

FS-PRI-002

TECHNOLOGY FACT SHEETS
FOR EFFLUENT TREATMENT PLANTS
ON TEXTILE INDUSTRY

PRIMARY CLARIFIER

SERIES: PRIMARY TREATMENTS

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PRIMARY CLARIFIER (FS-PRI-002)

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INDEX

1.- DESCRIPTION**1.1.- Clarifier typologies****2.- DESIGN****2.1.- Design parameters****2.2.- Design criteria****2.3.- Sludge production****2.4.- Removal efficiency****3.- SURFACE REQUIREMENTS****4.- OPERATIONAL PROBLEMS****BIBLIOGRAPHY****ANNEX 1.- UNIT PROCESSES GRAPHIC DESCRIPTION**



1.- DESCRIPTION

Primary clarification main objective is suspended solids (SS) removal from wastewater under the sole influence of gravity. In particular, settleable solids and floatable materials elimination is intended. Wastewater passes through the settling unit at a low velocity so that solids with a density significantly higher than water can settle. Additionally, materials with less density than water (e.g. oil and grease) will float.

A primary clarification unit produces a less turbid effluent (due to SS removal), and a primary sludge. This sludge uses to have an organic fraction; therefore, a DBO reduction is also achieved in this step. Process magnitude reduction depends on the type of process unit and raw water characteristics.

Overall, the adoption of primary clarification units represents fewer problems on the downstream biological process operation. For example, there will be a lower quantity of oil and grease and biomass accumulation in the biological reactor, minimizing possible settlements in the tank and reducing the tendency to “non filamentous” bulking of activated sludge biomass, etc.

Attending to the applicability of clarification, its use as a basic element on physical-chemical treatments has to be taken into account, that means, when it is combined with chemical coagulation and flocculation.

Primary clarification utility in the context of a conventional wastewater treatment is principally conditioned by two factors:

- Wastewater treatment warranty: Under the view of achieving a major treatment performance on every situation.
- Sludge treatment line adopted on the ETP.

The assurance requirements to ETP capacity will depend on respective importance of the treatment plant. In the case that, for any reason the biological treatment is not working properly, primary settling system permits the generation of a settled effluent on the place of a just pre-treated wastewater flow. Therefore, a major purification level will be guaranteed in this situation.

In general, the primary clarification is not recommended when the biological process has a low, or very low, organic load rate, e.g. extended aeration processes. This means, assuming that settleable organic matter forms part of the substrate to be degraded by biological reactor biomass.

1.1.- Clarifier typologies

Static clarifiers without sludge recirculation are those of general use. Primary sludge normally contain organic matter that can be degraded on an anaerobic process with gas production, leading to particle floatation, and odor generation. It is a kind of sludge which needs further stabilization.

With regard to plain form of a clarifier, it may be rectangular or circular. The following figures present images and diagrams of different primary settlers.

As reflected on the images, clarifiers can be process unit with many industrial equipment: moving arm, bottom scrapers and skimmers (bottom and surface respectively), baffles, etc. The main purpose of this equipment is the continuous removal of sludge and floatable matter that accumulates the unit.

