COMPARISON AMONG THE MOST FREQUENTLY USED SYSTEMS FOR WASTEWATER TREATMENT IN DEVELOPING COUNTRIES

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ABSTRACT

The paper presents a series of tables, figures and charts which can be used for the preliminary selection of wastewater treatment systems, specially in developing countries. The systems analysed are: stabilization ponds, activated sludge, trickling filters, anaerobic systems and land disposal. Within each system, the main process variants are covered. A main summary table for quantitative analysis is presented, including easily usable information based on per capita values (US$/cap, W/cap, m² area/cap, m³ sludge/cap). Other tables for qualitative comparison among systems are also included, one based on a one-to-five-star scoring and the other on a balance between advantages and disadvantages of the main treatment processes. The sludge treatment and disposal is also covered, including a comparative analysis based on a scoring system.

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KEYWORDS

Appropriate technology, developing countries, process selection, sludge handling, wastewater treatment.

INTRODUCTION

Nowadays there is a wide variety of systems which can be applied for wastewater treatment. While in industrialised countries the number of alternatives may be somewhat more limited due to the more stringent effluent quality standards usually applicable, in developing countries as a whole the breadth of choices to be analysed may be higher. This fact stems from the diversity of effluent standards encountered throughout these countries, ranging from very conservative to very relaxed criteria. Additionally, the cost component and the operational requirements, while important in the industrialised countries, play a much more decisive role in the developing countries. A further aspect in the developing countries is the high contrast usually observable between urban areas - periphery - rural areas. All these points make the preliminary selection of the more appropriate systems for the intended application a critical step, many times overlooked in less careful designs.

Figure 1 presents a comparison of important aspects in the selection of wastewater treatment systems, analysed in terms of developed and developing countries. The comparison is forcibly very general, due to the specificity's of each country and the high contrasts usually observable within the developing countries. The items are organised in a decreasing order of importance in the developed countries, according to the author’s perception. In these countries, critical items are: efficiency, reliability, sludge disposal aspects and land
requirements. In developing countries, these first items are organised in a similar way of decreasing importance, but have a smaller magnitude, compared to developed countries. The major difference lies in what can be considered to be the critical items for developing countries: construction costs, sustainability, simplicity and operational costs. These items are important for developed countries, but cannot be considered to be critical.

![Diagram of Important Aspects in the Selection of Wastewater Treatment Systems]

**Fig. 1. Important aspects in the selection of wastewater treatment systems.**
A comparison between developed and developing countries.

The objective of the paper is to present elements for a preliminary comparison among the systems most frequently used for the secondary treatment of domestic wastewater, with a particular view to developing countries, under tropical or sub-tropical conditions. The items analysed should help the consultant or even members of the organised community to make a first evaluation and preliminary selection of the treatment systems which could present a higher potential applicability for each case under consideration. The information is presented as a series of tables, which make up for most of the paper.

**TREATMENT SYSTEMS ANALYSED**

The main systems and the variants analysed are:

- **Stabilisation pond systems** (facultative, anaerobic - facultative, facultative aerated, completely mixed aerated - sedimentation)
- **Activated sludge systems** (conventional, extended aeration, sequencing batch reactors)
- **Trickling filter systems** (low rate, high rate)
- **Anaerobic systems** (upflow anaerobic sludge blanket reactor, anaerobic filter)
- **Land application systems** (slow rate, high rate, subsurface infiltration, overland flow)

Figure 2.a to 2.e presents the flowsheets of the liquid phase (wastewater) of the variants analysed. The list of treatment systems included is by no means exhaustive. Other systems currently applied also deserve a substantial merit. Among those can be mentioned simple natural systems such as constructed wetlands and even more sophisticated compact systems such as rotating biological contactors and aerated biofilters.
COMPARISON AMONG THE TREATMENT SYSTEMS

The comparative analysis among the various systems and their variants is presented in a series of tables, described below:

- **Quantitative comparison** (Table 1). Summary table, including information presented in a simplified way, such as %, US$/p.e., W/p.e., m² area/p.e., m³ sludge/p.e. etc (p.e. = population equivalents).
- **Qualitative comparison** (Table 2). Comparison on a one-to-five-star system of relevant aspects in the evaluation of treatment systems, including efficiency, economy, process and environmental problems.
- **Schematic comparison** (Figure 3). Visual comparison, based on bar charts. In the charts, variants of the same system (e.g. the various pond systems) are concentrated in the same bar. The main objective is only a general view of the various systems, without taking into consideration the specificities of each variant.
- **Advantages and disadvantages** (Table 3). The analysis is oriented mainly for the comparison of variants from the same system, even though it allows some comparison among different systems.

