The Preservation of Environmental Health via Water Treatment Processes and Clean Energy Practices

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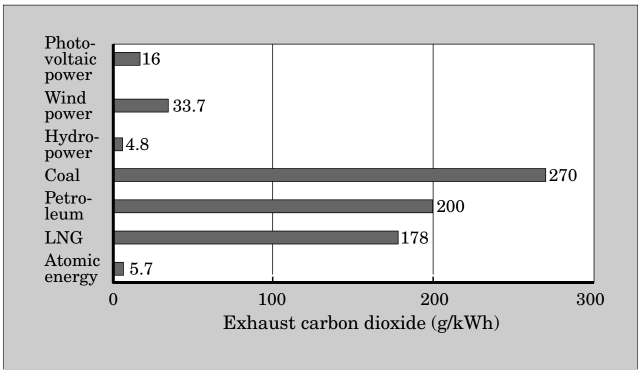
1. Introduction

At present, various types of chemical products are being produced and many of which are disseminated as into the environment. This phenomenon may be particularly problematic in instances where pollutants accumulate in waterbodies and therefore, have potential to contaminate public water supplies. Ironically, some pollutants known to deleteriously affect water quality are produced as by-products during water treatment processes. Also of concern is the fact that hydrosphere, such as lakes, marshes and rivers, may be contaminated by human wastes, thereby promoting the growth and propagation of many disease-causing microorganisms.

In addition to water quality issues, the Greenhouse effect, have also become a pressing environmental issue for the global community. For this reason, conservationalists have advocated for the more stringent regulation of greenhouse gases (mainly carbon dioxide) and have ardently encouraged the utilization of alternative energy sources, thus lessening our dependence on fossil fuels. The amount of carbon dioxide emitted from various power generation systems is contrasted in Fig. 1. As depicted in the figure, the dramatic reduction of greenhouse gases by employing new, alternative energy sources is significant.

Environmental preservation has begun to be considered from a global perspective. This trend is beginning to influence the technological advances in the field of environmental preservation.

Fig.1 Exhaust of carbon dioxide at each generation system



In this paper, Fuji Electric will present their recent technological advances in water quality analyzers and sensors for the improvement of our water resources. In addition, Fuji Electric will present their micro hydro-turbine generation systems and photovoltaic-wind power hybrid generation systems as countermeasures to the global problem of environmental preservation.

2. Water Pollution

2.1 Heavy metals and organic micro-pollutants

Typically, large quantities of heavy metals are not found in waterbodies because emission into the environment is strictly regulated. However, trace quantities of certain heavy metals may be common in the environment and may originate from such mundane items as electronic parts, batteries, etc. Heavy metals from industrial activities may also contaminate aquatic environs. For example, some heavy metals, such as lead, may be released into the environment as they "solve" out from metallic piping. In addition, the plating industry uses cyanide and large quantities of heavy metals, which may be inadvertently released into the aquatic systems.

Agricultural chemicals may result in the discharge of organic micro-pollutants into the environment. In such instances, contamination typically occurs as agricultural chemicals utilized in rice fields, farms, golf links, etc. are mobilized and transported into waterbodies by the surface runoff associated with precipitation events. Pollutants associated with surface runoff will undoubtedly pose a hazard to aquatic environments in the future and therefore, the monitoring of these systems has become an important issue in aquatic preservation. "Water security monitors" developed by Fuji Electric, utilize the nitrifying bacteria Nitrosomonas. These "water security monitors" can accurately detect very small concentrations of the above mentioned hazardous pollutants and thereby, allow the continuous monitoring of the quality of water flowing into a source of city water (Fig. 2).

