ICETT

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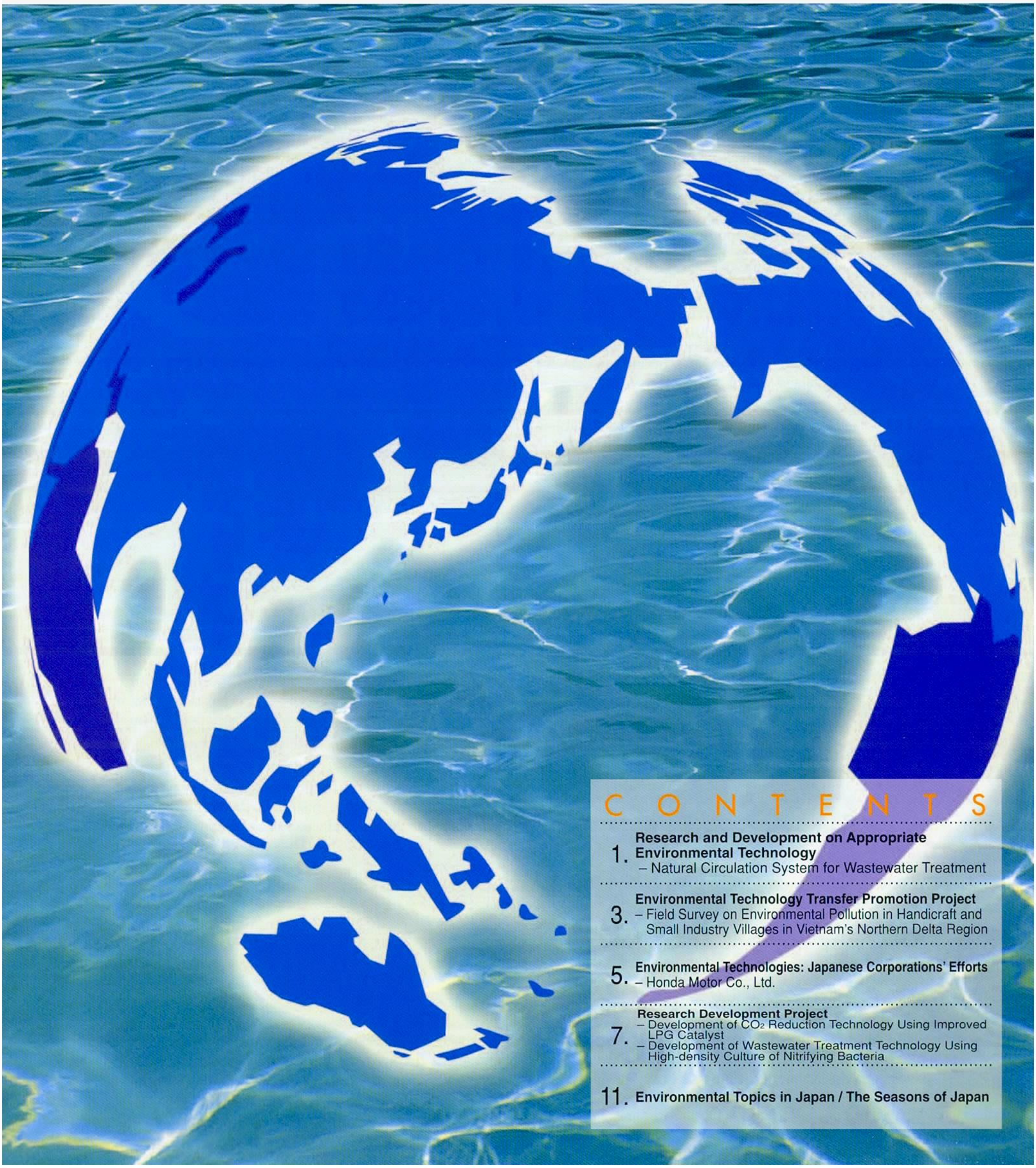
INTERNATIONAL CENTER FOR ENVIRONMENTAL TECHNOLOGY TRANSFER



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Joint Research for the Establishment of Natural Circulation System for Wastewater Treatment under Environmental Cooperation Program for Asia (ECPA)

1. Background and Concept

The aim of this research and development project is to transfer appropriate environmental-conservation technology to developing countries in Asia and elsewhere. Conducted on request by Mie Prefecture, this project started in fiscal 1996.

This project has been carried out by the following steps: 1) Conducting a basic needs survey to determine what types of technology would be required; 2) Selection of specific, practical technologies to satisfy these needs; and 3) Seeking out organizations with which to conduct joint research and on embarking on basic research. As a result of this process, the "Natural Circulation System for Wastewater Treatment" developed by a group led by Prof. Matsumoto, the Graduate School of University of Tokyo, was adopted as appropriate technology. This technology is suitable for the treatment of domestic wastewater – a priority in economically-developing Asian countries – and organic industrial wastewater generated from food manufacturing and processing, livestock breeding and other industries.

In fiscal 2000, based on our research findings to date, the Kingdom of Thailand was chosen as the site for practical research on technology for the Natural Circulation System of wastewater treatment and the subsequent dissemination activities, undertaken jointly with the Asian Institute of Technology (AIT), Chulalongkorn University (CU) and the Thailand Environment Institute (TEI). With the working concept being the development of a simple, small-scale, domestic wastewater treatment facility, to be situated immediately following the wastewater source, and with removal of organic pollutants as the guiding idea, a pilot plant was constructed. Data derived from the pilot plant was collected, with the aim of demonstrating the effectiveness of a wastewater treatment system that was simple in design, easy to operate and control, inexpensive to build and maintain, and used materials readily available locally.

The overall wastewater treatment system was developed to serve as a positive link in the creation of a recycling-oriented society. Used/discarded materials were to be reused as filter media, and the wastewater, itself, was to be recycled.

2. Overview of Research

A pilot plant was installed at the "Building Together Association (BTA)" housing complex, which is located in the Bangkapi District of northeastern Bangkok (See Figure 1.). Wastewater used for research purposes was pumped from the storage tank of the domestic wastewater of the 2,300 BTA residents, as well as the little wastewater generated by home industries (simple operations, such as making window sashes and artificial flowers). This wastewater was characterized by containing a considerable amount of fecal matter, being anaerobic, and containing no heavy metals.

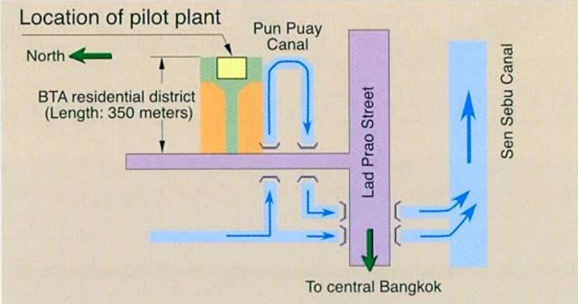


Fig. 1: Sketch map of the BTA housing complex and environs, in Bangkok's Bangkapi District

The pilot plant used for this research project was composed of a combination of five anaerobic and aerobic tanks, connected in tandem and based on gravity flow (See Fig. 2.). Wastewater was treated by means of microorganisms, which were attached to a filter media contained in each of the tanks. Construction of the pilot plant began in September 2000, and it has been in full operation since the following November. Sampling was conducted once a week, and the samples were analyzed by AIT and CU.