Obviously this type of general approach is forcibly superficial. The intention is not to present values and criteria which cover all the possibilities and local aspects of the various countries. Given their ample regional diversity, there will naturally be designed or operating treatment systems which present distinct characteristics from those covered in the paper. This divergence, instead of representing a conflict, should be faced as an incentive to the widening of the data presented, reinforcing once again the relevance which needs to be attributed to the local conditions.

SLUDGE TREATMENT AND DISPOSAL

The analysis of the very important stage of sludge (solid phase) treatment and disposal is also presented as tables, which are described below.

- **Sludge processing** (Table 4). Sludge handling requirements in the various wastewater treatment systems.
- **Qualitative comparison** (Table 5). Comparison on a one-to-five-star system of relevant aspects in the evaluation of treatment systems, including efficiency, economy, process and environmental problems.

FINAL REMARKS

The overall analysis of the various wastewater treatment processes leads to the conclusion that there is no ideal system applicable to all conditions. Each situation must be analysed individually, with the constant concern of incorporating the local specificities in the stage of investigation and decision. In sewage treatment, the adoption of standard solutions and designs is very difficult. If, on one hand, this could appear as a complicating factor, on the other hand it should be realized that this is one of the aspects which make wastewater treatment so fascinating. Only through the opening of multiple avenues one can really reach an efficient, economical and adequate solution, not only in the design stage, but mainly throughout the operational life of the treatment plant (von Sperling, 1994).

REFERENCES


WASTE STABILIZATION POND SYSTEMS

Fig. 2.a. Flowsheets of waste stabilization pond systems
ACTIVATED SLUDGE SYSTEMS

CONVENTIONAL ACTIVATED SLUDGE
(Continuous flow)

EXTENDED AERATION
(Continuous flow)

SEQUENCING BATCH REACTORS
(Intermittent flow)

Fig. 2.b. Flowsheets of activated sludge systems
**TRICKLING FILTER SYSTEMS**

**LOW RATE TRICKLING FILTER**

**HIGH RATE TRICKLING FILTER**

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**ANAEROBIC SYSTEMS**

**UPFLOW ANAEROBIC SLUDGE BLANKET REACTOR**

**SEPEC TANK - ANAEROBIC FILTER**

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Fig. 2.c. Flowsheets of trickling filter systems

Fig. 2.d. Flowsheets of anaerobic systems
LAND DISPOSAL SYSTEMS

LOW-RATE INfiltrATION

RAPID INfiltrATION

SUBSURFACE INfiltrATION

OVERLAND FLOW

Fig. 2. e. Flowsheets of land disposal systems
Table 1. Typical characteristics of the main wastewater treatment systems

