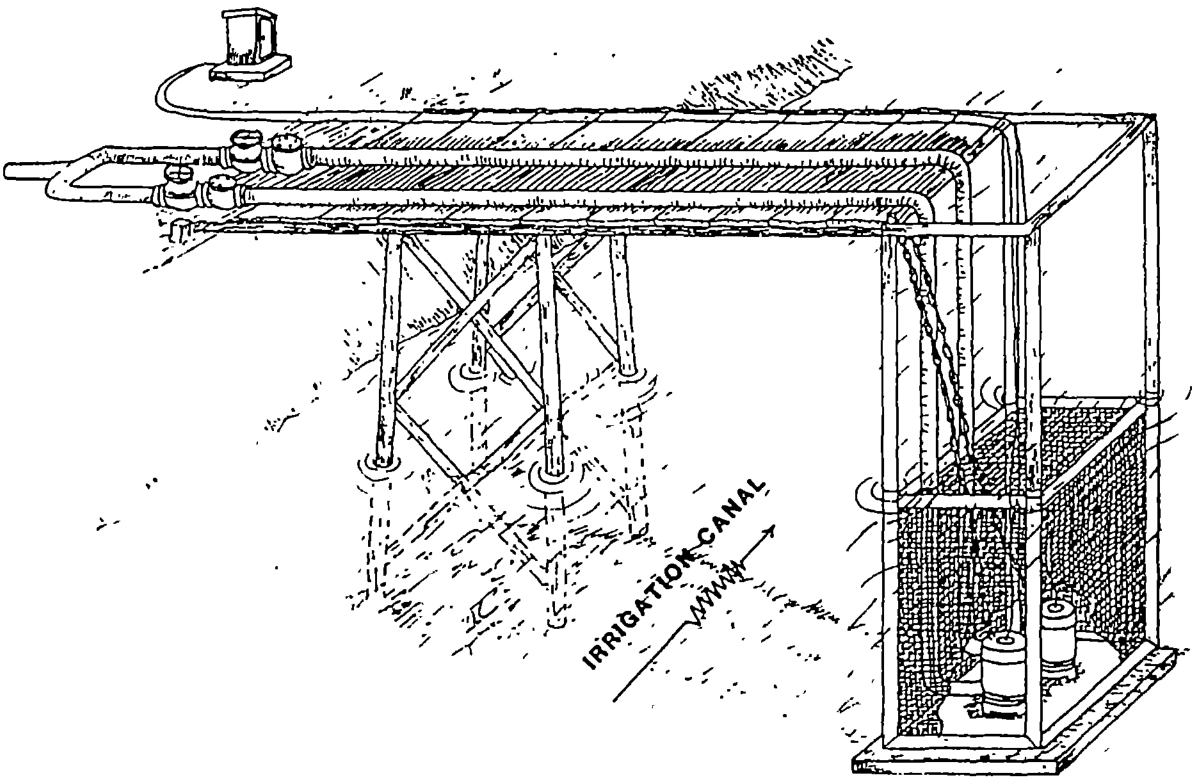



*Fig. 3. Intake in irrigation channel.*

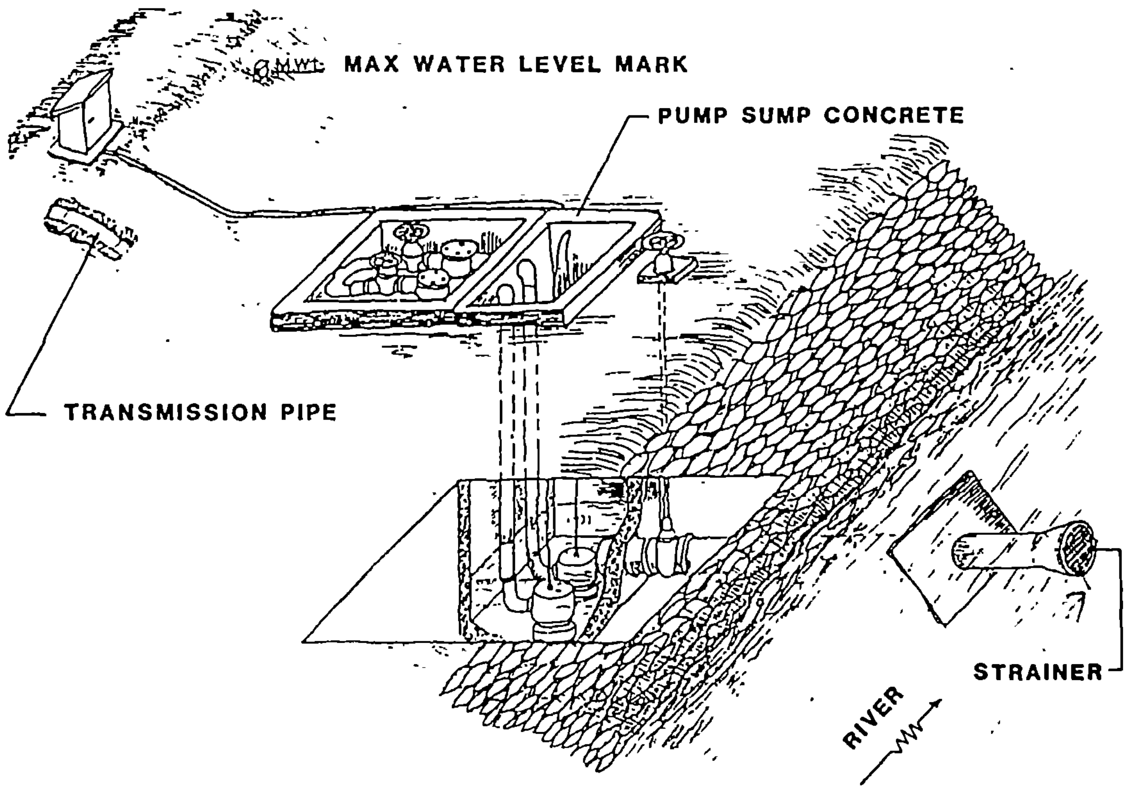
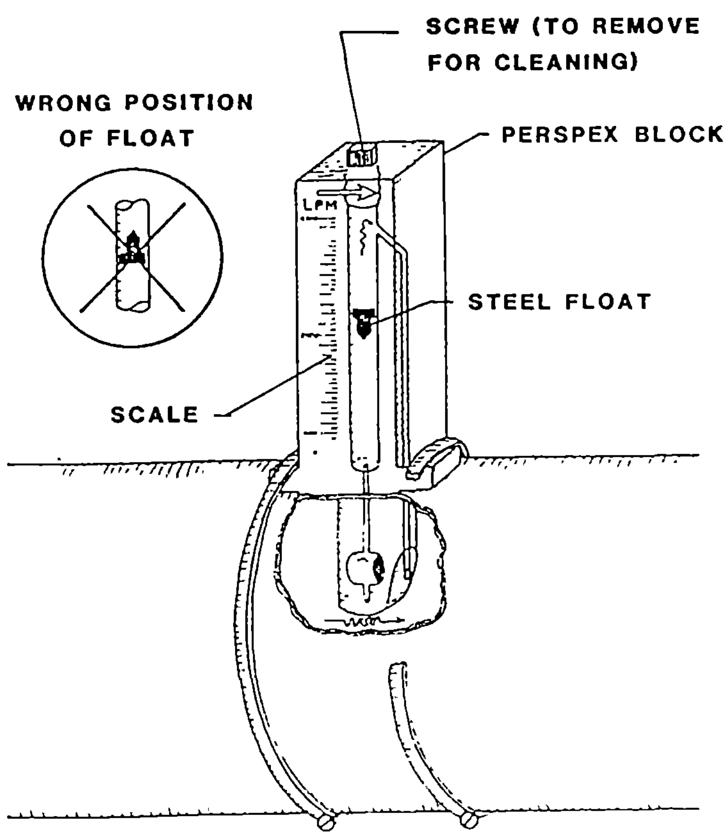



*Fig. 4. Intake on flooded river bank.*

## 6. RAW WATER FLOW MEASUREMENT AND CONTROL

The capacity of the running intake pump(s) can be controlled by turning the main valve in the transmission pipe that connects the intake pumps with the purification plant.
When the valve is fully opened the maximum flow is reached.
On the pipeline from intake to plant, a water flow meter such as a rotameter, or a V-notch with a stilling well has to be installed.

- The rotameter directly indicates the flow in the transmission pipe in litres per minute.
  In the meter a small part of the main water stream flows upward through a vertically installed perspex tube, provided with a reading scale.
  At the small part of the main water stream is proportional to the main flow, the main flow can be calculated.




1 LPM = 1 LITRE PER MINUTE = $\frac{60}{1000}$ $m^3/h$

*Fig. 5. Rotameter.*

- A V-notch with a stilling well consists of a compartment in which the water can quietly flow to a typically shaped weir (V-notch), over which it is discharged.
  The water level is measured upstream of the weir and must be converted into the flow by calculating the formula.

  $Q = 0.00139\ H^{(5/2)}$ [l/s], where H is the overflow level of the water above the point of the V-notch, in [m].

By reading the flow meter and turning the flow control valve, the desired raw water flow can be adjusted.

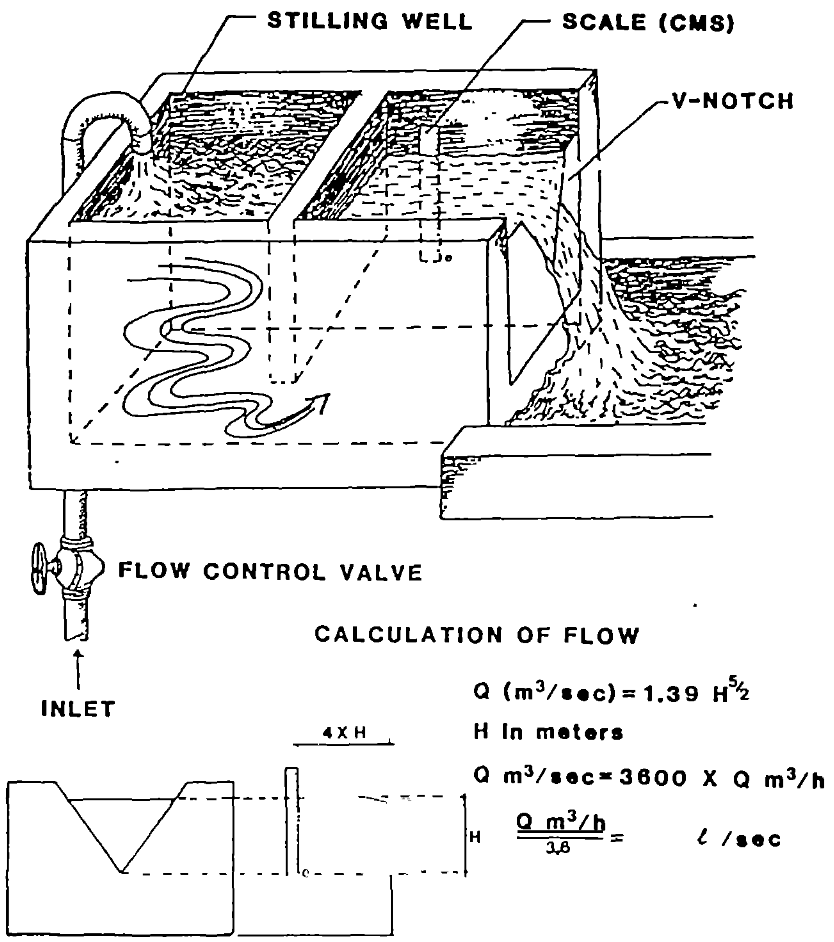
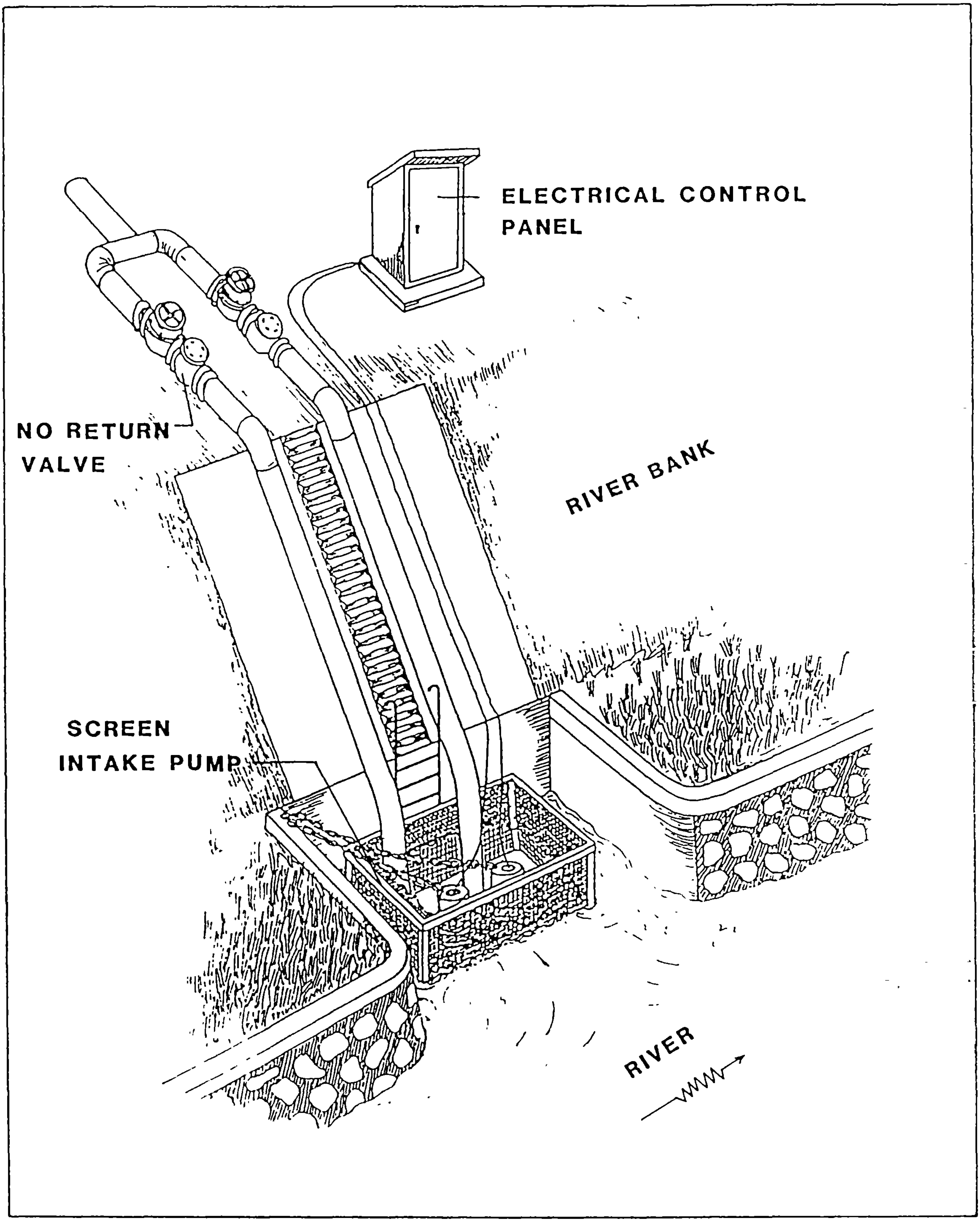


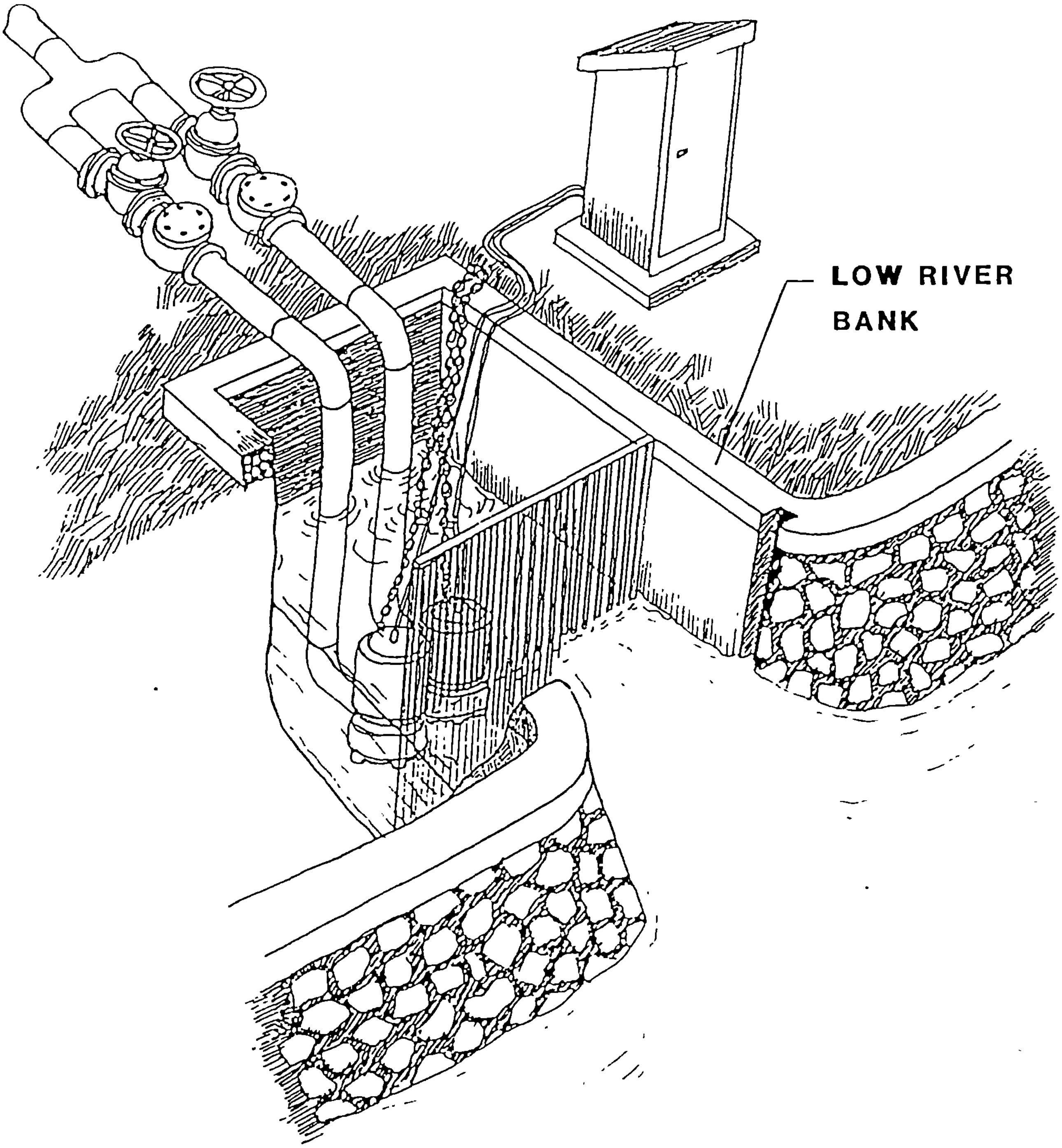

*Fig. 6. Stilling well and V-notch.*

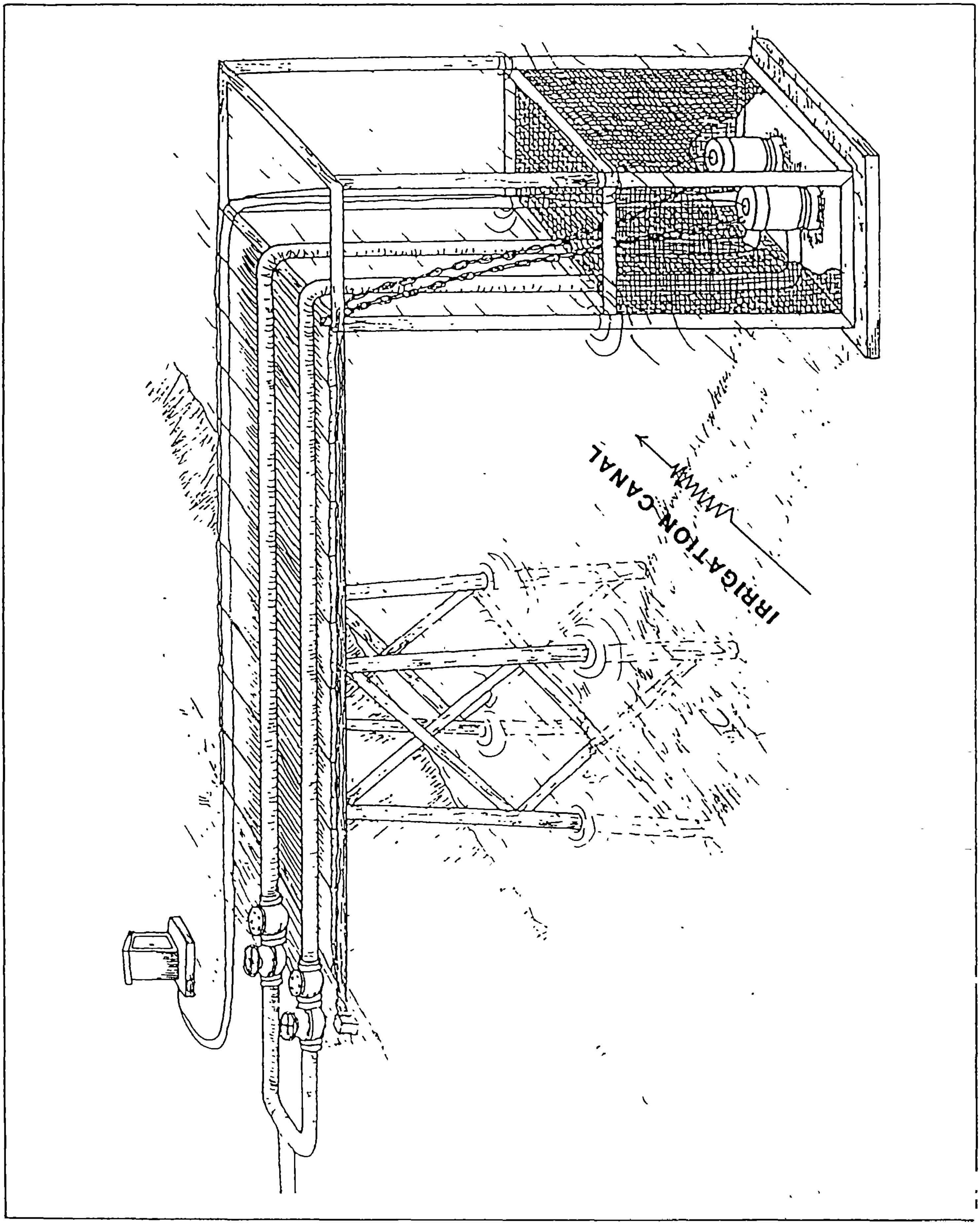
## 7. SUMMARY

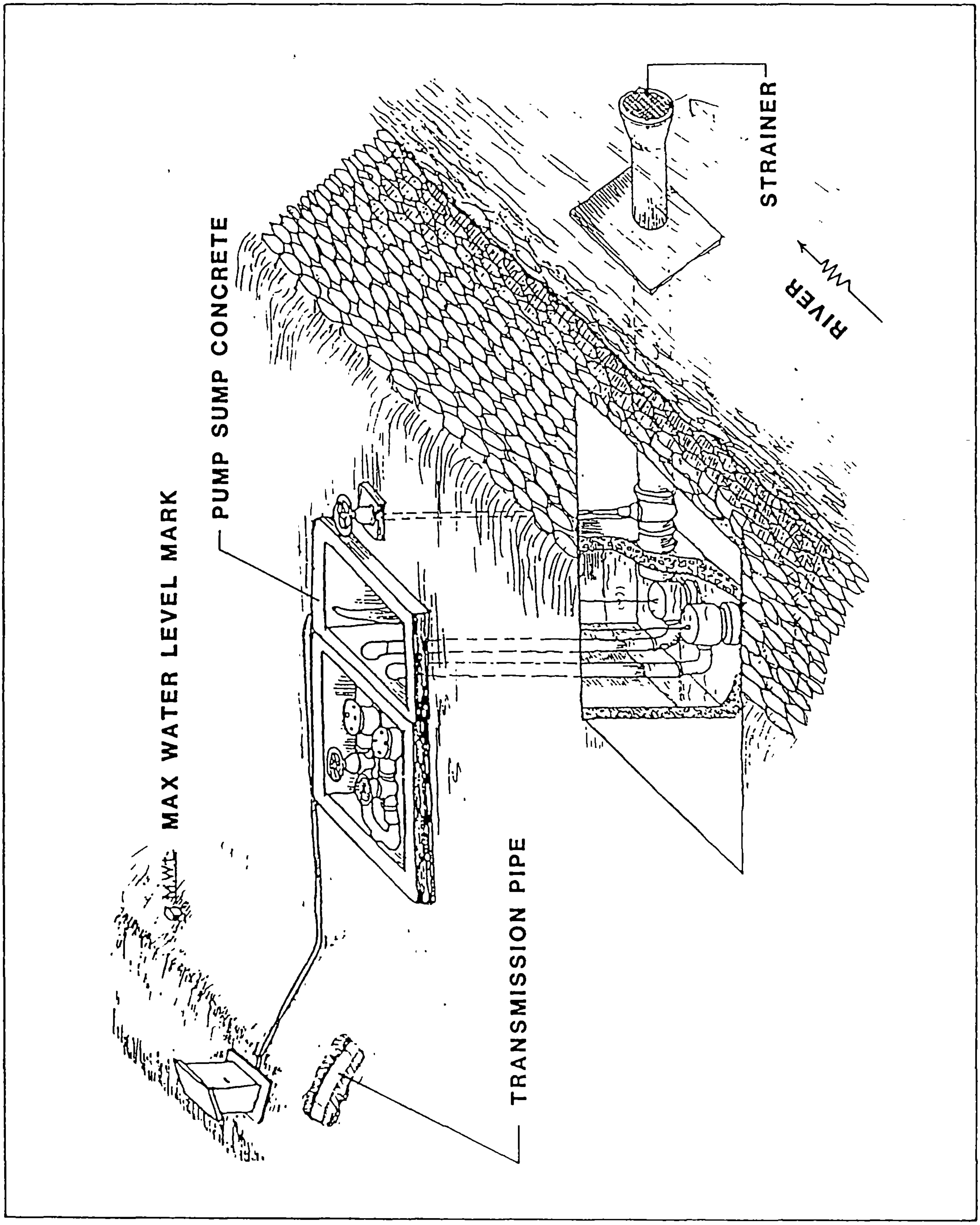
- The main elements of surface water abstraction are:
  - . raw water source;
  - . intake (of several types);
  - . flow measuring and control;
  - . piping and fittings.

