

consumption during deodorization. This also means that a gain in deodorization capacity can be achieved through higher temperature operation and this allows the refiner to reduce the overall operating cost with minimal or hardly any capital outlay.

However, all is not well with deodorization at higher temperatures, especially so if it is carried out for prolonged periods. Excessive temperatures coupled with prolonged processing time may result in chemical changes in the oils, thus affecting the final quality of the refined oils.

It is important to note here that the residence time in the deodorizer, i.e. holding time of the oil at deodorization temperature, also determines the degree of damage. There are some empirical relationships which say that while damage to the oil doubles for every 20°C rise, the damage is halved if the residence time is halved (1). Although reduction in residence time reduces the damage to the oil, adequate time has to be provided for thermal degradation of carotenoid pigments and oxidation products of the oil (*Figure 2*).

Elevated temperatures and prolonged deodorization times also promote additional losses of tocopherols and tocotrienols which are volatile under these conditions (2). Because tocopherols and tocotrienols, which are present in crude palm oil, act as powerful natural antioxidants and have nutritional activities, optimal operating conditions are those which retain these compounds in their active form (*Table 1*).

Information available from literature suggests that adverse refining conditions may result in polymerization, isomerization and randomization of the triglycerides. Thermal polymerization results in the formation of dimers and polymers. Studies done by PORIM, however, indicate that present refining conditions used by Malaysian refiners pose little or no danger of artifacts being formed at significant levels in the refined oils (3). Palm oil also suffers less changes than the more unsaturated oils like soyabean, sunflower and rapeseed oils (4) (*Figure 3*).

*Figure 4* shows the effect of longer residence times and higher temperatures on the SOS SSO ratio of palm oil. Such changes are totally unacceptable for the production of palm mid-fraction (4).

It was found that there is no effect on the fatty acids and triglyceride composition when palm oil is refined unless the oil is thermally abused as shown in *Table 2*. *Figure 5* shows the effect of time and temperature on the formation

of trans acids (C18:1 and C18:2tt and C18:2ct) (3).

What then are the optimal deodorization operating conditions for reducing undesirable chemical changes and retaining the desirable compounds in the oil? Willems quotes Unilever's recommendation that, in order to keep dimers at less than one percent and to avoid randomization, the upper limit of 240 °C and 120 minutes should not be exceeded during refining of palm oil. Alternatively, a temperature of 270 °C with a maximum residence time of 30 minutes might be acceptable (4). The latter set of conditions is also quoted in other references (2) as a guide for optimum operation.

## REFERENCES

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# ● POLLUTION CONTROL

## TREATMENT OF PALM OIL REFINERY WASTEWATER

The flow and the characteristics of the wastewater from a palm oil refinery depends very much on the type of refining process employed, the production schedule and the types of downstream processes in addition to oil refining. All these factors contribute to the complexity of the wastewater produced. The variability in the strength, composition and flow of the wastewater accounts for much of the difficulty and the expense associated with the treatment of refinery effluents.

The refineries in Malaysia can be classified into the following three categories based on the type of operation:

- Category A : Physical refining and dry tractionation
- Category B : Physical refining and detergent fractionation

TABLE 1 : Categories of palm oil refineries and recommended effluent treatment systems

| Category | Processes                           | Treatment System                   |
|----------|-------------------------------------|------------------------------------|
| A        | Physical and Dry                    | Biological                         |
| B        | Physical and Detergent              | Physico-chemical<br>and Biological |
| C        | Physical, Chemical<br>and Detergent |                                    |