<table>
<thead>
<tr>
<th>TREATMENT SYSTEMS</th>
<th>REMOVAL EFFICIENCY (%)</th>
<th>REQUIREMENTS</th>
<th>CONSTRUCT. COSTS (US$/inhab)</th>
<th>TOTAL HYDRAULIC DETENTION TIME (days)</th>
<th>QUANTITY OF SLUDGE TO BE HANDLED (m³/inhab.year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BOD</td>
<td>N</td>
<td>P</td>
<td>LAND (m²/inhab)</td>
<td>POWER (W/inhab)</td>
</tr>
<tr>
<td>PRELIMINARY TREATMENT</td>
<td>0 - 5</td>
<td>-0</td>
<td>-0</td>
<td>&lt;0.001</td>
<td>2 - 8</td>
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<tr>
<td>PRIMARY TREATMENT</td>
<td>35 - 40</td>
<td>10 - 25</td>
<td>10 - 20</td>
<td>0.03 - 0.05</td>
<td>10 - 30</td>
</tr>
<tr>
<td>FACULTATIVE POND</td>
<td>75 - 90</td>
<td>30 - 50</td>
<td>20 - 60</td>
<td>60 - 99</td>
<td>2.0 - 5.0</td>
</tr>
<tr>
<td>ANAEROBIC POND - FACULTATIVE POND</td>
<td>75 - 90</td>
<td>30 - 50</td>
<td>20 - 60</td>
<td>60 - 99</td>
<td>1.5 - 3.5</td>
</tr>
<tr>
<td>FACULTATIVE AERATED LAGOON</td>
<td>75 - 90</td>
<td>30 - 50</td>
<td>20 - 60</td>
<td>60 - 96</td>
<td>0.25 - 0.5</td>
</tr>
<tr>
<td>COMPLETE AERATED SEDIMENT POND</td>
<td>75 - 90</td>
<td>30 - 50</td>
<td>20 - 60</td>
<td>60 - 99</td>
<td>0.2 - 0.5</td>
</tr>
<tr>
<td>CONVENTIONAL ACTIVATED SLUDGE</td>
<td>85 - 93</td>
<td>30 - 40 (a)</td>
<td>30 - 45 (a)</td>
<td>60 - 90</td>
<td>0.2 - 0.3</td>
</tr>
<tr>
<td>EXTENDED AERATION (CONTINUOUS FLOW)</td>
<td>93 - 98</td>
<td>15 - 30 (a)</td>
<td>10 - 20 (a)</td>
<td>65 - 90</td>
<td>0.25 - 0.35</td>
</tr>
<tr>
<td>SEQUENCING BATCH REACTOR</td>
<td>85 - 95</td>
<td>30 - 40 (a)</td>
<td>30 - 45 (a)</td>
<td>60 - 90</td>
<td>0.2 - 0.3</td>
</tr>
<tr>
<td>LOW RATE TRICKLING FILTER</td>
<td>85 - 93</td>
<td>30 - 40 (a)</td>
<td>30 - 45 (a)</td>
<td>60 - 90</td>
<td>0.5 - 0.7</td>
</tr>
<tr>
<td>HIGH RATE TRICKLING FILTER</td>
<td>80 - 90</td>
<td>30 - 40 (a)</td>
<td>30 - 45 (a)</td>
<td>60 - 90</td>
<td>0.3 - 0.45</td>
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<td>UPLAND ANAEROBIC SLUDGE BLANKET</td>
<td>60 - 80</td>
<td>10 - 25</td>
<td>10 - 20</td>
<td>60 - 90</td>
<td>0.05 - 0.10</td>
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<td>70 - 90</td>
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<td>60 - 90</td>
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<tr>
<td>SLOW RATE INFILTRATION</td>
<td>94 - 99</td>
<td>65 - 95</td>
<td>75 - 99</td>
<td>&gt; 99</td>
<td>10 - 50</td>
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<tr>
<td>RAPID INFILTRATION</td>
<td>86 - 98</td>
<td>10 - 80</td>
<td>30 - 99</td>
<td>&gt; 99</td>
<td>1 - 6</td>
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<tr>
<td>SUBSURFACE INFILTRATION</td>
<td>90 - 95</td>
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<td>85 - 95</td>
<td>&gt; 99</td>
<td>1 - 5</td>
</tr>
<tr>
<td>OVERLAND FLOW</td>
<td>85 - 95</td>
<td>10 - 20</td>
<td>20 - 50</td>
<td>90 - 99</td>
<td>1 - 6</td>
</tr>
</tbody>
</table>


Notes:
NA: not applicable
Energy requirements do not include the eventual raw sewage pumping
(a) An additional nutrient removal can be obtained through modifications in the process.
Table 2. Relative comparison among the domestic wastewater treatment systems