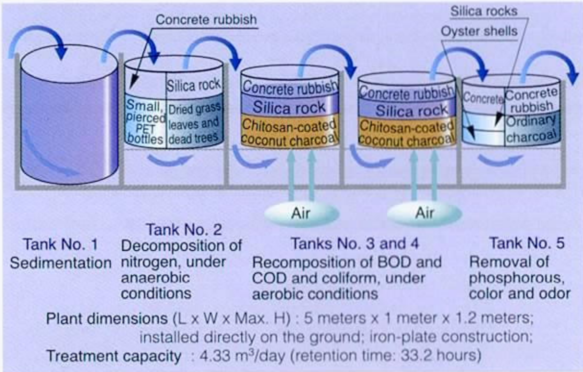


Fig. 2: Structure of the Natural Circulation System Wastewater Treatment Plant at the BTA

3. Findings and Observations

The results of wastewater treatment conducted at the pilot plant are shown in Table 1. High water temperature and other conditions typical of tropical areas, like Thailand, worked effectively against microorganism activity, resulting in generally good removal of biological oxygen demand (BOD), suspended solids (SS) and other pollutants (Treated water had an average BOD value of 17 mg/l and an average SS value of 3 mg/l, for a rate of removal of 85 percent and 93 percent, respectively.). Such favorable results were predictable, based on research findings from 1999. And the pilot plant confirmed that wastewater treatment facilities using locally available materials could also provide considerable efficacy. COD removal, however, was not quite as effective (Treated water had an average COD value of 31 mg/l, for a rate of removal of 80 percent.). And, although a qualitative finding, it is significant that BTA residents were both surprised and extremely satisfied with how the treatment facility succeeded in transforming the malodorous, brown influent into odorless, colorless, clear effluent (See Photo 1.).

Photo 1: Comparison of wastewater (influent) and treated water

The treatment system did not excel, however, in removing nitrogen, phosphorous and other eutrophication agents (Treated water had an average nitrogen value of 24 mg/l and an average phosphorous value of 5 mg/l, for a rate of removal of 26 percent and 4 percent, respectively.), as the influent contained high amounts of human waste. This being the case, it was proposed that further evaluation of the system and the way it is operated was required, in terms of its ability to remove nutrients from the influent. Three proposals, in particular, are under consideration: 1. In-system improvement, such as applying the circulation process of treated water into the primary tank or modifying the filter media; 2. Improving the way in which the system is operated and maintained, and; 3. Conducting additional treatment, before or after the existing system.

Next, we compared our findings to objective indexes. When compared to "Building Effluents: Standard Values", to be issued by the Ministry of Science, Technology and Environment, in Section 55 of the Act, the influent already met the standards for total dissolved solids (TDS) and nitrogen, at the time in which it entered the system. The system did, however, succeed in bringing the BOD value of the treated water well within the maximum permitted values for category "A", the most stringent standards. As such, the quality of the treated water can be said to have attained a certain, overall level of purity (See Table 2.).

Today, this pilot plant has become the facility closely related to the daily lives of the residents at the BTA housing complex. Residents inspect the pumps every morning as system maintenance and recycle the treated water for use in watering plants and other applications.

Table 1: Performance of Natural Circulation System Wastewater Treatment Plant
(Based on data from Feb. through Mar. 2001)

Pollutant indicator	Units	Average value in influent	Average value in effluent (after treatment)	Ex. of value under favorable conditions (date)	Average rate of removal/ improvement (%)	Data obtained during/on
BOD	mg/l	115	17	1 (2/22)	85	Feb.1 ~ Mar.15
CODCr	mg/l	163	31	23 (2/8)	80	Feb.1 ~ Mar.15
SS	mg/l	39	3	0 (3/8)	93	Feb.1 ~ Mar.15
TDS	mg/l	490	210	–	57	Feb. 14, 2001
Nitrogen (TKN)	mg/l	33	24	8 (2/8)	26	Feb.1 ~ Mar.29
Phosphorous (T-P)	mg/l	5	5	4 (3/22)	4	Feb.1 ~ Mar.29
Turbidity (ppm)	ppm	164	4	1 (2/1)	97	Feb.1 ~ Mar.15
Coliform groups	MPN/ 100ml	4.6×10^7	6.6×10^5	4×10^4 (3/29)	99	Feb.1 ~ Mar.29
Fecal coliform group	MPN/ 100ml	2.1×10^7	3.5×10^5	2×10^4 (3/29)	99	Feb.1 ~ Mar.29

Sources: AIT, CU

Table 2: Thailand's proposed "Building Effluents: Standard Values"

Pollutant indicator	Units	Maximum permitted values/range, by category				
		A	B	C	D	E
pH	mg/l	5-9	5-9	5-9	5-9	5-9
BOD	mg/l	20	30	40	50	200
Solids:						
SS	mg/l	30	40	50	50	60
Sedimentary	mg/l	0.5	0.5	0.5	0.5	–
TDS	mg/l	500	500	500	500	–
Sulfides	mg/l	1.0	1.0	3.0	4.0	–
Nitrogen (TKN)	mg/l	35	35	40	40	–
Oils, fats and grease	mg/l	20	20	20	20	100

Source: Proposed Section 55 of the Ministry of Science, Technology and Environment's Science, Technology and Environment Act

4. Local Acceptance and Future Aims
- Voluntary Activities and the Spread of Technology -

This joint research project brought about cooperation between research institutes, on a level that transcended sectarianism. Residents of the BTA housing complex, too, participated actively in all stages of this project, from construction of the pilot plant, to its operation and maintenance, to publicizing the project throughout the local community.

In addition to research activities, the project included technical seminars for government officials, technicians, researchers, business leaders and other interested parties in Bangkok, as well as a grassroots level seminar to increase awareness among general residents. On the grassroots level, in particular, we received an unprecedented degree of participation from the general community (110 people representing various residential districts within Bangkok, and 10 other people).

Such success attracted the attention in our project and the pilot plant, bringing a steady stream of visitors from nearby residential areas and local governments from other regions to observe our activities (See Photo 2.). The municipality of Rayong, which is ICETT's partner in the ongoing Environmental Cooperation Program for Asia (ECPA), conducted by request of Mie Prefecture, is setting up plans for the construction of a full-scale wastewater treatment facility applying this technology. In addition to having made the BTA housing complex a demonstration site, ICETT intends to make the most out of the opportunity provided by the interest shown in this research project by local governments, residential districts and individual people, by offering support to interested parties.

Photo 2: On-site observation by the Municipality of Rayong

Field Survey on Environmental Pollution in Handicraft and Small Industry Villages in Vietnam's Northern Delta Region

Introduction

ICETT has been engaged, since fiscal 1993, in conducting programs designed to provide economically-developing countries with support in the handling of environmental pollution, as per request by the Japan's Ministry of Economy, Trade and Industry (METI). These programs include investigating the degree and characteristics of pollution in developing countries, finding out the technology suited to the sites for smooth dissemination, and proposing comprehensive measures to resolve the existing pollution problems in those countries. In fiscal 2000, ICETT conducted "Field Survey on Environmental Pollution in Handicraft and Small Industry Villages in the Northern Delta", which was proposed by the Vietnamese government, at the Green Aid Plan (GAP) Policy Dialogue between Japan and Vietnam.

Background and Aim

Based on the reform (Doimoi) policy initiated in 1986, Vietnam underwent a liberalization of its economy and other aspects of society, including the introduction of the principles of a market-based economy. These changes have enabled Vietnam to achieve solid economic growth, since 1992.