TABLE 2. Wastewater characteristics of palm oil refineries

| Parameters <sup>+</sup>         | Category      |      |                |       |                |        |
|---------------------------------|---------------|------|----------------|-------|----------------|--------|
|                                 | A             |      | B              |       | C              |        |
|                                 | Range         | Mean | Range          | Mean  | Range          | Mean   |
| Temperature (°C)                | 28 - 44       | 35   | 33 - 52        | 42    | 42 - 70        | 57     |
| pH                              | 3.8 - 7.0     | 5.3  | 2 - 6          | 4.9   | 2 - 7.0        | 3      |
| Biochemical Oxygen Demand (BOD) | 50 - 1,500    | 530  | 760 - 5,400    | 2,640 | 1,420 - 19,600 | 4,178  |
| Chemical Oxygen Demand (COD)    | 1,000 - 3,000 | 890  | 1,440 - 14,600 | 5,729 | 4,000 - 33,100 | 7,696  |
| Total Solids (TS)               | 20 - 2,000    | 580  | 1,480 - 14,000 | 2,050 | 2,500 - 45,000 | 15,000 |
| Suspended Solids (SS)           | 20 - 1,000    | 332  | 790 - 1,800    | 1,170 | 425 - 2,000    | 2,070  |
| Total Nitrogen (TN)             | 20 - 1,000    | 49   | 7.5 - 17.5     | 11.7  | 0.1 - 12.5     | 6.3    |
| Phosphorus                      | 1.0 - 600     | 4.1  | 0.4 - 3.0      | 1.3   | 8 - 16.5       | 11.8   |
| Total Fatty Matter (TFM)        | 25 - 600      | 215  | 1,150 - 2,600  | 1,580 | 400 - 16,500   | 3,548  |

\* A Physical Refining and Dry Fractionation  
 B Physical Refining and Detergent Fractionation  
 C Physical, Chemical Refining and Detergent Fractionation

+ All in mg/l except pH and temperature.