<table>
<thead>
<tr>
<th>TREATMENT SYSTEMS</th>
<th>REMOVAL EFFICIENCY</th>
<th>ECONOMY</th>
<th>RESISTANCE TO VARIATIONS</th>
<th>RELIABILITY</th>
<th>INDEPENDENCE</th>
<th>LESS RISKS OF ENVIRONMENTAL PROBLEMS</th>
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<tr>
<td></td>
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<td>N &amp; P</td>
<td>COLIF</td>
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<td>ENERGY</td>
<td>CONSTRUCTION</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
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<td>0</td>
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<td>0</td>
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<td>++</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>ANAEROBIC POND - FACULTATIVE POND</td>
<td>+++</td>
<td>++</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>FACULTATIVE AERATED LAGOON</td>
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<td>++</td>
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<td>+++</td>
<td>+++</td>
<td>+++</td>
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<td>COMPLETE MIXED AERAT. - SEDIMENT POND</td>
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<td>++</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>CONVENTIONAL ACTIVATED SLUDGE</td>
<td>++++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
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<tr>
<td>EXTENDED AERATION (CONTINUOUS FLOW)</td>
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<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
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<tr>
<td>SEQUENCING BATCH REACTOR</td>
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<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>LOW RATE TRICKLING FILTER</td>
<td>++++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
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<tr>
<td>HIGH RATE TRICKLING FILTER</td>
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<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>UPFLOW ANAEROBIC SLUDGE BLANKET</td>
<td>++++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>SEPTIC TANK - ANAEROBIC FILTER</td>
<td>++++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
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<tr>
<td>GLOFF RATE INFLATION</td>
<td>++++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>RAPID INFLATION</td>
<td>++++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>SUBSURFACE INFLATION</td>
<td>++++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>OVERLAND FLOW</td>
<td>++++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
</tbody>
</table>

Note: the scoring is relative to each column only, and not gencral to all items. The scores can vary widely depending on local circumstances

+++++ : most favourable
+++   : least favourable
+++ , + : intermediate, in decreasing order
0 : null effect
+ / ++++: variable with the process, equipment, variation or design
### COMPARISON AMONG THE TREATMENT SYSTEMS

#### EFFICIENCY

**Efficiency in BOD Removal (%)**
- **Land Disp.**
- **Anaerobic**
- **Trick. Filter**
- **Activ. Sludge**
- **Ponds**

**Efficiency in Coliform Removal (%)**
- **Land Disp.**
- **Anaerobic**
- **Trick. Filter**
- **Activ. Sludge**
- **Ponds**

#### COSTS

**Construction Costs (US$/ha)**
- **Land Disp.**
- **Anaerobic**
- **Trick. Filter**
- **Activ. Sludge**
- **Ponds**

**Operational Costs (Qualitative)**
- **Land Disp.**
- **Anaerobic**
- **Trick. Filter**
- **Activ. Sludge**
- **Ponds**

#### REQUIREMENTS

**Land Requirements (m²/ha)**
- **Land Disp.**
- **Anaerobic**
- **Trick. Filter**
- **Activ. Sludge**
- **Ponds**

**Power Requirements (kW/ha)**
- **Land Disp.**
- **Anaerobic**
- **Trick. Filter**
- **Activ. Sludge**
- **Ponds**

#### BY-PRODUCTS AND OPERATIONAL SIMPLICITY

**Quantity of Sludge to Handle (m3/ha/ann)**
- **Land Disp.**
- **Anaerobic**
- **Trick. Filter**
- **Activ. Sludge**
- **Ponds**

**Operational Simplicity (Qualitative)**
- **Land Disp.**
- **Anaerobic**
- **Trick. Filter**
- **Activ. Sludge**
- **Ponds**

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Fig. 3. Schematic comparison among the main wastewater treatment systems.
### Table 3. Advantages and disadvantages of the main wastewater treatment systems