Another aquatic environmental hazard are the endocrine-disrupting chemicals or hormone disrupters,

Fig.2 Measuring principle of water security monitor

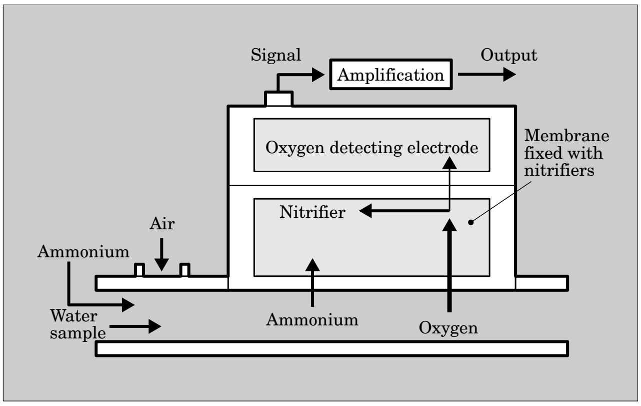
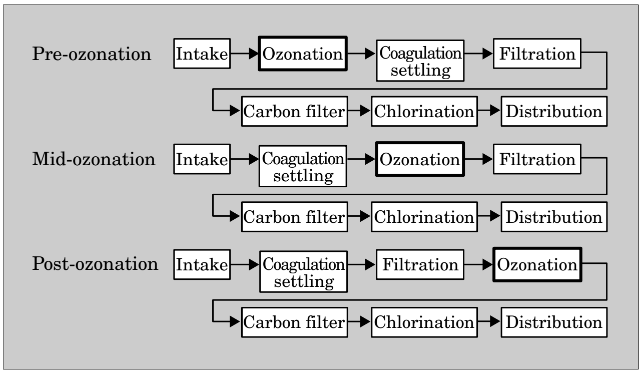


Fig.3 Advanced water treatment process



such as dioxins. In January 2000, legislation entitled "Specific Legislation for Dioxins and Analogous" was enacted thus regulating the concentration of dioxin permissible in discharged waters. In addition to this recent legislation, the interim guideline for drinking water quality standards has determined the allowable dioxin concentration to be $\leq$ 1 pg-TEQ/L. To treat organic micropollutants, an advanced oxidation process, which consists of a combination treatment of ozone, hydrogen peroxide, and ultraviolet radiation is being developed. Experiments on river water demonstrate that concentrations of trihalomethane formation potential (THMFP) and dissolved organic carbon (DOC) linearly decrease in proportion to the duration of simultaneous exposure to ultraviolet radiation and ozone [(1)].

2.2 Disinfection byproducts (DBP)

Disinfection byproducts differ from other pollutants in the respect that they are generated during the water treatment process. This unfavorable reaction occurs as chlorine, used in the disinfection process, reacts with organic substances to produce trihalomethane, a suspected carcinogen. The toxicity of these pollutants has justifiably resulted in the heightened concern over disinfection byproducts. Unfortunately, trihalomethane is just one of several hazardous chlorinated organic materials that are generated by chlorination treatment of city water. The identification of trihalomethane production from water treatment plants attracted the concern of the general public. However, the presence of trihalomethane and odor and tastes producing micropollutants in urban drinking waters has pushed forward the introduction of an advanced water treatment process (Fig. 3).

Unfortunately, new water treatment processes have resulted in the production and dissemination of new disinfection byproducts. For example, elevated levels of bromine ions in untreated water may react with ozone to produce a hazardous chemical which may deleteriously affect human tissues. Bromate ions are generated as below:

$$O_3 + Br^- \rightarrow O_2 + OBr^-$$

$$O_3 + OBr^- \rightarrow \frac{1}{2} O_2 + BrO_3^-$$

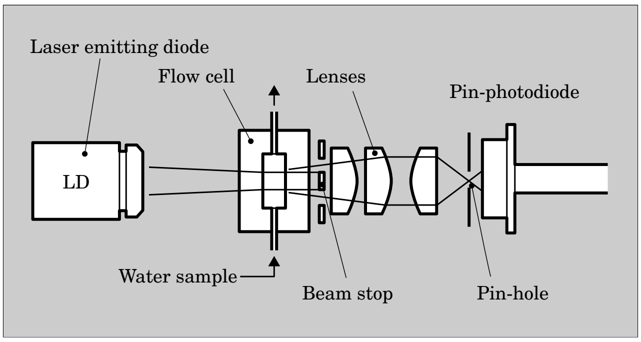
In the above reaction, following oxidation and decomposition of ozone and the trihalomethane precursor, bromic acid ions are formed by a reaction between excessive dissolved ozone and bromine ions. Fuji Electric is currently elucidating the mechanism of bromate formation as well as developing new technologies, which would regulate its formation.

