# Two-phase Activated Sludge System with Doubled Processing Capacity and 80% Reduction of Excess Sludge Production

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Currently, there are many wastewater treatment facilities both in Japan and abroad. More than half of them employ a method called the “activated sludge process” in which biochemical treatment is conducted using microorganisms (hereafter referred to as an activated sludge facility).

Mitsubishi Heavy Industries Mechatronics Systems, Ltd. (MHI-MS) has developed a “two-phase activated sludge system (hereafter referred to as the two-phase system)” which can be installed by conducting simple modifications of the activated sludge facilities in operation. With this system, as much as an 80% reduction in excess sludge production can be achieved, while the processing capacity can be as much as doubled. Deliveries of this system to major food factories, chemical plants, etc., are increasing steadily (**Figure 1**). Our product is highly valued because we have received comments from our clients, including “The running costs were substantially cut down,” “It is helpful to fulfill corporate social responsibility (CSR)” and “The processing capacity remained the same even under increased unsteady loading conditions.”

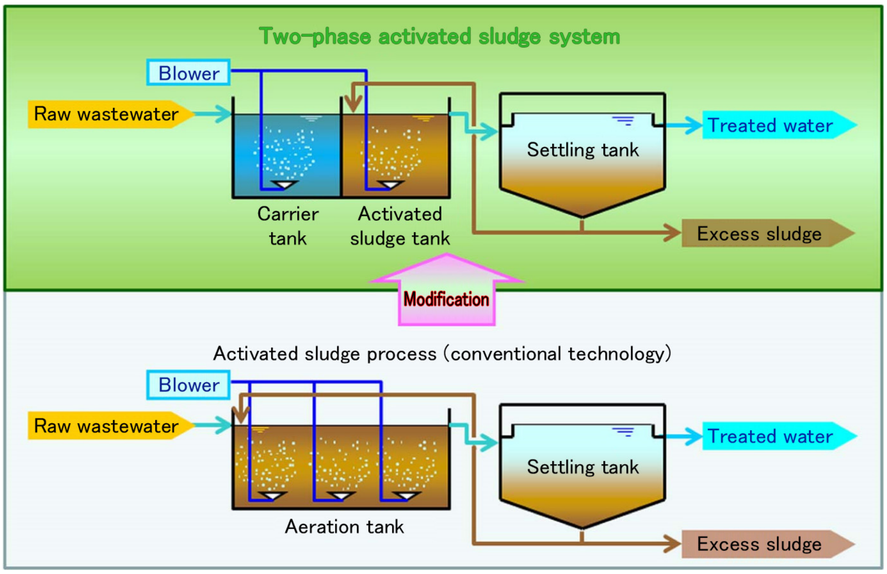


**Figure 1 Structure of the two-phase activated sludge system**

## 1. Production development background and market needs

### 1.1 Outline of the activated sludge process (conventional technology)

In the activated sludge process, dissolved organics in wastewater are biodegraded by activated sludge (i.e., a mix of bacteria and animalcules such as protists and metazoa). The process proceeds as follows:

(1) Wastewater flows into a biological treatment tank called the “aeration tank” where activated sludge is retained. Air is then sent into the tank, increasing the concentration of dissolved oxygen in the tank (for the respiration of the activated sludge) while keeping the microorganisms and the dissolved organics in wastewater mixed/agitated.

(2) The bacteria decompose/assimilate the dissolved organics.
(3) The animalcules (protists and small metazoa) then prey on the bacteria. However, as the bacteria in the activated sludge take the form of flocks(floating aggregates), some of them escape from the predators. Consequently, both bacteria and animalcules are present in the activated sludge.
(4) The mixed liquor of the activated sludge and the treated water enters the settling tank. It is kept still there to allow the activated sludge with a specific gravity larger than water to settle, discharging the supernatant water as treated water.
(5) The activated sludge settled and separated in the settling tank is recycled back to the aeration tank for biological treatment. The increase of the sludge is discharged as "excess sludge."
(6) The discharged excess sludge is dehydrated (occasionally dried/burnt) to reduce the volume before being disposed of as industrial waste.

The solids retention time (SRT), which is an indicator of the time span for activated sludge to decompose organics and grow is approximately 5 days. On the other hand, the time for bacteria to decompose organics and double the population ranges from several tens of minutes to a few hours. This indicates that the bacteria in activated sludge are prey for animalcules and their capability of organic decomposition is considerably hampered. As SRT is included as a design criterion for the activated sludge facility, a large area is needed for installation.