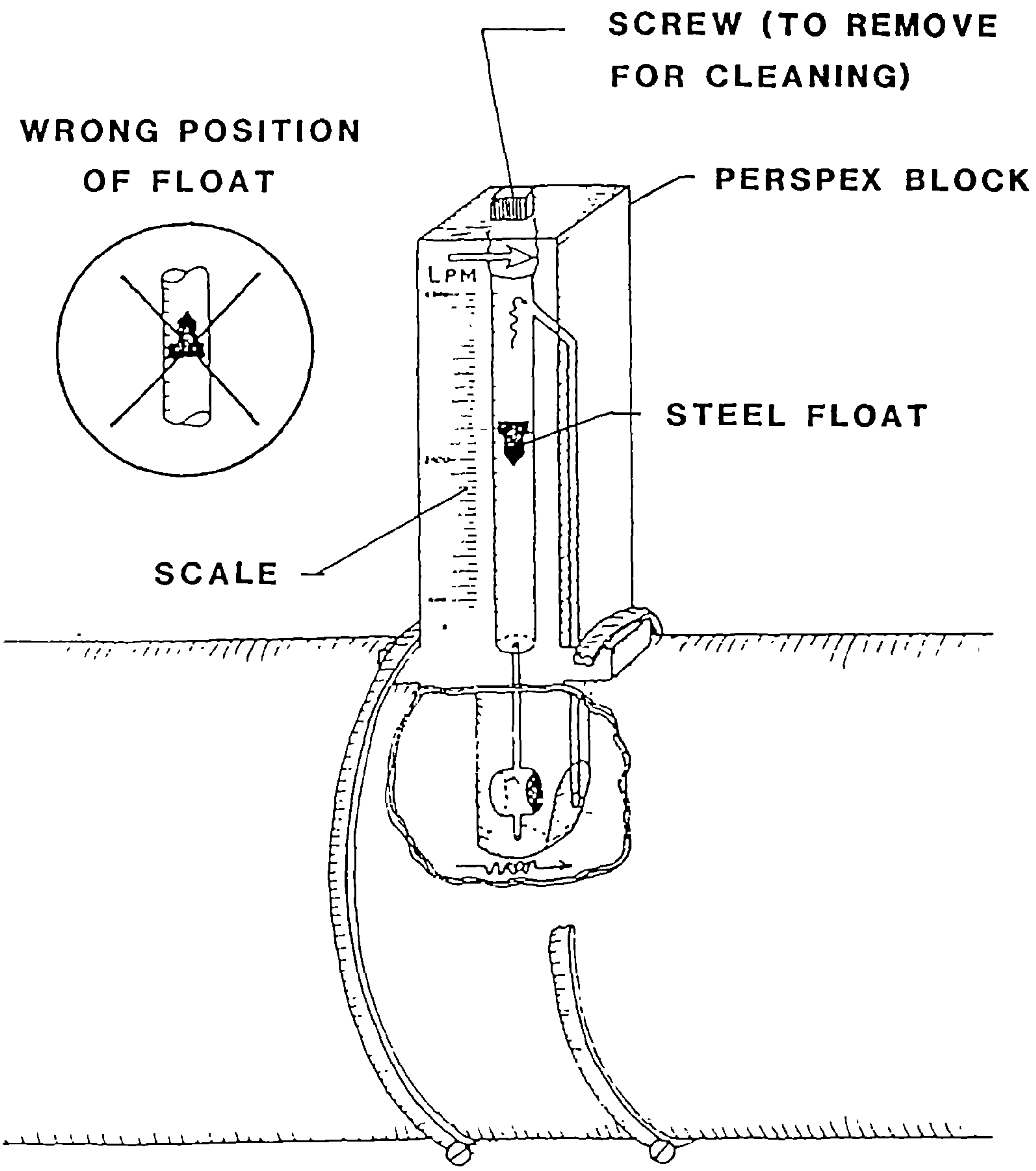
* * *


ELECTRICAL CONTROL PANEL
NO RETURN VALVE
RIVER BANK
SCREEN
INTAKE PUMP
RIVER

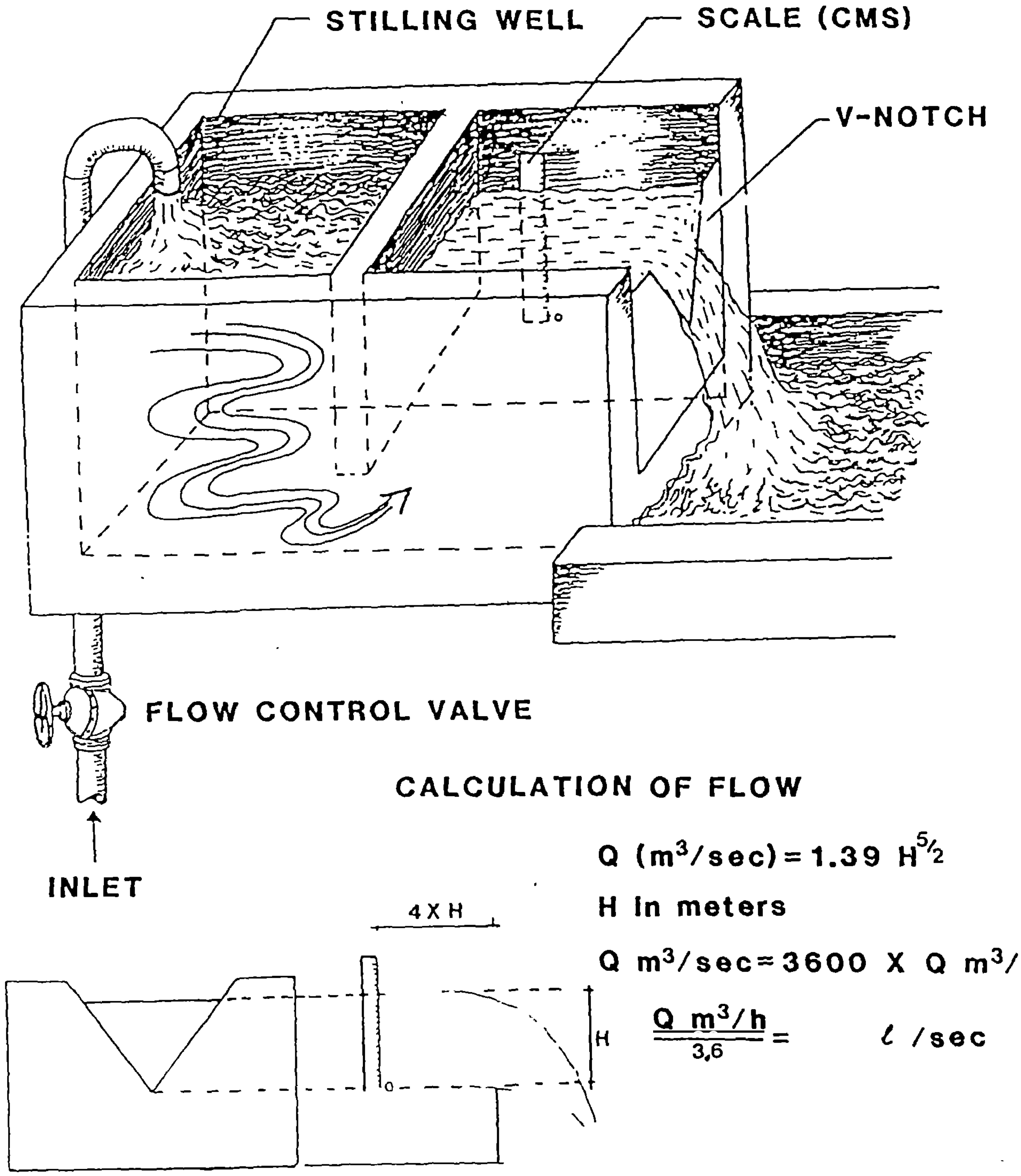

LOW RIVER
BANK


IRRIGATION CANAL


STRAINER
RIVER
PUMP SUMP CONCRETE
MAX WATER LEVEL MARK
MWL
TRANSMISSION PIPE




$$1 \text{ LPM} = 1 \text{ LITRE PER MINUTE} = \frac{60}{1000} \text{ m}^3/\text{h}$$




**CALCULATION OF FLOW**

$Q\ (m^3/sec) = 1.39\ H^{5/2}$

H in meters

$Q\ m^3/sec = 3600\ X\ Q\ m^3/$

$\frac{Q\ m^3/h}{3,6} = \quad \ell\ /sec$

| Module : EVALUATION OF WATER SOURCES | Code : TWG 030 |
|---|---|
| | Edition : 19-03-1985 |
| Section 1 : INFORMATION SHEET | Page : 01 of 01/10 |

| | |
|---|---|
| Duration : | 45 minutes. |
| Training objectives : | After the session the trainees will be able to :<br>- evaluate the quality of groundwater and surface water;<br>- list the requirements for treatment of groundwater as well as surface water in case water quality standards are exceeded. |
| Trainee selection : | - Head of Technical Department;<br>- Head of Section Planning & Supervision;<br>- Head of Section Production;<br>- Head of Sub-section Water Treatment;<br>- Head of Sub-section Planning. |
| Training aids : | - Viewfoils : TWG 030/V 1-2;<br>- Handout : TWG 030/H 1. |
| Special features : | - |
| Keywords : | Shallow, deep and artesian groundwater/surface water/water quality improvement. |

| | |
|---|---|
| 1. **Groundwater** | |
| - The following groundwater sources can be distinguished:<br>. shallow groundwater;<br>. deep groundwater;<br>. artesian groundwater. | Use white board |
| - The water quality of the source must be compared with the drinking water standards this gives the following possibilities.<br>. all parameters are within the limits stated as preferable no water treatments is required;<br>. the parameters are in the range "acceptable - preferable" improvement has to be taken into consideration;<br>. some parameters exceed the level "maximum - acceptable" : improvement by water treatment will be necessary. | Use white board |
| - Contaminants, mostly present in shallow, deep and artesian groundwater are:<br>. aggressive $CO2$;<br>. iron and mangenese;<br>. ammonia;<br>. salt. | Use white board |
| - With the exception of shallow groundwater, groundwater is usually free from bacteriological contamination. | |
| - Review of the most common quality improvement processes:<br>. removal of colour caused by iron by aeration and filtration, otherwise by coagulation and contact filtration;<br>. raising the pH by aeration or by lime dosing;<br>. removal of iron by aeration followed by filtration;<br>. removal of mangenese by filtration;<br>. removal of ammonia by breakpoint chlorination;<br>. raising the oxygen content by aeration;<br>. removal of aggressive $CO_2$ by aeration, dosing of lime or marble filtration. | Show V 1 |

## 2. Surface water

- Surface water comprises all waters present at the surface of the earth. This includes: *(Use white board)*
  . rivers;
  . irrigation canals;
  . lakes;
  . small brooks.

- To evaluate surface water sources, water quality data over extended periods (one year or more) must be compared with drinking water standards. This gives the following possibilities: *(Use white board)*
  . the results are within the limits stated as "preferable" : the water can be used directly for drinking water purposes;
  . the results are in the range "acceptable - preferable" : improvement has to be taken into consideration;
  . some parameters exceed the "maximum acceptable" standard frequently: water treatment is required.

- Most commonly the following parameters must be corrected: *(Show V 2)*
  . suspended solids;
  . turbidity and colour;
  . ammonia content;
  . micro-organisms.

- Review of the most common quality improvement processes. *(Show V 2)*
  . removal of colour by coagulation/flocculation followed by sedimentation and/or rapid filtration;
  . removal of suspended solids by sedimentation;
  . removal of turbidity by coagulation/flocculation followed by sedimentation and/or rapid filtration;
  . removal of ammonia by breakpoint chlorination;
  . removal of micro-organisms by chlorination or slow sand filtration. *(Give H 1)*

Groundwater quality improvement processes — TWG 030/V 1

| PARAMETERS NORMALLY EXCEEDING THE STANDARDS FOR GROUND WATER | RECOMMENDED TREATMENT PROCESS |
|---|---|
| •Colour caused by iron | Aeration /filtration |
| •Low pH | Aeration or lime dosing or marble filtration |
| •High $CO_2$ content | Aeration or lime dosing or marble filtration |
| •High iron content | Aeration/filtration |
| •High manganese content | Filtration |
| •High ammonia content | Chlorination |
| •Low oxygen content | Aeration |

Surface water quality improvement processes — TWG 030/V 2

| PARAMETERS NORMALLY EXCEEDING THE STANDADS FOR SURFACE WATER | RECOMMENDED TREATMENT PROCESS |
|---|---|
| • Colour | Coag /Flocc/ Sedimentation; Coag /Flocc / Rapid Filtration |
| • Turbidity | Coag /Flocc/ Sedimentation; Coag /Flocc / Rapid Filtration |
| • Suspended Solids | Sedimentation |
| • Ammonia Coukent | Chlorination |
| • Micro organisms | Chlorination |

Evaluation of water sources — TWG 030/H 1

1. **GROUNDWATER**

The following groundwater sources can be distinguished:
- shallow groundwater;
- deep groundwater;
- artesian groundwater.

To evaluate groundwater sources the water quality of the source must be compared with the drinking water standards in order to sort out the requirements for water treatment. The following procedure is used:

a. If all parameters are within the limits stated as "preferable", the water can be used directly for drinking water purposes.
b. If parameters are in the range "acceptable-preferable", water quality is not directly objectionable; improvement within a certain time span has to be taken into consideration.

c. If some parameters are above the levels "maximum-acceptable" quality improvement by (enhanced) water treatment will be necessary.

Contaminants, mostly present in shallow, deep and artesian groundwater are:

- Salt, due to mixing of fresh water with saline water coming from the sea ($Na^+$ - $Cl^-$ - $Ca^{2+}$ - $HCO_3^-$ - $SO_4^{2-}$).

- Iron and manganese, due to dissolving of inorganic iron and manganese salts in the underground.

- Ammonia, produced by natural anaerobic digestion of organic matter in the underground.

- Aggresive carbon dioxide.

With the exception of shallow groundwater, groundwater sources are normally free from bacteriological contamination.

In the following table a brief review is given of the treatment processes that are normally required for the improvement of certain groundwater quality parameters.

REVIEW OF TREATMENT PROCESSES FOR GROUNDWATER

| Parameter | Treatment |
|---|---|
| 1. Colour | - Normally caused by iron; is removed by aeration followed by filtration.<br>- If caused by other chemical matter : chemical treatment with alum, to be executed in a rapid sand filter (contact or direct filtration). |
| 2. pH | - Too low due to a high $CO_2$ content; is corrected by aeration, for lowering the $CO_2$ content, or dosing of lime or soda ash (pH correction). |
| 3. Iron | - Iron can only be removed if present as trivalent ion. Therefore the divalent iron has to be converted to trivalent form by aeration or by oxidizing agents such as chlorine. The insoluble compounds formed by the trivalent iron are subsequently removed by filtration or by sedimentation. |
| 4. Manganese | - A high manganese content can be lowered by sand filtration. However, it should be kept in mind that this is a katalytic oxidation process in which iron is oxidized prior to manganese. |
| 5. Ammonia | - A number of possibilities are available to control the level of ammonia, such as ion exchange, trickling filtration, and break point chlorination. |
| 6. Dissolved oxygen | - In case dissolved oxygen levels (DO) are beyond the water quality standards, an increase of DO can readily be achieved by aeration. |
| 7. Hardness (Ca+Mg) | - Commonly water hardness is reduced with a softener resin. However, this treatment is expensive and hardly to be recommended for groundwater hardness removal. |

REVIEW OF TREATMENT PROCESSES FOR GROUNDWATER (Continued)

| Parameter | Treatment |
|---|---|
| | However, if the concentration of bicarbonate is relatively high, a reduction of hardness can be achieved by raising the pH with sodium hydroxide. |
| 8a. Aggressive Carbon dioxide | - To remove aggressiveness, a number of processes can be used such as aeration, lime dosing and marble filtration.<br>Using the aeration process, a reduction of the total carbon dioxide concentration is achieved.<br>The aeration process can be used for types of water with a rather low pH, a high bicarbonate-calcium ratio and a relatively high carbon dioxide content.<br>The lime dosing process reduces water aggresiveness by two mechanisms: raising the pH of the water and lowering the bicarbonate-calcium ratio. The lime dosing process is, therefore, appropriate for water with a rather low bicarbonate-calcium level.<br><br>Marble filtration finally removes aggressive carbon dioxide by dissolving the calcium carbonate. At moderately aggressive carbon dioxide levels marble filtration is most successful. |
| 8b. Scaling effects | - If the concentration of aggresive carbon dioxide is negative, the water potentially gives rise to scaling.<br>The scaling potential of water can be neutralized by lowering the pH with an acid.<br><br>Although the water quality standard prescribes an absence of aggressive carbon dioxide in water, in practice levels from -10 mg/l to 10 mg/l are acceptable. |
| 9. Bacteriological conditions | - Normally groundwater is free from bacteriological organisms. However, if the bacteriological count exceeds the levels set in the water quality standard, two ways are open to improve the bacteriological quality of water: slow sand filtration or chemical disinfection (sodium hypochlorite, calcium hypochlorite or chlorine gas are commonly used for this). |

In case a water quality evaluation shows that the quality standards are not met, recommendations must be given to incorporate water treatment in the water supply system, or to adapt existing treatment processes. In giving these recommendations, keep in mind the various treatment processes that may be used and try to minimize the number of different processes.

## 2. SURFACE WATER

Surface water comprises all water present at the surface of the earth; this includes not only rivers, but also irrigation canals, lakes, small brooks, and so on. The evaluation of surface water sources within the framework of this manual will be limited to those sources that are abundant and a potential source for drinking water.

The evaluation of surface water with regard to drinking water can be carried out by comparing the water quality data with the drinking water standards.
For this, the same procedure is followed as described earlier for groundwater.

Treatment of surface water differs considerably from treatment of groundwater. Groundwater in case of deep and artesian water, has been stored underground for a long time. During this period the water has become bacteriologically safe and free from suspended solids. Surface water originates from rain water, collected in the mountain area and flowing towards the sea, carrying erosion and waste materials. Surface water is contaminated with suspended solids, mainly clay minerals, and micro-organisms.

Most commonly only the following parameters have to be corrected for surface water : filterable residue (TSS), turbidity, ammonia and the bacteriological conditions.
The water treatment processes required for surface water comprise chemical coagulation, flocculation, sedimentation, rapid sand filtration and chemical disinfection.

For the selection of the appropriate treatment system, the following notes can be used as a guideline:

REVIEW OF TREATMENT PROCESSES FOR SURFACE WATER

| Parameter | Treatment |
|---|---|
| 1. Colour | - In general the colour of water is effectively removed by chemical treatment, comprising coagulation with alum, flocculation, sedimentation and filtration. |
| 2. pH | - pH values of surface water are normally neutral. A high pH value may be the result of algae activity. Removal of algae can be accomplished with micro-strainers. |
| 3. Filterable residue | - Mainly present as suspended matter. Removal of these particles depends on the particle size and density. Larger particles, with relatively high settling rates, can be removed effectively in a plain sedimentation tank, while smaller particles are removed by sand filtration. |
| 4. Turbidity | - Turbidity can effectively be reduced by chemical treatment, comprising coagulation with alum, flocculation and sedimentation. Since this process yields an effluent with a certain residual turbidity, filtration completes the chemical treatment process. |
| 5. Ammonia | - Ammonia can be removed by breakpoint chlorination (if only a chemical treatment process is involved) or by slow sand filtration. |
| 6. Bacteriological conditions | - Normally the bacteriological count exceeds the standards, so inactivation of micro-organisms, either biologically with slow sand filtration, or chemically with strong oxidizing agents such as chlorine, sodium hypochlorite or calcium hypochlorite, has to be carried out. |

## 3. SUMMARY

Two main sources of water are identified : groundwater and surface water.

Comparing the quality parameters of the water source with the relevant water quality standards shows whether (additional) water treatment is necessary or to be recommended.
Specific treatment processes can be indicated for controlling the various water quality parameters.

* * *

| TITLE : | CODE : |
|---|---|
| 1. Ground water quality improvement process | TWG 030/V 1 |
| 2. Surface water quality improvement process | TWG 030/V 2 |

| PARAMETERS NORMALLY EXCEEDING THE STANDARDS FOR GROUND WATER | RECOMMENDED TREATMENT PROCESS |
|---|---|
| • Colour caused by iron | Aeration /filtration |
| • Low pH | Aeration or lime dosing or marble filtration |
| • High $CO_2$ content | Aeration or lime dosing or marble filtration |
| • High iron content | Aeration/filtration |
| • High manganese content | Filtration |
| • High ammonia content | Chlorination |
| • Low oxygen content | Aeration |

| PARAMETERS NORMALLY EXCEEDING THE STANDADS FOR SURFACE WATER | RECOMMENDED TREATMENT PROCESS |
|---|---|
| • Colour<br>• Turbidity | Coag /Flocc/ Sedimentation<br>Coag /Flocc / Rapid Filtration |
| • Suspended Solids | Sedimentation |
| • Ammonia Coukent | Chlorination |
| • Micro organisms | Chlorination |

| | |
|---|---|
| Duration : | 90 minutes. |
| Training objectives : | After the session the trainees will be able to:<br>- recite the basic elements and objectives of the water treatment facilities and relations between them (for surface water);<br>- to construct a typical scheme for surface water treatment. |
| Trainee selection : | - All employees of water enterprise. |
| Training aids : | - Viewfoils : TTG 051/V 1;<br>- Handout : TTG 051/H 1. |
| Special features : | - A tape-slide presentation is available and might be used after this session. |
| Keywords : | Water intake/coagulation flocculation/sedimentation/filtration/neutralization/disinfection/clear water storage/distribution/power supply. |

1. **Introduction**

- The main elements of surface water treatment are: *(Show V 1)*
  a. Raw water Intake;
  b. Water Purification;
  c. Neutralization;
  d. Disinfection;
  e. Clear water storage;
  f. Distribution;
  g. Power supply.

- A subdivision of water purification can be made in :
  a. Coagulation/flocculation;
  b. Sedimentation;
  c. Filtration.

2. **Raw water intake**

- The aims of raw water intake are: *(Use whiteboard)*
  . the intake of water from river or lake;
  . to transport the water from intake to the purification plant;
  . to control the amount of clear water to be produced;
  . to elevate the raw water from source level up to the level required at the plant inlet.

3. **Water purification**

- The purification of the surface water comprises:
  . removal of solid particles present in the raw water;
  . lowering the turbidity to an acceptable standard;
  . decreasing the amount of colour causing substances;
  . reducing the amount of micro-organisms and biological matter in the raw water.