In the shadow of strong economic growth, however, environmental pollution became increasingly serious. In 1993, Vietnam enacted an environmental protection law and has been attempting to deal with its pollution problems. The reality remains, nevertheless, that because of outdated production facilities, a lack of appropriate facilities to control pollution, etc., most enterprises, including even government-run enterprises, cannot take any measures against pollution. Many small and medium-sized commercial enterprises, which form the majority of Vietnamese industry, suffer from a lack of funds, technology and human resources. There is concern that these companies will cause a further and severe environmental pollution.

In view of the above, METI made a contact with ICETT to act on a request from the Vietnamese government. In partnership with the Vietnamese Ministry of Science, Technology and Environment (MOSTE) and the Center for Consultancy, Training & Transfer of Technology, ICETT conducted the survey on handicraft and small-industry villages (called "traditional-industry villages", because of the traditional industries they maintain) in the Northern Delta.

Preliminary survey : Oct. 1 - 8, 2000
Formal survey : Nov. 26 - Dec. 24, 2000

Through consultation with MOSTE, the following five areas were chosen as the survey sites: the provinces of Vinh Phuc, Ha Tay, Bac Ninh and Thai Nguyen and the suburbs of Hanoi. The survey was to focus on four types of industry: food processing, textile including dying, paper manufacturing and metal plating.

Photo 1 Meeting with the Vinh Phuc People's Council

Results of the survey

Much of Vietnam's traditional industry conducts business in units of two-to-three family members or 20-to-30 people. Similar businesses, producing the similar items, tend to group themselves in the same area, in groups of from 10 to 200, 300 or more. Food processing enterprises, which depend on agricultural products for raw materials, are almost always operated as side business of agricultural farms, with the workers' living premises doubling as the workplace. Fifty-seven percent of the subjects of the survey described here were small-scale businesses, employing 10 or fewer people.

Photo 2 Wastewater sampling

The following problems were brought to light, as a result of this survey.

1 Environmental pollution caused by untreated wastewater

Wastewater from the workplace is discharged untreated, along with domestic wastewater, and eventually flows into public rivers. Food-processing enterprises discharge wastewater containing high levels of BOD and COD; metal plating operations release wastewater containing heavy metals and other harmful materials; and paper mills produce wastewater containing harmful materials and many suspended solids. The wastewater effects the size and quality of nearby agricultural harvests and seeps into groundwater supplies, causing problems in the maintenance of good-quality drinking water.

2 Health damage caused by burning coal

Vietnam has abundant natural coal resources, making coal a very widely-used fuel. A particularly large quantity of coal is burned in the smelting furnaces of the steel industry and in the kilns of the ceramics industry. Our survey found claims that many people living in the vicinity of such industries suffer from bronchial ailments, caused by the release of coal smoke. There were even cases in which companies were paying annual reparations to farmers, for the environmental pollution caused by their exhaust gas.

3 Abandoned solid waste

In Vietnam, unlike Japan, industrial and domestic waste is not separated, nor are there any programs established for the systemized collection and appropriate disposal of waste. Solid waste is discarded in backyards, vacant lots, rivers, ponds and other places. Poor road conditions in traditional-industry villages is making worse these circumstances.

4 Lack of quantitative understanding on environmental pollution

Commercial enterprises engaged in traditional industries are aware of the circumstances described in numbers 1. through 3., above, but they do not understand the quantitative environmental pollution they face. Moreover, these enterprises do not even fully understand what kinds of wastewater and exhaust gas they are emitting, nor the quantities they are emitting. These circumstances hamper efforts to determine specific measures with which to deal with the pollution.

5 Workplace problems

Aside from environmental problems, we received the strong impression that corporate awareness/concern about the working environment is quite low, in traditional-industry villages. Things lie scattered about the floors, machinery with moving parts is operated without any safety measures, and dangerous work is performed without any protective gear and even food-processing operations are conducted in such filthy workplaces. Work-related injury or occupational diseases could occur at any moment. Perhaps this is the greatest problem facing traditional-industry villages.

Photo 3 Paper (including toilet paper) manufacturing site

Proposed measures for dealing with pollution problems

Based on the findings of this survey, the following countermeasures could be proposed to control environmental pollution caused by traditional-industry villages in Vietnam.

1 The creation of centralized industrial zones

Because production sites in traditional-industry villages are intimately linked to the living environment of village residents, wastewater, exhaust gas, refuse and other waste generated at the workplace has an immediate effect on residents. Separating the workplace (production site) from residential areas would diminish the effects of workplace pollution on them. Moreover, creating a centralized industrial zone installing shared treatment facilities for wastewater, exhaust gas and refuse would result in an immense reduction in pollution. The preparation of land, installation of facilities to provide a stable supply of electricity and water, creation and maintenance of transportation systems and obtaining of other necessary infrastructure components, however, rests entirely on the securement of funds.

Photo 4 Holding pond near a village

2 Installation of community wastewater-treatment facilities

Near almost all traditional-industry villages, there is a holding pond where wastewater sits, before it runs into the rivers. The efficacy of such reservoirs has yet to be ascertained, but if, through natural purification, the wastewater is transformed into good-quality water, it can be utilized for the irrigation of crops. It would appear possible to select wastewater treatment technology that is appropriate for the quality and quantity of the wastewater and the size of the holding pond in question, then switch from the holding pond to wastewater treatment facilities that could provide a higher level of water purity.

3 Installation of simple, anaerobic wastewater-treatment facilities

One noodle manufacturer was in the process of constructing an anaerobic wastewater treatment facility, that generates methane gas. The project described here was finished prior to the completion of the facility, so the outcome is unknown. The cost of construction, however, was less than 20,000 Japanese yen. If that system succeeds in treating wastewater, and if that methane generated can be effectively used as fuel, this would be one wastewater treatment method worth consideration.

4 Introduction of the concept of cleaner production

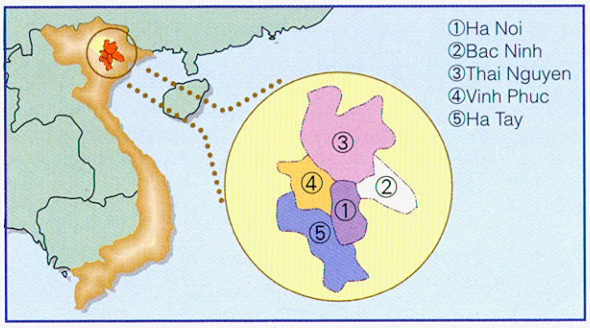
Improved productivity and a reduction in the amount of pollutants generated could result from improving outdated and inefficient production facilities and processes currently in use. This is the concept of "cleaner production". Cleaner production holds that an effective way to tackle environmental pollution is to do so while giving top priority to revenue-generating improvements and focusing on strengthening the commercial enterprise concerned.

5 Introduction of the 5S Principle

After examining family-run and small-scale factories, we feel that rather than focusing on environmental pollution, it is much more important to instill an awareness of the 5S Principle, which states that Sorting, Setting in order, Shining, Standardizing, and Sustaining (this principle is referred to in many ways, including the "can do" program: C – Clean up, A – Arrangement, N – Neatness, D – Discipline and O – Ongoing improvement) are so important to a production operation as the base of all good production activities. The more they take root, the more know-how these companies will have regarding safety, hygiene and environmental conservation, the better they will be at achieving safety, hygiene and environmental conservation-related goals, and the more they will feel inclined to make improvements on their own. All of this will lead to a betterment of the environment.