Furthermore, thirty to 50 wt% of the treated dissolved organics in wastewater end up being excess sludge, demanding enormous amounts of energy and costs for the dewatering, drying, burning and disposal of industrial waste.

### 1.2 Problems of the activated sludge method (conventional technology) and market needs

(1) Demand for the enhancement of capacity and space-saving

Domestically, changes in the circumstances surrounding production have created demand for enhancement of processing capacity.

There are projects for new construction because of aging facilities in Japan and many new/additional facilities will be built overseas. In every case, there is a need for space saving solutions.

(2) Need for reduced sludge production

The expense incurred in excess sludge disposal accounts for a large portion of the total running costs for a wastewater treatment facility. Excess sludge discharges from domestic activated sludge facilities are increasing every year, raising the issues of disposal sites and increased disposal expenses. Thus, there is a growing need for reduced sludge production.

### 1.3 Problems with existing technologies for reduced sludge production

Most existing technologies for reduced sludge production convert microorganisms in excess sludge soluble to substrates, which are then biodegraded by activated sludge to reduce the weight. The technologies for sludge dissolution include ozone treatment, the alkali dissolution method, the high temperature decomposition method and mechanical crushing. All of them are costly in terms of facility construction and require proper operation control techniques.

Because of the increased load resulting from dissolution, 10% to 20% of the processing capacity of an activated sludge facility has to be left unused when such technologies are introduced. This is one of the main obstructive factors to the prevalence of the technologies.

## 2. Product features and advantages

### 2.1 Division of microorganisms in activated sludge into two phases

The two-phase system is a biological treatment technology in which bacteria and animalcules in activated sludge are divided into two phases according to the following procedure and the advantages of each biota are utilized.

(1) The biological treatment tank (aeration tank) is divided into two. In the upstream tank, the retention time is set to be shorter than the SRT of animalcules and longer than the bacterial doubling time, creating an environment in which only bacteria can reproduce themselves. Accordingly, bacteria are the dominant biota here.

(2) The upstream tank contains special carriers which have a porous structure with a continuum of passages 10 to 20 μm in diameter and that can exclusively hold densely-populated bacterial inhabitants. Consequently, the number of bacteria in the upstream tank (hereafter referred to as the carrier tank) can be steadily maintained high.

(3) The downstream tank is the activated sludge tank. As there is an inflow of many bacteria from the carrier tank, the biota of the downstream tank is dominated by animalcules that prey on the bacteria and decompose/assimilate them.

## 2.2 Advantages of our product

**Table 1** shows the outcomes after the introduction of the two-phase system by modifying the existing facility of a major seasonings factory.

**Table 1 The effects of the introduction of our two-phase system by modifying an existing facility**

| | Existing facility | After modification |
|---|---|---|
| Quantity of treated water | 640 $m^3$/d | 720 $m^3$/d<br>(Max: 840 $m^3$/d) |
| BOD level in raw water | 1,500 mg/L | 1,500 mg/L<br>(Max: 2,600 mg/L) |
| BOD level in treated water | ≤ 25 mg/L | ≤ 25 mg/L |
| SVI | ≥ 200 | ≈40 |
| Sludge production rate (organics) | 100% | 20% to 40%<br>(i.e., 60% to 80% reduction) |

The product advantages are best characterized by the simultaneous realization of many improvements such as enhanced capacity (space saving), the usability of existing facilities, the reduced production of excess sludge and an improved sludge volume index (SVI; an indicator of sludge sedimentability).

(1) Enhanced capacity (space saving)

In the two-phase system, the treatment process of dissolved organics in wastewater proceeds as described below. Compared with the activated sludge process, the processing capacity can be enhanced up to as much as double. (In the case of new construction, the spatial allocation for the installation of the biological treatment tank can be reduced by as much as half the area of the activated sludge process).

[1] In the carrier tank, bacteria can decompose/assimilate organics and multiply without the presence of predators and therefore get dispersed throughout (hereafter referred to as suspended bacteria). The speed of decomposition/assimilation of organics in wastewater by the suspended bacteria is 10 to 20 times faster than the activated sludge. As the suspended bacteria can quickly respond to influent load fluctuations (substrate change and load variation), the two-phase system is less affected by load variations.