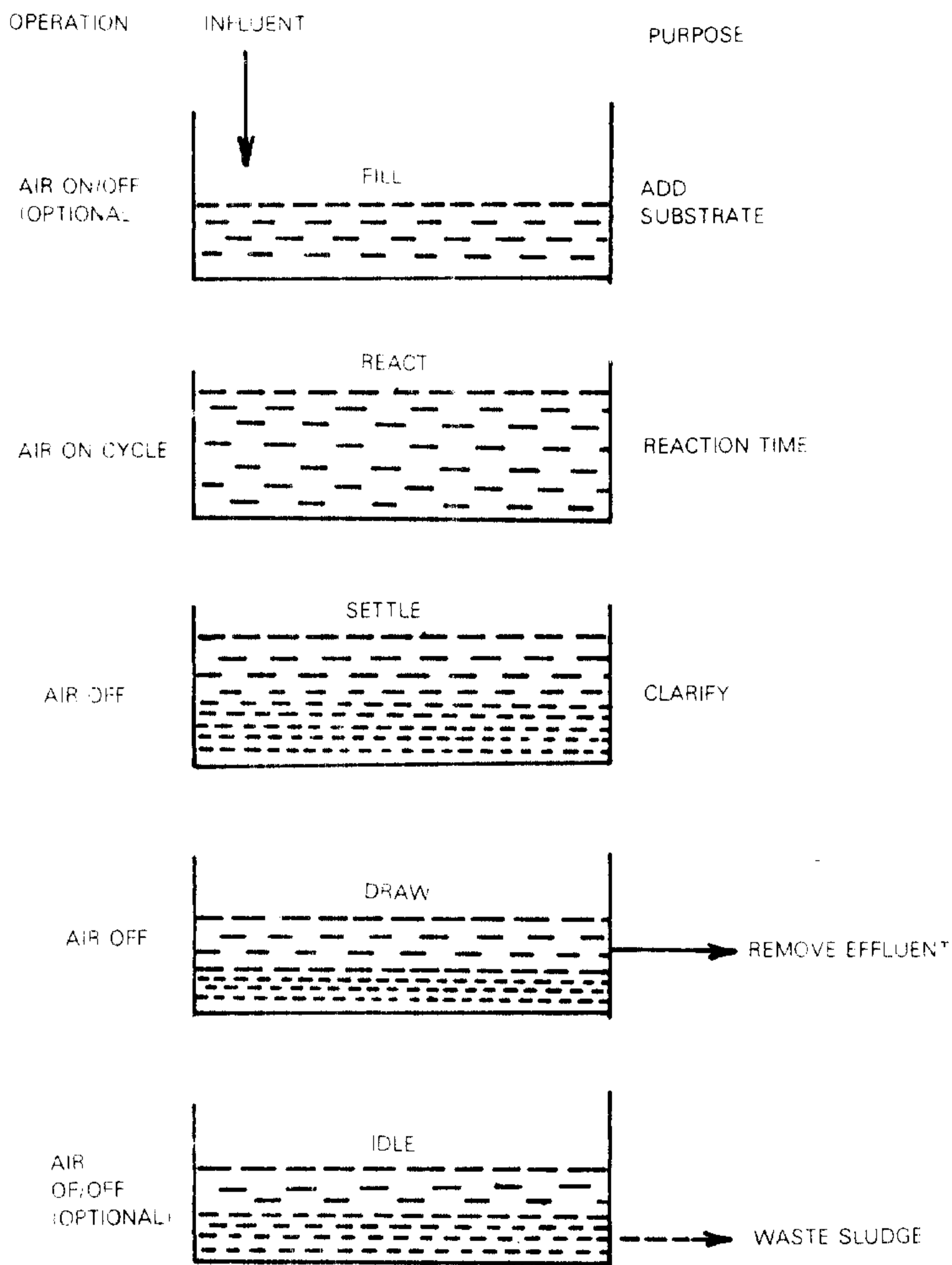


Figure 1. Typical SBR operation for one cycle

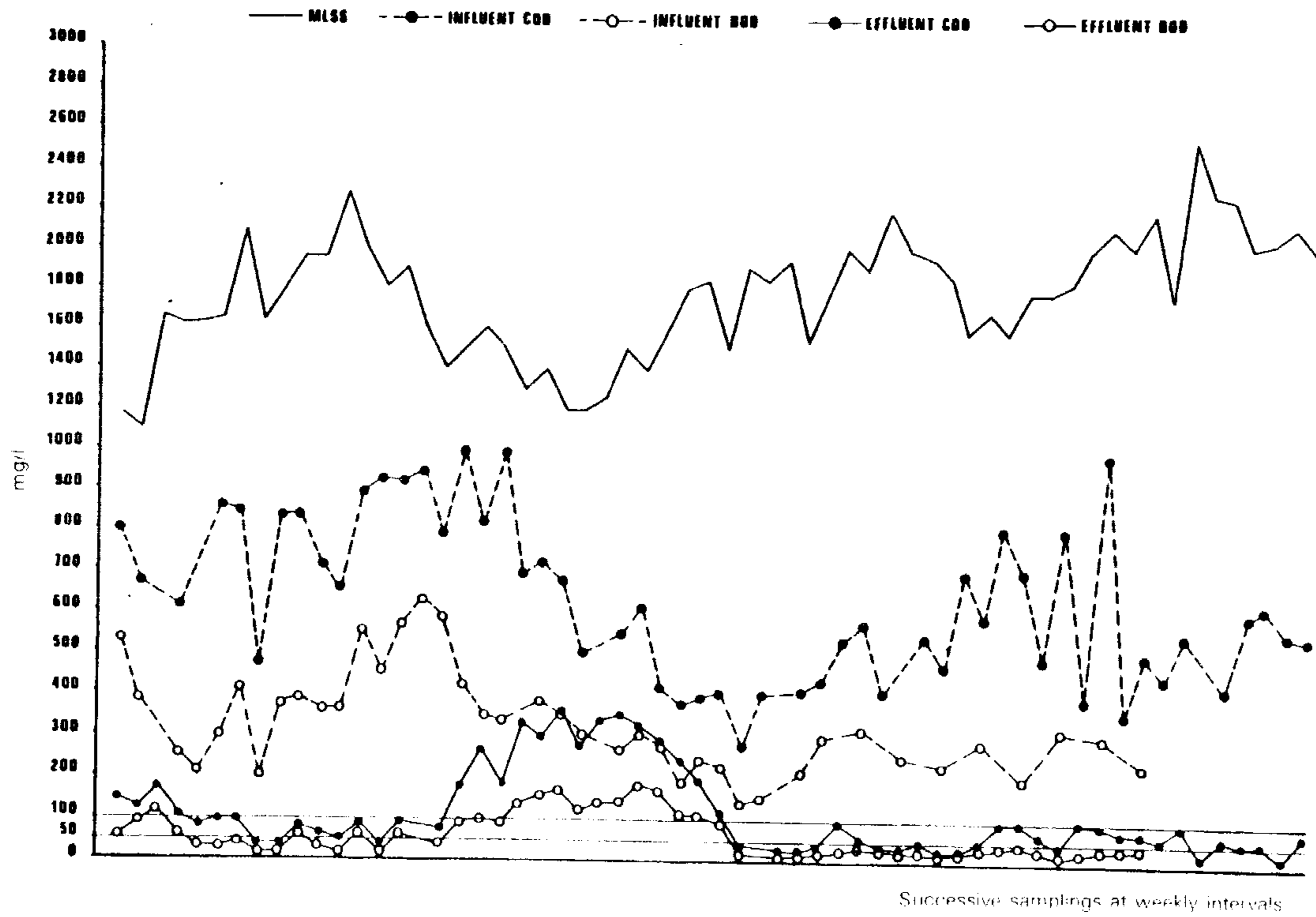


Figure 2 SBR effluent system at P.O. Port Klang

Category C Physical and chemical refining and detergent fractionation.

The recommended effluent treatment system for each category is shown in *Table 1*. These recommendations are based on PORIM's *ad hoc* research to evaluate the efficacies of the treatment systems currently adopted by the industry. *Table 2* shows the wastewater characteristics of the three categories.

PORIM, together with the National University of Singapore, has developed a simple and compact system, called Sequencing Batch Reactor (SBR) for the treatment of wastewater from the physical refining process. This process has gone through laboratory and pilot scale testings and has now been fully adopted by some refineries.

### Principles of SBR Process

As the name implies, SBR is a fill-and-draw activated sludge process. The system operates in time rather than space, *i.e.* all unit operations/processes take place, one after another, in the same tank instead of moving to a second tank for the continuation of the treatment. There are, generally, five discrete operational periods or modes during one cycle of each reactor. They are identified as: fill, react, settle, decant and idle. The purpose of each period, with the exception of idle is self-explanatory. In a multiple tank configuration one of the tanks could be in wait or idle mode. A typical SBR operation is shown in *Figure 1*.

The removal of organics, measured as biochemical oxygen demand (BOD), and nutrients (nitrogen and phosphorus) occurs through the SBR process. Bacteria found in the SBR are mostly facultative in nature. During the fill phase, when oxygen is absent, the organics will be removed anaerobically. The aerobic removal of organics will take place during the react phase when oxygen is abundant. The oxygen requirement should be calculated on the basis of the aerobic removal of BOD. However, if ammoniacal nitrogen is present, extra oxygen is required to meet the oxygen demand by the nitrogen. The oxygen requirement for organics removal is 1.5 to 2.0 kg per kg of BOD applied and the oxygen requirement for ammoniacal nitrogen removal is 4.6 kg per kg of ammoniacal nitrogen applied.