6 Providing of environmental education for local residents and others

As mentioned above, the government, commercial enterprises and residents do not have a good understanding of the environmental pollution they face, in terms of quantities. For this reason, no effective and accurate measures have yet been found to deal with pollution. Adding to the problem is the low awareness among commercial enterprises of the need to obey environmental regulations. Commercial enterprises must be made to truly understand the importance of observing environmental regulations and how these standards are linked to the promotion of local development. There is a strong need for the construction of a systematic means for educating both industry and residents about the environment with local government (People's Committees) in control, through engagement with cooperatives and other bodies that support the development of small and medium-sized enterprises – so that entire communities or regions can work actively toward improving the environment. It should also be added that the Vietnamese government needs to make sure all current environmental regulations are appropriate, modifying them where needed, and construct and maintain a system that even small-scale businesses can observe, if they really try.



Location of the survey sites

Toward a Production System that Embodies Comprehensive Recycling

Aiming for Zero Waste – "Zero Emissions"

Suzuka Factory, Honda Motor Co., Ltd.

Honda Motor Co., Ltd. is directing major effort toward the construction of a production system that incorporates means for the comprehensive recycling of all by-product waste. Dubbed the "Green Factory Plan", the aim of this environment-oriented plan is to ensure that each and every step of the production process places the minimal possible load on the global environment and utilizes resources with maximum efficiency.

Specifically, this means reducing the refuse and air and water pollutants emitted from our production plants and decreasing energy consumption as much as possible, to curtail the emission of carbon dioxide. And toward this goal, Honda Motor Co.'s Suzuka Factory, in Mie Prefecture, is aiming to be the first factory in the automobile industry to achieve "zero" generation of landfill waste, in an effort to integrate the entire factory into the global society and make it "a factory with which local residents are proud".

1. Reducing waste and protecting the air environment

The Suzuka Factory incinerator was renovated in March 1998, to minimize exhaust gas and with the intention of enabling the recovery and re-utilization of waste heat as energy. A boiler designed to recycle waste-heat was installed in conjunction with the incinerator. Steam from the boiler is used for turbines generation and then introduced into the production process.

The Suzuka Factory has been implementing measures to bring dioxin emissions under 0.1 ng-TEQ/Nm^3, since well before emissions regulations were established by law. One such measure, employing a catalyst designed to break down dioxins – an industry first – succeeded in greatly reducing the quantity of dioxins contained in the exhaust gas emitted by the factory.

Dioxins are also generated when cutting oil, used in various machining processes, is incinerated. For this reason, the Suzuka Factory has initiated special controls, such as the introduction of cutting oil that does not contain chloride compounds, in an attempt to curb the amount of dioxins generated as waste.

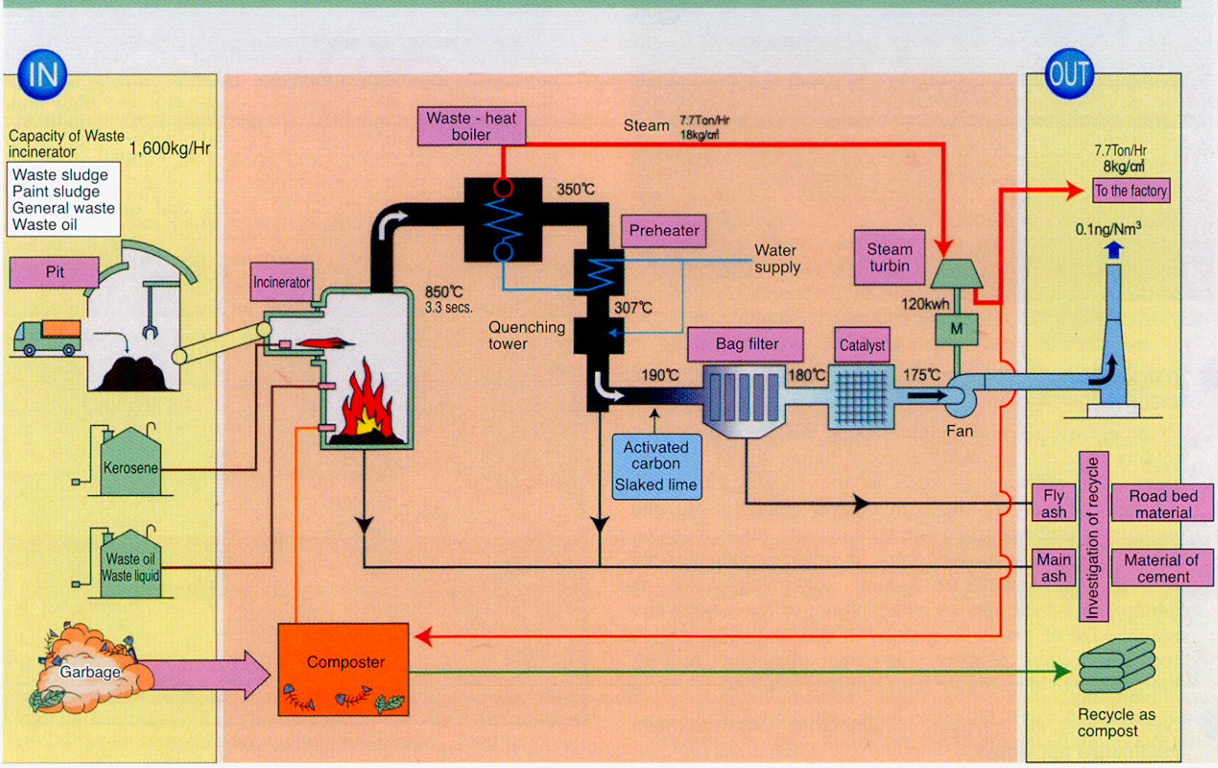
2. "Zero" generation of industrial waste destined for landfill

The Suzuka Factory generated approximately 2,160 metric tons of landfill waste, in 1995. Implementation of exhaustive measures for the separation and recycling of waste enabled this the Suzuka Factory, in September 1999, to become first such facility in the industry to achieve "zero" generation of landfill waste. By April 2000, the same waste-generation-control measures had been initiated at all Honda Motor Co.'s workplaces. Specifically, these measure include improving the yield-per-unit obtained from raw materials, re-utilizing "used" materials in the production process, and recycling waste.

A. Reducing waste at its origin, by improving yield from raw materials, etc.

- Improving the efficiency of paint lines
- Extending the useful life of lubrication and cutting oils
- Reduction of sludge generated in the treatment of wastewater

Honda Motor Co., Ltd. Suzuka Factory Flowchart of Incinerator



B. Recycling and re-utilization in production line

- Waste oil, waste sand from casting, waste thinner, plastic offcuts, etc.
- Separating combined resin offcuts and re-utilizing them as raw materials

C. Recycling

a. Using waste sand from casting as roadbed material

The 1,200 metric tons of waste sand generated each year from the casting process is recycled, by providing it to manufacturers of roadbeds.

b. Using wastewater sludge in cement manufacturing

Sludge generated during the treatment of wastewater is kneaded together with other waste, then recycled, by providing it to cement manufacturers.

c. Using incinerator ash in roadbeds and cement

Combustion residue (main ash) is recycled, by providing it to cement manufacturers, for use as raw material. Dust (fly ash), on the other hand, contains toxic substances; so, for recycling, it is heated to between 1,500 and 1,600 degrees centigrade, at an iron mill, to fuse it and detoxify it. It is then solidified and used as roadbed material. We are also involved in a variety of other recycling tests, such as ways to use incinerator ash in the manufacture of tiles.

d. Using cafeteria refuse as compost, etc.