[2] In the treated water of the carrier tank (regarding the suspended bacteria and some types of dissolved organics), the biochemical oxygen demand (BOD), which is an indicator of organic concentration, can be reduced down by as much as 30% to 40% relative to the raw water (e.g., BOD level in raw water: 1,000 mg/L → BOD level in the treated water of carrier tank: 300 to 400 mg/L).

[3] The suspended bacteria in the treated water of the carrier tank are then preyed on, decomposed and assimilated by animalcules in the downstream tank of activated sludge. As the suspended bacteria are dispersed and have a poorer flock structure, they are easy prey for animalcules. Thus, compared with conventional activated sludge, a larger quantity of animalcules with greater diversification will appear and dominate the biota, making the two-phase system less affected by load variations.

(2) Usability of existing facilities

When modifying an existing activated sludge facility for the installation of the two-phase system, by following the procedure given below, the modification can be completed within a short period with almost no discontinued operation of the wastewater treatment facility.

[1] If the aeration tank is not divided, install a partition (its construction method without water drainage is patent pending).

[2] Install a screen on the partition for carrier separation.

[3] Charge carriers in the upstream tank.
[4] Modify part of the return sludge line.

(3) Reduced production of excess sludge

The production rate of excess sludge shrinks by as much as 20% to 40% of the activated sludge process according to the following mechanism (i.e., the produced amount of excess sludge is reduced by 60% to 80%).

[1] In the downstream tank of activated sludge, excess sludge is produced depending on the levels of inflowing organics. The organic concentrations in the treated water of the carrier tank are decreased by as much as 30% to 40% of the raw water.
[2] Many of the animalcules in the downstream tank of activated sludge are large in size. Therefore, more of the obtained energy is consumed for purposes other than assimilation and reproduction, lowering the assimilation/reproduction rate (i.e., produced amount of excess sludge).

(4) Improved SVI of the settling tank (volume per unit weight)

The downstream tank of activated sludge contains many diversified animalcules and many of them are large in size. This lowers the SVI, improving the solid-liquid separability in the settling tank and making maintenance and management easy.

## 3. Short payback period and CSR contribution

**Figure 2** shows an example of running cost reductions.

The cost incurred in the modification of an existing activated sludge facility to install the two-phase system is expected to be recovered within 3-5 years because of the reduced running cost of the modified facility.

As the use of our product can reduce industrial waste and energy consumption, it also helps our clients to fulfill their CSR. For this reason, demand for our product is increasing every year both domestically and overseas, in spite of the current financial situation for investment in non-production facilities such as wastewater treatment facilities remaining severe.

Calculation parameter values

| | |
|---|---|
| Quantity of treated water | 750 m³/d |
| BOD level in raw water | 1,600 mg/L |
| Electricity expense per unit | 8 yen/kWh |
| Industrial waste disposal expense per unit | 17,700 yen/ton |

Thousands of yen/year

| | Conventional technology | Thousands yen/year |
|---|---|---|
| Disposal cost of industrial waste (sludge) | 21 240 | 4 248 |
| Electricity cost | 3 730 | 3 320 |
| Chemicals cost | 2 730 | 540 |
| Total | 27 700 | 8 108 |
| Reduction in cost | —— | 19 592 |
| Reduction rate | —— | 71% |

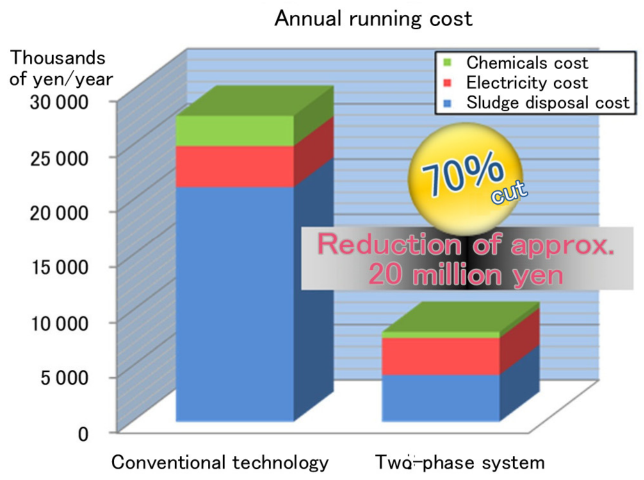


**Figure 2 Comparison of the annual running costs**