Note: After purification the water is still not potable because it will still be bacteriologically contaminated.

| | |
|---|---|
| **4. Units of water treatment** | |
| Coagulation/flocculation | Use whiteboard |
| - Coagulation/flocculation is carried out for the removal of colloids and suspended matter. | |
| - Coagulation comprises:<br>. the addition of chemical solutions (alum and sodah ash) to the water;<br>. rapid mixing to obtain a quick dispersal of the chemical solutions in the water. | |
| - Flocculation comprises:<br>. slow stirring of the water;<br>. a certain detention time to enable the small flocs from coagulation to grow to bigger flocs. | |
| Sedimentation | |
| - The aim of sedimentation is:<br>. to remove the bulk of the flocs from the flocculated water through settling by gravity. | |
| Filtration | |
| - The aim of filtration is:<br>. to remove the small amount of solid particles, originally present in the raw water or remaining after sedimentation in the chemical treated water. | |
| **5. Neutralization** | |
| - Neutralization is the addition of lime or soda ash (solution) to the water either in the coagulation step or after filtration. | Use whiteboard |
| - The aims of neutralization are:<br>. to reach an optimum pH for the chemical reactions of alum;<br>. to avoid corroding and scale formation in the piping system of the distribution network. | |

| | |
| --- | --- |
| **6. Disinfection** | |
| - Disinfection is the addition of active chlorine (kaporit) to the purified water. | Use whiteboard |
| - The aim of disinfection is:<br>. to kill all bacteria and other micro-organisms still in the clear water (after filtration) which otherwise may cause waterborne diseases to the consumers. | |
| **7. Clear water storage** | |
| - The water production does not at all times comply exactly with the demand for water. Therefore, a reservoir is necessary, with a storage capacity large enough to supply water even in times when production does not comply with demand for water. | |
| **8. Power supply** | |
| - Power supply is needed at most locations for:<br>a. Intake pumps;<br>b. Dosing pumps for addition of chemicals (except when gravity dosing systems are applied);<br>c. Cleaning of filters (backwashing);<br>d. Distribution pumps;<br>e. Lighting;<br>f. Service water supply;<br>g. Other mechanical equipment. | Use whiteboard |
| - Power is mostly supplied by a generator set, sometimes by a PLN connection. | Use whiteboard |

9. **Summary**

- The main elements of surface water treatment are:
  . Raw water intake;
  . Water purification;
  . Neutralization;
  . Disinfection;
  . Storage in clear water reservoir;
  . Distribution;
  . Power supply.

- Of course, buildings (gensets, pumps, storage of chemicals, office & laboratory) also belong to the treatment plant package.

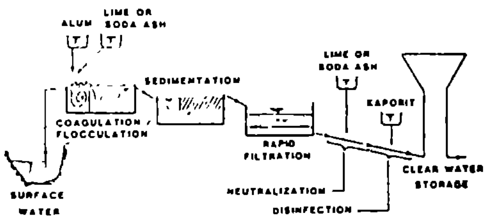
Give H 1

---

A tape-slide presentation is available on this subject.
If the presentation is used:
- Let trainees rest (in classroom) for 10 minutes;
- Show tape-slide presentation (15 minutes);
- Invite questions.

| | |
|---|---|
| Module : **WATER TREATMENT PROCESSES AND FACILITIES - SURFACE WATER** | Code : TTG 051 |
| | Edition : 18-03-1985 |
| Section 3 : T R A I N I N G   A I D S | Page : 01 of 01 |

Surface water treatment — TTG 051/V 1




Water treatment processes and facilities - surface water — TTG 051/H 1

## 1. INTRODUCTION

The main elements of surface water treatment are:
a. Raw water intake;
b. Water purification;
c. Neutralization;
d. Disinfection;
e. Clear water storage;
f. Distribution;
g. Power supply.

## 2. RAW WATER INTAKE

The aims of the raw water intake are:
- To take in water from a river or lake;
- To transport water from the intake to the purification plant;
- To control the amount of raw water delivered;
- To elevate the raw water from source level up to the level required at the plant inlet.

## 3. WATER PURIFICATION

The purification of the surface water comprises:
- The removal of solid particles present in the raw water;
- Lowering the turbidity to acceptable standards;
- Decreasing the amount of colour causing substances;
- Reducing the amount of micro-organisms and biological matter present in the raw water.

Note:

After purification the water is still not potable, because the water will still be bacteriologically contaminated.

## 4. UNITS OF WATER TREATMENT

### Coagulation/flocculation

Coagulation/flocculation is carried out in order to remove colloids and suspended matter.

The first step, coagulation comprises:
- The addition of chemical solutions (usually alum and soda ash) to the water;
- A rapid mixing to obtain reactions of the chemicals with the impurities in the water.

Flocculation, the second step, comprises:
- Slow stirring of the water;
- A certain detention time to enable the small flocs formed during coagulation, to grow bigger.

**Sedimentation**

Sedimentation is applied in order to remove the bulk of the flocs through settling by gravity.

**Filtration**

Filtration has to remove the solid particles either originally present in the raw water or remaining after the sedimentation step or chemical treatment (coagulation/flocculation).

## 5. NEUTRALIZATION

Neutralization is the addition of lime or soda ash (solution) to the water either in the coagulation step or after the filtration step.

The objectives for the addition of the chemicals are:
- To reach an optimum pH for the chemical reactions of alum during the coagulation step;
- to avoid corroding and scale formation in the piping system of the distribution network.

## 6. DISINFECTION

Disinfection is the addition of active chlorine (kaporit) to the purified water.
Disinfection will achieve the killing of bacteria and other micro-organisms still present in the clear water, which otherwise may cause waterborne diseases to the consumers.

## 7. CLEAR WATER RESERVOIR

The water production usually doesn't comply exactly with the demand of water.
To assure an all-time water supply, a reservoir with a properly designed storage capacity has to be in operation.

## 8. POWER SUPPLY

Power supply is needed at most locations. Power is required for:
- Intake pumps;
- Dosing pumps for addition of chemicals (except for gravity dosing systems);
- Cleaning of filters (backwash pumps);
- Distribution pumps;
- Lighting;
- Service water supply;
- Mechanical equipment.

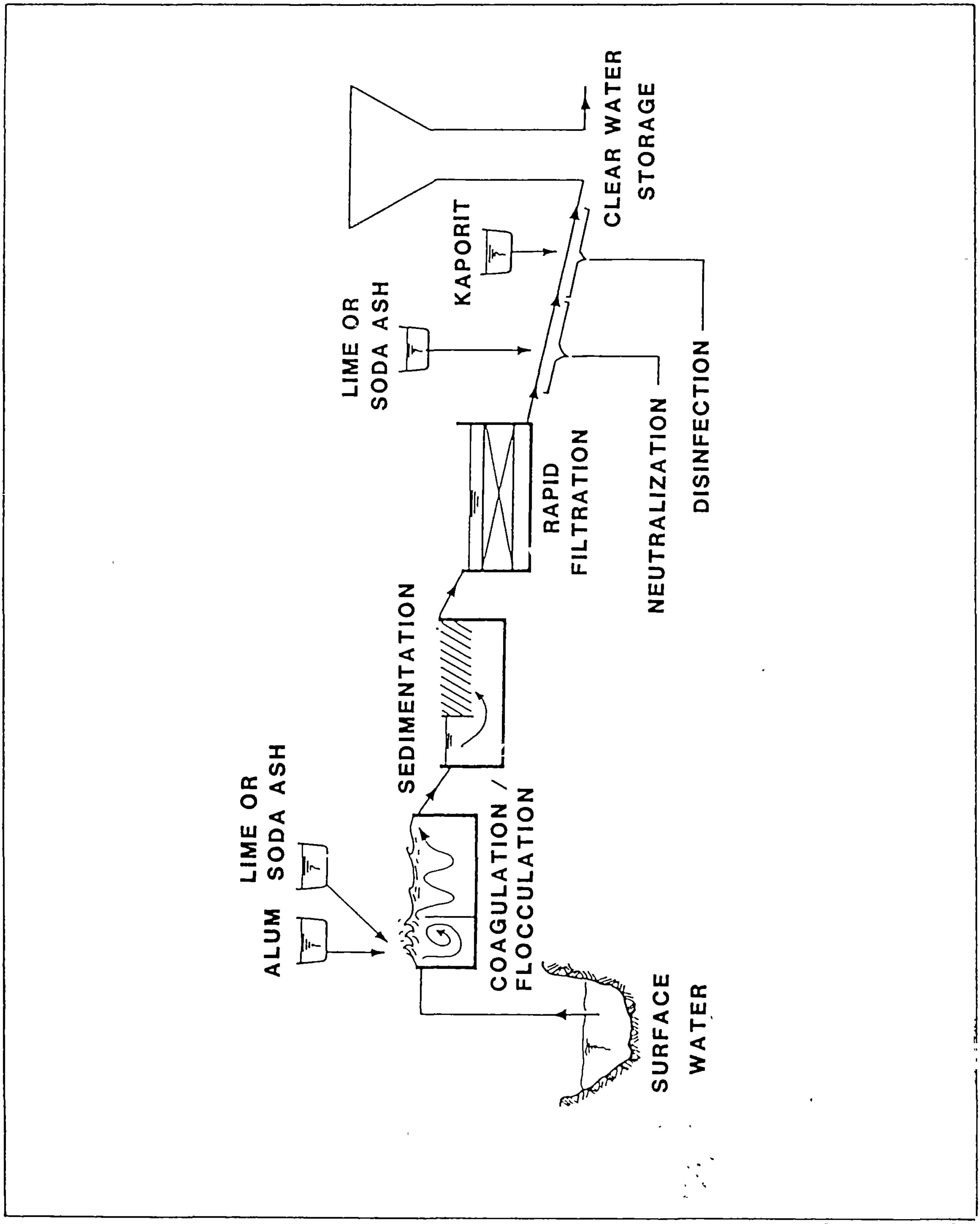
Power supply is mostly obtained from a generator set. Sometimes a PLN connection or a combination of both provides the required power for the electro-mechanical equipment.

## 9. SUMMARY

This session provides a review of treatment facilities for surface water treatment. The water treatment elements are:
- Raw water intake;
- Water purification;
- Neutralization;
- Disinfection;
- Storage reservoir;
- Distribution;
- Power supply.

Of course, buildings for gensets, pumps, storage of chemicals, office and laboratory belong also to the treatment plant.

* * *


CLEAR WATER
STORAGE
KAPORIT
LIME OR
SODA ASH
DISINFECTION
NEUTRALIZATION
RAPID
FILTRATION
SEDIMENTATION
LIME OR
SODA ASH
ALUM
COAGULATION /
FLOCCULATION
SURFACE
WATER

| | |
|---|---|
| Module : **WATER TREATMENT EFFICIENCY** | Code : TTG 060 |
| | Edition : 18-03-1985 |
| Section 1 : **I N F O R M A T I O N   S H E E T** | Page : 01 of 01/12 |

| | |
|---|---|
| Duration : | 45 minutes. |
| Training objectives : | At the end of this section the trainee will be able to :<br>- list the basic requirements for water treatment quality control;<br>- identify that information from physico/chemical/bacteriological water examination has to be used in relation to the relevant treatment process;<br>- identify the methodology of water treatment quality control. |
| Trainee selection : | - Director of Water Enterprise;<br>- Head of Planning Section;<br>- Head of Technical Department;<br>- Chief/Head of the Laboratory. |
| Training aids : | - Viewfoils : TTG 060/V 1-4;<br>- Handouts : TTG 060/H 1. |
| Special features : | - |
| Keywords : | Water treatment efficiency/raw water/clarified water/filtered water/clear water/distributed water. |

| | |
|---|---|
| **1. Introduction** | |
| - Basic process information comprises:<br>. the main function of each treatment unit;<br>. the design specifications regarding treatment efficiency;<br>. parameters and circumstances influencing the process. | Use whiteboard |
| - From this basic information the following information is obtained:<br>. the key parameters to be monitored;<br>. an efficiency forecast;<br>. a clear view of reasons for possible deviations in process efficiency. | Use whiteboard |
| **2. Groundwater treatment scheme** | Show V 1<br>Explain the treatment process |
| - A typical groundwater scheme consists of:<br>. water intake by wells;<br>. aeration;<br>. filtration;<br>. chlorination. | |
| - The aims of the treatment steps are:<br>. aeration : the oxidation of iron (II) to the insoluble iron (III);<br>. filtration : the removal of the iron hydroxides formed by iron III;<br>. chlorination : to prevent bacterial growth in the distribution system. | |
| - Secondary factors influencing the process are:<br>. aeration : pH and DO, both important for the oxidation reaction;<br>. filtration : filter bed clogging;<br>. chlorination : the chlorine demand by oxidizable matter. | |
| - Four sampling points are indicated, namely:<br>. raw water;<br>. filtered water;<br>. clear water;<br>. distributed water. | Show V 1 |

| | |
| --- | --- |
| - The basic water quality monitoring programme includes:<br>. the residual chlorine in the clear water;<br>. the total iron content in the raw water;<br>. the total iron content in the clear water. | |
| - If the iron content in the clear water does not comply with drinking water standards, the reason for the process failure may be:<br>. the oxidation of the Fe (II) at the aeration step is not complete due to a too low oxygen content or changed pH value;<br>. the filter is clogged; backwashing is necessary. | Show V 2 |
| - If the residual chlorine content of the clear water does not comply with the required value (0.5 mg/l) the reason for the failure may be:<br>. the dosing of chlorine is incorrect (check solution strength and dosing flow rate);<br>. the concentration of iron (II) is too high (incomplete aeration);<br>. oxidizable matter is present, so the chlorine demand is higher than expected. | Show V 2 |
| - Additional parameters that have to be measured for the water quality monitoring are:<br>. pH;<br>. dissolved oxygen (DO). | Use whiteboard |
| - When the aeration remains incomplete an additional dose of chlorine after the aeration step can be considered. | |
| 3. **Surface water treatment scheme** | Show V 3 |
| - A typical surface water treatment scheme comprises:<br>. chemical treatment with alum (coagulation/follucation);<br>. sedimentation; | |

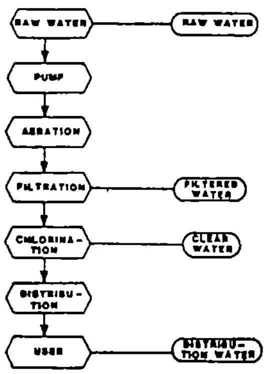
| | |
|---|---|
| . filtration;<br>. disinfection. | |
| - Five sampling points are indicated:<br>. raw water;<br>. clarified water;<br>. filtered water;<br>. clear water;<br>. distributed water. | Point at scheme of V 3 |
| - The aims of the treatment units are:<br>. chemical treatment : reduction of the concentration of suspended and colloidal matter;<br>. filtration : removal of the residual turbidity;<br>. disinfection : inactivation of micro-organisms in the clear water and prevention of bacterial growth in the distribution network. | |
| - Secondary factors influencing the process are:<br>. chemical treatment : pH and turbidity of the raw water and the alum dosing concentration;<br>. filtration : turbidity of the clarified water and clogging of the filterbed;<br>. disinfection : the chlorine demand of the filtered water. | Use whiteboard |
| - The basic parameters for monitoring process efficiency are:<br>. turbidity and pH of raw water;<br>. turbidity and pH of clarified water;<br>. turbidity and pH of filtered water;<br>. residual chlorine content and turbidity of clear water. | Use whiteboard |
| - If the clear water turbidity is too high (> 1 NTU) the following factors must be controlled: | Show V 4 |

  . filter is clogged; backwashing is necessary;
  . the coagulation flocculation process is not functioning properly; adjustment of the alum dosing or pH correction is necessary.

- If the residual chlorine content in the clear water is too low it is possibly due to: (Show V 4)
  . a wrong dosing rate;
  . a changed chlorine demand of the water.

- If the bacteriological condition is not according to the standards the residual chlorine content must be adjusted.

Groundwater treatment — TTG 060/V 1

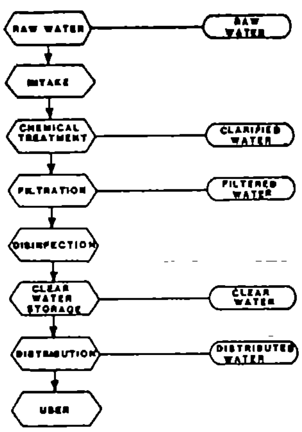



Groundwater treatment efficiency — TTG 060/V 2

**MONITORING PROCESS EFFICIENCY FOR GROUND WATER TREATMENT**

| BASIC PARAMETER | FAILURE | REMEDIE |
|---|---|---|
| Iron | Too high in clear water | Filter must be backwashed<br>Aeration unit must be checked |
| Residual chlorine | too low in clear water | Determine chlorine demand and adjust the dosing rate |

Surface water treatment — TTG 060/V 3




Surface water treatment efficiency — TTG 060/V 4

**MONITORING PROCESS EFFICIENCY FOR SURFACE WATER TREATMENT**

| BASIC PARAMETER | FAILURE | REMEDIE |
|---|---|---|
| pH | too low in clear water | Neutralization with lime or soda ash |
| | too low in clarified water | pH correction with lime or soda ash at coagulation |
| Turbidity | too high in clarified water | Execute jar test and adjust dose of coagulant according to the result |
| | too high in filtered water | Filter must be back washed |
| Residual chlorine | too low in clear water | Determine the chlorine demand and adjust the dosing rate |

Water treatment efficiency — TTG 060/H 1

1. **INTRODUCTION**

Within the framework of this module two basic types of water supply schemes will be discussed to give an insight in the method of water quality control applied to treatment processes.
The first is a groundwater treatment system in which iron is removed by aeration, filtration, disinfection storage of water in a clear water reservoir prior to distribution is included.
The second scheme selected is a surface water treatment system, consisting of a chemical treatment of the water with alum (treatment steps : coagulation, flocculation, sedimentation, followed by filtration, disinfection and subsequent water storage prior to distribution.

Before elaborating on any set-up for identifying treatment efficiencies and implementing water quality control, basic process information has to be collected.
This may consist of:

a. The main function of each treatment step.
b. The design specifications with regard to treatment efficiency;
c. Parameters or circumstances influencing the process (or efficiency).

From (a) information is obtained on the key parameters to be monitored;
from (b) an efficiency forecast is drawn up by the design engineers while finally from (c) information is obtained on circumstances and parameters to be monitored in order to obtain a clear view of reasons for deviations in treatment process efficiency or process interruption.

2. **GOUNDWATER TREATMENT SCHEME**

A typical groundwater scheme is shown in figure 1.
Groundwater is pumped from a well, and enters an aeration unit. By introducing oxygen, the divalent iron will be converted to the trivalent form which immediately forms the insoluble iron hydroxide.
At the subsequent filtration step the iron hydroxide will be removed.
The last step, chlorination, is performed to guarantee a bacterio logically safe water.

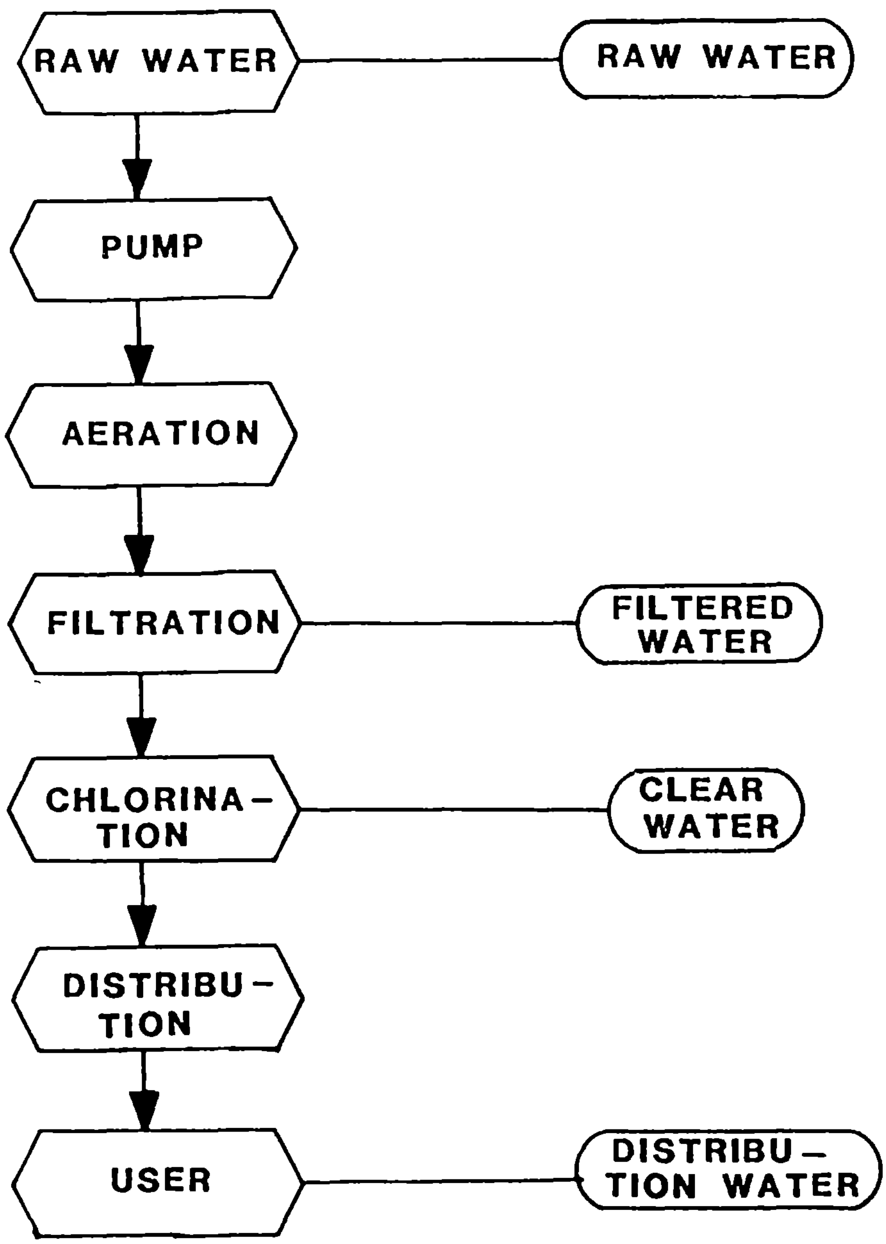



*Fig. 1. Typical groundwater treatment.*

The aims of the treatment steps are:
aeration : oxidation of iron;
filtration : removal of iron hydroxides;
chlorination : prevention of bacterial growth.

Secondary factors influencing the process are:
aeration : pH value and dissolved oxygen concentration, both important for the oxidation reaction of divalent iron;
filtration : clogging of the filter bed;
chlorination : organic matter content, the presence of divalent iron.

In the scheme four sampling points are indicated:

- Raw water.
- Filtered water.
- Clear water.
- Distributed water.

The basic water quality monitoring programme is related to the following parameters:

- Free chlorine in the clear water.
- Total iron in the raw water.
- Total iron in the clear water.

If the iron content in the clear water does not comply with the standards for drinking water, the secondary factors have to be taken into account, to identify possible reasons for process failure, which may be:

- The oxidation of Fe (II) at the aeration step is not complete due to a too low oxygen content or changed pH value.

- The filter is clogged, backwashing is necessary.

If the chlorine content of the clear water does not comply with the required value (0.2 - 0.5 mg/l) the reason for the failure may be:
- the dosing of chlorine is not correct (check solution strength and dosing flow rate);
- the concentration of iron (II) is too high (incomplete aeration);
- oxidizable matter is present.

From this example it will be clear that <u>additionally</u> only the parameters dissolved oxygent (DO) and pH have to be measured.
If the DO content is close to 0 and the pH is far below the equilibrium pH, the aeration will be incomplete and therefore an additional dose of chlorine, immediately after the aeration step, may be considered.

3. **SURFACE WATER TREATMENT SCHEME**

For surface water treatment plants a scheme similar to that for groundwater treatment can be worked out.
A typical treatment scheme is shown in figure 2.

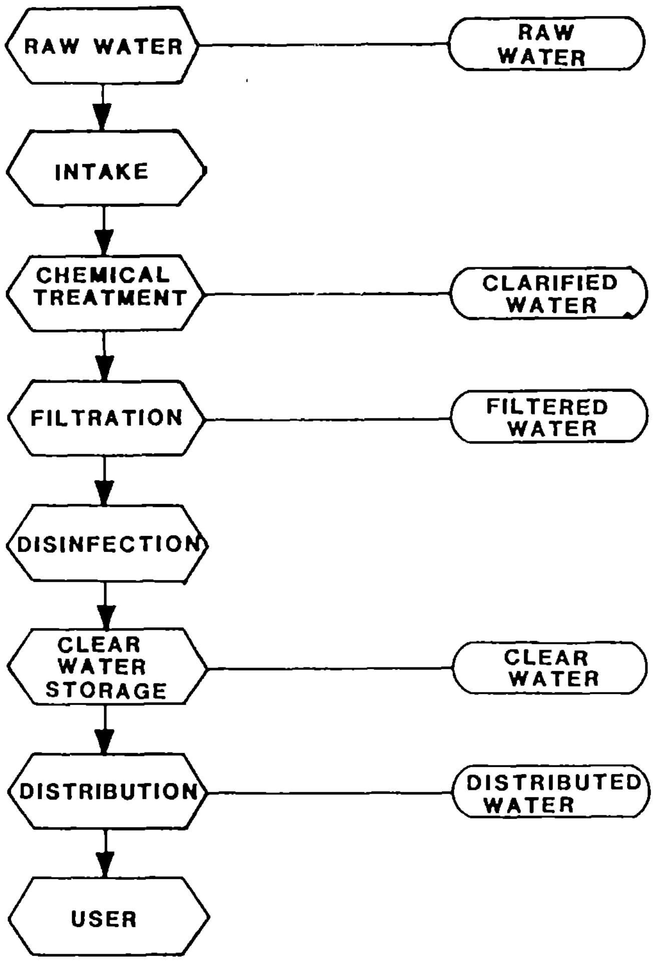



*Fig. 2. Typical surface water treatment.*

The treatment steps are: chemical treatment with alum (coagulation/flocculation/sedimentation), filtration and disinfection.
The disinfectant dosage shall be such that a residual chlorine concentration of 0.2 - 0.5 mg/l is maintained in order to prevent bacterial growth in the distribution system.