<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>WASTE STABILIZATION POND SYSTEMS</th>
<th>ACTIVATED SLUDGE SYSTEMS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ADVANTAGES</td>
<td>DISADVANTAGES</td>
</tr>
<tr>
<td></td>
<td>• Basic efficiency in BOD removal</td>
<td>• High construction and operation costs</td>
</tr>
<tr>
<td></td>
<td>• Efficient in pathogen removal</td>
<td>• High energy consumption</td>
</tr>
<tr>
<td></td>
<td>• Simple construction, operation and maintenance</td>
<td>• Need of sophisticated operation</td>
</tr>
<tr>
<td></td>
<td>• Low construction and operation costs</td>
<td>• High mechanization level</td>
</tr>
<tr>
<td></td>
<td>• No mechanical equipment</td>
<td>• Relatively sensitive to toxic loads</td>
</tr>
<tr>
<td></td>
<td>• Almost no energy requirements</td>
<td>• Need of sludge treatment and disposal (although stabilization is not necessary)</td>
</tr>
<tr>
<td></td>
<td>• Satisfactory resistance to load variations</td>
<td>• System with higher energy consumption</td>
</tr>
<tr>
<td></td>
<td>• Sludge removal practically not necessary</td>
<td>• High mechanization level (although lower than conventional activated sludge)</td>
</tr>
<tr>
<td></td>
<td>• Same as facultative ponds</td>
<td>• Need of sludge treatment and disposal (although stabilization is not necessary)</td>
</tr>
<tr>
<td></td>
<td>• Lower land requirements compared to single facultative ponds</td>
<td>• System with higher energy consumption</td>
</tr>
<tr>
<td></td>
<td>• Relatively simple construction, operation and maintenance</td>
<td>• High construction and operation costs</td>
</tr>
<tr>
<td></td>
<td>• Lower land requirements compared to facultative ponds and anaerobic-facultative ponds</td>
<td>• Higher instilled power than other activated sludge systems</td>
</tr>
<tr>
<td></td>
<td>• Greater independence than climatic conditions compared to facultative ponds and anaerobic-facultative ponds</td>
<td>• Need of sludge treatment and disposal (variable with conventional or extended mode)</td>
</tr>
<tr>
<td></td>
<td>• Slightly larger efficiency in BOD removal compared to facultative ponds</td>
<td>• Usually more competitive for smaller populations</td>
</tr>
<tr>
<td></td>
<td>• Satisfactory resistance to load variations</td>
<td>• Presence of equipment</td>
</tr>
<tr>
<td></td>
<td>• Low possibility of odour problems</td>
<td>• Slight increase in the sophistication level</td>
</tr>
<tr>
<td></td>
<td>• Same as facultative aeration lagoon</td>
<td>• Land requirements still high</td>
</tr>
<tr>
<td></td>
<td>• Same as facultative aeration lagoon (except land requirements)</td>
<td>• Relatively high energy requirements</td>
</tr>
<tr>
<td></td>
<td>• Same filling of the sedimentation lagoon with sludge (2 to 5 years)</td>
<td>• Same as facultative ponds</td>
</tr>
<tr>
<td></td>
<td>• Need of continuous or periodic (2 to 5 years) sludge removal</td>
<td>• Possible odour nuisance in anaerobic pond</td>
</tr>
<tr>
<td></td>
<td>• Possible need of recycling final effluent, in order to control odours</td>
<td>• Possible odour nuisance in anaerobic pond</td>
</tr>
<tr>
<td></td>
<td>• Need of a large distance to nearby houses</td>
<td>• Possible need of recycling final effluent, in order to control odours</td>
</tr>
<tr>
<td></td>
<td>• Presence of equipment</td>
<td>• Slight increase in the sophistication level</td>
</tr>
<tr>
<td></td>
<td>• Land requirements still high</td>
<td>• Relatively high energy requirements</td>
</tr>
<tr>
<td></td>
<td>• Relatively high energy requirements</td>
<td>• Same as facultative aeration lagoon</td>
</tr>
<tr>
<td></td>
<td>• Same filling of the sedimentation lagoon with sludge (2 to 5 years)</td>
<td>• Need of continuous or periodic (2 to 5 years) sludge removal</td>
</tr>
<tr>
<td></td>
<td>• Need of continuous or periodic (2 to 5 years) sludge removal</td>
<td>• Possible environmental problems with noises and odours</td>
</tr>
<tr>
<td></td>
<td>• Same as facultative aeration lagoon</td>
<td>• Possible environmental problems with noises and odours</td>
</tr>
<tr>
<td></td>
<td>• Lower land requirements compared to all pond systems</td>
<td>• Possible environmental problems with noises and odours</td>
</tr>
<tr>
<td></td>
<td>• Same as facultative aeration lagoon</td>
<td>• Possible environmental problems with noises and odours</td>
</tr>
</tbody>
</table>