2.3 Microbial pathogens

Chlorine disinfection has been introduced and adopted for public and wastewater treatment in Japan. This highly successful method is both economical and efficient. As a consequence, water contamination problems have been of only minimal significance for many years. However, recent concerns regarding the production of trihalomethane has relegated the problems associated with disinfection to be considered once more. For example, recent events such as the infection of Cryptosporidium in the Town of Ogose, in Saitama Prefecture, Japan in June 1996 has re-ignited research into the problem of pathogen infestation of waterbodies and demonstrated the importance of disinfection processes in water treatment systems. The fact that Cryptosporidium infestation in city water cannot be adequately controlled by chlorine disinfectant alone has illustrated the importance of treatment process monitoring and operational control. The "Interim guideline for Cryptospordium inactivation in drinking water" was adopted in August 1996 and revised in 1998. These guidelines specified that the turbidity of filtered water should be maintained below 0.1 degree. Accordingly, the importance of the filter backwash operation (the procedure necessary to meet this low-turbidity standard for treated water) has been re-emphasized. As such, highly sensitive turbidimeters developed by Fuji Electric have been deployed in many water purification plants and are being utilized for the monitoring and control of filtered water (Fig. 4).

Another issue of concern regarding the use of chlorine and/or chlorine compounds which are emitted

Fig.4 Measuring principle of high sensitive turbidimeter (Forward scattered light detection as particle number)



into the aquatic environment, is their deleterious affect on aquatic organisms. This concern has sparked interest in the introduction of UV disinfection systems (Fig. 5).

2.4 Water treatment technologies in the future

In Japan, from the 1980s to 2000, the growth and development of water treatment facilities has mirrored that of the economy. That is, with the changing circumstances of a growing economy, to the collapse of a "bubble economy" and subsequent shift to a slow-growth economy, the construction of water treatment facilities has changed from increasing the number and enlargement of facilities, to the construction of advanced treatment facilities and subsequently to small-scale facilities.

Indeed, the development of water treatment technologies has changed in response to the well documented environmental problems which threaten human health. For example, in the field of potable water treatment, first a physico-chemical treatment was introduced; this was followed by the introduction of a biological treatment which utilizes ozone and biological activated carbon (BAC), which was followed by membrane filtration. The effectiveness of treatment with ozone and BAC as a technology to remove micropollutants and to suppress trihalomethane has been proven in many water purification plants. Membrane technology, which differs from conventional technologies that remove pollutants on the order of mg/L, may virtually remove all pollutants over a definite particle size. As such, this technique has significantly changed the concept of water treatment. In the future, it is likely that the combined treatment of ozone, BAC and membrane filtration will continue to ensure that waters discharged from treatment systems pose no health risk. Fuji Electric is working to address these issues in a project entitled ACT 21. Experimental results up to the present suggest that when ozone-resisting membranes are employed and dissolved ozone concentration in the filtered water after pre-ozone treatment is maintained at levels greater than 0.2 mg/L, a flux (filtered water quantity per unit time and unit membrane area) four times larger than that without pre-ozone treatment can be obtained steadily (Fig. 6).