Five sampling points are indicated:
- Raw water.
- Clarified water.
- Filtered water.
- Clear water.
- Distributed water.

Before implementing water quality control, it is necessary to identify the aims of the subsequent steps in the treatment system:

Chemical treatment : reduction of the concentration of suspended solids and colloidal matter (turbidity and colour);

Filtration : removal of any remaining turbidity;

Disinfection : inactivation of micro organisms in the clear water and prevention of bacterial growth in the distribution network.

Secondary factors that may influence the processes, are:

Chemical treatment : pH and turbidity of raw water, alum dosing concentration;

Filtration : turbidity of clarified water, clogging of the filter bed;

Disinfection : the chlorine demand of the treated water.

Basic monitoring of treatment process efficiency has to take into account the following parameters:

Turbidity and pH of raw water, clarified water, and filtered water (of each filter) and residual chlorine content and turbidity of the clear water.

The turbidity of the filtered water, which equals the turbidity of the clear water, has to comply with the standards for drinking water. For treated surface water the recommendation is a turbidity lower than 1 NTU.

If the process efficiency under normal circumstances does not comply with the expected efficiencies the secondary factors have to be taken into account.

Possibilities are:

- The clear water turbidity is too high, possibly due to:
  . clogged filter, so backwashing is necessary;
  . not proper functioning of the coagulation/flocculation process, so adjusting the alum dosing rate or base dosing rate (pH correction) is necessary.

  If all these inspections fail, the need for a treatment expert is obvious.

- The residual chlorine content of the clear water is too low; the dosing rate has to be checked:
  In case no deviations are found, the chlorine demand has to be determined again.

- The bacteriological condition is not according to the standards : check the residual chlorine content; if it is too low, readjust the chlorine dosage.

The above list cannot be complete, but it serves as an indication of the way in which water quality control may contribute to a proper process operation.

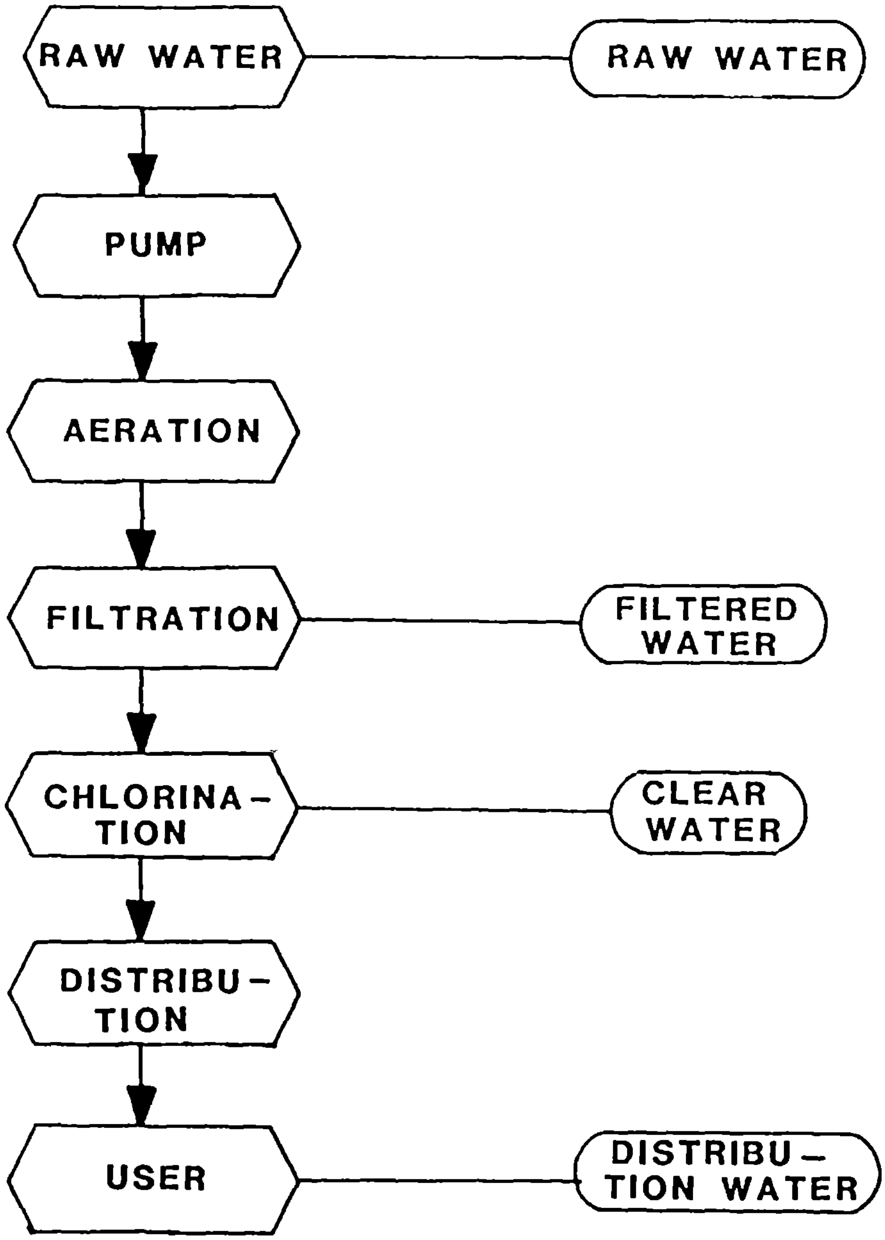
## 4. SUMMARY

In order to assess the efficiency of water treatment, basic process information is required on the main function, design specifications and process influencing parameters of each unit. From these key parameters, efficiency forecasts and possible causes of deviations in process efficiency can be deduced.
Examples of sampling locations, treatment processes and the ways in which their efficiency can be monitored, are given for a typical groundwater treatment plant and a typical surface water treatment plant.

* * *

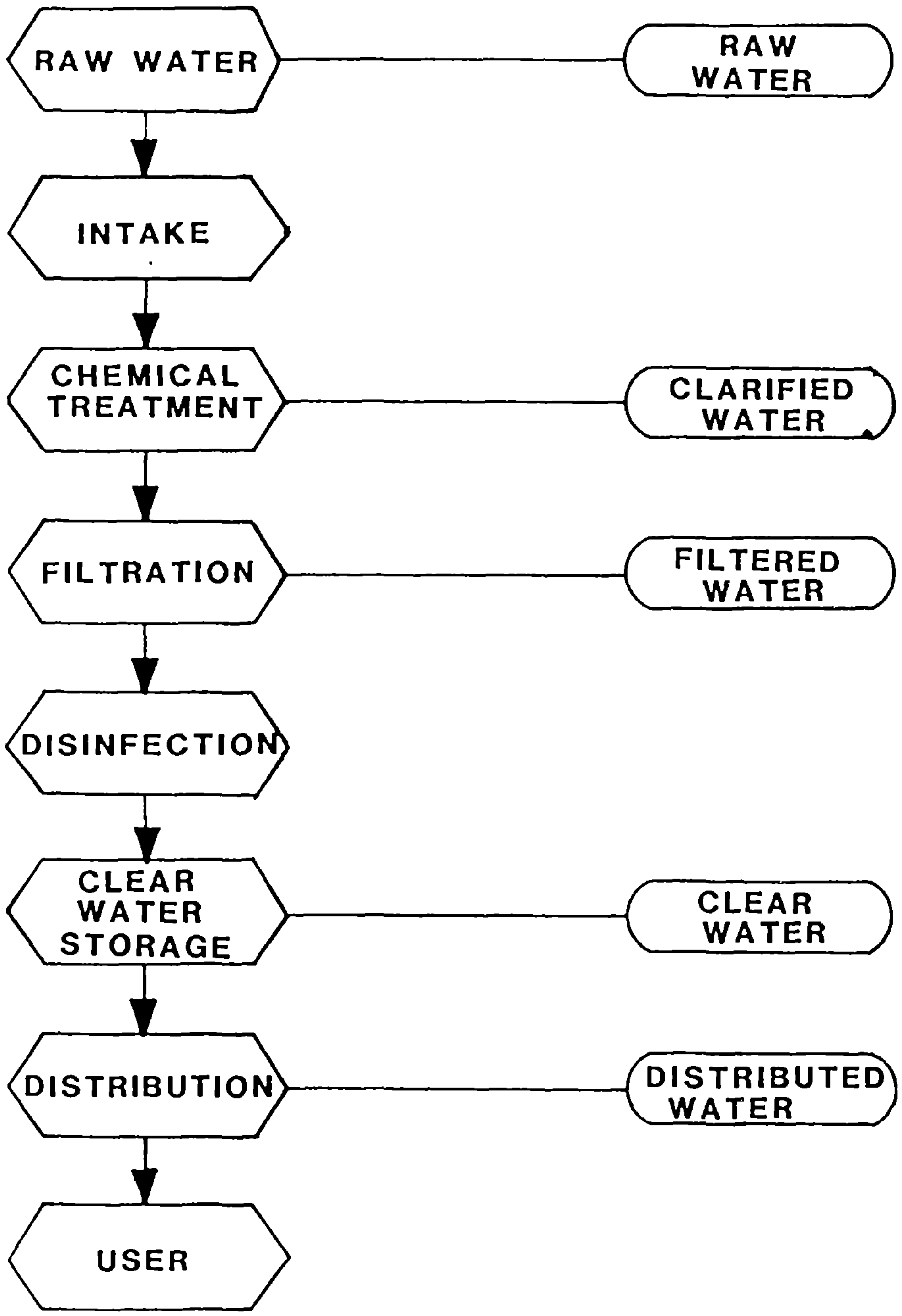
| | |
|---|---|
| Module : WATER TREATMENT EFFICIENCY | Code : TTG 060 |
| | Edition : 17-04-1985 |
| Annex : V I E W F O I L S | Page : 01 of 05 |

| TITLE : | CODE : |
|---|---|
| 1. Ground water treatment | TTG 060/V 1 |
| 2. Ground water treatment efficiency | TTG 060/V 2 |
| 3. Surface water treatment | TTG 060/V 3 |
| 4. Surface water treatment efficiency | TTG 060/V 4 |


RAW WATER
RAW WATER
PUMP
AERATION
FILTRATION
FILTERED WATER
CHLORINA-TION
CLEAR WATER
DISTRIBU-TION
USER
DISTRIBU-TION WATER

# MONITORING PROCESS EFFICIENCY FOR GROUND WATER TREATMENT

| BASIC PARAMETER | FAILURE | REMEDIE |
|---|---|---|
| Iron | Too high in clear water | Filter must be backwashed<br>Aeration unit must be checked |
| Residual chlorine | too low in clear water | Determine chlorine demand and adjust the dosing rate |


RAW WATER
INTAKE
CHEMICAL TREATMENT
FILTRATION
DISINFECTION
CLEAR WATER STORAGE
DISTRIBUTION
USER
RAW WATER
CLARIFIED WATER
FILTERED WATER
CLEAR WATER
DISTRIBUTED WATER

# MONITORING PROCESS EFFICIENCY FOR SURFACE WATER TREATMENT

| BASIC PARAMETER | FAILURE | REMEDIE |
|---|---|---|
| pH | too low in clear water | Neutralization with lime or soda ash |
| | too low in clarified water | pH correction with lime or soda ash at coagulation |
| Turbidity | too high in clarified water | Execute jar test and adjust dose of coagulant accor- ding to the result |
| | too high in filtered water | Filter must be back washed |
| Residual chlorine | too low in clear water | Determine the chlo- rine demand and ad just the dosing rate |

| Module : DISINFECTION | Code : TTG 150 |
|---|---|
| | Edition : 18-03-1985 |
| Section 1 : INFORMATION SHEET | Page : 01 of 01/13 |

| | |
|---|---|
| Duration : | 90 minutes. |
| Training objectives : | After the session the trainees will be able to:<br>- distinguish free chlorine, usable combined chlorine and unusable combined chlorine;<br>- determine the ideal dose of chlorine;<br>- indicate how to remove an excess of ammonia;<br>recite different types of dosing systems. |
| Trainee selection : | - Head of Technical Department;<br>- Head of Section Production;<br>Head of Sub-section Water Treatment;<br>- Water Treatment Plant Operator;<br>- Head of Sub-section Laboratory;<br>- Laboratory Assistant. |
| Training aids : | - Viewfoils : TTG 150/V 1-3;<br>- Handout : TTG 150/H 1. |
| Special features : | |
| Keywords : | Disinfection/chlorine/pathogenic organisms/free chlorine/usable-combined chlorine/unusable-combined chlorine/coliform/E-coli/kaporit/constant head box/MOM dosing system/dosing pumps/gasification equipment. |

| | |
|---|---|
| **1. Disinfection** | |
| - Disinfection is the addition of chlorine to water to be consumed. | Use whiteboard |
| - Chlorine will kill bacteriological organisms. | |
| - Pathogenic organisms must be killed because they cause disease and death to human beings. | |
| **2. Theory** | |
| <u>Reactions of chlorine in water:</u> | |
| - When chlorine is added to the water the following reactions take place:<br>. reaction with water molecules called hydrolysis;<br>. formation of <u>active</u> compounds the so-called <u>free chlorines</u><br>a) hypochlorous acid (HOCl) and<br>b) ionic hypochlorite ($OCl^-$);<br>. reaction with ammonial nitrogen ($NH_4^+$) to so called <u>usable combined chlorine</u>:<br>a) monochloramine ($NH_2Cl$);<br>b) dichloramine ($NHCl_2$);<br>c) trichloramine ($NCl_3$);<br>. formation of so-called <u>unusable combined chlorine</u> by oxidation of:<br>a) organic materials;<br>b) iron ($Fe^{2+}$ --> $Fe^{3+}$);<br>c) nitrite ($NO^{2-}$ --> $NO^{3-}$);<br>d) $H_2S$ ($S^{2-}$ --> $SO_4^{2-}$) (smell). | Show V 1 |
| - The most active disinfecting compounds are:<br>. HOCl & $OCl^-$ (free chlorine). | Use whiteboard |
| - Less active compounds are:<br>. $NCl_3$ )<br>. $NHCl_2$ ) (usable combined chlorine)<br>. $NH_2Cl$ ) | |
| - Inactive compounds are:<br>. products of the last type of reactions forming unusable combined chlorine. | |

| | |
|---|---|
| - Free and usable combined chlorine together are called total chlorine, so the free chlorine content is included in the total chlorine parameter. | |
| Amount of chlorine needed | |
| - The chlorine dose to be applied for the disinfection of the water is that amount which is necessary to destroy all pathogenic organisms before the water is coagulated. | Use whiteboard |
| - Some pathogenic organisms are more resistant than others, requiring a higher dose for their inactivation. | |
| - Destruction of all micro-organisms depends on:<br>. quantity of disinfectant applied;<br>. type of compounds produced;<br>. time available for reaction. | Use whiteboard |
| How to determine the ideal dose of chlorine | |
| - All coliforms (E-coli) in the sample should be destroyed by the dose applied. | |
| - E-coli is a reference organism with a greater resistance than normal pathogenic organisms. | |
| - The following parameters should be considered:<br>. available time between the addition of chlorine and its consumption by the water;<br>. quantity of chlorine needed to kill all E-coli within available contact time;<br>. the types of disinfectants produced in the water. | |
| - But: all E-coli killed does not mean all viruses or cystes have been killed. | |

- Therefore:
  . the turbidity of purified surface water should be less than 1 FTU at all times;
  . the amount of residual combined chlorine should always be 0.2 - 0.5 mg/l (in the distribution system);
  . bacteriological tests should prove that all E-coli have been killed and thus disinfection is satisfactory.

- Only in that case can the disinfection of treated water be considered complete.

- Warning 1:
  It does not mean the distributed water is bacteriologically safe;

  Warning 2:
  All water to be consumed still has to be boiled for at least 20 min. at 100°C;

  Warning 3:
  Consumers should be permanently informed about warning 2.

INVITE QUESTIONS
INTRODUCE BREAK OF 10 MINUTES IN CLASSROOM

Removal of excess of ammonium

- An excess of chlorine must be added for converting $NH_4^+$ into (inert) $N_2$.

Use whiteboard

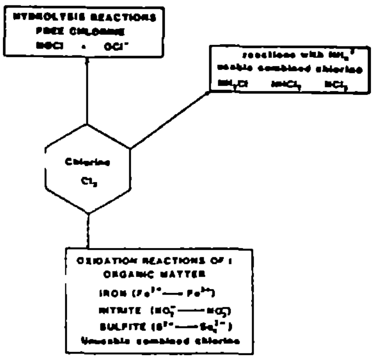
- The chlorine consumption is 6 to 10 times the $NH_4^+$ concentration if this is more than 2 mg/l.

- After 2 hours contact time the free chlorine content should be 0.5-1.0 mg/l (the maximum value is 1 mg/l). In that case disinfection can also be considered completed.

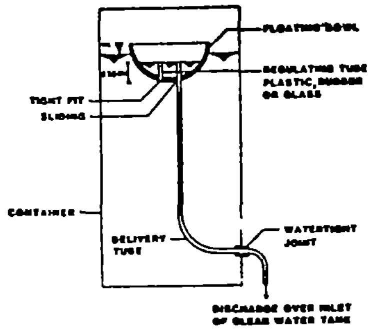
| | |
|---|---|
| 3. **Chemicals applied for disinfection by chlorine** | |
| - Kaporit, a white powder, contains 60% active chlorine; It has to be dissolved in water before dosing. | Use whiteboard |
| - Sodium hypochlorite, a solution, contains 150 g active chlorine per litre of solution. | |
| - Liquid chlorine contains 100% active chlorine. It has to be gasified before dosing. Only suitable for large treatment plants. | |
| 4. **Types of dosing system** | |
| - Gravity dosing by: | |
| . constant head box; | Show V 2 |
| . MOM dosing system. | Show V 3 |
| - Dosing pumps. | |
| - Gasification equipment for big plants. | |
| 5. **Summary** | Give H 1 |

| Module : DISINFECTION | Code : TTG 150 |
|---|---|
| | Edition : 18-03-1985 |
| Section 3 : T R A I N I N G   A I D S | Page : 01 of 01 |

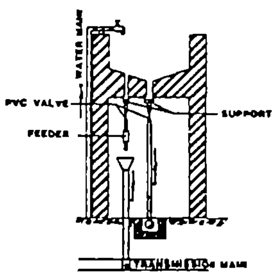
**Reactions of chlorine in water** — TTG 150/V 1




**Gravity dosing constant head** — TTG 150/V 2




**MOM-bak dosing system** — TTG 150/V 3




**Disinfection** — TTG 150/H 1

## 1. DISINFECTION

Disinfection is the addition of an active chlorine compound to drinking water in order to kill bacteriological organisms, especially pathogenic organisms, which otherwise would cause diseases and death to human beings.

## 2. T H E O R Y

### Chemical reactions

When chlorine is added to water, it will hydrolise, combine with ammonia, with organic material as well as with other chemical substances, to produce a large variety of compounds. Some of these compounds have disinfectant properties.

- Hydrolysis reactions
  Chlorine interacts with the water molecules to produce hypochlorous acid (HOCl) and ionic hypochlorite ($OCl^-$). These compounds are called free chlorine.

- Oxidation - reduction reactions
  a. Ammonial nitrogen in contact with chlorine produces chloramines (monochloramine $NH_2Cl$, dichloramine ($NHCl_2$) and trichloramine ($NCl_3$), which are called usable combined chlorine.
  b. Chlorine also reacts with organic matter and chemical substances ($Fe^{2+}$, $NO_2^-$ and $H_2S$), from which different chlorine compounds are produced, which are called the unusable combined chlorine.

Each of the compounds produced by the chlorine in the water has distinct properties. Some are very active disinfectants such as HOCl and $OCl^-$, other are less but still effective such as $NHCl_2$ and $NCl_3$, and the remaining are ineffective or do not have disinfecting power such as organic and inorganic chlorines.

### Chlorine dose

The chlorine dose to be applied for disinfection of water, is that amount which is necessary to destroy all pathogenic organisms before the water is consumed.

The application of this criterion will raise two problems:

a. The term "pathogenic organisms" involves micro-organisms such as bacteria, viruses, cystes and spores, which have a distinct resistance to chlorine.

b. The possibility to destroy these micro-organisms before the water reaches the consumer, is highly dependent of:
- the quality of disinfectant applied;
- the type of disinfectant compounds produced;
- the time available for reactions.

**Determination of the ideal dose**

For the determination of the chlorine dose the following parameters are important:

a. Typical organisms or reference organisms (coliforms, E-coli) are intended to be destroyed. Their elimination is considered an indication that all pathogens have died.

b. The time available between the addition of the chlorine to the water and the consumption of chlorine by the water.

c. The quantity of chlorine that is needed to destroy the reference organisms within the available reaction time.

d. The type of disinfectants formed in the water ($HOCl$, $NH_2Cl$, etc.) depending on the pH, ammonium content and organic matter content of the water.

Traditionally, coliforms (E-coli) have been used as the reference organisms, because they are more resistant than the pathogenic organisms.
Consequently, the presence of viruses and cystes, whose resistance is many times larger to that of coliforms, is not taken into account. The reason for this is that the determination of these organisms is very complicated.
Fortunately, the processes of coagulation, sedimentation and filtration retain a large part of these viruses and cystes.
This is why these processes must be carried out with the utmost care in case surface water is treated; the lowest turbidity possible (lower than 1 FTU at all times) must be obtained. The lower the turbidity, the lower the content of pathogenic organisms.

The minimum residual combined chlorine amounts (in mg/l), that produce 100% destruction of E-coli at a temperature of 25°C and a pH value as indicated, are listed below:

| pH | Reaction Time | | |
|---|---|---|---|
| | 10 min. | 20 min. | 60 min. |
| 6.5 | 1.50 | 0.90 | 0.30 |
| 7.5 | 1.80 | 1.50 | 1.90 |
| 8.5 | 1.80 | 1.80 | 1.20 |

However, completeness of disinfection can only be checked by bacteriological tests. Moreover, frequent measuring of the residual chlorine should be carried out, and it is desirable to use a method of analysis which separately establishes the levels of both the free and the combined chlorine.

BUT: ALL E-COLI KILLED DOES NOT MEAN THAT ALL VIRUSES OR CYSTES HAVE BEEN KILLED.

Therefore (resuming):

1. The turbidity of purified surface water must be lower than 1 FTU at all times.

2. The amount of residual combined chlorine in the distribution system should always be 0.2 - 0.5 mg/l.

3. Bacteriological tests should prove that all E-coli have been killed and thus, disinfection is satisfactory.

ONLY WHEN THESE THREE CONDITIONS ARE FULFILLED CAN THE DISINFECTION OF TREATED WATER BE CONSIDERED TO BE COMPLETED.

Warning 1

It does not mean the distributed water is bacteriologically safe.

Warning 2

All water to be consumed still has to be boiled at 100°C for at least 20 min. to be absolutely safe.

Warning 3

Consumers should be permanently informed about warning 2.

**Removal of excess ammonium**

When ammonium ($NH_4^+$) is present in the raw water, it will not be removed by the processes of coagulation, sedimentation and filtration.
Active chlorine is able to convert the ammonium into the inert substance $N_2$ (Nitrogen). This conversion takes about 20 minutes. The amount of active chlorine that will be consumed in this reaction is approximately 6 times the concentration of the existing amount of $NH_4^+$ (as ammonium ion). For seriously polluted water (many organic substances) the chlorine amount needed can increase until 6 to 10 times the existing ammonium concentration ($NH_4^+$). Ammonium oxidation, which should preceed disinfection, must be carried out when the concentration of $NH_4^+$ in the purified water exceeds a value of 0.5 mg/l.

Applying the above rules for disinfection, this means that maintaining a residual amount of free chlorine of 0.5-1.0 mg/l in the treated water for at least 1 hour, will complete the oxidation of ammonium.

## 3. CHEMICALS APPLIED FOR DISINFECTION BY CHLORINE

The chemicals used most often for disinfection are:

- Kaporit, a white powder, containing 60% active chlorine. It must be dissolved in water before dosing.

- Sodium hypochlorite, a solution that contains 150 g of active chlorine per litre of solution.

- Liquid chlorine, stored in pressured cylinders or vessels, contains 100% active chlorine. It needs to be gasified before dosing. Liquid chlorine is only suitable for large treatment plants.

4. TYPES OF DOSING SYSTEMS

The following dosing systems can be distinguished:
- gravity dosing with constant head box;
- gravity dosing with MOM dosing system;
- proportional dosing system;
- pumped dosing system.