Raw refuse from the cafeteria is recycled, by turning it into fertilizer, using steam generated in the incinerator.

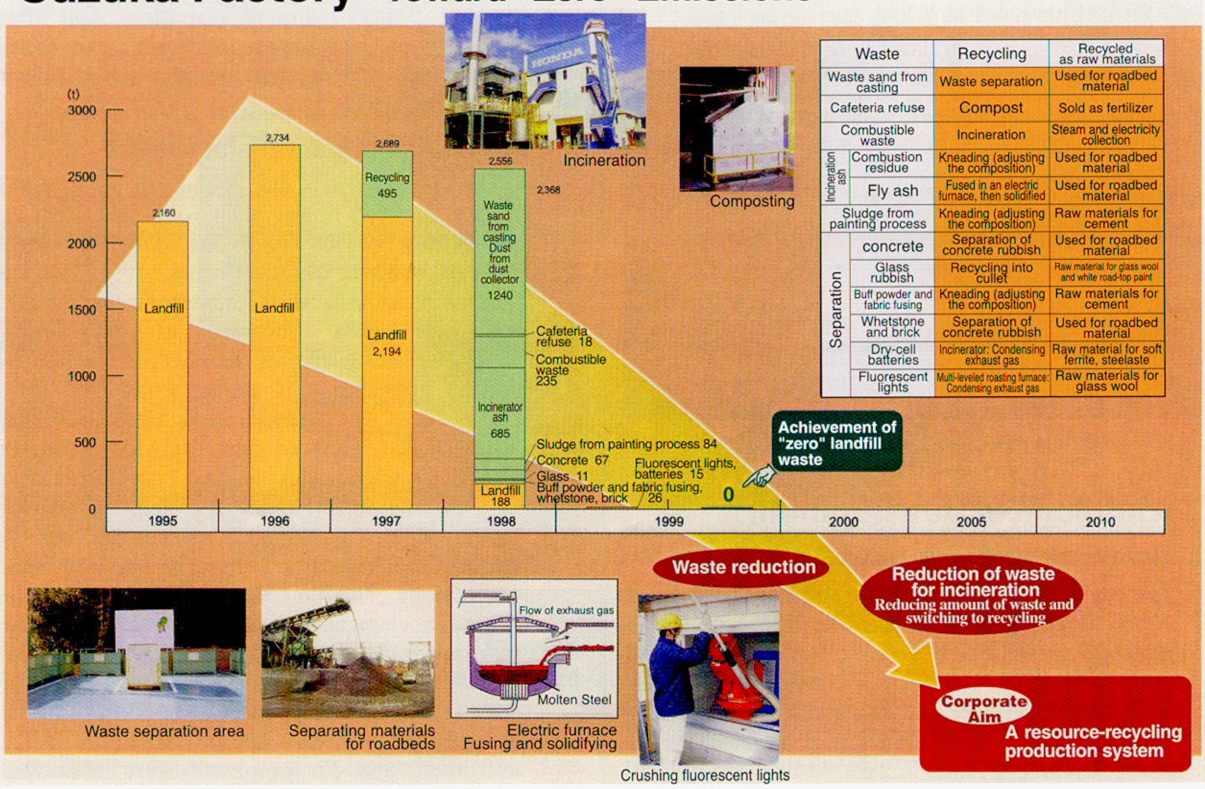
Some incinerator ash is transformed into tiles.

3. Continued expansion and new applications

Honda Motor Co. will continue to broaden the application of its waste treatment and recycling program, toward the goal of achieving "zero emission" of air and water pollutants. Separation and recycling of waste will be further strengthened, with the aim of eventually avoiding the need to use the company incinerator, at all. We intend to recycle the wastewater generated by the entire factory, to the point where no wastewater leaves the premises.

Plans call for our second cogeneration system to begin operation in 2002, as part of our efforts to enhance the efficient use of energy and reduce carbon dioxide emissions. Future undertakings aimed at making Honda Motor Co. a "zero emission" company will continue to earn the respect of the local community.

Suzuka Factory Toward "Zero" Emissions



Waste		Recycling	Recycled as raw materials
Waste sand from casting		Waste separation	Used for roadbed material
Cafeteria refuse		Compost	Sold as fertilizer
Combustible waste		Incineration	Steam and electricity collection
Incineration ash	Combustion residue	Kneading (adjusting the composition)	Used for roadbed material
	Fly ash	Fused in an electric furnace, then solidified	Used for roadbed material
Sludge from painting process		Kneading (adjusting the composition)	Raw materials for cement
Separation	concrete	Separation of concrete rubbish	Used for roadbed material
	Glass rubbish	Recycling into cullet	Raw material for glass wool and white road-top paint
	Buff powder and fabric fusing	Kneading (adjusting the composition)	Raw materials for cement
	Whetstone and brick	Separation of concrete rubbish	Used for roadbed material
	Dry-cell batteries	Incinerator: Condensing exhaust gas	Raw material for soft ferrite, steelaste
	Fluorescent lights	Multi-leveled roasting furnace: Condensing exhaust gas	Raw materials for glass wool

Research Development Project

Development of CO_2 Reduction Technology Using Improved LPG Catalyst

Group S, Niigata Laboratory and Tsurumi Laboratory, ICETT
Nippon Petroleum Gas Co., Ltd. Toshiba Corporation

【Project time frame】

Fiscal year 1996 ～ 2000

【Background】

The aim of this project was to develop an improved catalyst for liquid petroleum gas (LPG) fuel (a very convenient fuel, in that it causes no fuel infrastructure problems) and apply it to highly-energy-efficient fuel cells, to reduce carbon dioxide emissions associated with power generation and to raise demand for fuel cells.

LPG has a larger average molecular weight than town gas (13A), and contains a greater proportion of carbon atoms than town gas. As such, it is widely known that the steam reforming reaction of LPG is highly likely to cause carbon deposition (on the catalyst), even when employing catalysts that have been proven effective with town gas.

For these reasons, we developed in fiscal 1996 an improved catalyst with good performance in suppressing carbon deposition. The catalyst was subjected to a performance evaluation and strength test, during fiscal year 1997 and 1998, at the test stand at the Keihin Works of Toshiba. During the same period by using a full-scale fuel cell (See Photo 1 and Fig. 1), the environmental performance and characteristics with the passage of time of the improved catalyst and the stability and durability of the full-scale fuel cell were verified at the Niigata Terminal of Nippon Petroleum Gas Co. In fiscal year 1999 and 2000, the reformer that was downsized and a semi-commercial model, into which the improved catalyst was loaded, was tested.

Photo 1: LPG fueled fuel cell power plant

【Technological development】

A. Development of an improved catalyst

The evaluation of durability for sulfur poisoning and carbon deposit and compressive strength of the improved Nickel-based catalyst, which was loaded into a single-tube reformer was conducted for 2,000-hour using LPG fuel that contained approximately 600ppb sulfur and test-stand reactor at a steam/carbon (S/C) ratio of 2.5.