**Notes:**
- **Activated Sludge Systems:**
  - *Conventional Activated Sludge (continuous flow):*
    - High efficiency in BOD removal
    - Notification usually achieved (tropical countries)
    - Possibility of biological N & P removal
    - Low land requirements
    - Operational flexibility
    - Reliable, provided enough supervision is given
    - Low possibilities of odours, insects and worms
  - *Extended Aeration (continuous flow):*
    - Same as conventional activated sludge
    - System with higher efficiency in BOD removal
    - Consistent nitrification
    - Simple than conventional activated sludge
    - Less sludge produced compared to conventional activated sludge
    - Sludge stabilization in the reactor itself (separate digester not necessary)
    - High resistance to variations in load and to toxic loads
    - Satisfactory independence from climatic conditions
  - *Sequencing Batch Reactors (intermittent flow):*
    - High efficiency in BOD removal
    - Satisfactory N and possibly P removal
    - Low land requirements
    - Simple than the other activated sludge systems
    - Less equipment than the other activated sludge systems
    - Operational flexibility (variation of cycles)
    - Secondary settler and recycle pumps not necessary
  - **Advantages:**
    - High construction and operation costs
  - **Disadvantages:**
    - Higher instilled power than other activated sludge systems
    - Need of sludge treatment and disposal (variable with conventional or extended mode)
    - Usually more competitive for smaller populations
<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
</tr>
</thead>
</table>
| **LOW RATE TRICKLING FILTER** | • Higher efficiency in BOD removal  
• Consistent treatment (tropical countries)  
• Land requirements relatively small  
• Simpler than activated sludge  
• Mechanization level relatively small  
• Simple mechanical equipment  
• Sludge stabilization in the filter itself | • Less operational flexibility than activated sludge  
• Higher construction costs  
• Higher land requirements compared to high rate filters  
• Relative dependence on the ambient temperature  
• Relative sensitivity to toxic loads  
• Need of sludge treatment and disposal (although stabilization is not necessary)  
• Possible problems with flies  
• High head loss |
| **HIGH RATE TRICKLING FILTER** | • Good efficiency in BOD removal (although lower than low rate filters)  
• Low land requirements  
• Simpler than activated sludge  
• Higher flexibility than low rate filters  
• Higher resistance to load variations than low rate filters  
• Less possibilities of odours | • Operation slightly more sophisticated than low rate filters  
• High construction costs  
• Relative dependence on the ambient temperature  
• Need of complete sludge treatment and disposal  
• High head loss |

<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
</tr>
</thead>
</table>
| **UPFLOW ANAEROBIC SLUDGE BLANKET REACTOR** | • Reasonable efficiency in BOD removal  
• Very low land requirements  
• Low construction and operation costs  
• Low energy consumption  
• No packing media  
• Simple construction, operation and maintenance  
• Very small sludge production  
• Sludge stabilization in the reactor itself  
• Sludge handling requires only disposal  
• Fast restart after interrupted operation | • Difficulty in complying with stringent effluent standards  
• Effluent not aesthetically pleasant  
• Unsatisfactory N & P removal  
• Possibility of odours  
• Slow process start-up  
• Relatively sensitive to load variations  
• May require post-treatment |
| **ANAEROBIC FILTER** | • Same as upflow anaerobic sludge blanket (except need of packing media)  
• Good adaptation to different types and concentrations of wastewater  
• Good resistance to variations in load | • Difficulty in complying with stringent effluent standards  
• Effluent not aesthetically pleasant  
• Unsatisfactory N & P removal  
• Possibility of odours  
• Risks of clogging  
• High concentration of suspended solids in the effluent  
• Restricted to treatment of influent with low suspended solids concentrations |

<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
</tr>
</thead>
</table>
| **SLOW RATE INFILTRATION** | • Very high efficiency in BOD and coliform removal  
• Satisfactory efficiency in N & P removal  
• Combined method for treatment and final disposal  
• Simple construction, operation and maintenance  
• Low construction and operation costs  
• Good resistance to variations in load  
• No sludge to be treated  
• Soil fertilization and conditioning  
• Payback of investment from irrigation of agricultural areas  
• Groundwater recharge | • Very high land requirements  
• Possibility of odours  
• Possibility of insects and worms  
• Relatively dependent on climate and nutrient requirements from vegetables  
• Dependent on soil characteristics  
• Risk of contamination of vegetation to be consumed, in case of unsaturated application  
• Possibility of contamination of agricultural workers (with spray)  
• Possibility of chemical effects on soil, vegetation and groundwater (in case of industrial discharge)  
• Difficult control of irrigated vegetables  
• Application must be interrupted or reduced in rainy periods |
| **RAPID INFILTRATION** | • Same as slow rate infiltration (although efficiency in pathogen removal is lower)  
• Lower land requirements compared to slow rate infiltration  
• Low dependence on ground slope  
• Application throughout the year | • Same as slow rate infiltration (but with lower land requirements and possibility of application all year round)  
• Potential groundwater contamination with nitrates |
| **SUBSURFACE INFILTRATION** | • Same as rapid infiltration  
• Possible economy with intercepting lines  
• No odour problems  
• Above ground area can be used as parks  
• No dependence on climatic conditions  
• No problems with vegetable and water contamination | • Same as rapid infiltration  
• Need of space until to allow alternation of application (use and rest)  
• Larger systems need permeable soils to reduce land requirements |
| **OVERLAND FLOW** | • Same as rapid infiltration (with generation of final effluent and with higher dependence on ground slope)  
• System with lower dependence on soil characteristics (among the land disposal systems) | • Same as rapid infiltration  
• Greater dependence on ground slope  
• Generation of final effluent, which needs further disposal |
Table 4. Sludge handling in the main wastewater treatment systems