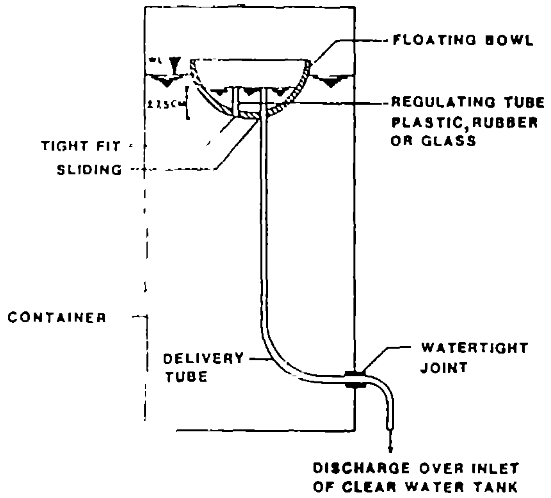



*Fig. 1. Constant head box system.*

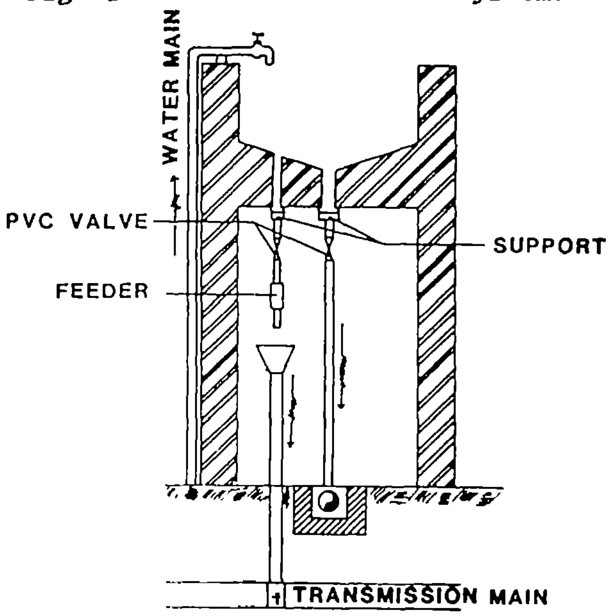



*Fig. 2. MOM dosing system.*

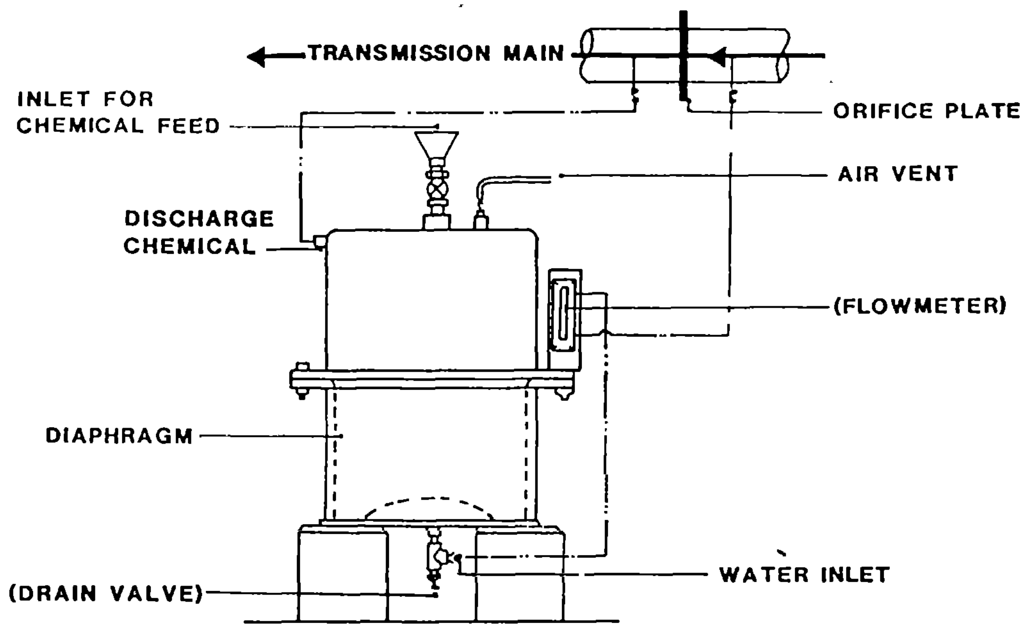



*Fig. 3. Proportional dosing system.*

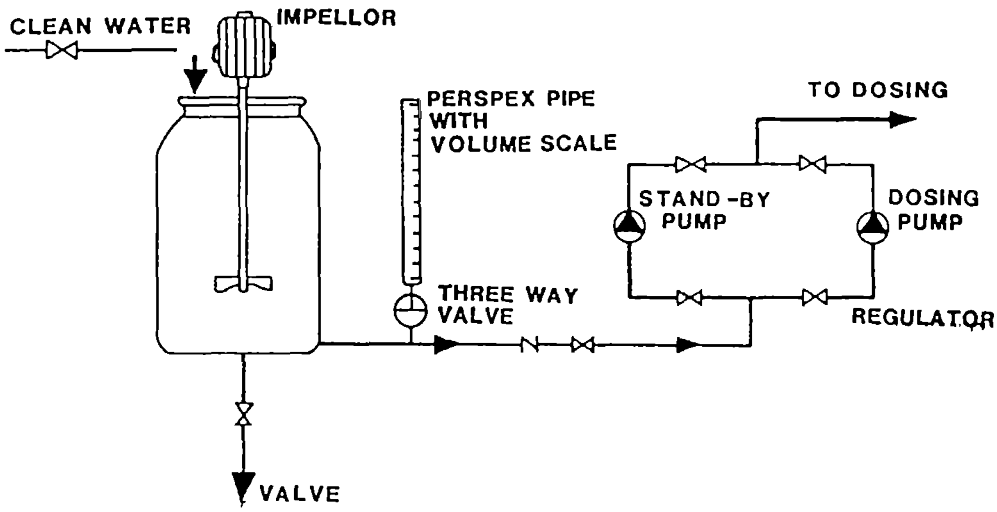


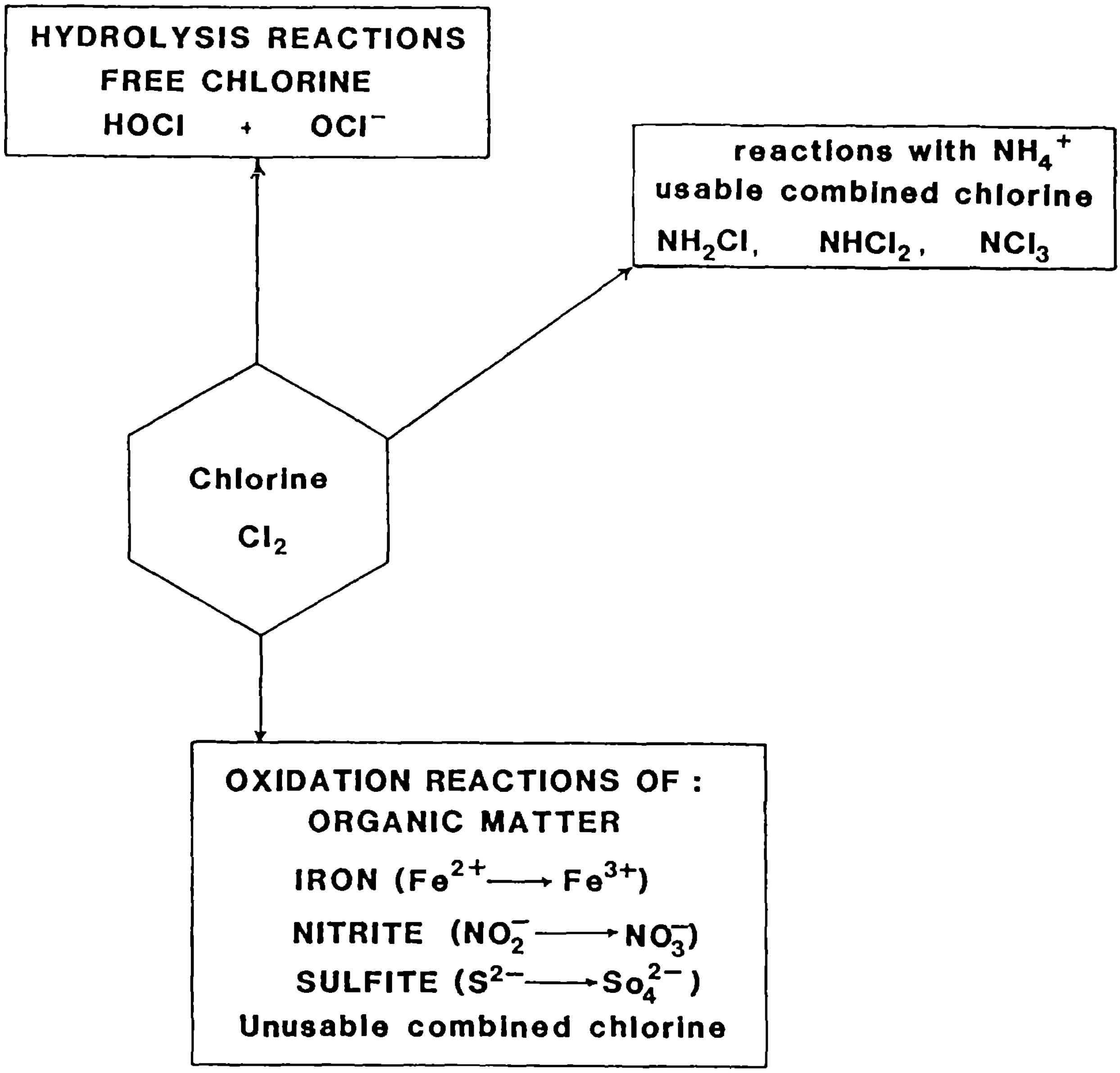

*Fig. 4. Pumped dosing system.*

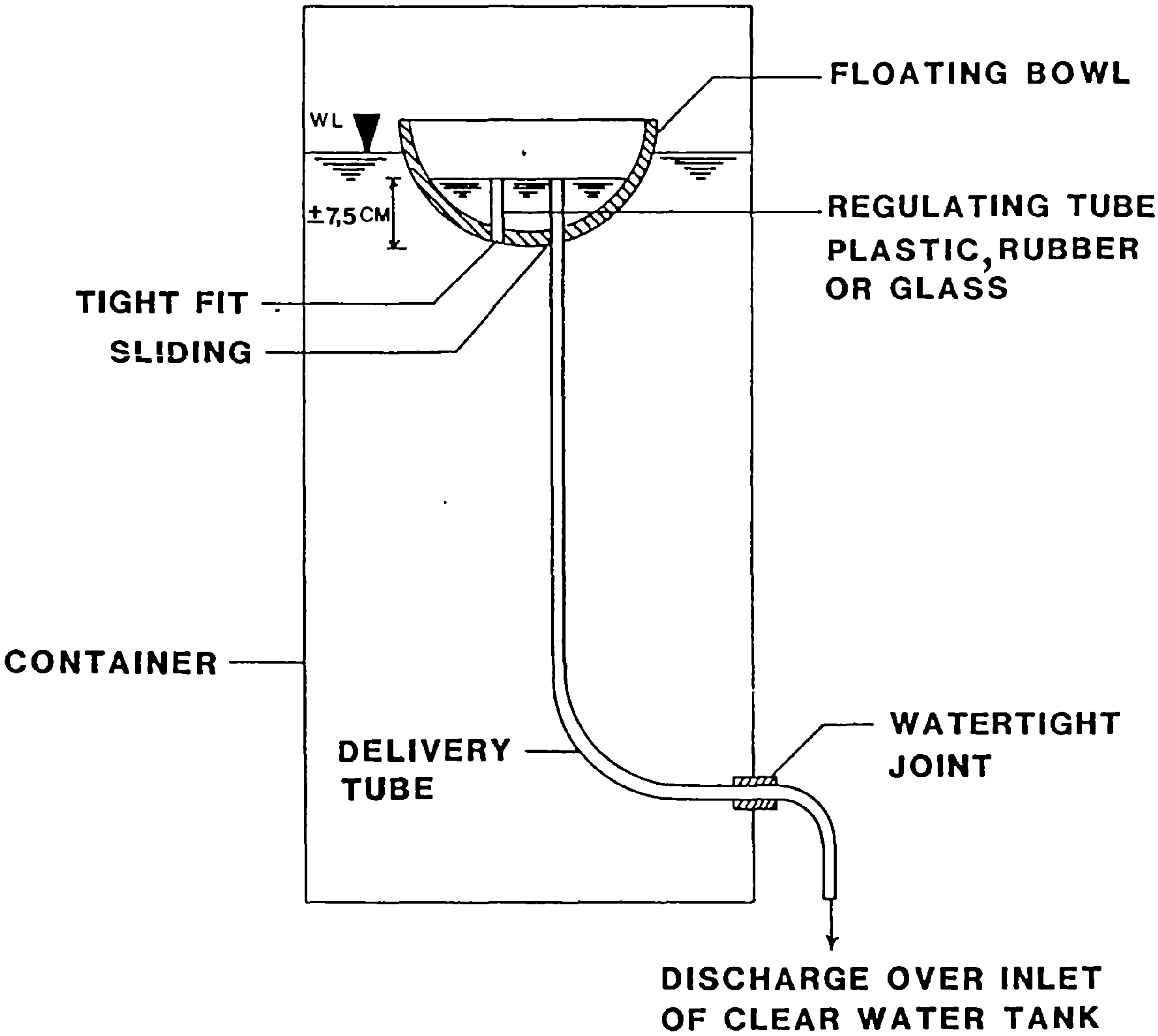
## 5. SUMMARY

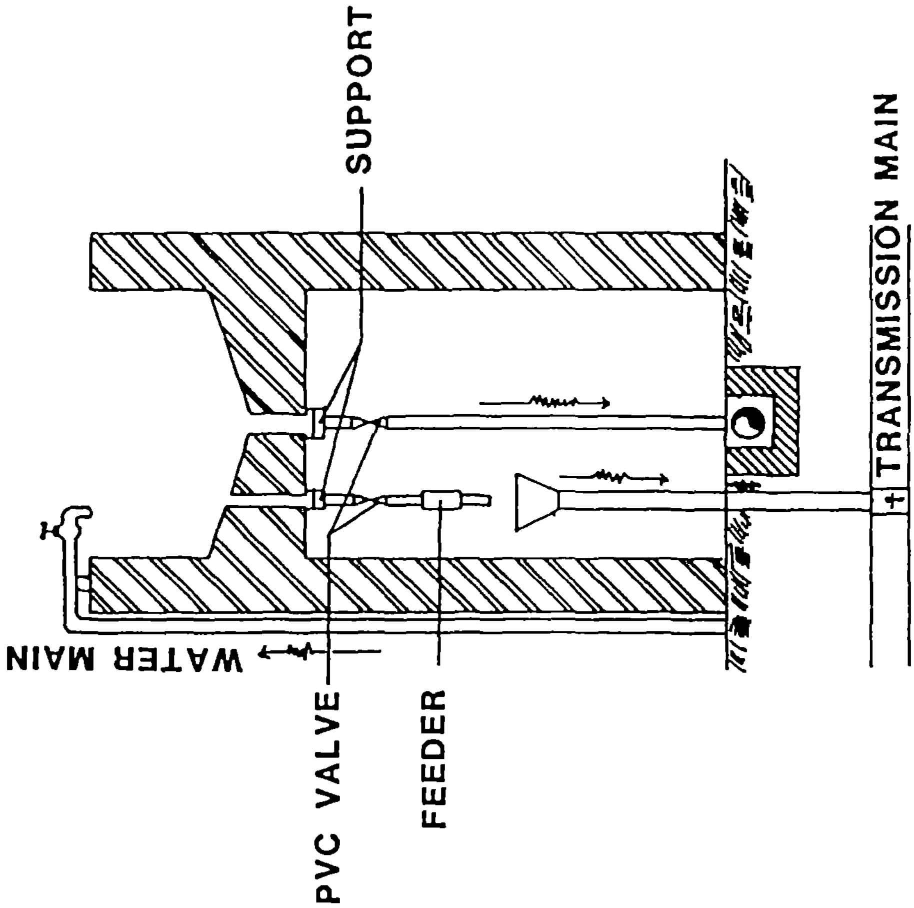
The objectives of disinfection are to add a certain amount of active chlorine to clear water in order to kill pathogenic organisms which cause disease. Therefore a certain detention time is needed during which the active chlorine can react.

During this detention time, bacteria and other micro-organisms should be killed. To achieve this, the correct dose of kaporit or other chemicals must be applied.
In some cases, an existing excess of ammonium has to be removed by adding an additional amount of active chlorine to the water.

* * *


HYDROLYSIS REACTIONS
FREE CHLORINE
HOCl + $OCl^-$
reactions with $NH_4^+$
usable combined chlorine
$NH_2Cl$, $NHCl_2$, $NCl_3$
Chlorine
$Cl_2$
OXIDATION REACTIONS OF :
ORGANIC MATTER
IRON ($Fe^{2+} \longrightarrow Fe^{3+}$)
NITRITE ($NO_2^- \longrightarrow NO_3^-$)
SULFITE ($S^{2-} \longrightarrow So_4^{2-}$)
Unusable combined chlorine


FLOATING BOWL
WL
±7,5 CM
REGULATING TUBE
PLASTIC, RUBBER
OR GLASS
TIGHT FIT
SLIDING
CONTAINER
WATERTIGHT
JOINT
DELIVERY
TUBE
DISCHARGE OVER INLET
OF CLEAR WATER TANK


SUPPORT
WATER MAIN
PVC VALVE
FEEDER
TRANSMISSION MAIN

| Module : COAGULATION/FLOCCULATION | Code : TTG 200 |
|---|---|
| | Edition : 18-03-1985 |
| Section 1 : INFORMATION SHEET | Page : 01 of 01/22 |

| | |
|---|---|
| Duration : | 90 minutes. |
| Training objectives : | After the session the trainees will be able to:<br>- list the chemicals used for coagulation;<br>- recite the mechanisms of coagulation;<br>- recite various operation procedures for coagulation/flocculation practice. |
| Trainee selection : | - Head of Technical Department;<br>- Head of Section Production;<br>- Head of Sub-section Water Treatment;<br>- Head of Sub-section Laboratory. |
| Training aids : | - Audio-visual programme "Water Treatment";<br>- Viewfoils : TTG 200/V 1-10;<br>- Handout : TTG 200/H 1. |
| Special features : | - |
| Keywords : | Coagulation/colloids/destabilization/flocculation/rapid mixing/stirring. |

1. **Principles**

- The coagulation/flocculation process is used in the treatment of surface water for the removal of turbidity, especially when caused by colloids.

- Colloids have to be removed because they cause:
  . turbidity;
  . colour;
  . taste.

- Colloids are smaller than suspended matter, but larger than dissolved solids.  *Use white board*

- Aspects of colloids and their removal are:
  . they have a negative surface charge;
  . they repel each other;
  . they form a stabilized suspension which is not settleable;
  . by the addition of chemicals they may be agglomerated, to form settleable particles.

- The coagulant used is Alum ($Al_2(SO_4)_3$) in which the $Al^{3+}$ is the destabilising agent.  *Use whiteboard*

- The coagulation/flocculation process is divided into:

  a. Coagulation:
     . dosing of coagulant;
     . rapid mixing;
     . destabilisation;

  b. Flucculation:
     . gentle mixing;
     . floc formation.

| | |
| --- | --- |
| 2. **Mechanisms** | |
| Coagulation | |
| - Aspects of colloids:<br>. there are several millions of particles in one litre of raw water;<br>. sizes are in the range of $10^{-4}$ - $10^{-6}$ mm;<br>. together not more than 0.1 mg in weight;<br>. causing a great deal of turbidity and colour;<br>. stabilized suspension because of their negative surface charge. | Show V 1 |
| - Destabilisation is neutralization of the negative surface charges by adding positive ions. | |
| - Agglomeration is the growing together of the destabilised particles by mass attracting forces. | |
| Flocculation | |
| - Flocculation comprises two processes when alum is used:<br>. agglomeration of colloids due to destabilization by $Al^{3+}$ ions;<br>. adsorption to insoluble $Al(OH)_3$ molecules which are formed by the hydrolyses of the $Al^{3+}$ ions. | Show V 2 |
| 3. **Characteristics** | |
| Coagulants | |
| - The coagulants used most often are:<br>. alum ($Al_2(SO_4)_3$;<br>. ferric chloride ($FeCl_3$). | Use whiteboard |
| - Optimal coagulation is dependent on:<br>. optimal dose of coagulant;<br>. optimal pH during the process. | Show V 3 |

- Optimal dose of coagulant depends on the nature of the raw water:
  . pH;
  . temperature;
  . turbidity;
  . chemical composition.

- Optimal dose must be determined periodically by executing a jar test.

- Optimal pH must be determined periodically by executing a jar test.

- pH will decrease during the process due to hydrolysis reactions of alum.

- For optimum pH, addition of base may be necessary: — Use whiteboard
  . caustic soda NaOH;
  . lime $Ca(OH)_2$;
  . soda ash $Na_2CO_3$.

Mixing and flocculation — Show V 4

- Rapid mixing to make the dispersal of coagulant and base added to the water rapid and uniform.

- Gentle stirring to create a great number of collisions and thus a growing of flocs.

- The difference between the coagulation and flocculation chambers are:
  . the coagulation chamber is very small, the rate of flow is high;
  . the flocculation chamber is large, the rate of flow is low.

- The optimal G.t value must be obtained because :
  . value too small : growing of flocs is too slow;
  . value too high : flocs will disintegrate.

| | |
|---|---|
| **4. Operation** | |
| Preparing an alum solution | |
| - Properties of alum:<br>. granular powder;<br>. available in bags or barrels;<br>. grey-white to light brown colour;<br>. crystalline acidic material;<br>. corrosive qualities. | |
| - Explain the preparation of a 10% solution strength<br>. 10% (by weight alum);<br>. 90% (by weight water);<br>. 1 kg water equals 1 litre in volume;<br>. alum must be obtained from the granular powder with a commercial strength of x %. | Use whiteboard |
| Preparing a base solution | |
| - Preparing a base solution is done in the same way as an alum solution. | |
| Dosing of coagulant and base | |
| - For a correct dosing the following data must be obtained regularly:<br>. flow of raw water Q (l/sec);<br>. strength of prepared solutions (coagulant and base);<br>. optimal dose of coagulant or base, x (mg/l). | Show V 6 |
| - These figures are obtained by:<br>. measuring Q by raw water meters or overflow weirs;<br>. calculating S before preparation;<br>. executing a jar test. | Use whiteboard |
| - The dosing rate is calculated as follows :<br>$q = x * \frac{342}{27} * \frac{100}{S} * \frac{1}{D} * 10^{-6} * Q$ : | Use whiteboard |

- . x is given by the jar test, expressed in mg/l $Al^{3+}$;
- . * 342/27 gives the required dose expressed in mg/l alum;
- . * 100/S gives the required dosing expressed in mg/l solution;
- . * $1/D * 10^{-6}$ gives the required dosing expressed in l/l solution;
- . * Q gives the dosing rate expressed in l/sec solution.

The dosing rate of base

- The dosing rate of base:

$$q = x * \frac{100}{S} * \frac{1}{D} * 10^{-6} * Q :$$

x is now given by a titrimetrical determination, whereby x base is added to 1 litre of solution (containing the optimal dose of coagulant) until the optimal pH (given by the jar test) is reached.

- The same calculation as for alum is valid with the exception of the factor 342/27.

Dosing equipment

- Two essential parts of the dosing equipment are: Show V 5
  - . storage tank;
  - . flow controller.

- The functions of the dosing tank and flow controller are:
  - . the dosing tank contains the prepared solution at a constant level to create a constant head;
  - . the flow controller can be adjusted to give the desired rate of flow.

| | |
|---|---|
| - The dosing rate is checked manually by.<br>. filling a calibrated cylinder of 100 ml;<br>. measuring the time for filling with a stop watch;<br>. calculating the dosing rate as: | Show V 7 |

$$q = \frac{0.1}{t} \quad (l/sec)$$

Rapid mixing

- There are two groups of rapid mixing devices:
  - . hydraulic;
  - . mechanical.

| | |
|---|---|
| - Hydraulic rapid mixers are:<br>. channels or chambers with baffles;<br>. overflow weirs;<br>. hydraulic jumps. | Show V 8 |
| - With mechanical rapid mixing the power required is imparted by impellers, propellors or turbines. | Show V 9 |

Flocculation

| | |
|---|---|
| - Flocculation devices can be divided into:<br>. mechanical flocculators;<br>. hydraulic flocculators. | Show V 10 |

5. **Operation problems**

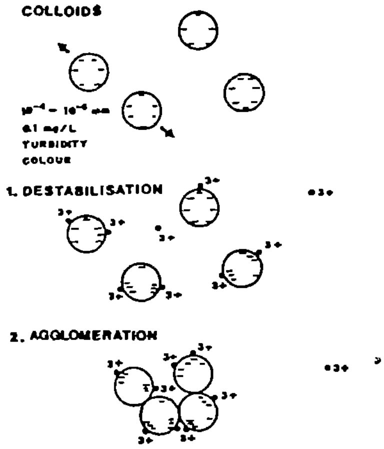
- The failing of floc formation may be the result of various mistakes in the operation process like:
  - . prepared solution doesn't have the correct strength;
  - . dosing rate is too low;
  - . dose of coagulant and/or base is wrong;
  - . flocs break up.

