Technical Innovations in Waste Water Treatment

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More efficient waste water treatment technologies are required to cope with tightening regulations on the quality of treated water from waste water treatment plants. We have developed a three-step feed, biological nitrogen removal process and a submerged membrane filtration, which considerably improve treated water. Moreover, KOBELCO ECO-SOLUTIONS CO., LTD. has built fifteen functioning waste water plants with a new activated sludge process that generates little or no excess sludge.

Introduction

In the field of waste water treatment, the history of KOBELCO ECO-SOLUTIONS CO., LTD. started in December 1957 with the establishment of a water treatment division. We concluded a technical assistance contract on water treatment equipment with Pfaudler Permutit, Inc., a leading US based company in the water treatment industry, and started selling products, such as clarifiers, filters, heating-type degasifiers and ion-exchange equipment.

The memorable first equipment was a pure water system for a Benson boiler, delivered to the Nadahama works of Kobe Steel in 1958. Since then, we have expanded our business both in public and private sectors, including water treatment plants and water/sewage works, and have established a position as an integrated water treatment company.

In October 2003, the environmental business division of Kobe Steel was placed under the administration of our company, which enhanced our product menu for sewage treatment business. We are also pursuing other environment-related eco-solution businesses, including solid waste treatment.

This article introduces the original technologies of KOBELCO ECO-SOLUTIONS CO., LTD.(KES), with special focus on new technologies characterized by the keywords "High-level treatment", "Energy saving" and "Recovery".

1. Biological treatment technology (Three step biological nitrogen removal process)

The multi-step nitrogen removal process developed by KES is a variation of a biological nitrogen removal processes, using activated sludge. The system comprises multiple steps of nitrogen removal tanks and denitrification tanks, in which water flows are dispensed in equal amounts to each denitrification tank, and has the following features:

(1) High nitrogen removal rate
(2) Reduced tank sizes
(3) Easiness of operation and maintenance

The following equation calculates the nitrogen balance at the final step of the multi-step nitrogen removal process;

$$\frac{C_{\mathrm{NO_3,\,out}}}{C_{\mathrm{N,\,in}}}=\frac{1}{N}\cdot\frac{1}{1+r+R_{\mathrm{N}}} \quad \cdots\cdots\cdots (1)$$

where; N, number of steps; r, sludge return rate; RN, circulation rate at the final step; $C_{\mathrm{N,\,in}}$, inflow nitrogen concentration subject to nitrification (mg/l) and $C_{\mathrm{NO_3,\,out}}$, outflow nitrate-nitrogen concentration (mg/l)

The equation shows that the nitrogen removal rate ($C_{\mathrm{NO_3,\,out}}/C_{\mathrm{N,\,in}}$) is determined by the number of steps, sludge return rate and circulation rate at the final step. From the equation, the number of steps required to remove nitrogen by 80% is calculated to be three, assuming the sludge return rate of 0.5 and circulation rate at the final step of 0.5.

The outline of a multi step nitrogen removal process is shown in **Figure 1**, in which the number of steps is three. Flocculating agents may be added to the final step to remove phosphorous.