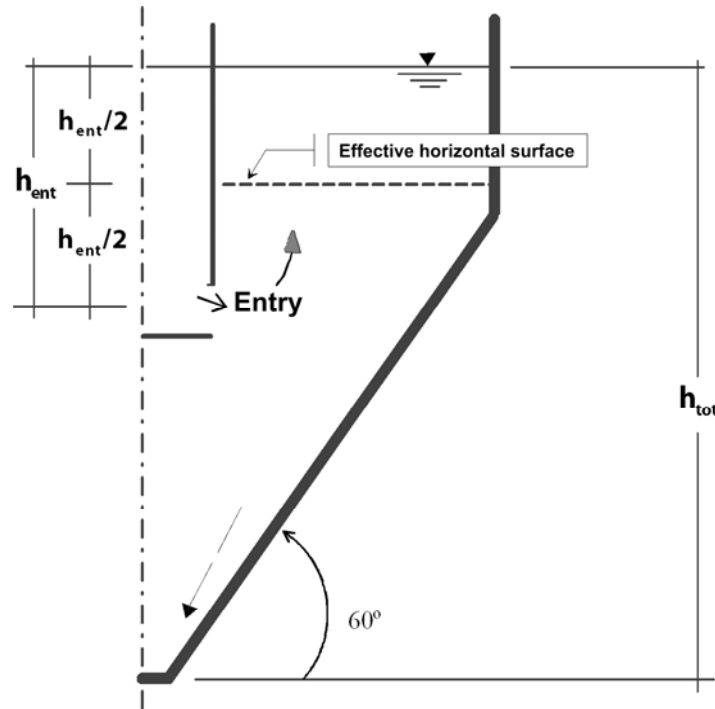


Figure 1.- General diagram of a cone-shaped clarifier without moving bridge.

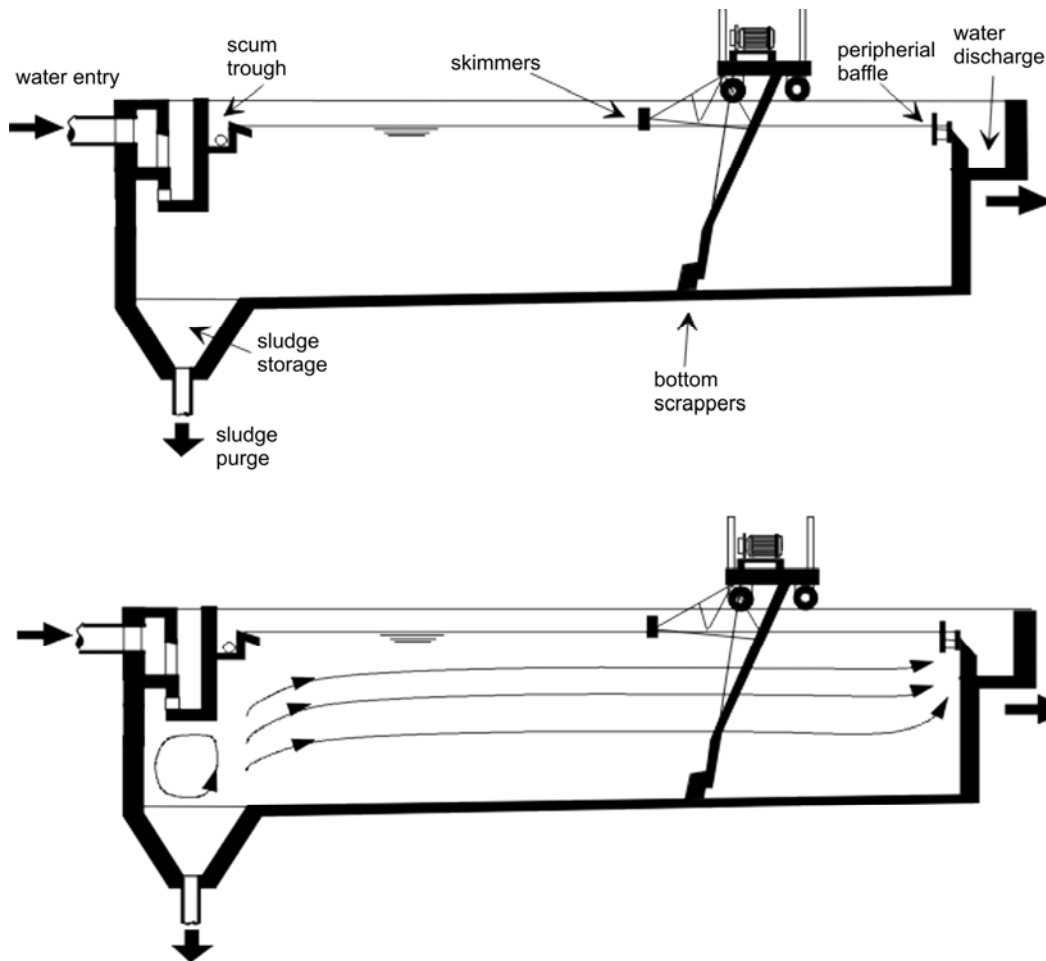


Figure 2.- General diagrams of a rectangular clarifier with moving bridge.