- The remedies for correcting the faults are, respectively:
  - prepare a new solution with the correct strength;
  - regularly check the dosing rate and adjust when necessary;
  - execute a jar test to obtain optimal dosing information;
  - adjust the stirring of the water.

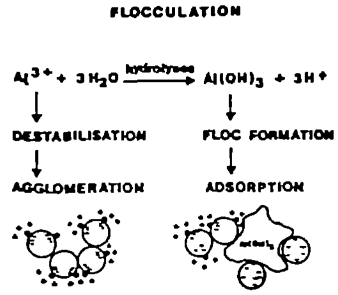
6. **Summary**

Give H 1

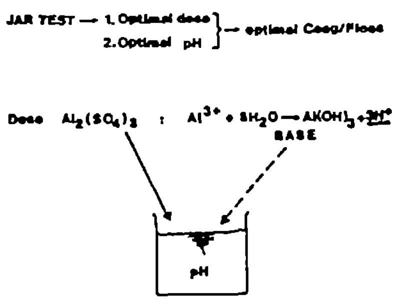
Mechanisms of coagulation — TTG 200/V 1



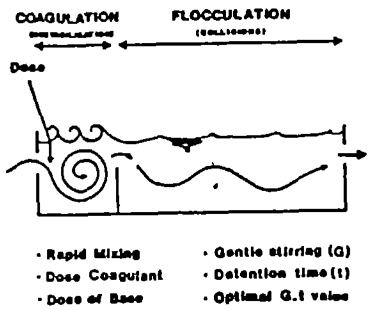

Mechanisms of flocculation — TTG 200/V 2



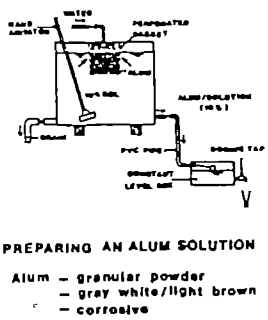

Dose of alum and base — TTG 200/V 3



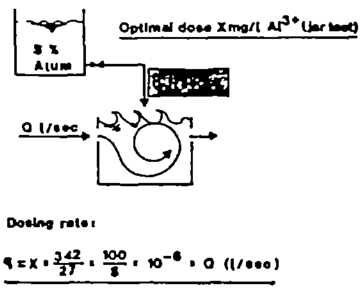

Coagulation and flocculation — TTG 200/V 4



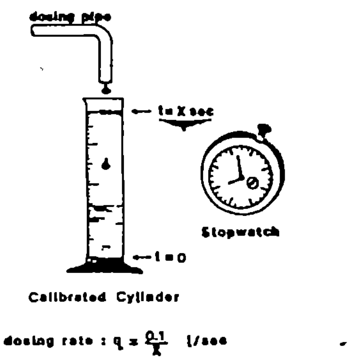

Preparing an alum solution — TTG 200/V 5



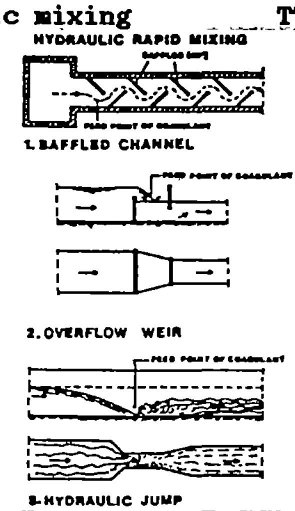

Calculating the dosing rate — TTG 200/V 6



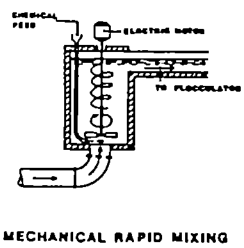
### Checking the dosing rate — TTG 200/V 7



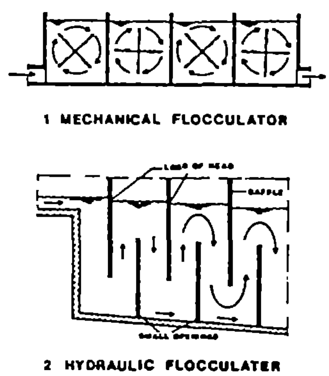

### Hydraulic mixing — TTG 200/V 8




### Mechanical mixing — TTG 200/V 9




### Flocculators — TTG 200/V10




### Coagulation/ flocculation — TTG 200/H 1

## 1. PRINCIPLES

Coagulation and flocculation in water treatment practice are the processes by which finely divided, suspended and colloidal matter in the water is made to agglomerate and form flocs. This enables their removal by subsequent sedimentation and/or filtration.

Colloids have to be removed, because they cause turbidity and colour. Surface waters in tropical countries often are turbid and contain colouring material. Turbidity may result from soil erosion, growth of algae or animal debris brought into the water by surface runoff. Colour may be imparted by substances leached from decomposed organic matter, leaves, or soil such as peat.

Colloidal particles (colloids) are midway in size between dissolved solids and suspended matter. They are kept in suspension ("stabilized") by electrostatic repulsion which occurs because colloids usually have a negative surface charge.

The electrostatic repulsion between the negative particles effectively cancels the mass attraction forces (van der Waal's forces) that would bring the particles together. This means, however, that the particles will remain too small to be removed effectively by sedimentation or filtration. For this reason chemicals (coagulants) must be added in order to neutralize the surface charges and enable the particles to agglomerate. Once agglomerated, particles have reached a sufficient size and density for their removal to become easier.

The coagulant used most often is aluminium sulphate ($Al_2(SO_4)_3$) in which the aluminium ions with a three-fold positive charge are the neutralizing (or destabilizing) agents.
The coagulation/flocculation process can be divided into two stages:

<u>Coagulation</u>:

The dosing of coagulant into the raw water, followed immediately by rapid mixing so destabilization of the colloidal particles will occur immediately.

<u>Flocculation</u>:

The gentle stirring of the water during a certain time which is needed to allow the particles to grow together and to form flocs.

## 2. MECHANISMS

### Coagulation

One litre of raw water may contain several millions of particles with sizes in the range of $10^{-4}$-$10^{-6}$ mm. Although these particles together may not count for more than 0.1 mg in weight, they may represent a large part of the turbidity and colour causing substances. Therefore they have to be removed to produce acceptable, clear drinking water.

Since colloidal particles carry a negative surface charge, thus repelling each other, they don't coalesce to form larger agglomerates which can be removed by sedimentation or filtration. These repulsive forces can be taken away by adding positively charged ions which will neutralize the surface charges, thus enabling the particles to grow together and form bigger particles or agglomerates.

Summarizing, we can distinguish two processes following the addition of positive ions:

- Destabilization, or neutralization, of the negative surface charges of the colloids by positive ions;
- Agglomeration, or growing together of the destabilized particles by the mass attraction forces (van der Waal's forces).

### Flocculation

In addition to the destabilization of the colloids by aluminium, also other mechanisms are responsible for the agglomeration or flocculation. After dissolution of alum in water the following hydrolysis reaction will occur:

$$Al^{3+} + 3\ H_2O \longrightarrow Al(OH)_3 + 3H^+$$

The insoluble $Al(OH)_3$ molecules will grow together when the water is stirred gently, forming a gelatinous voluminous structure (floc) with a great adsorbing capacity. Colloids and agglomerated destabilized colloids will be adsorbed effectively to these structures (flocs) which can be removed easily by sedimentation or filtration, thus removing the colloids as well.

So the addition of alum will lead to two mechanisms with respect to flocculation:

1. Agglomeration of colloids:
   Part of the $Al^{3+}$ ions will be not reacting with water. They destabilize the colloids.

2. Adsorption of colloids:
   To the insoluble product $Al(OH)_3$, formed from the remaining part of the $Al^{3+}$ ions by hydrolysis.

## 3. CHARACTERISTICS

### Coagulation

Alum ($Al_2(SO_4)_3$; aluminium sulphate) is by far the most widely used coagulant but iron salts (e.g. ferric chloride; $FeCl_3$).can be used as well.

Optimal dose

For good coagulation, the optimal dose of coagulant should be fed into the water and properly mixed with it. The optimal dose will vary depending upon the nature of the raw water and its overall composition (pH, temperature, turbidity, chemical composition). It is not possible to compute the optimal coagulant dose for a particular raw water. A laboratory experiment called "jar test" is generally used for the periodic determination of the optimal dose.

The optimum dose normally varies between 3 and 15 mg/l $Al^{3+}$ (5-20 mg/l $Fe^{3+}$).

Optimal pH

Addition of aluminium (or iron) salts will lower the pH of the water, due to hydrolysis reactions of the salts.

$$Al^{3+} + 3H_2O \longrightarrow Al(OH)_3 + 3H^+$$

Optimal coagulation, however, will take place at a certain pH value which depends on the nature of the raw water and its overall composition. Again this optimal pH value must be determined by a laboratory experiment, the "jar test".

For alum, the pH range for optimum coagulation is quite narrow, ranging from 6.5 to 7.5 (for ferric sulphate 5.5 to 9.0). In order to maintain an optimum pH, pH correction may be necessary, leading to a simulataneous addition of a base like caustic soda ($NaOH$), lime ($Ca(OH)_2$) or soda ash ($Na_2CO_3$).

**Mixing and flocculation**

When coagulants are added to water and thoroughly mixed, the reaction is almost instantaneous. As soon as flocs form, a further gentle stirring is advantageous in order to let the floc particles coalesce and grow bigger. There is a similarity between the two actions in so far that the water must be stirred. However, the first action, preceding floc formation, must be violent; the second, following floc formation, should be gentle.

Rapid mixing

Rapid mixing aims at the immediate dispersal of the entire dose of chemicals throughout the mass of raw water. To achieve this, it is necessary to agitate the water violently and to inject the chemical in the most turbulent zone, in order to ensure its uniform and rapid dispersal.

The mixing has to be rapid, because the hydrolysis of the coagulant is almost instantaneous (within a few seconds). The destabilization of colloids also takes very little time.
The detention time during rapid mixing will be in the range of 30 seconds to 5 minutes, depending on the design of the installation.

Flocculation

Flocculation is the process of gentle and continuous stirring of coagulated water with the purpose of forming flocs that can be readily removed by settling or filtration. The efficiency of the flocculation process is largely determined by the number of collisions between the minute coagulated particles per unit of time.

In the design of a flocculator installation not only the velocity gradient (G) should be taken into account, but also the detention time (t). The product G.t is a measure for the number of particle collisions, and thus for the floc formation action.

The formula for computing the velocity gradient is:

$$G = \sqrt{\frac{P}{\nu V}}$$ , in which

G = velocity gradient ($sec^{-1}$);
P = power transmitted to the water (Watt);
V = volume of water to which the power is applied; where applicable : the volume of the mixing tank or basin ($m^3$);
$\nu$ = dynamic viscosity of water (Pas or $Ns/m^2$)
($1.14 \times 10^{-3}$ Pas at a water temperature of 15°C;
$1.01 \times 10^{-3}$ Pas at 20°C; $0.90 \times 10^{-3}$ Pas at 25°C).

Table: VALUES OF VELOCITY GRADIENT (G) AND DETENTION TIME (t) FOR FLOCCULATION

| Design Factor | G ($sec^{-1}$) | t (sec) | G.t |
|---|---|---|---|
| Range | 10 to 100 | 1,200 to 1,800 | 30,000 to 150,000 |
| Typical Value | 45 to 90 | 1,800 | 50,000 to 100,000 |

For each individual flocculator, the optimal G.t value should be selected carefully, and taken as high as is consistent with the optimal formation of flocs without causing disruption or disintegration of the flocs after they have formed:
- a too high G.t value will disintegrate the flocs;
- a too low G.t value will not bring the particles together to form flocs.

## 4. OPERATION

### Preparing an alum solution

Alum is available as a granular powder in bags or barrels. It is a grey-white to light-brown crystalline acidic material with corrosive qualities.

The most common method of dosing the alum is in the form of a solution. Such a solution (usually of 5 to 10% strength) is prepared in special tanks with a holding capacity of 10 or more hours coagulant feeding requirements. Two tanks are required, one in operation, while the solution is being prepared in the other.

When using alum, one should keep in mind that in solutions of less than 1 percent strength, the chemical is hydrolyzed (i.e. forms agglomerates with the chemical feed water) before it is dosed into the raw water. To prevent this, the solution should always have a strength of more than 1.5 percent.

## Strength of solutions

In mixing solutions of any chemical it should be noted that a 10% solution means that 10 parts of the chemicals should be added to 90% parts of water (by weight) to get 100 parts of solution, and so on.

An 8% solution would contain 8 kg of chemical and 92 kg of water. Percentages normally relate to the actual subtance (e.g. alum) being handled and not to any of the basic elements (e.g. aluminium) included therein.

For instance: we want to prepare a 10% solution of alum ($Al_2(SO_4)_3$) with a volume of 500 litres.

- 1 litre water means 1 kg by weight, so 500 litres mean 500 kg;
- We need 450 kg of water (90%);
- We need 50 kg of alum (10%);
- 50 kg of alum must be obtained from the granular powder with a commercial strength as indicated in the manufacturer's specifications. Let us call this strength c % alum. So if we need 50 kg of alum we must add (100/c) x 50 kg of granular powder.

## Preparing a base solution

Preparing a base solution with caustic soda, lime or soda ash is done in the same way as described for alum in the previous section.
The following specifications can be given:

| | Available form | Commercial strength | Container | Appearance | Prepared strength |
|---|---|---|---|---|---|
| Caustic soda | flakes, lumps (solution) | 96-99% NaOH | drums, bulk | white, alkaline, very corrosive, hygroscopic, dangerous to touch | 1-10% NaOH |
| Lime $Ca(OH)_2$ | powder | 80-95% $Ca(OH)_2$ | bags, barrels, bulk | white powder, caustic | 1-5% $Ca(OH)_2$ |
| Soda ash $Na_2CO_3$ | powder, crystals | 98-99% $Na_2CO_3$ | bags, barrels, bulk | white powder, caustic | 1-10% $Na_2CO_3$ |

**Dosing of coagulant and base**

For a correct dosing the following data must be obtained regularly:
- flow of raw water Q (l/sec), measured by raw water meters in the inlet pipe, overflow weirs, etc;
- strength of the prepared solutions of coagulant or base, S (% in weight);
- optimal dose of coagulant or base, X (mg/l).

The optimal dose must be determined and adjusted by executing a "jar test". The jar test may be briefly described as follows:

JAR TEST:

A series of samples of water are placed on a special multiple stirrer and the samples are dosed with a range of coagulant, e.g. 5, 10, 15, 20 and 25 mg/l. They are stirred vigorously for about one minute. Then follows a gentle stirring (10 minutes), after which the samples are allowed to settle for 30 to 60 minutes. The samples are then examined for colour and turbidity and the lowest dose of coagulant which gives satisfactory clarification of the water is noted and called the optimal dose.

A second test involves the preparation of samples with the pH adjusted so that the samples cover a range (e.g. pH = 6; 6.5; 7; 7.5 and 8). The coagulant dose determined previously is added to each beaker. Then follows stirring, flocculation and settlement as before. After this, the samples are examined and the optimum pH is determined. From this figure the optimal dose of base giving the required pH can be calculated.

The dosing rate of coagulant can now be calculated as follows:

1. Calculate the required optimal dose:

   the required optimal dose in mg/l $Al^{3+}$ is given by the jar test

   X mg/l $Al^{3+}$

   the required optimal dose must be expressed in mg/l $Al_2(SO_4)_3$

$$X * \frac{342}{27} \quad \frac{\text{(molar weight of } Al_2(SO_4)_3)}{\text{(molar weight of Al)}} \text{ mg/l } Al_2(SO_4)_3$$

   Note: Alum is normally commercially available in a hydrated form, i.e. as $Al_2(SO_4)_3.18H_2O$ and has then a molar weight of 666. In all calculations this molar weight shall be applied, unless a different type of Alum is used.

2. Calculate the dosing of solution to 1 litre of water:

   the required dosing of S% $Al_2(SO_4)_3$ solution

$$X * \frac{342}{27} * \frac{100}{S} \text{ mg of solution}$$

1 kg of solution equals 1/D litres in volume (for a 10% solution of alum; D = 1.05), or:

$$X * \frac{342}{27} * 1/D * \frac{100}{S} * 10^{-6} \text{ litres of solution}$$

3. Calculate the dosing rate of solution:

   the raw water flow equals Q l/sec, requiring:

$$X * \frac{342}{27} * \frac{100}{S} * 1/D * 10^{-6} * Q \text{ l/s (solution dosing rate)}$$

<u>The dosing rate of base must be determined as follows</u>

1. Calculate the required dose:

   The required optimal pH is given by the jar test. In a laboratory test determine titrimetrically the required dose of base needed to obtain the desired pH (How many mg of base should be added to 1 litre of water containing the optimal dose of coagulant, in order to reach the desired pH value, measured by a pH meter). Required dose:

   X mg/l base

2. Calculate the dosing of solution to 1 litre of water:

   The required dosing of a S% base solution is:

$$X * \frac{100}{S} \text{ mg solution}$$

   1 kg of solution equals 1/D litre in weight: (for a 10% solution of soda ash, D = 1.1, or:

$$X * \frac{100}{S} * 1/D * 10^{-6} \text{ l of solution}$$

3. Calculate the dosing rate of the solution:

   the raw water flow equals Q l/sec, requiring:

$$X * \frac{100}{S} * 1/D * 10^{-6} * Q \quad \text{l/sec (solution dosing rate)}$$

**Dosing equipment**

The two essential parts of a dosing system are a tank in which a solution of the correct strength may be stored, and a dosing rate (flow) controller. The tank should hold 24 h supply and be duplicated so that one tank may be in service while the other is being replenished. There should be some sort of continuous stirring mechanism to obviate the risk of settlement after initial preparation.

The dosing mechanism should be capable of being controlled manually. There are two kinds of dosers: gravity-feed, and displacement pumps or tippers. The dosing rate can be altered in the former by altering the size of the outlet orifice in a constant-head tank, in the latter by altering the length of piston stroke of the specially made plunger pumps. The speed at which tippers operate can also be regulated.

The dosing rate can always be checked manually by filling a calibrated cylinder with the solution dosed and measuring the time that elapses for a 100 ml or 1 l discharge.

**Rapid mixing**

Many devices are used to provide rapid mixing for the dispersal of chemicals in water. Basically, there are two groups:
- hydraulic rapid mixing;
- mechanical rapid mixing.

Hydraulic rapid mixing

For hydraulic rapid mixing, arrangements are used such as: channels or chambers with baffles that produce turbulent flow conditions, overflow weirs, and hydraulic jumps. Rapid mixing may also be achieved by feeding the chemicals at the suction side of pumps. With a good design, a hydraulic mixer can be as effective as a mechanical mixing device.

Mechanical rapid mixing

With mechanical mixing the power required for agitation of the water is imparted by impellers, propellors or turbines.

Generally, mechanical rapid mixers are less suitable for small treatment plants than hydraulic ones since they require a reliable and continuous supply of power.

**Flocculation**

Flocculation is the process of gentle and continuous stirring of the coagulated water, following rapid mixing. There are mechanical and hydraulic flocculators.

In mechanical flocculators the stirring of the water is achieved with devices such as paddles, paddle wheels or rakes.

In hydraulic flocculators, the flow of the water is so influenced by small hydraulic structures that a stirring action results. Typical examples are: channels with baffles, and flocculator chambers placed in series.

The main shortcomings of hydraulic flocculators are:
- no adjustment is possible to changes in raw water composition;
- no adjustment is possible to the water production rate of the treatment plant;
- the head loss is often substantial;
- they may be difficult to clean.

## 5. OPERATION PROBLEMS

The purpose of the coagulation/flocculation process is the conditioning of water to form flocs that can be readily removed by settling or filtration. Problems occurring during the process are restricted to the failing of floc formation, thus leading to a remaining turbidity and colour in the effluent of the sedimentation or filtration unit that follows the coagulation/flucculation process. The failing of floc formation may be the result of various mistakes in the operation of the process which will be mentioned hereafter.

**Prepared solution does not have the correct strength**

The correct strength of the alum solution should be 10%. A solution of 1% alum will hydrolize before dosing. The optimal dosing of coagulant or base will not take place when the strength of the solution is not as expected.

**The dosing rate is too low**

One should check the dosing rate regularly and adjust it if necessary. The dosing rate should be in accordance with the optimal dose required, as determined by the jar test.

**Wrong dose of coagulant and base**

Due to changes in water quality the required optimal dose and pH will change regularly. Therefore, jar tests must be carried out regularly, in order to recognize the need for adjusting the dose of coagulant and base in time.

**Break-up of flocs**

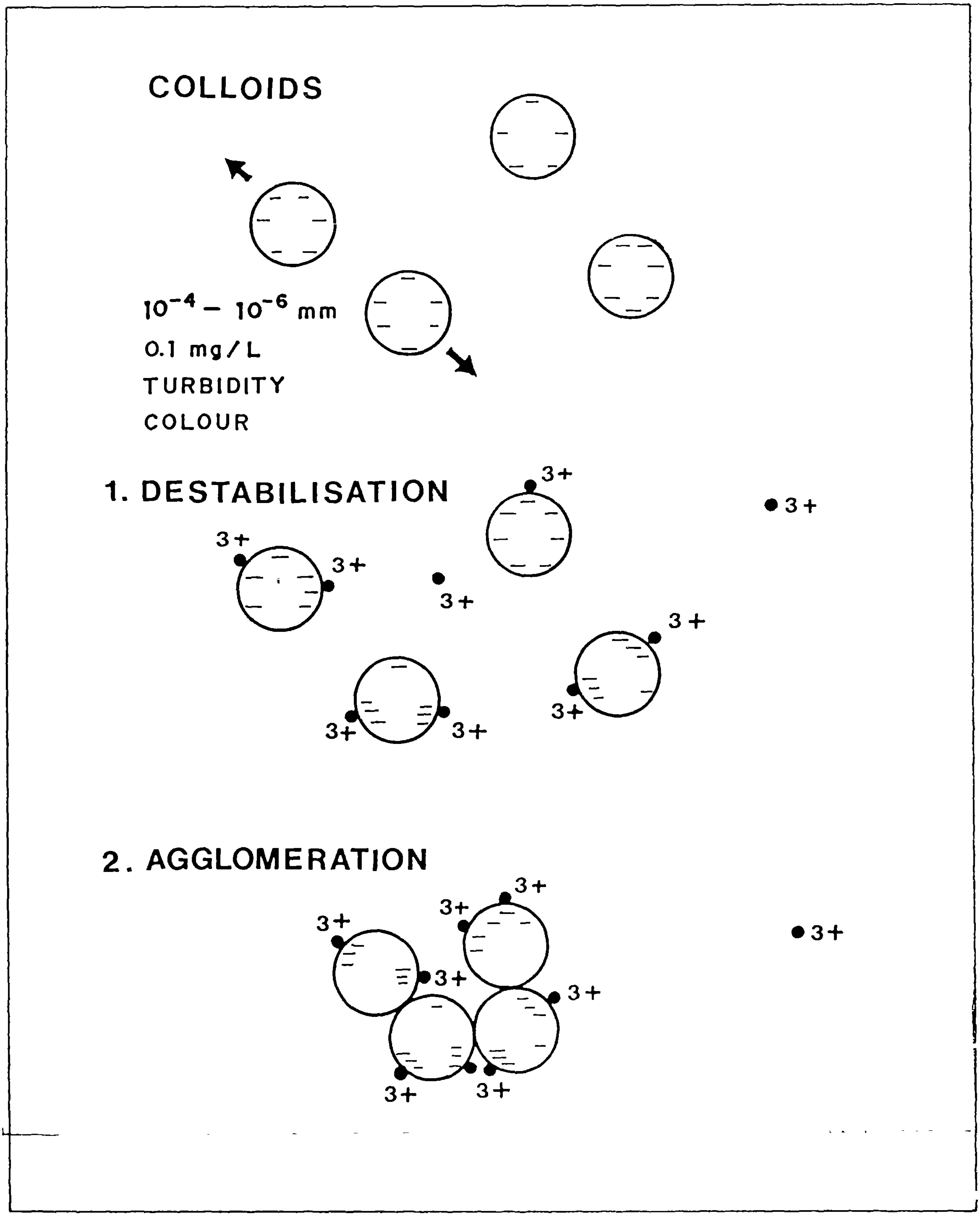
Due to a great turbulence in the flocculation unit the flocs will be broken (break-up). The stirring of the water should now be adjusted by controlling the flow or stirring devices.

## 6. SUMMARY

Coagulation/flocculation is the process in water treatment whereby colloidal matter, always present in surface water, is made to agglomerate and form flocs. For this purpose the chemicals alum and lime or soda ash are added. Main operational activities consist of preparing an alum solution and calculating the desired dosing rate. Optimal coagulation asks for an optimal dose of alum and an optimal pH, so a sharp control of process efficiency is necessary.