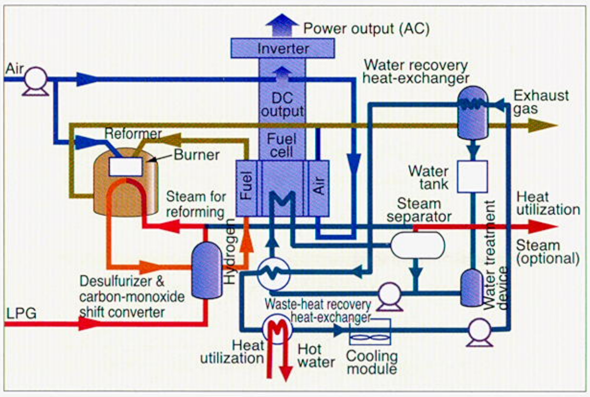


Fig. 1: Process flow chart of 200-kW fuel cell

Test results showed that, under the conditions described above, carbon deposition does not occur, despite the occurrence of a small amount of sulfur poisoning in the improved nickel-based catalyst. However, as it was observed that at S/C ratio of less than 2.5, carbon deposition does occur, the minimum S/C value was established at 2.5. The minimum S/C ratio for the improved catalyst, as obtained through this testing, was reflected in empirical testing using an actual LPG fuel-cell plant.

B. Empirical testing which used Single-tube reformer

The soundness, characteristics and environmental evaluation of an LPG fueled fuel-cell power plant, in which a single-tube reformer was employed, were conducted, by comparing the characteristics obtained at the outset of plant operation between after 3,000 hours and 10,000 hours of operation. And after 11,000 hours of operation the improved nickel-based catalyst which was loaded into the actual power plant was evaluated.

1.) Evaluation of plant characteristics

The characteristics and soundness of the LPG fueled fuel-cell power plant were evaluated, by comparing various conditions of the reformer-related equipment (desulfurizer, reformer and carbon monoxide shift converter), using rated operation data obtained at the initial characteristics testing of the plant, in June 1997, at the characteristics testing conducted after 3,000 hours of operation, in October 1997, and after 10,000 hours of operation, in November 1998. Characteristics testing conducted after 10,000 hours of operation revealed that the rate of reforming was within a valid range, that an appropriate hydrogen utilization rate had been maintained, and that there were no problems regarding changes with the passage of time in the reforming process. Very little change with the passage of time was recorded in the loss of pressure in the improved catalyst bed and in the exhaust gas from the combustion burner in the reformer, and no problems were observed.

Favorable findings were obtained, too, regarding the characteristics with the passage of time of the fuel cell, and its current and voltage, after approximately 11,000 hours of operation.

2.) Evaluation of environmental load from plant operation

The dust, nitrogen oxides and sulfur oxides emitted by the LGP fueled fuel-cell power plant were measured during rated operation, to determine the environmental load characteristics of the plant, when generating power using LPG as the fuel. All of the emissions measured were significantly below emission standards, confirming the sound environmental performance of the LPG fueled fuel cell power plant (See Fig. 2.).

Emissions measured		Amount found in emissions	Measurement method
Dust	Density (g/m³N)	Less than 0.01*	JIS ZZ8808 Round-filter method
	O_2: 7% converted	Less than 0.01*	
Nitrogen oxides	Density (ppm)	Less than 2.5*	JIS K0104 Chemiluminescence method
	O_2: 7% converted	Less than 2.5*	
Sulfur oxides	Density (ppm)	Less than 5	JIS K0103 Nephelometry method
	Emission volume (m³/h)	Less than 0.01*	

* Below measurable limits

Fig. 2: Emissions measured from LPG fueled fuel-cell power plant

3.) Evaluation of catalyst samples from reformer of actual LPG fueled fuel-cell power plant

Catalyst samples were taken from the single-tube reformer, after it had been in operation for 11,000 hours, at the LPG fueled fuel-cell power plant used in this development project. The samples were examined for their reforming performance, compressive strength, and carbon and sulfur content, to determine what, if any, changes with the passage of time they experience, when used in an actual fuel cell. No carbon deposition was observed, despite the increase in sulfur content found at the inlet of the catalyst bed. The strength of the catalysts was also found to have remained sound, with almost no deterioration observed. Figure 3 shows the relationship between carbon-sulfur content and the location of the catalyst samples.

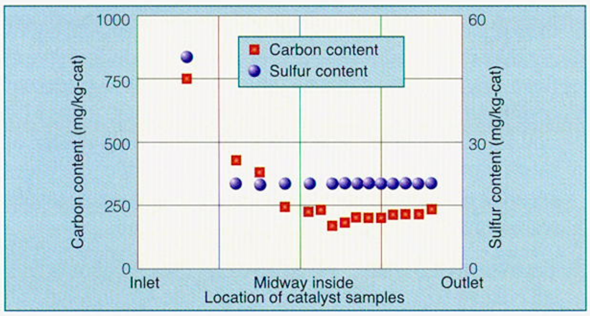


Fig. 3: Carbon-sulfur content in catalyst samples from actual LPG fueled fuel-cell power plant

C. Empirical operations testing at LPG fueled fuel-cell power plant — New multi-tube reformer

In fiscal year 1999 and 2000, the operation of a new, multi-tube reformer was examined. Testing was conducted to determine the characteristics of the multi-tube reformer at low steam/carbon ratios. The characteristics testing results conducted after 17,000 hours of plant operation (6,000 hours after operation of the multi-tube reformer commenced) were compared with the results recorded after 10,000 hours of operation, to evaluate the soundess of the plant and its operation performance. Low steam/carbon ratio testing was conducted after 23,000 hours of operation, to examine the possibility and effect of low steam/carbon operation.

1.) Evaluation of plant characteristics

The characteristics test conducted on the plant in March 2000, after 17,000 hours of operation, was compared with the characteristics test performed after 10,000 hours of operation. The comparison revealed that the efficiency in generating power has gone approximately one percent. It is presumed that this result is due to the approximately 40 percent less of a pressure drop in the catalyst bed, when the new multi-tube reformer was employed, as compared to when the single-tube reformer was used, and to an improvement in reforming efficiency. As such, we confirmed that the new multi-tuber reformer provides good performance. This boosted efficiency in generating power would result in a 24-ton reduction in carbon-dioxide emissions, on a yearly basis. No particular abnormalities in the passage of time were observed to have occurred in the fuel cell, and the plant was found to be operating stably.

2.) Evaluation of low steam/carbon ratio characteristics

In February 2001, the steam/carbon ratio was lowered from 3.5 to 3.0, and then, to 2.7, to test plant performance under low steam/carbon ratio conditions. At all the steam/carbon ratios, it was observed that increasing the temperature setting of the reformer by 10℃ maintained the methane conversion rate and hydrogen utilization rate within the control limits.

Moreover, the increase in steam, which can be used as waste heat, was measured at 22 kg/h, at a steam/carbon ratio of 3.0, and 37 kg/h, at a steam/carbon ratio of 2.7, for an increase in steam-heat recovery efficiency of 2.3% and 3.9%, respectively.

[Conclusion]

The clear documentation of various characteristics of LPG fueled fuel-cell power plants, obtained through the long-term empirical testing described in this report, has shown that LPG fuel cells are highly efficient, environmentally sound, reliable and durable. Testing also provided a clear picture of the form in which LPG fueled fuel-cell power plant can become commercially viable. Using the results of this developmental project, the first LPG fueled fuel-cell power plant designed for the general-consumer use are scheduled to begin generating power in the summer of 2001. We intend to continue applying the results of this development project, to promote the widespread utilization and broad application of fuel cells that are effective in reducing carbon-dioxide emissions.

Development of Wastewater Treatment Technology Using High-density Cultivation of Nitrifying Bacteria

Group G, Niihama Laboratory, ICETT
Sumitomo Chemical Co., Ltd.