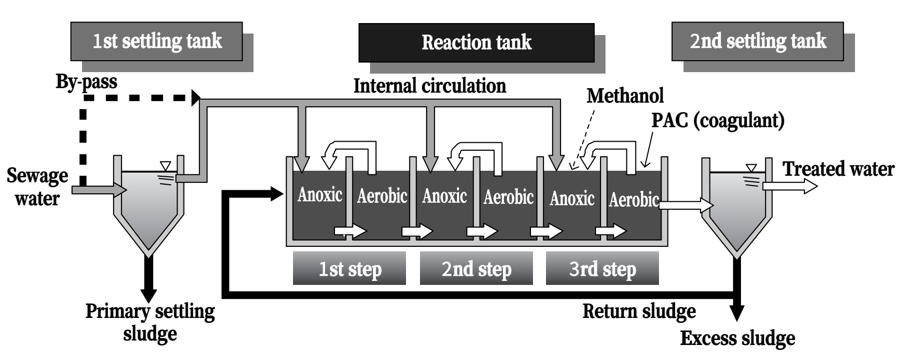

Fig. 1 Three step-feed biological nitrogen removal process

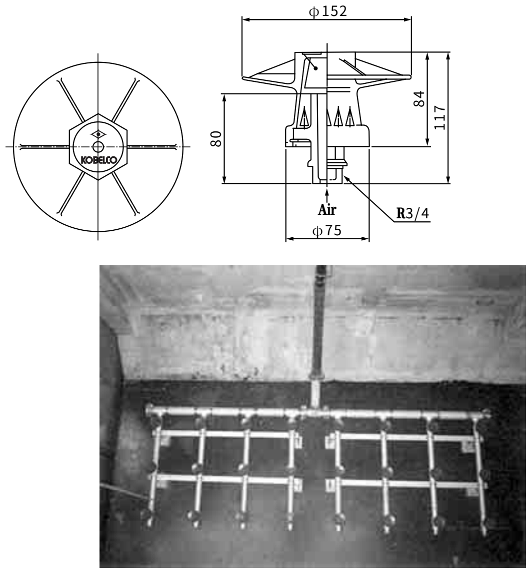

Photo 1 Complete mixing equipment with coarse bubble

We also developed a coarse air bubble mixing apparatus for agitating the denitrification tanks used for the multi-step nitrogen removal process[1)]. The coarse air bubble mixing apparatus (**Photo 1**) is our original system for agitating tanks with air, while maintaining anaerobic conditions. The apparatus is running cost (power cost), which saves 90% of the power consumed by conventional apparatuses. The development, in collaboration with the Mechanical Engineering Research Laboratory of Kobe Steel, fully exploited rheological analysis technologies and led to optimization of operations, including intermittent aerations.

2. Membrane treatment technology (Water recovery system)

Conventionally, either a gravity sedimentation method or a coagulating sedimentation method has been employed for solid-liquid separation processes. However, both methods occupy large footprints. Because of this, membrane processes have been assessed for water purification processes in which removal of suspended solids is the main object. KES participated in several national projects such as MAC21, ACT21, e-Water and accredited several membranes as suitable for this process[2)]. With recent improvement in membrane technology, membranes are being applied to wastewater treatments in which suspended solids concentrations are even higher.

As an example, KES is pursuing a new "water supply business" for the electronics industry, by utilizing water recovered from industrial effluent through a membrane system. **Photo 2** shows the membrane module which is the core of the water recovery system. In order to expand the application

Photo 2 Membrane treatment system for water recovery

Photo 3 Pilot scale equipment of hollow fiber membrane

of the system, a pilot plant was built at the Kakogawa Works of Kobe Steel, at which site the system is being applied to effluent from a steel making process.

KES has also commercialized a hollow fiber membrane system[3)] combined with a conventional activated sludge method (**Photo 3**), which have been widely used for organic wastewater treatment. The new hybrid system occupies only a quarter of the footprint occupied by the conventional equipment.

3. Chemico-physical treatment technology (for valuable metal recovery)

Conventionally, heavy metals in wastewater have been precipitated as hydroxides and disposed as industrial waste. If heavy metals are collected in states of alloys, instead of hydroxides, the alloys collected are recovered as valuable metals.

Table 1 shows standard reduction potentials of various metallic ions. In water solutions of metals, metals with higher reduction potentials (or lower ionization tendencies) can be precipitated with metals with lower reduction potentials (or higher ionization tendencies). For example, iron (Fe), added to a water solution containing copper ion ($Cu2+$), causes the following reaction, reducing copper ion ($Cu2+$) into metallic copper (Cu) precipitate.

$$Fe + Cu^{2+} \rightarrow Cu + Fe^{2+} \quad \cdots\cdots (2)$$

The above process is called "cementation"[4)] and has been used in the copper industry, in which scrap iron

Table 1 Standard reduction potential of various metallic ion

Electrode system	E°/V
$Mg^{2+}+2e=Mg$	−2.37
$Al^{3+}+3e=Al$	−1.66
$Zn^{2+}+2e=Zn$	−0.76
$Fe^{2+}+2e=Fe$	−0.44
$Cd^{2+}+2e=Cd$	−0.4
$In^{3+}+3e=In$	−0.34
$Co^{2+}+2e=Co$	−0.28
$Ni^{2+}+2e=Ni$	−0.25
$Sn^{2+}+2e=Sn$	−0.14
$Pb^{2+}+2e=Pb$	−0.13
$(2H^{+}+2e=H_2)$	0
$Cu^{2+}+2e=Cu$	0.34
$Ag^{+}+e=Ag$	0.8
$Pd^{2+}+2e=Pd$	0.92
$Pt^{2+}+2e=Pt$	1.2
$Au^{3+}+3e=Au$	1.45

has been utilized. However, the produced copper has only low purities, due to mixing with iron. KES developed a new valuable metal recovery process (**Figure 2**) which enables the recovery of almost pure metals by stripping away the metal precipitates in the cementation process by using ultrasonic irradiation.