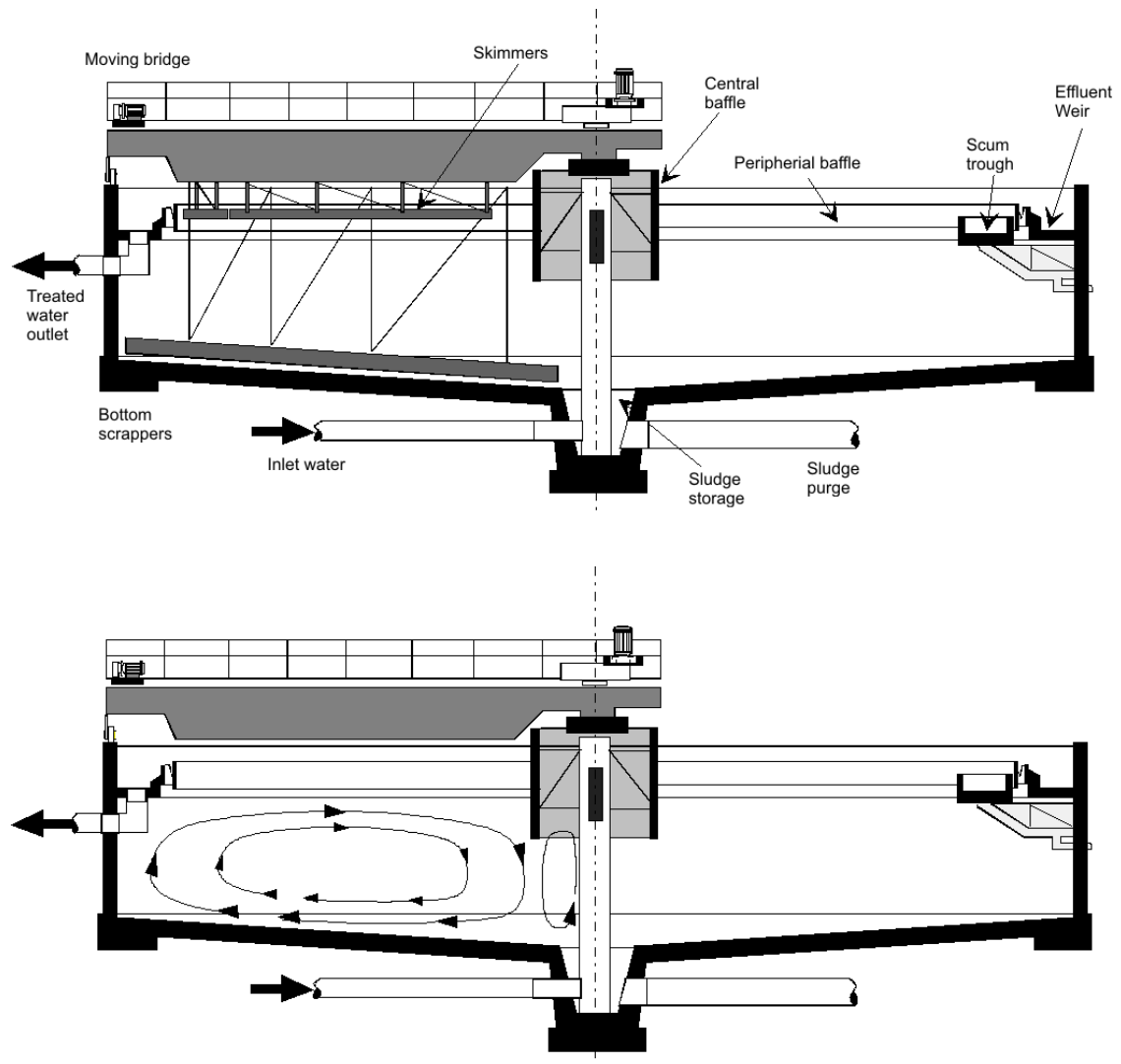


Figure 3.- General diagrams of a circular clarifier with moving bridge.