【Project time frame】

Fiscal year 1999 - 2000

【Objectives】

Preventing eutrophication in natural water systems, which gives rise to red tides, toxic microcystis and other problems, is one of the most important hurdles to clear in protecting the global aquatic environment. Eutrophication is caused by nutrients – organic material, nitrogen and phosphorous – in sewage and industrial wastewater. Although widely used, the activated-sludge process of wastewater treatment is limited stable and effective nitrogen removal from wastewater, because it is dependent on the action of physiologically-fragile nitrifying bacteria (hereinafter called nitrifiers).

The ICETT Niihama Laboratory conducted a research and development project with two main aims. The one was developing a high-performance nitrogen removing process for practical use, based on a novel technology for high-density culture of nitrifiers. The other was evaluating the efficacy of loading high-density-cultured nitrifiers, as a kind of exogenous microbial agent, into activated sludge of very limited in removing nitrogen to stimulate a quick recovery (or reactivation).

【Details of technological development】

Figure 1 provides an overview of the novel nitrifiers' high-density-culture technology, which is the basis of this research and development project. The key of this technology consists in aggregant formation by mixing activated sludge with coal fly ash, one of industrial wastes derived from e.g. thermoelectric power station. Microbes, including nitrifiers, are immobilized in the aggregant. Thereafter, nitrifiers-specific propagation is enabled through continuous culture which involves logarithmically increasing over time the amount of ammonia supplied to the aggregant. Preceding this project, two major technologies were known to obtain high concentrations of nitrifiers: 1) forming a biofilm on a surface of a macro-carrier, and 2) entrapping microbes in polymer gels. Preliminary lab-scale experiments had indicated that the present technology we employed in this project had many advantages over above-mentioned traditional technologies. For example, the present technology enabled production of nitrifying-bacterial culture at much higher concentrations than either of the traditional technologies and was capable of achieving nitrification rate (ammonium nitrogen removed per unit volume and time) at such an extremely high level as approximately 1,000 mg-N/l・h.

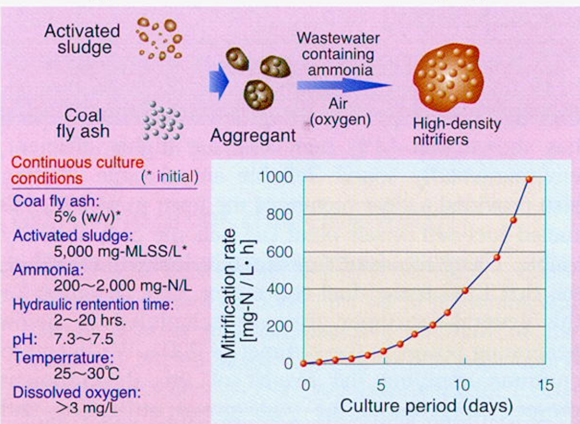


Fig. 1: Outlines of the present technology – high-density culture of nitrifiers

1. Optimizing conditions for the high-density culture of nitrifiers

We examined and attempted to optimize a number of factors related to the nitrifiers' high-density-culture technology, which had been established at lab-scale prior to the research project, towards to practical use.

A. Examining factors that could affect the propagation of nitrifiers

Before starting the research project, only one kind of coal fly ash for immobilizing microbes and only one kind of activated sludge as a source of nitrifiers had been tested. The research project resulted that the differences in quality or in origin of these materials hardly affect nitrifiers in their propagation. Randomly obtained these materials were useful for high-density culture of nitrifiers with no problem.

B. Evaluating treatment of wastewater containing high concentrations of ammonia

Applicability of the present technology to treatment of wastewater containing high concentrations of ammonia, which was generally derived from petrochemical manufacture etc., was evaluated. For example, wastewater of chemical fertilizer plant was tested, and effective treatment was carried out employing the present technology.

2. Optimizing the storage of high-density-cultured nitrifiers

The other way to use high-density culture of nitrifiers suggested that they could be administered as a sort of microbial agent to activated sludge in order to compensate and reactivate its partially or entirely lost nitrification activity. For such purpose, it is necessary to optimize storing conditions of the high-density-cultured nitrifiers without reducing their highly concentrated nitrifying activity. A variety of factors which may affect the storage of nitrifiers were investigated. The results indicated that stringent aerobic condition must be kept in the culture to prevent from accumulating nitrite ions. Under the optimized condition, high level of nitrification activity could be maintained within approximately a month even at room temperature (25℃). Besides viable nitrifiers could be stored for several months or over under refrigeration.

3. Confirming and optimizing the efficacy of nitrifiers in nitrification recovery

A study was conducted on the utilization of a nitrifying-bacterial agent as a practical means for reviving or reactivating the nitrification activity of wastewater treatment plant that was reduced its nitrification activity or faced with unexpected excess ammonia load.

Fig. 2 showed the successful reactivation of nitrification activity by nitrifying-bacterial agent

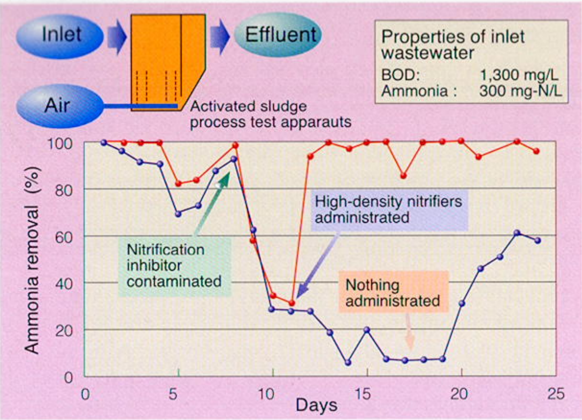


Fig. 2: Effect of high-density nitrifiers in recovering the nitrification activity of damaged activated sludge

applied to activated sludge. A lethal amount of a chemical inhibitory to nitrifiers was contaminated to sound activated sludge for the sake of damaging its nitrification artificially. After confirming the inhibitory substance had completely flowed out of the system, the concentrated nitrifying-bacterial agent was administrated at a quantity equivalent to the original nitrification activity of the activated sludge. Immediate revive of nitrification activity was observed. After a number of weeks without adding any of the nitrifying-bacterial agent, the activated sludge was left under a low level of nitrification activity.

Using the nitrifying-bacterial agent was found to be effective not only in recovering activated sludge from damage due to nitrification inhibition for instance, but also in promoting nitrification activity in the case of unexpected excess ammonia load. A correlation was observed between the dosage of nitrifying-bacterial agent and the period of reactivating nitrification activity up to sufficient level. This enables to design an optimal (minimum) dosage of the agent at any situation.

4. Commencement of empirical study

Scale-up and demonstration test were carried out to study practical utilization of the present technology. Only an approximate 2.2 l vessel had been employed as a culture tank of nitrifiers to decide the optimum culture conditions. As the first step of the scale-up trials, a 150 l bench-scale testing apparatus was employed to clarify requisites for magnification. The bench-scale experiments reflected the laboratory data properly and enabled the basic design for a mini pilot-scale plant. At the next step, a detailed design and construction of the mini pilot-scale plant with 3 m^3 culture tank was completed. The mini-pilot plant was operated to evaluate the laboratory and bench-scale experimental results. Fig. 3 showed a view of the entire mini-pilot plant.