In the process of developing the system, field tests were carried out at the Chofu Plant of Kobe Steel (**Photo 4**), which resulted in a recovery rate for copper of 85% in average.

The method is applicable to various metals, but it is more feasible if applied to the recovery of metals with high values. Indium (In) is a valuable metal used as a raw material of ITO (Indium Tin Oxide), which is used in flat panel displays and solar cells. In order to secure the resource, the Ministry of Economy,

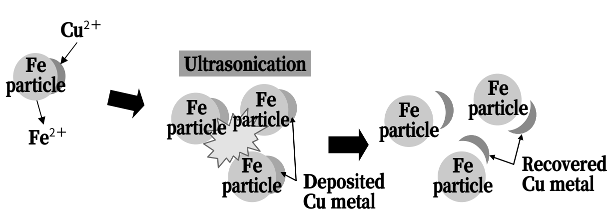

Fig. 2 Principle of Cu recovery by cementation combined with ultrasonication

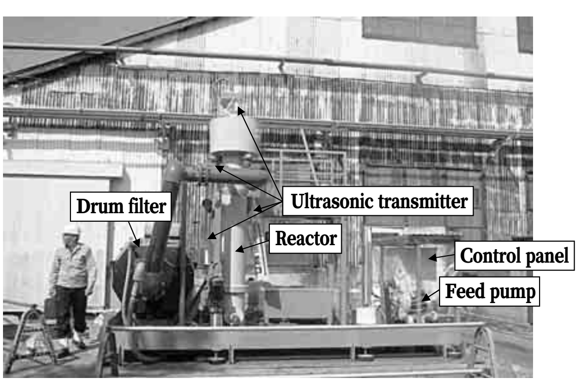

Photo 4 Pilot scale equipment of metal recovery system

Trade and Industry is promoting development of the metal's recycle technology and discussing state stockpiling. KES has made trials to recover indium from waste liquid crystal display (LCD) panels and etching effluent of LCD manufacturing plants. In both cases higher than 90% recovery rates of indium were confirmed[5].

4. Equipment diagnosis business (Biological diagnostic technology)

Biological processes are widely used for the wastewater treatment of domestic sewage and factory effluent; however, there has been no method available to evaluate biological activities in the process and its operation and maintenance have relied on human experience . With recent advancement in the analysis of microorganisms based on molecular biology, such as quantitative PCR and T-RFLP, it has become possible to identify quite accurately the numbers of certain types of bacteria quickly.

KES is developing a next-generation water treatment management system, which monitors gene information of microorganisms to maintain water treatment operations. The next-generation system will allow operators to evaluate the operating conditions of biological water treatment facilities objectively.

We monitored the number of ammonium oxidizing bacteria, nitrite reducing bacteria, and nitrous oxide reducing bacteria for five months at the biological nitrification / denitrification facility installed in the IPP division of Kobe Steel, and evaluated the relation between the number of bacteria and the process performance. As a result, it was found that the total nitrogen load per a copy of nitrite reducing bacteria (nitric reducing bacteria (mg-TN / (copy・d)) correlates well with the TN of the treated water(**Figure 3**)[6]. The fact indicates the possibility that, by maintaining and controlling the number and activities of nitric reducing bacteria, the water treatment facility can be operated in a stable manner. We propose a biological diagnostic system of tracing the behaviors of indicator bacteria