2.- DESIGN

2.1.- Design parameters

The most important sizing parameters in the primary clarifiers design are:

- **Surface hydraulic loading rate:**

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

Where:

HLR = Surface hydraulic loading rate (m/h)

Q = primary effluent flow (m³/h)

A = settling tank area (m²)

- **Hydraulic retention time:**

$$HRT = \frac{V}{F} = \frac{A h}{F}$$

Where:

HRT = Hydraulic retention time (h)

h = Side water depth (m)

V = Effective settling volume (m³)

- **Weir overflow rate:**

$$WOR = \frac{F}{W_L}$$

Where:

WOR = Weir overflow rate (m³/h/m)

W_L = weir length (m)

2.2.- Design criteria

Generally, limit values are established for surface loading rate, HRT and tank efficient depth, which are related to one another (see proposed values in the following table). HRT is in a range between 1.5 and 2.5 hours. Several sources recommend not to prolong HRT unduly because organic matter tends to rot quickly generating significant operating problems. This makes that sometimes, necessary theoretical tank depth can reach values as low as 2.0 to 2.5 meters.

The value of the weir overflow rate has an established limitation to avoid sludge drag-out from the bottom of the clarifier. This way it can be stated a maximum of 10 m³/h/m.

Furthermore, a yield of 50% reduction in SS is an attainable design goal (range: 50 to 70%). BOD₅ can be reduced from 20 to 40%.

In order to avoid interferences caused by the sludge blowdown system, the bottom scrapers maximum speed is limited, which in the case of a circular clarifier is given by the peripheral speed. Similarly, the maximum retention time of the sludge is limited in the concentrator to avoid anaerobiosis and consequent process disruption, mainly the sludge flotation.

In addition to the above-mentioned, there are other practical design criteria of primary settling, for example:

- The central baffle in a circular clarifier with central feed normally has dimensions which usually comply with the following relations: 1) diameter is normally from 0.05 to 0.20 of clarifier diameter, 2) its depth is between 1/3 and 1/5 of the maximum depth of the clarifier.
- The slope of the floor of a rectangular clarifier is usually 1%. In a circular clarifier it could be up to 10%.
- In rectangular clarifiers length/width ratio is between 1.5 and 7.5 (usually 3). In circular clarifiers the radius/height is usually between 2.5 and 8.

In the following table, primary clarifiers design parameters values are established.



Table 1.- Summary of design values for primary settling.

Parameter		Value
Removal efficiency ⁽¹⁾	SS	≥ 60 %
	DBO ₅	≥ 30 %
HLR	Q _{ave}	≤ 1.0 m/h
	Q _{max}	≤ 1.5 m/h
HRT	Q _{ave}	≥ 2 h
	Q _{max}	≥ 1 h
WOR (F _{peak}) ⁽²⁾		≤ 10 m ³ /h/m
Side water depth ⁽²⁾		≥ 2.50 m (maximum 5 m)
Overhead space		>= 0.50 m
Primary sludge concentration (for calculation)		1%
Primary sludge extraction period		10 h/day
Bottom scrappers velocity		circular < 120 m/h rectangular < 60 m/h
Bottom slope	Circular (with scrappers)	8 %
	Rectangular (with scrappers)	2 %
Central baffle (circular, central feeding)	Diameter	10 % a 20 % de of clarifier diameter
	Depth	1 a 2 m
Scum baffle	Depth	≥ 30 cm
Sizing ⁽³⁾	Length/width ratio	3 - 5
	Maximum length	40 m
	Maximum width	12 m
	Maximum diameter	40 m
Sludge sump storage time ⁽⁴⁾		< 5 h

(1) In case of wastewaters with a high sedimentable solids fraction, maximum removal efficiency could be higher.

(2) With the aim of minimizing the sludge drag-out with the effluent

(3) Maximum limitation taking into account constructive effects, climatology, etc.