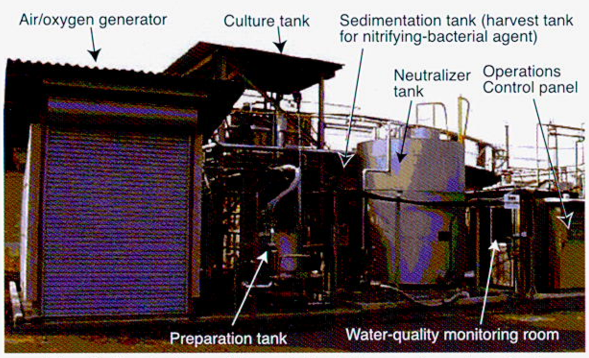


Fig. 3: Front view of the mini-pilot experimental plant

The important requisites for scale up the present technology were how to maximize the transfer of substrates especially oxygen and how to maintain the appropriate concentration of biomass (bacterial cell harvest) in the culture tank. Oxygen uptake by nitrifiers was limited beyond a certain cell density in the culture tank. Therefore, a device for supplying hyper-concentrated oxygen gas was recommended. Concerning on controlling the appropriate biomass concentration, optimal concentration of the mixed liquor suspended solids (MLSS) and biomass occupation in the MLSS were determined so as to keep ideal fluidization and precipitation of the MLSS, such that neither excess nor deficiency would occur in the substrate.

Fig. 4 showed the results of the mini-pilot experiment. The newly constructed plant began to operate with checking out its performance. For this reason, a little longer period of time was required to start up it than the small-scale experiment (Fig. 1). Besides, the system could not help shutting down for two days, starting on the 26th day of operation, due to supplemental construction. Thereafter the mini-pilot plant was restarted with a rather low ammonia load. Despite these disturbances, the nitrifying-bacterial propagation in the nini-pilot plant almost reflected the results obtained in the small-scale experiments. The mini-pilot experiment suggested that a sufficient level of nitrification activity for practical use, 600 mg-N/l・h, was available within a fairly short period of time. The mini-pilot plant was subsequently operated for 250 days thereafter to verify the results obtained from the small-scale and bench-scale experiments. It continued to maintain high levels of nitrification activity throughout the operation.

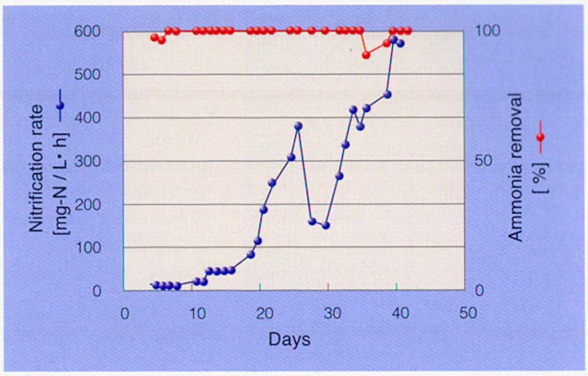


Fig. 4: Ammonia removal following start of the mini-pilot experiment

All of the above described experiments indicated that the present technology would be sufficiently practicable.

【Conclusions】

This project comprises one more step in the bringing to fruition a wastewater treatment technology that: makes effective use of coal fly ash (an industrial waste product); enables considerably more effective treatment of wastewater containing high concentrations of ammonia, which is generally considered difficult to treat by traditional technologies; and can utilize the high-density of a microbial agent to revive the nitrification activity of activated sludge. Through this project, the groundwork has been prepared for the practical application of this extremely valuable technology.

As a future work, we will try to materialize the present technology, in other words, to develop a process capable of effectively treating not only nitrogen but organic waste drainage, employing the high-density immobilization of microbes as a key technology.

Environmental Topics in Japan

Japan in the 20th century achieved economic development on the back of mass production, mass consumption, and mass waste. Inherent faults in this structure, however, have started leading us into a dead end.

As the amount of waste we generate continues to increase, final disposal sites for landfill are becoming scarce. We are running out of places to throw our garbage. (According to the 2001 White Paper on the Environment, there were only 11.2-years-worth of final-disposal sites remaining in Japan, for general refuse, as of 1997, and no more than 1.6-years-worth remaining for industrial waste, as of 1999. We are reaching the limits.) To make matters worse, illegal waste disposal is also increasing. It is up to us, our entire society, to think about ways to resolve the problem of waste. We must promote stepped-up recycling programs and other measures to make efficient use of resources and reduce the load we place on the environment. Toward this aim, the "Basic Law on Promoting a Recycling Society" was enacted in May 2000, incorporating a wide range of approaches aimed at the construction of a sustainable socioeconomic system for the 21st century.

The "Basic Law on Promoting a Recycling Society" defines as recyclable resources all items and substances that can be recovered from general refuse and other waste and used again. Appropriate means of dealing with waste are provided in the law, in order of priority - "reduction", "reuse", "recycling/recovery (of heat)", and, lastly, "appropriate disposal". By compelling producers of goods to use special care in selecting and preparing materials, to display materials/ingredients on packaging, to recycle certain products after they have been disposed of, and to carry out other measures, the law aims to facilitate recycling and appropriate disposal, throughout society. The law stipulates that producers, themselves, must bear the responsibility for taking care of their products, after they have been disposed of.

This new piece of legislation promotes an ideology. Simultaneously with its enactment, seven related laws were either established or revised (details to be provided in the next issue of ICETT News). Regardless of these laws, however, creation of a sustainable society requires that national and local governments, as well as businesses and all of the people of Japan work together, with mutual understanding, toward the common goal of changing the "mass production, mass consumption, mass waste" flow. These days, hardly a day passes in which the problem of waste disposal is not taken up in the newspapers and television. For the future of the planet, and for the future of our children and those who follow, we must, all of us, pool our wisdom and solve this problem.

The Seasons of Japan

Fireworks

The stunning colors of Japan's autumn foliage and the "Setsubun" festival, celebrating the start of spring, have been featured in earlier issue. Here we present summer in Japan.

Real summer in Japan starts after the rainy season, which lasts from early June through mid July. Temperatures rise to between 30℃ and 35℃, especially on the Pacific side of the country, and hot and humid days become the norm. Fireworks ("hanabi", in Japanese) are a special treat that lends magic to Japanese summers. They come in all shapes and sizes -from small, family-style sparklers and crackers, to the grandiose skyrockets and ground displays handled by fireworks professionals. Truly memory-making are summer fireworks festivals, where thousands or even tens of thousands of fireworks light up the night sky. Summer revelers throng to fireworks festivals throughout the summer, hosted all over Japan.

That thunderous boom that rattles the ground, followed by a spectacular shower of brilliant color that lights up the night sky, makes one forget the summer heat, if even for a moment. Fireworks, written "flower-fire" in Japanese, blossom suddenly, into a wide variety of shapes and colors. Some resemble big chrysanthemums or peonies, while others splash across the sky like a breeze full of small blooms and petals, and still others cascade in streaks, like the drooping branches of a willow tree. As one "flower-fire" after another bursts aglow above expectant crowds, there is no end to the variety, beauty or excitement.

On a side note, summer can also mean "natsubate" - that lethargic feeling, when the summer heat zaps your energy. Many people find that they have even lost their appetite. The traditional delicacy for such occasions is. . . eel! Barbecued eel on rice, called "unadon", is a combination of savory, slightly smoked filets of eel, with a bittersweet soy-sauce-based sauce on top. Providing good nutrition and famous as a high-energy food, eel is a favorite summer treat, sure to stimulate everybody's - well, almost everybody's - appetite.

ICETT

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