* * *

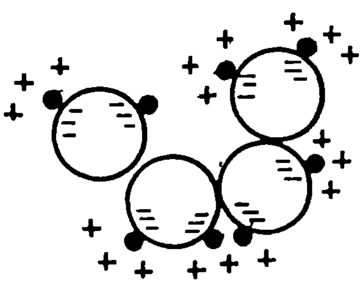
| Module : COAGULATION/FLOCCULATION | Code : TTG 200 |
| --- | --- |
| | Edition : 18-03-1985 |
| Annex : V I E W F O I L S | Page : 01 of 11 |

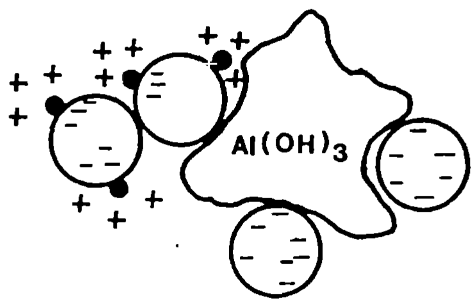

COLLOIDS
10⁻⁴ – 10⁻⁶ mm
0.1 mg/L
TURBIDITY
COLOUR
1. DESTABILISATION
3+
2. AGGLOMERATION
3+

# FLOCCULATION

$$Al^{3+} + 3H_2O \xrightarrow{\text{hydrolyses}} Al(OH)_3 + 3H^+$$

| $Al^{3+}$ | $Al(OH)_3$ |
| --- | --- |
| ↓ | ↓ |
| DESTABILISATION | FLOC FORMATION |
| ↓ | ↓ |
| AGGLOMERATION | ADSORPTION |

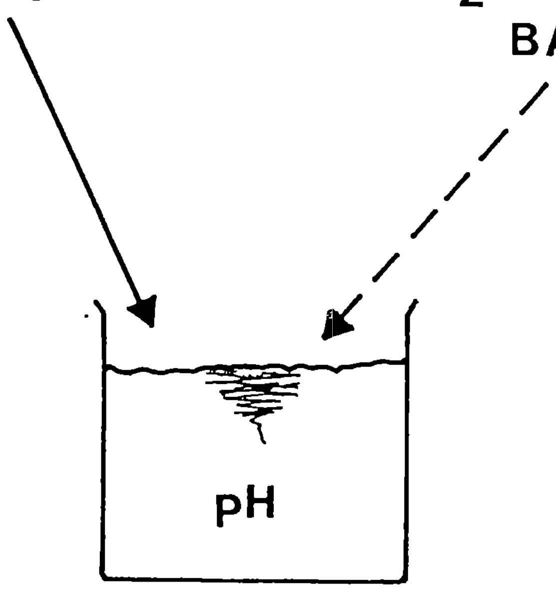


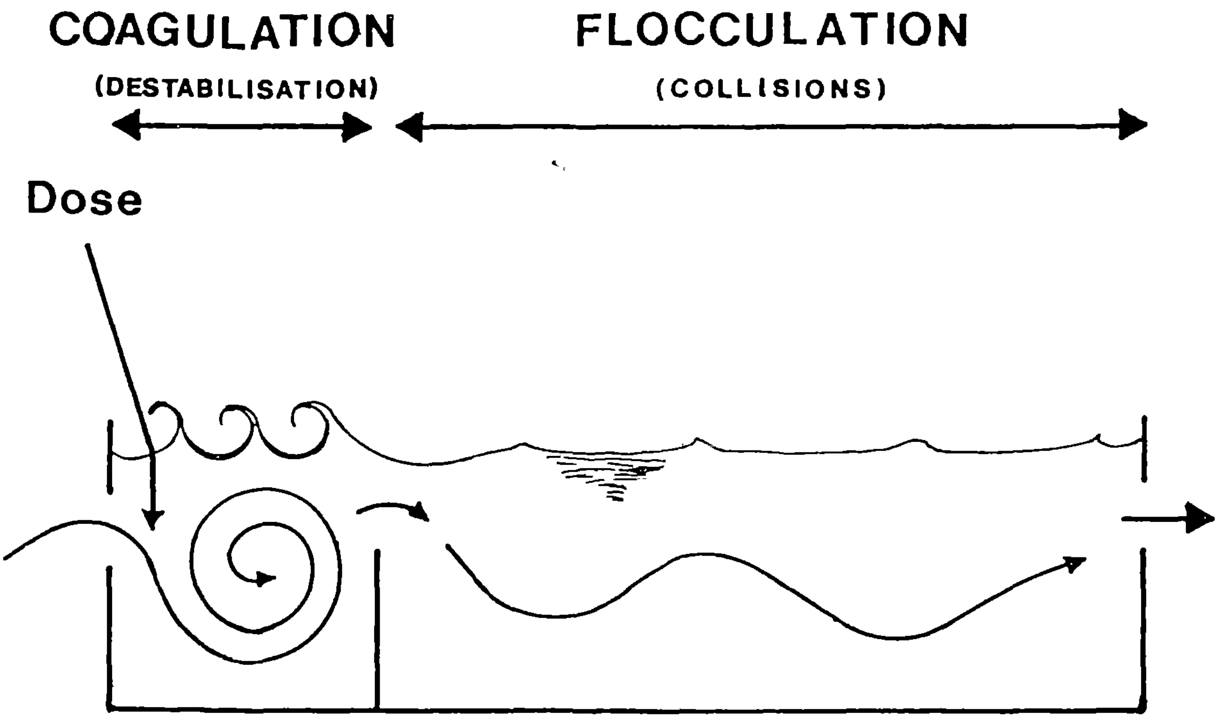


JAR TEST → 1. Optimal dose
2. Optimal pH } → optimal Coag/Flocc

Dose $Al_2(SO_4)_3$ : $Al^{3+} + 3H_2O \rightarrow Al(OH)_3 + \underline{3H^+}$

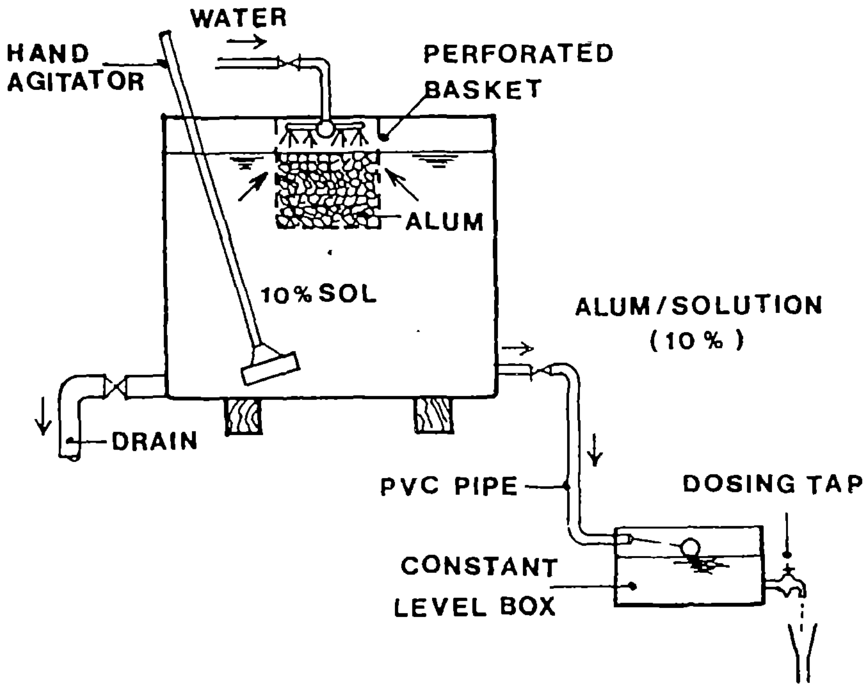
BASE






- Rapid Mixing.
- Dose Coagulant
- Dose of Base

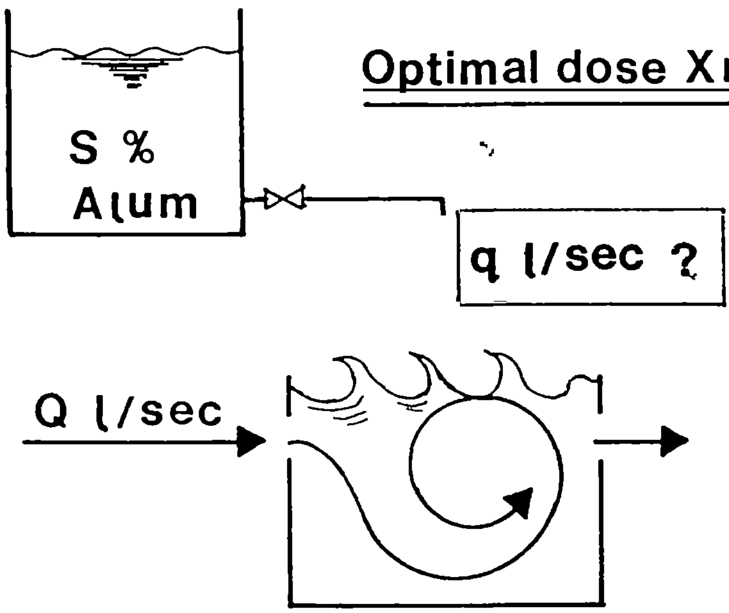
- Gentle stirring (G)
- Detention time (t)
- Optimal G.t value




# PREPARING AN ALUM SOLUTION

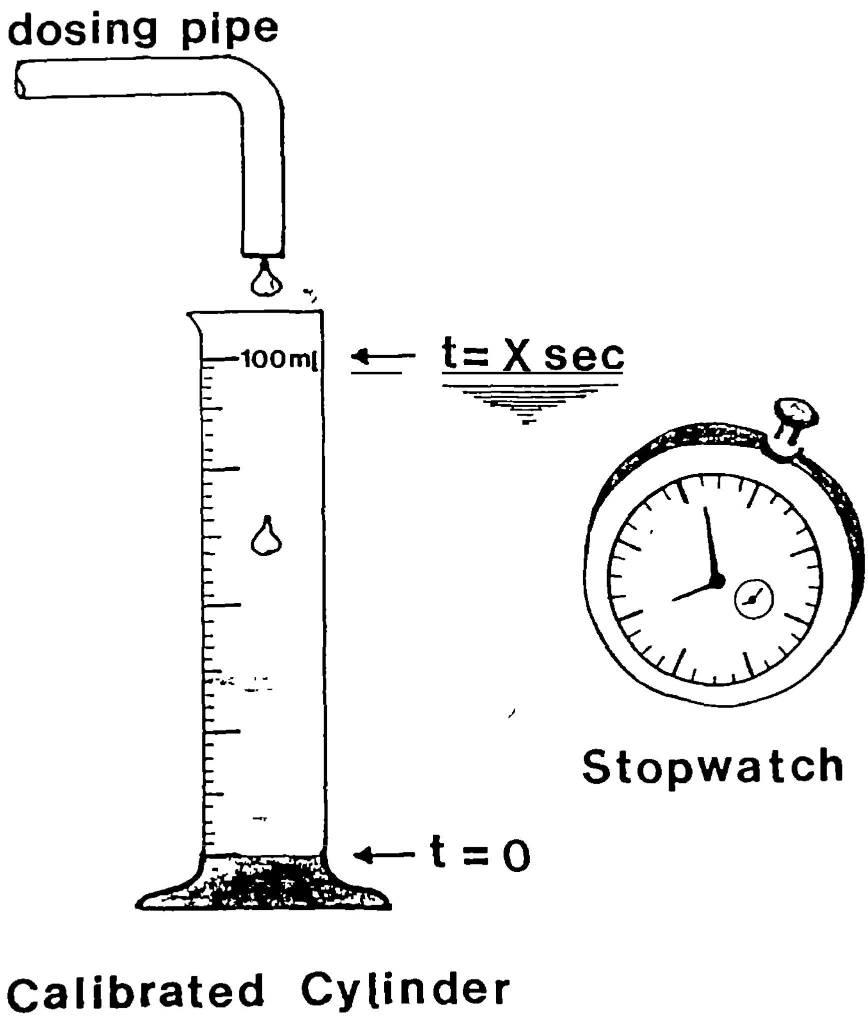
Alum
- granular powder
- gray white/light brown
- corrosive

Optimal dose X mg/l $Al^{3+}$ (jar test)



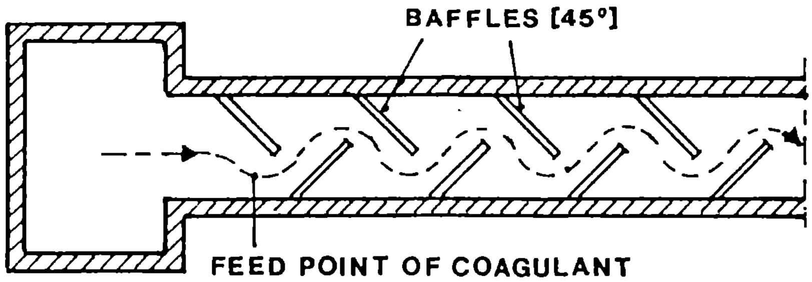

**Dosing rate:**

$$q = X \times \frac{342}{27} \times \frac{100}{S} \times 10^{-6} \times Q \quad (l/sec)$$

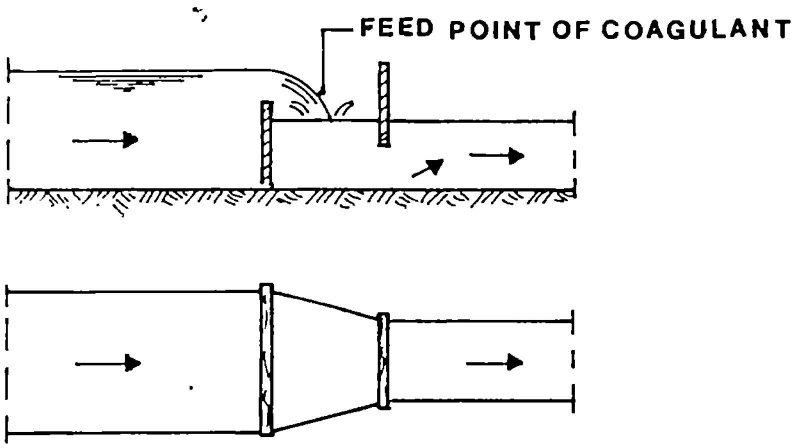



dosing rate : $q = \frac{0.1}{X}$ l/sec

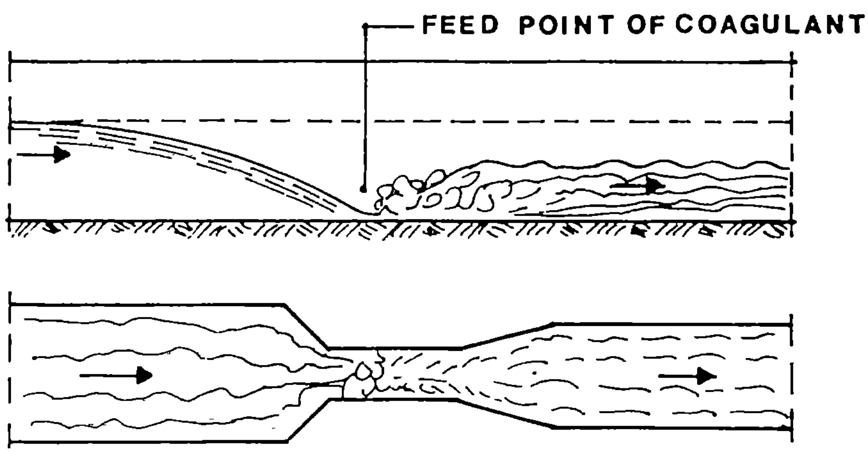
# HYDRAULIC RAPID MIXING



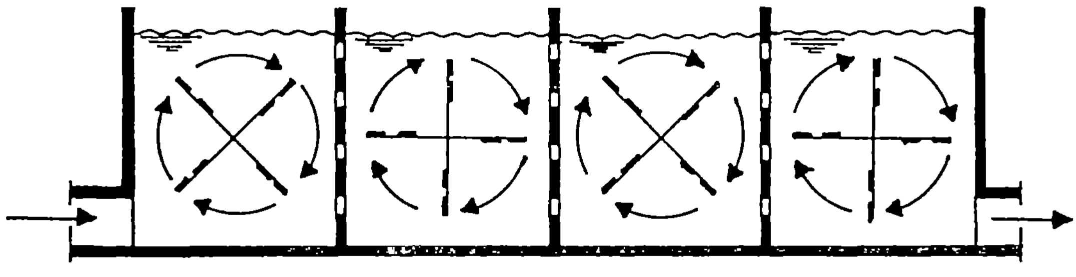

1. BAFFLED CHANNEL



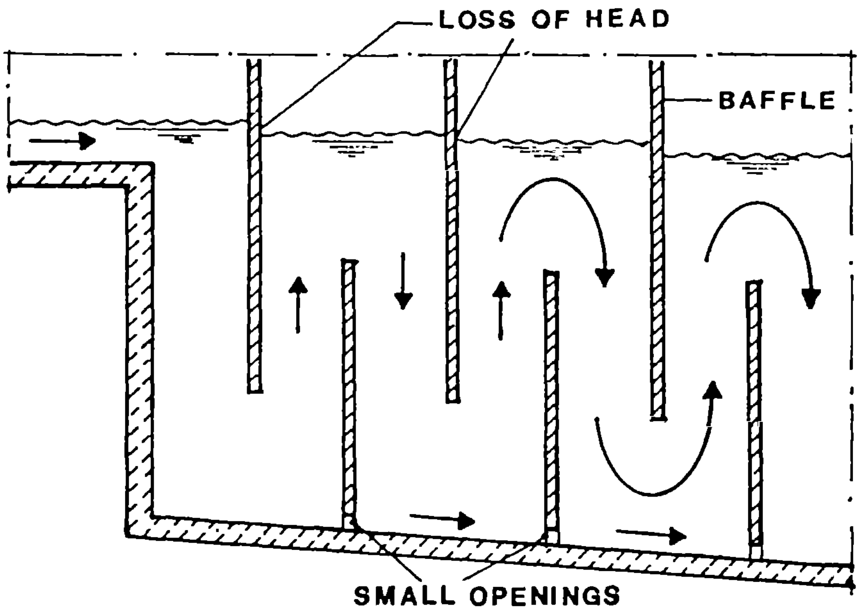

2. OVERFLOW WEIR



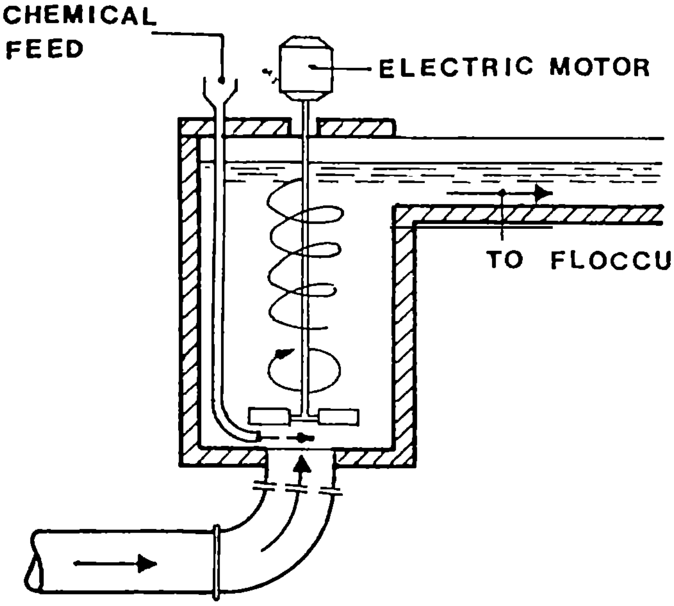

3. HYDRAULIC JUMP



1. MECHANICAL FLOCCULATOR




2. HYDRAULIC FLOCCULATER




MECHANICAL RAPID MIXING

| Module : **SEDIMENTATION** | Code : TTG 250 |
|---|---|
| | Edition : 18-03-1985 |
| Section 1 : **I N F O R M A T I O N  S H E E T** | Page : 01 of 01/14 |

| | |
|---|---|
| Duration : | 90 minutes. |
| Training objectives : | After this session the trainees will be able to:<br>- describe the principles and background of sedimentation;<br>- recognize various types of sedimentation basins. |
| Trainee selection : | - Head of Technical Department;<br>- Head of Section Production;<br>- Head of Sub-section Water Treatment;<br>- Water Treatment Plant Operator;<br>- Head of Sub-section Laboratory. |
| Training aids : | - Viewfoils : TTG 250/V 1-5;<br>- Handout : TTG 250/H 1. |
| Special features : | - |
| Keywords : | Sedimentation/surface loading/sedimentation basins/horizontal flow settling tank/radial flow settling tank/tilted plate settler/sludge blanket unit. |

| | |
|---|---|
| **1. Introduction** | |
| - The settling of suspended particles takes place when:<br>. the velocity of flow is low;<br>. turbulence is absent;<br>. particles have a higher density than the water. | |
| - Settling basins may be divided into tanks with:<br>. horizontal flow;<br>. vertical flow;<br>. radial flow. | Use whiteboard |
| - The efficiency of the settling process is reduced by:<br>. turbulence;<br>. cross circulation. | |
| - Therefore a special inlet and outlet structure is required. | |
| - Cleaning of settling tanks is done by:<br>. draining the sludge;<br>. pumping the sludge;<br>. cleaning the tank manually. | |
| **2. Characteristics** | |
| - Sedimentation efficiency depends on:<br>. settling velocities of the particles;<br>. surface loading of the sedimentation unit. | Use whiteboard |
| <u>Settling velocity</u> | |
| - Efficiency changes with water quality depending on:<br>. suspended solids content;<br>. colloids present. | Use whiteboard |
| - Suspended solids settle easily, giving a high sedimentation efficiency. | |
| - Efficiency is higher when particles are heavier. | |

| | |
|---|---|
| - Colloids will remain in suspension, thus decreasing the efficiency; | |
| - Coagulation/flocculation must be carried out as a preliminary step in order to make the colloids settleable and to increase the efficiency. | |
| <u>Surface loading</u> | |
| - Surface load So = Q/A;<br>where : Q = flow rate ($m^3$/h).<br>A = surface area of sedimentation unit ($m^2$). | Use whiteboard |
| - Particles with a settling velocity higher than So will be completely removed. | |
| - Sedimentation efficiency is higher when So becomes smaller by:<br>. decreasing Q (lower production!);<br>. increasing the surface area. | |
| **3. Configuration of sedimentation unit** | |
| - Sedimentation basins have four major zones:<br>. inlet zone;<br>. settling zone;<br>. sludge storage and removal;<br>. outlet zone. | Write on whiteboard |
| **4. Types of sedimentation units** | |
| - There are four types of sedimentation basins: | |
| <u>Horizontal flow basins</u> | Show V 1 |
| - Sludge is gathered in a sludge cone by mechanical scrapers. | |
| - Efficiency will increase when extra bottoms are installed so the surface loading will become smaller. | |

| | |
| --- | --- |
| Radial flow basins | Show V 2 |
| - Sludge is collected in a sludge cone at the centre by a mechanical, rotating scraper. | |
| Tilted plate settlers | Show V 3 |
| - The efficiency is greatly increased by the use of tilted plates or tubes (surface loading decreases). | |
| - Sludge will move to the bottom of the tank by gravity. | |
| Sludge blanket unit | Show V 4 |
| - Velocity decreases when water flows upward. | |
| - Sludge is retained in/by the blanket. | |
| - The sludge blanket unit is mostly used after a coagulation/flocculation process. | |
| **5. Problems during operation** | |
| Accumulation of scum at the surface | |
| - Accumulation of scum is due to the flotation of light material. | |
| - Scum must be removed by:<br>. skimming devices;<br>. simple buckets. | |
| Disturbance of sedimentation | |
| - The sedimentation process can be disturbed by:<br>. changes in water quality;<br>. temperature changes. | |
| - Settlement is favoured by:<br>. coarse-grained sediments;<br>. higher temperature;<br>. low turbidity. | Show V 5 |

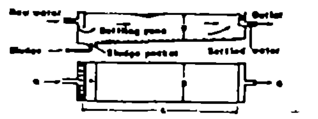
- Settlement is hindered by:
  . colloids;
  . cold water;
  . high turbidity.

- Surface load can be adjusted to:
  . a low value at bad conditions (low production);
  . a higher value at good conditions.
  Adjustment can be done by operating the inlet valve.