(4) In order to avoid sludge rot and hydrolyzing

2.3.- Sludge production

In primary settling process, the sludge purge quantity is extracted from the following expression:

$$P_{1S} = Q_{ave} \cdot SS \cdot R \cdot 10^{-5}$$

Where:

P_{1S} = Average daily sludge production (kg SS/day)

Q_{ave} = Average flow rate (m³/d)

SS = Suspended solids average concentration in the affluent wastewater (mg/L)

R = SS removal in the primary clarification (%)

If sludge density is indicated as the same as water, primary sludge volume can be estimated as:

$$F_{1S} = \frac{P_{1S}}{10 C}$$

Where:

F_{1S} = Average primary sludge flow rate (m³/day)

C = Primary sludge concentration (%)

Primary sludge concentration is limited to 1% for calculations (table 1). Sludge extraction period will be 10 hours/day

2.4.- Removal efficiency

For the load and/or effluent concentration calculation, the following removal efficiencies are determined:

- SS = 50 %
- DBO₅ = 20 %

3.- AREA REQUIREMENTS

Table 2.-Primary clarification surface requirements estimation.

FLOW (m ³ /h)	HLR (m ³ /h/m ²)	
	1	1,5
	AREA REQUIREMENTS (m²)	
5	5	3
10	10	7
20	20	13
30	30	20
40	40	27
50	50	33
60	60	40
70	70	47
80	80	53
90	90	60
100	100	67

4.- OPERATION PROBLEMS

In order to avoid septic conditions that make sludge float and release gases that could resuspend an already settled sludge fraction, a continuous purge is required.

Digestion gases by reloaded sludge (CO₂, methane, etc.) are difficult to extract and can pass-through the primary clarifier reaching downstream processes.

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ANNEX 1

GRAPHIC DESCRIPTION OF PROCESS UNITS

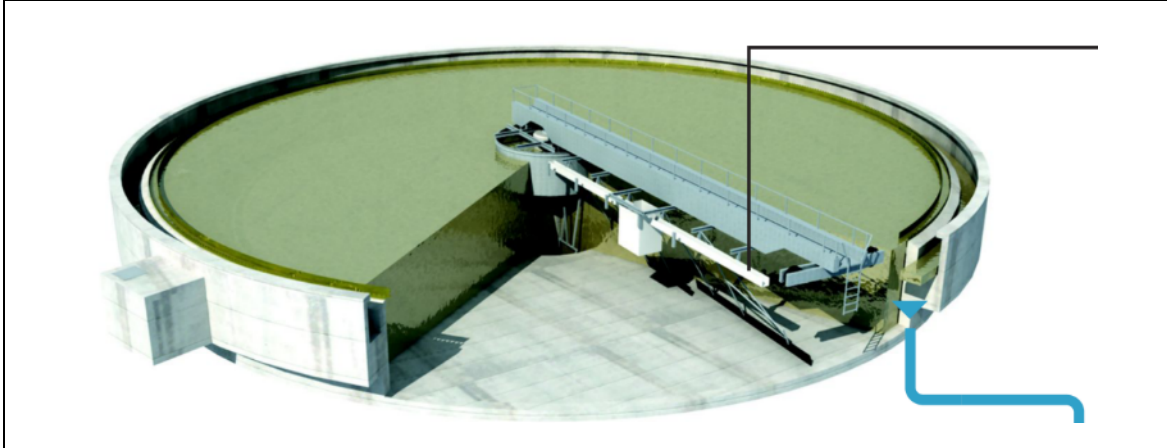


Figure 1
General diagram of a circular primary settling tank.