<table>
<thead>
<tr>
<th>WASTEWATER TREATMENT SYSTEMS</th>
<th>REMOVAL FREQUENCY</th>
<th>THICKENING</th>
<th>DIGESTION</th>
<th>DEWATERING</th>
<th>FINAL DISPOSAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRIMARY TREATMENT variable (a)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>FACULTATIVE POND</td>
<td>&gt; 20 years</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>ANAEROBIC POND - FACULTATIVE POND</td>
<td>&gt; 20 years</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>FACULTATIVE AERATED LAGOON</td>
<td>~ 10 years</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>COMPLETE MIXED AERATION - SEDIMENT POND</td>
<td>&lt; 5 years</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>CONVENTIONAL ACTIVATED SLUDGE</td>
<td>continuous</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>EXTENDED AERATION (CONTINUOUS FLOW)</td>
<td>continuous</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>SEQUENCING BATCH REACTOR</td>
<td>continuous</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>LOW RATE TRICKLING FILTER</td>
<td>continuous</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>HIGH RATE TRICKLING FILTER</td>
<td>continuous</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>UPFLOW ANAEROBIC SLUDGE BLANKET</td>
<td>variable</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>SEPTIC TANK - ANAEROBIC FILTER</td>
<td>variable</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>SLOW RATE INFILTRATION</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RAPID INFILTRATION</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SUBSURFACE INFILTRATION</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OVERLAND FLOW</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(a) Removal some times per day in conventional primary settlers and once every 6-12 months in septic tanks
Table 5. Relative comparison among the sludge treatment systems

<table>
<thead>
<tr>
<th>OPERATION PROCESS</th>
<th>UNIT</th>
<th>REDUCTION EFFICIENCY</th>
<th>ECONOMY IN REQUIREMENTS</th>
<th>ECONOMY IN COSTS</th>
<th>RESISTANCE CAPACITY</th>
<th>RELIABILITY</th>
<th>SIMPLICITY</th>
<th>INDEPENDENCE ON CLIMATE</th>
<th>LOWER POSSIBILITY OF ODOURS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SLUDGE VOLUME</td>
<td>ORGANIC MATTER BY SLUDGE</td>
<td>LAND</td>
<td>ENERGY</td>
<td>CONSTRUCTION</td>
<td>O &amp; M</td>
<td>FLOW VARIATIONS</td>
<td>INFlluENT QUALITY VARIATIONS</td>
</tr>
<tr>
<td>THICKENING</td>
<td>Gravity</td>
<td>++</td>
<td>0</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td></td>
<td>Floation</td>
<td>++</td>
<td>0</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td></td>
<td>Mechanical</td>
<td>+++</td>
<td>0</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>STABILISATION</td>
<td>Aerobic</td>
<td>*</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td></td>
<td>Anaerobic</td>
<td>+</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>DEWATERING</td>
<td>Drying beds</td>
<td>+++</td>
<td>0</td>
<td>+</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td></td>
<td>Sludge lagoons</td>
<td>+++</td>
<td>0</td>
<td>+</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td></td>
<td>Mechanical</td>
<td>++++/++++</td>
<td>0</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
</tbody>
</table>

Note: the scoring is relative to each column only, and not general to all items. The scores can vary widely depending on local circumstances.

+++++: most favourable  
++++, +++: intermediate, in decreasing order  
+: least favourable  
*: null effect  
+/+++++: variable with the process, equipment or design