The SBR system can be operated in either conventional activated sludge mode or extended aeration mode. The mode of operation will definitely determine the number of cycles, the

size of reactors and the requirement for sludge treatment facility. The operating strategy, the ultimate water quality objectives, construction cost of sludge treatment unit and the associated power consumption could determine which of the two alternatives is the most-effective technology.

As shown in *Figure 1* all the reactions take place in a single reactor. During the settling period the sludge settles to the bottom of the reactor. Only the supernatant is discharged during the decant period. It does not require a sludge recycle pump to recycle the settled sludge to the reactor basin as does the conventional activated sludge system.

To date, four refineries have constructed SBR systems to treat their wastewaters. All the four refineries employ the physical refining process. One plant has been fully commissioned. The performance has been very encouraging as shown in *Figure 2*. The discharge BOD and SS are consistently below the DOE standards.

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## ● PROCESS AUTOMATION

### BASIC CONCEPTS IN PROCESS CONTROL : PART TWO

*In Part I, we provided an introduction to feedback control and feedforward control. Part II provides a continuation to the basic concepts discussed in Part I.*

#### Inside a Feedback Controller

Regardless of the hardware used for implementation, the concept of feedback control remains the same. The first feedback mechanisms were mechanically connected directly to the process and the manipulated variable. When pneumatic and electronic transmission made central control rooms possible, pneumatic and electronic controllers were developed.

The state of the art today is distributed control through digital systems, and controllers now often exist in software. Digital systems may have an extensive selection of features such as automatic alarming, output clamps, and built-in linearization or signal compensation. However, none of these change the basic function of the feedback controller — to solve the control problem.