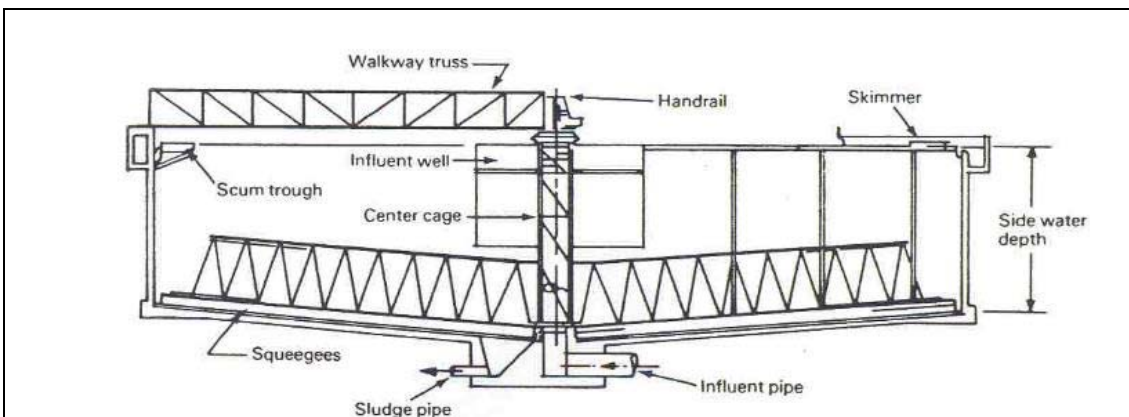


Figure 2
Diagram of main circular primary clarifier elements



Figure 3
General view of a rectangular clarifier with chain skimmers.

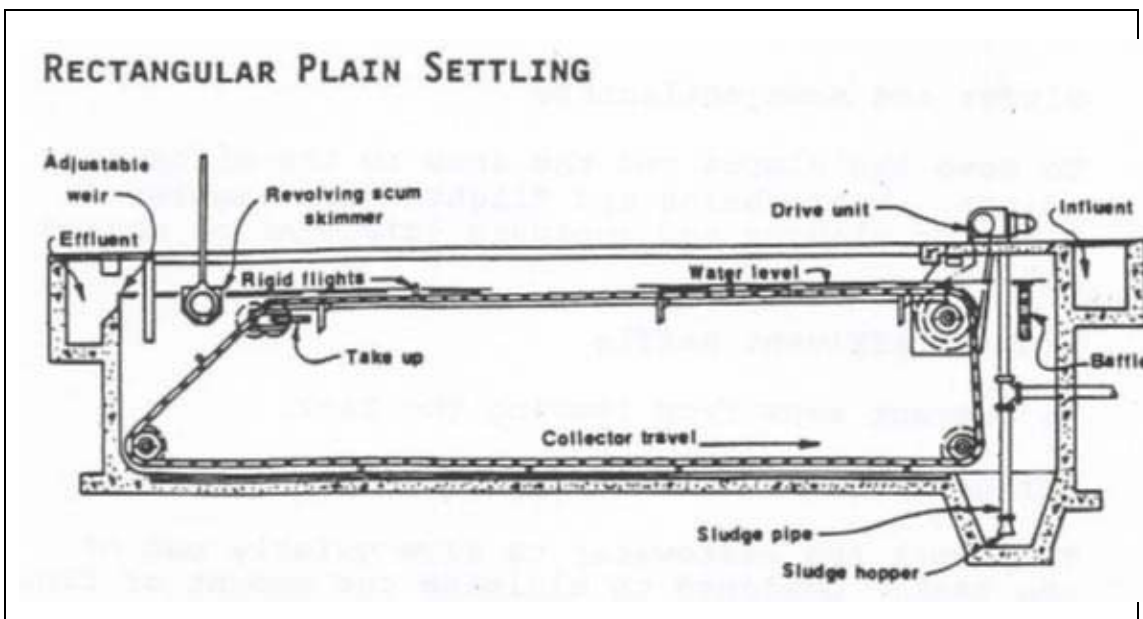


Figure 4
General diagram of a rectangular-plan clarifier and its main elements. Sludge and scum extraction systems by chain scrapers and skimmers.



Figure 5
Detail of sludge and scum extraction system by chain scrapers and skimmers



Figure 6
Detail of central baffle to optimize raw water entry.



Figure 7
Detail of a scum trough on a primary clarifier



Figure 7
Rotating skimmer arm with bottom scrapers in a circular clarifier



Figure 8
Rotating skimmer arm with bottom scrapers in a circular clarifier



Figure 10
Primary rectangular clarifiers with skimmers fixed to a moving bridge.