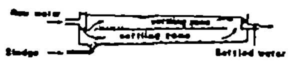
5. **Summary** — Give H 1

| Module : SEDIMENTATION | Code : TTG 250 |
|---|---|
| | Edition : 18-03-1985 |
| Section 3 : T R A I N I N G   A I D S | Page : 01 of 01 |

## Horizontal flow settling tanks — TTG 250/V 1

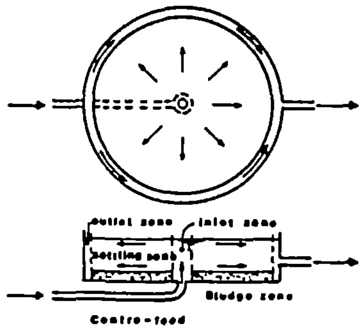


Rectangular horizontal flow settling tank



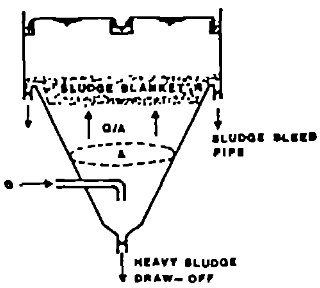
Settling tank with extra bottom

## Radial flow settling tank — TTG 250/V 2



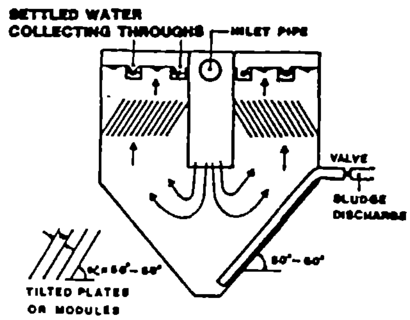

Radial flow settling basins

## Tilted plate settler — TTG 250/V 3




SLUDGE BLANKET UNIT

## Sludge blanket unit — TTG 250/V 4




TILTED PLATE SETTLER

## Sedimentation efficiency — TTG 250/V 5

SETTLEMENT

| FAVOURED BY : | HINDERED BY : |
|---|---|
| Coarse grained particles | Colloids |
| Higher temperature | Low temperature |
| Low turbidity | High turbidity |

## Sedimentation — TTG 250/H 1

## 1. PRINCIPLES

Sedimentation is the settling and removal of suspended particles that takes place when water stands still in, or flows slowly through a basin. Due to the low velocity of flow, turbulence will generally be absent or negligible, and particles having a mass density (specific weight) higher than that of the water will be allowed to settle. These particles will ultimately be deposited on the bottom of the tank, forming a sludge layer. The water reaching the tank outlet will thus be in a clarified condition.

Sedimentation takes place in any basin. Storage basins through which the water flows very slowly, are particularly effective but not always available. In water treatment plants, settling tanks specially designed for sedimentation are widely used. The most common design provides for the water flowing horizontally through the tank but there are also designs for vertical or radial flow. For small water treatment plants, horizontal-flow rectangular tanks generally are both simple to construct and adequate.

The efficiency of the settling process will be much reduced if there is turbulence or cross-circulation in the tank. To avoid this, the raw water should enter the settling tank through a separate inlet structure. Here the water must be divided evenly over the full width and depth of the tank. Similarly, at the end of the tank an outlet structure is required to collect the clarified water evenly. The settled material will form a sludge layer on the bottom of the tank. Settling tanks need to be cleaned out regularly. The sludge can be drained off or removed in another way. For manual cleaning (e.g. scraping), the tank must first be drained.

## 2. CHARACTERISTICS

The sedimentation efficiency depends on two parameters, provided that turbulence and cross-circulation are absent:
. settling velocities of the particles present;
. surface loading of the sedimentation unit.

### Settling velocities

Depending on the raw water composition, the water contains more or less suspended solids and or colloids.

Suspended solids may be easy to remove when the water is at rest, due to their greater specific density in comparison with the water, which will make them to settle. Therefore the sedimentation efficiency with respect to suspended solids will be high if many heavier particles are present.

Colloids, however, will stay in suspension even when the water is at rest, thus decreasing the filtration efficiency. In this case coagulation/flocculation as a preliminary step may be necessary in order to render the colloids settleable.

Note:

If sedimentation takes place without coagulation/flocculation as a preceeding step it is called plain sedimentation.

**Surface loading**

The surface loading (So) is defined as follows:

$$So = \frac{Q}{A}$$

with So = settling velocity (m/hr)
Q = flow rate ($m^3$/hr)
A = surface area of tank ($m^2$); for rectangular tanks: A = width x length.

Assuming an even distribution of all suspended particles in the water over the full depth of the tank (by way of an ideal inlet structure), particles having a settling velocity (S) higher than So will be completely removed, and particles that settle slower than So will be removed for a proportional part, S/So.

The formula shows that the sedimentation efficiency basically depends on the ratio between the influent flow rate and the surface area of the tank.
The lower the surface loading, the higher will be the sedimentation efficiency. It is independent of the depth of the tank. In principle there is no difference in sedimentation efficiency between a shallow and a deep tank.

## 3. CONFIGURATION OF SEDIMENTATION UNITS

Conventional settling basins have four major zones:
1. the inlet zone;
2. the settling zone;
3. the sludge storage and removal zone;
4. the outlet zone.

The following types of sedimentation basins will be discussed:

### Horizontal flow basin

In its traditional form a horizontal-flow basin resembles a large square or oblong box, filled almost to the top with water. The bottom is flat or has only a slight slope and the water is normally 3-4 m deep. Water enters at one end at or near the top and leaves at the other end over a surface weir. The basins are generally quite big. Smaller ones do exist but are not common.

They are very easy to build and operate. They are not "temperamental" and will put up with a lot of inexpert handling. Their considerable size makes it unlikely that sudden changes in raw water quality will take their operators by surprise. They "scale up" very favourably and are at their most economic in big works. They are also at their best when silt loads are exceptionally high: they precipitate silt quite well, have room to store it and are not too difficult to clean. Their cost per unit of volume is low, and although they are bulky in appearance they are normally very cheap in overall cost. They are, therefore, very good performers in big works on silty rivers and can be operated easily.

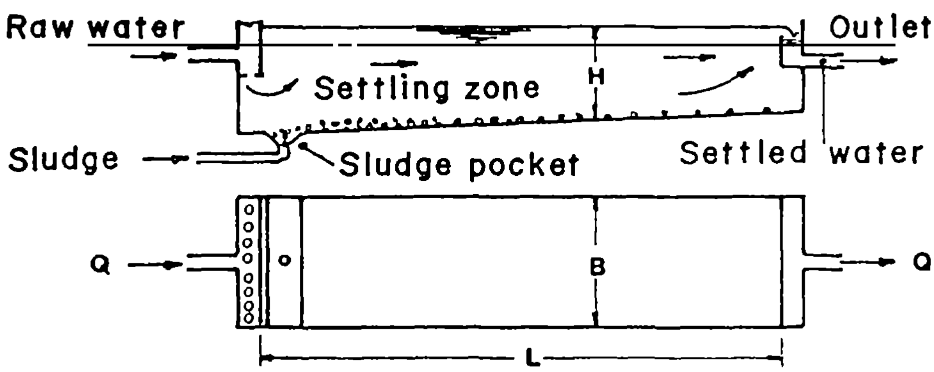



*Fig. 1. Rectangular horizontal flow settling tank.*

The sedimentation efficiency of the basin may be greatly improved by the installation of extra bottoms. The effective surface area will increase, lowering the surface load and thus improving the efficiency.

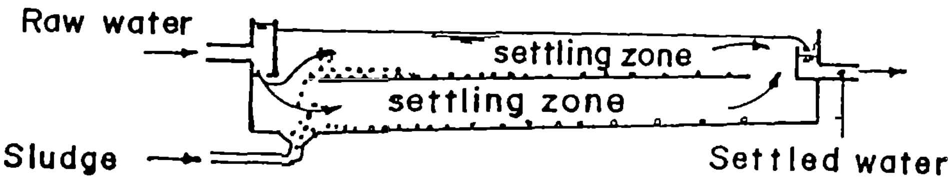



*Fig. 2. Setlling tank with extra bottom.*

**Radial flow basins**

There is no fundamental difference in hydraulic design between the rectangular cross-flow tanks and circular-shaped radial-flow tanks.

In a radial-flow basin the raw water enters through a central inlet and flows radially towards a continuous peripheral outlet weir. The same values for surface load are applied and much the same results are obtained. Obviously, radial flow velocities cannot be uniform because the cross-section increases with the radius, but this is not necessarily in itself a weakness, as maximum cross-section and therefore minimum velocity occurs where it is most needed, which is after the more rapidly settling particles have deposited.

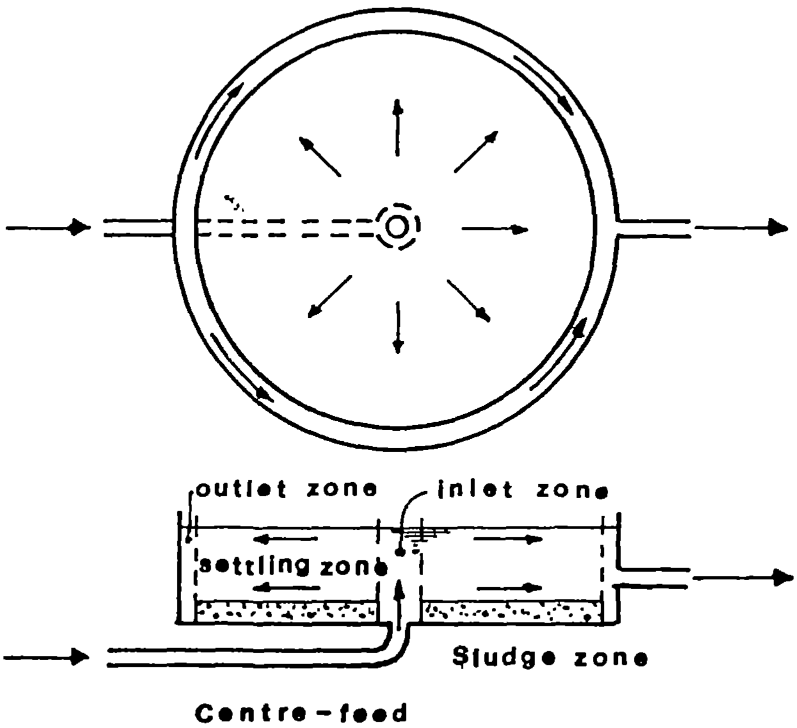



*Fig. 3. Radial flow settling basin.*

**Tilted plate settlers**

The improvement in settling efficiency which can be obtained by the installation of one extra bottom (tray) on a settling tank can be greatly increased by using more trays. The space between such trays being small, it is not possible to remove the sludge deposits manually with scrapers.

Hydraulic cleaning by jet washing would be feasible but a better solution is the use of self-cleaning plates. This is achieved by setting the playes steeply at an angle of 40° to 60° to the horizontal. The most suitable angle depends on the characteristics of the sludge which will vary for different types of raw water. Such installations are called tilted plate settling tanks.

For large tanks quite sophisticated systems of trays or plates have been devised but in small installations flat or corrugated plates and upward flow of the water are frequently the most suitable. For any clarification duty, tilted plate settling tanks have the advantage of packing a large capacity in a small volume. The effective surface being large, the surface loading will be low, and the settling efficiency, therefore, high. The surface loading may be computed as:

$$s = \frac{Q}{nA}$$

s = surface loading ($m^3/m^2$/hour);
Q = rate of flow ($m^3$/hour);
A = bottom area of the tank ($m^2$);
n = multiplication factor depending on the type and position of the tilted plates.

Water enters at the bottom of the settling tank, flows upward, passes the tilted plates, and is collected in troughs. As the water flows upwards past the plates the settleable particles fall to the plates. When they strike these, they slide downwards, eventually falling into the area beneath the plates, from where they can be removed.

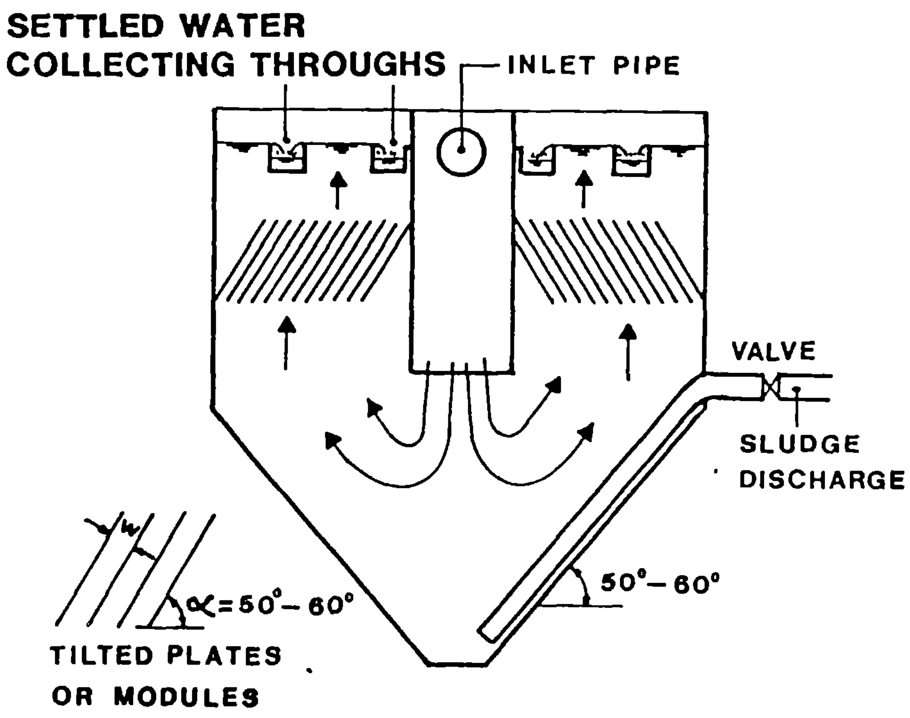



*Fig. 4. Tilted plate settler.*

**Sludge blanket unit**

For the removal of flocculent particles, the same horizontal flow basins as described may be applied, but in many cases better results can be obtained with vertical flow basins of larger depth and more elaborate inlet constructions to divide the incoming water as equally as possible over the entire tank bottom area.

A sludge blanket unit consists of a cone-shaped tank of great depth in which the velocity of upward flow gradually decreases. Near the top of the cone this displacement velocity will equal the settling velocity for a major part of the suspended flocs and here a stationary sludge blanket will form. In this blanket, the concentration of flocs is very high, promoting coalescence by which even finely divided suspended matter can be "filtered out". Withdrawal of sludge from the blanket can be controlled by a valve.

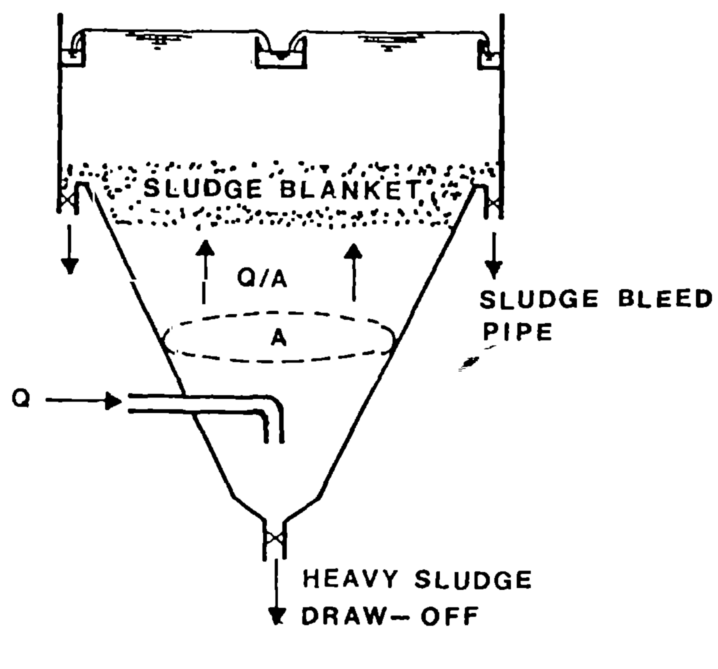



*Fig. 5. Sludge blanket unit.*

## 4. PROBLEMS DURING OPERATION

**Accumulation of scum at surface**

Floatable matter ascends naturally to the surface during substantial quiescence. The accumulated scum must therefore be removed regularly, with skimming devices or simple buckets.

**Disturbance of sedimentation**

Due to changes in water quality and temperature the sedimentation process can be disturbed or enhanced.
Factors which favour settlement are coarse-grained sediment, high temperatures and low turbidity; factors which hinder it are colloids, cold water, high turbidity and the coincidence of peak turbidity with peak water demand. One must look at the worst conditions in each case to decide how bad or good the situation may be at maximum works output, or, alternatively, how much water can be produced when the river turbidity is at its worst.

The recommended surface load can be adjusted by operating the inlet valve. The following recommendations can be given for horizontal-flow basins.

| Type | Q/A, $m^3$/day per $m^2$ | | |
|---|---|---|---|
| | Favourable conditions | Normal conditions | Unfavourable conditions |
| Without coagulant aids | 24 | 18 | 9 |
| With coagulant aids | 36 | 27 | 18 |

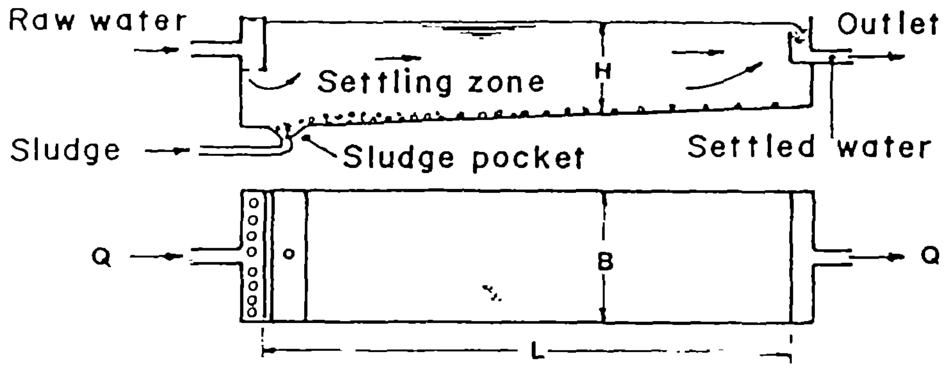
## 6. SUMMARY

Sedimentation is the settling of particles that takes place in a basin. Several sedimentation units are used, such as horizontal flow and radial flow basins, tilted plate settlers and sludge blanket units.

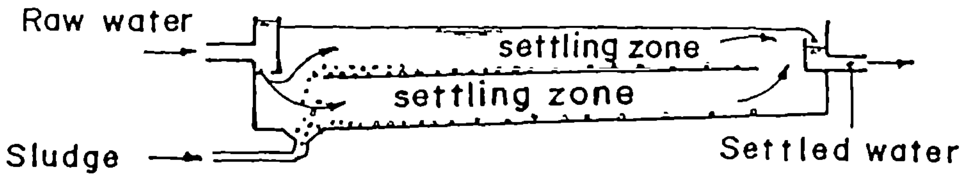
* * *

| Module : SEDIMENTATION | Code : TTG 250 |
|---|---|
| | Edition : 18-03-1985 |
| Annex : V I E W F O I L S | Page : 01 of 06 |

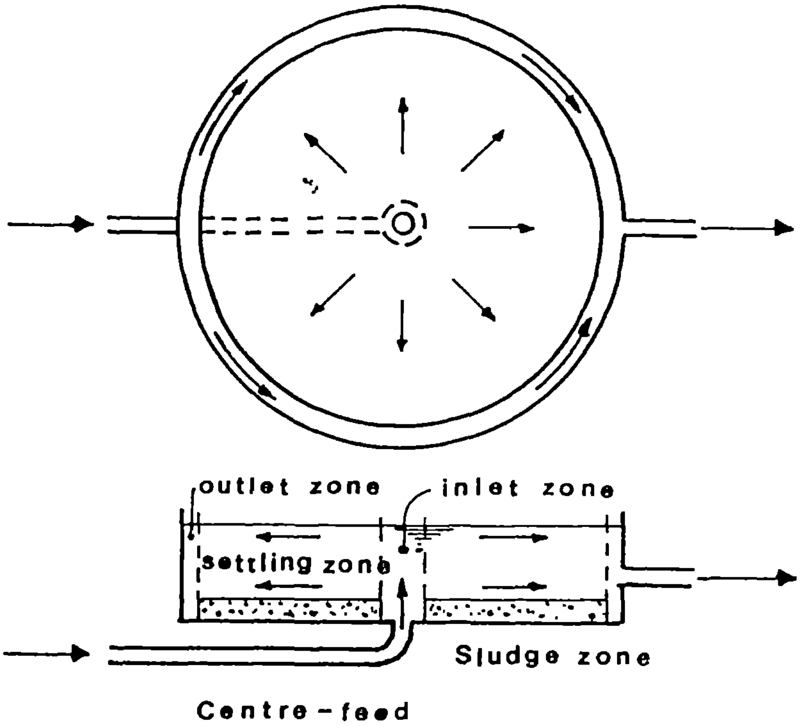
| TITLE : | CODE : |
|---|---|
| 1. Horizontal flow settling tanks | TTG 250/V 1 |
| 2. Radial flow settling tank | TTG 250/V 2 |
| 3. Tilted plate settler | TTG 250/V 3 |
| 4. Sludge blanket unit | TTG 250/V 4 |
| 5. Sedimentation efficiency | TTG 250/V 5 |



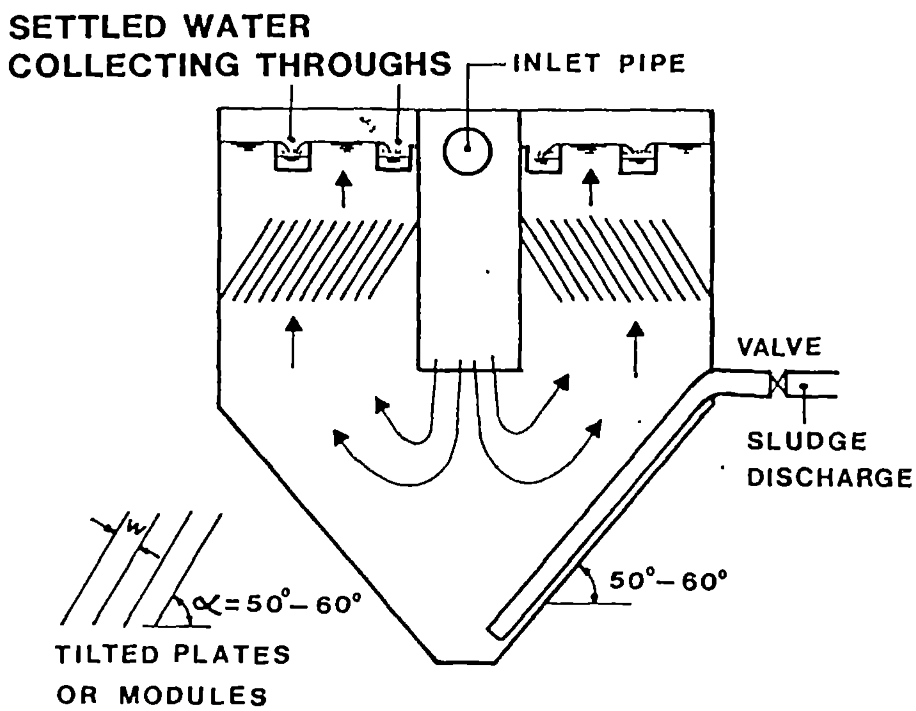

Rectangular horizontal flow settling tank



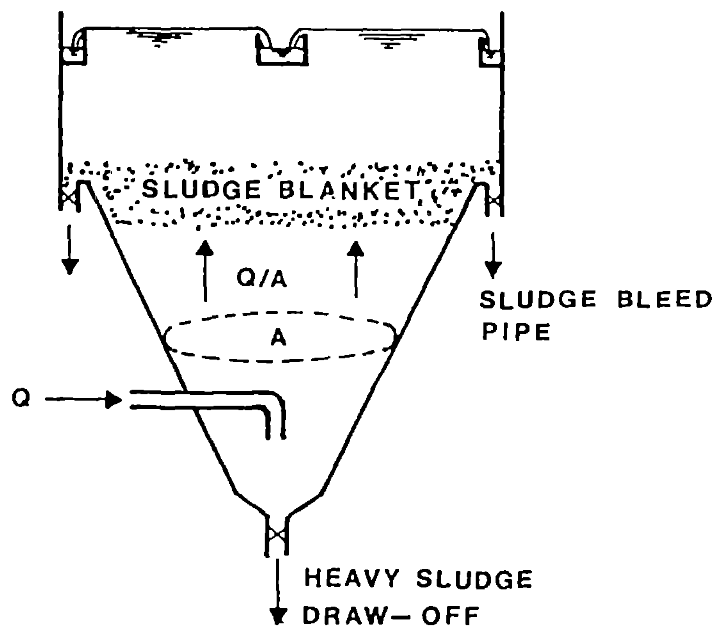

Settling tank with extra bottom




Radial flow settling basins




TILTED PLATE SETTLER




SLUDGE BLANKET UNIT

## SETTLEMENT

| FAVOURED BY : | HINDERED BY : |
|---|---|
| Coarse grained particles | Colloids |
| Higher temperature | Low temperature |
| Low turbidity | High turbidity |