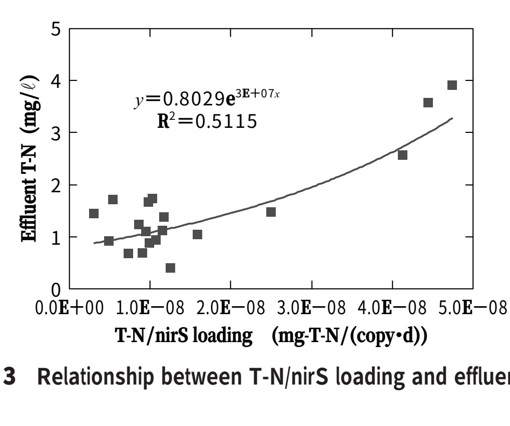

Fig. 3 Relationship between T-N/nirS loading and effluent T-N

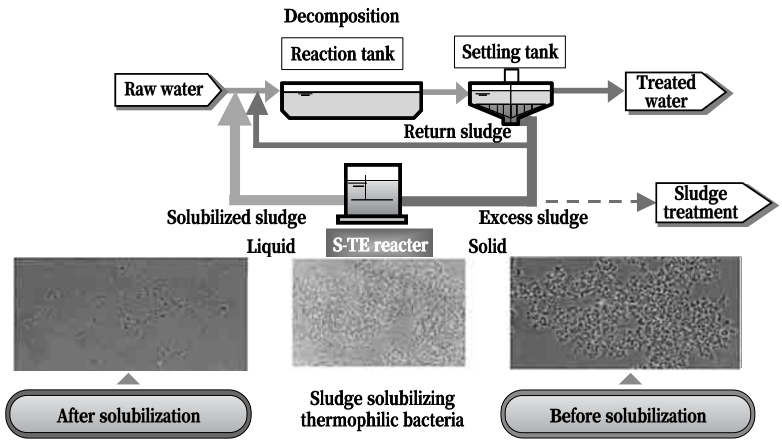

Fig. 4 Flow diagram of "S-TE PROCESS"

for operation to facilitate management and operation of wastewater treatment systems[6].

5. Sludge reduction technology ("S-TE PROCESS")

There is a strong demand for the reduction of excess sludge, as locating industrial waste disposal stations is becoming difficult and as the disposal costs becoming higher. In small to mid-sized disposal stations, the demand is particularly stronger, rather than the demand for utilizing the sludge as a resource. KES developed a new process, called "S-TE PROCESS", which does not require any draw of sludge under certain conditions. The new process uses an enzyme produced by thermophilic bacteria to solubilize sludge and to oxidize the solubilized slug into inorganic substances in a conventional biological reactor.

Figure 4 shows the flow diagram of an "S-TE PROCESS". In sludge reductions, the key issue is how to dissolve the rather strong cell walls of bacteria constituting the sludge in an efficient manner. The "S-TE PROCESS" dissolves the cell walls of bacteria using an enzyme produced by thermophilic bacteria and solubilize the sludge. The thermophilic bacteria, employed in this techonolgy, are naturally occurring bacteria without pathogenicity belonging to Bacillus stearothermophilus, actively proliferate at 60 to 70℃ and excrete enzyme to solubilize sludge under aerobic conditions. The thermophilic bacteria, on the other hand, lose activity and proliferation at temperatures lower than 50℃ and do not adversely affect the microorganism carrying out the water treatment, even if the sludge containing the bacteria is circulated into the existing treatment tanks. The system generally require no additional inoculation of the thermophilic bacteria, since a portion of the bacteria remains as spores at temperatures lower than 50℃, and is returned back to the sludge solubilization tank and regains activity at the temperature of the tank higher than 60℃ We have already delivered fifteen systems, including overseas delivery, mainly to private chemical factories.

We also have licensed the technology to three companies, one of which is Degremont, the largest water processing company of the world, and have started wide business activities.

Conclusions

Verification on actually treated water is essential for the development of water treatment processes; however, it is generally difficult because the water effluents from actual plants have a wide variety, making analysis difficult. KOBELCO ECO-SOLUTIONS CO., LTD., as a Kobe Steel Group company, can perform a range of verification tests and exchange information with users regarding effluent water quality and operating conditions. Thus, the alliance enables unique development of technologies.

Recent trend of water treatment is shifting from the "removal / disposal" to "recovery / utilization" scenario, and separation / refinement technologies have started to be built into water and sludge treatment processes. KES will take on the challenges of retrieving clean water from effluent water, recovering valuables from the remaining condensation and returning them back to the users.

References

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