Figure 11
Rectangular clarifier with chain scrapers bottom cleaning system



Figure 12
General view of a circular primary clarifier with moving arm.



Figure 13
General view of a circular primary clarifier with moving arm.

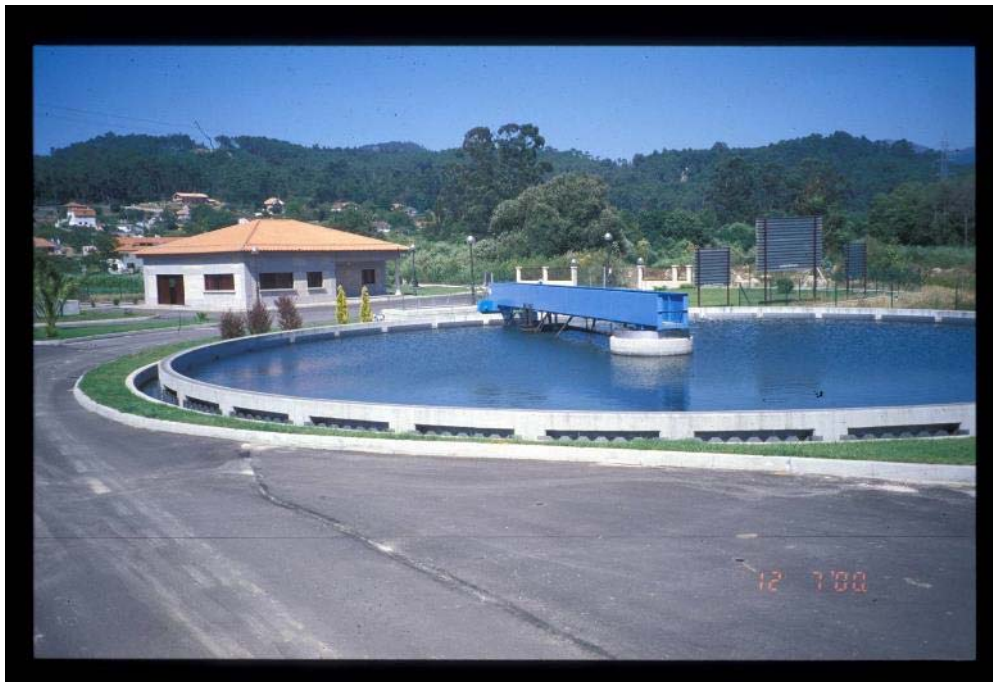


Figure 14
General view of a circular primary clarifier with moving arm.



Figure 15
General view of a circular primary clarifier with moving arm and central raw water distribution system



Figure 16
General view of a circular primary clarifier with moving arm and central raw water distribution system



Figure 17
Drive unit of a circular clarifier moving arm.



Figure 18
General view of a circular primary clarifier with moving arm and central raw water distribution system

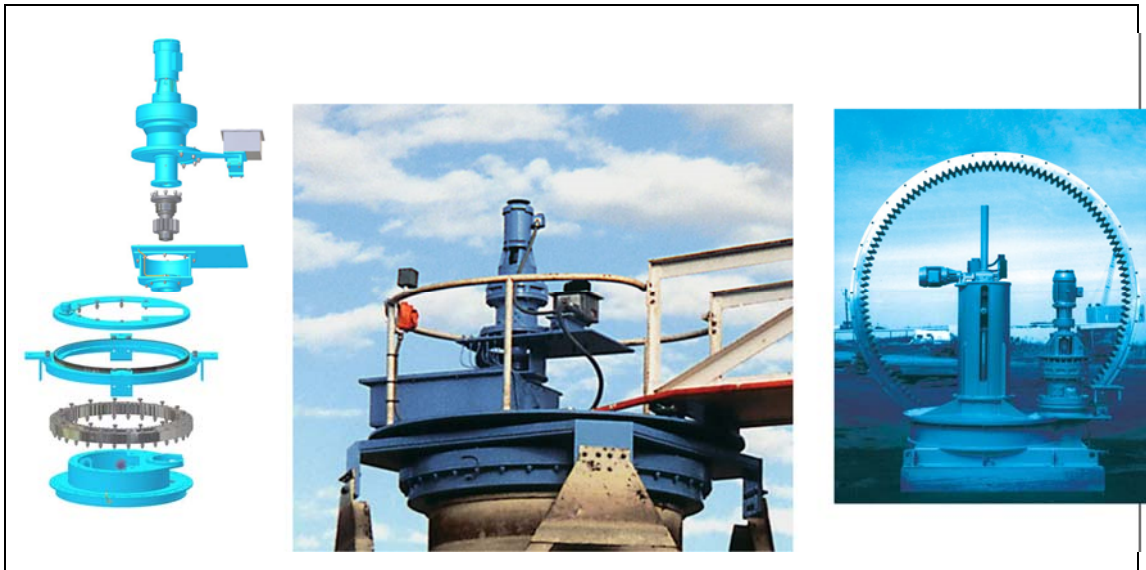


Figure 19
Drive unit of a moving arm skimmer system.



Figure 20
Double-baffle central feeding system



Figure 21
Detail of clarified water over the effluent weir: baffle and v-notch weir.



Figure 22
Detail of clarified water over the effluent weir: baffle and v-notch weir.



Figure 23
Detail of clarified water over the effluent weir: baffle and v-notch weir.



Figure 24
Double weir channel extraction system for clarified water



Figure 25
Clarified water extraction system by radial perforated tubes



Figure 26
Primary clarifier where sludge floating happened.



Figure 27
Scum trough



Figure 28
Scum trough



Figure 29
General view of a weir system, peripheral baffle and skimmers leading scum to the trough



Figure 30
Bottom scrapers system fixed to central drive unit.

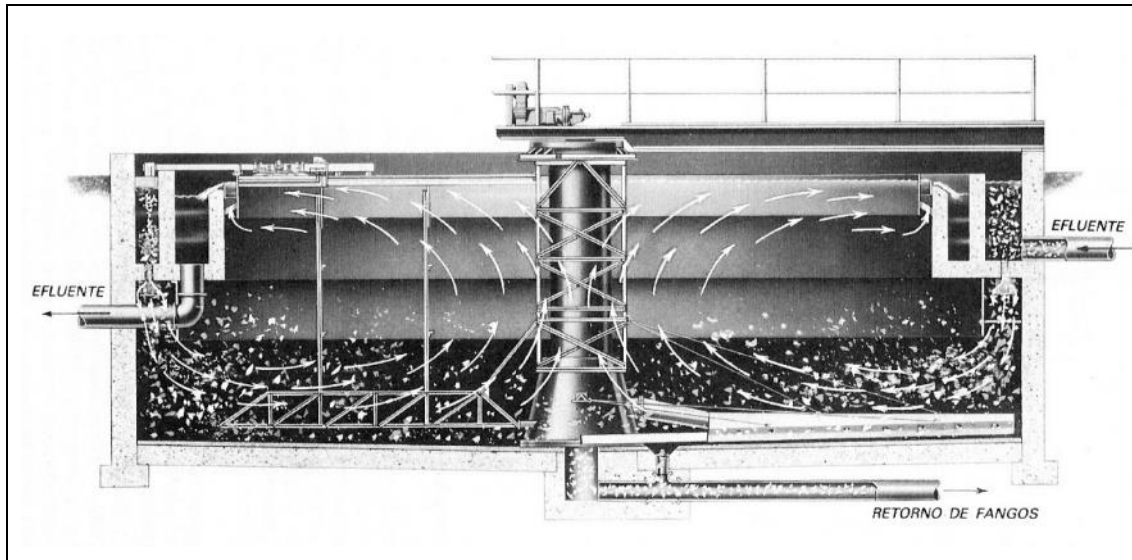


Figure 31
Settling tank with raw water entry and peripheral extraction of clarified water.



Figure 32
Detail for the clarified water extraction with scrapers system for floating matter removal.