Fig.5 Fuji's UV disinfection unit

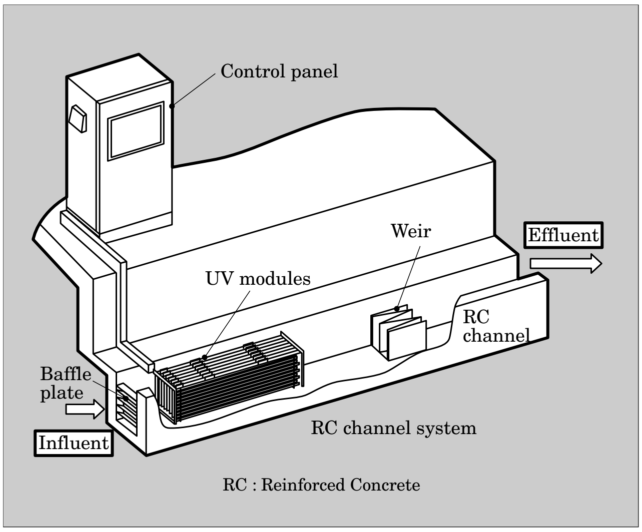
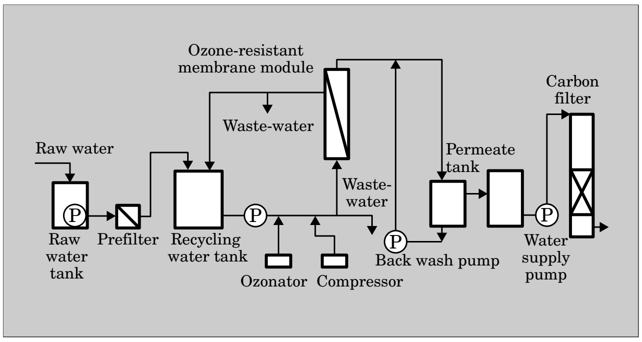


Fig.6 Advanced water treatment process with ozone-resistant membrane filtration



3. Recyclable Clean Energy and Environmental Protection

3.1 Micro hydroturbine generation system

Hydroturbine generation is the power generation system having the lowest carbon dioxide emissions. However, this technique has not been widely adopted by conservationalists because these large-scale hydraulic power plants usually require the construction of large-scale dams. Alternatively, micro hydroturbine generation systems, which provide an output of less than 500 kW, have been viewed favorably by conservationalists. This is due to the fact that the operation of micro hydroturbine generation systems is not dependent upon the construction of large-scale dams. Rather, they operate sufficiently in sites with water head less than 100 m and influent water flow of less than 3.5 m^3/s.

Several types of turbines are available for these systems, including Francis, Pelton, propeller and cross-flow. These turbines may be applied to various idle heads and influent water flows. Demand is increasing for micro hydroturbine generation system which utilize idle head in city water supply systems or in sewage water systems as well as head caused by discharge of agricultural waters to rivers. For example, in public water supply systems, it is possible to utilize water flowing from a raw water basin into a water treatment plant for power generation. Harnessing this previously untapped energy resource may result in the reduction of electrical costs. Furthermore, the Francis hydroturbine generation plant, such as the plant delivered to the Mid-Prefectural First Water Service in Gunma Prefecture, has been furnished with special devices which allow drinking waters after chlorination to be utilized while ensuring that waters are at an acceptable hygienic standard.

3.2 Photovoltaic-wind power hybrid generation system

Interest in photovoltaic-wind power hybrid generation systems is spreading due to manufactures' efforts toward cost reduction. These systems are well suited for secluded sites, such as in mountainous regions or on solitary islands where utility distribution is not available. In these scenarios, the construction of a stand-alone type power generation system equipped with back-up power source must take into account the capacity of the generation facility and the power consumption of the load equipment. A particularly successful example worth mentioning is the photovoltaic-wind power hybrid generation system that was delivered to Senjogatake Refuge in the Southern Japan Alps in Hase Village, Kami-Ina District, Nagano Prefecture in November 1999. Installed on this system was an on-site wastewater treatment system designed to treat wastewater from the refuge in order to preserve the natural environment in this mountainous region.

3.3 Wastewater treatment system and power supply system

The refuge mentioned above is located halfway up the mountain at 2,900 m above sea level, thereby making it difficult to supply both power and water (Fig. 7). Moreover, due to the uniqueness of this alpine ecosystem, environmentally sensitive techniques were required. Figure 8 depicts the wastewater treatment system of the refuge.

In this system, a two-stage treatment of anaerobic and aerobic treatments is adopted, enabling the decomposition of organic substances and the reduction of biochemical oxygen demand (BOD) (Fig. 9).

Water treated by this system is re-circulated by a returning pump and then used as flush water for lavatories. Thus, the discharge of water into the environment is minimized.

Figure 10 depicts the construction of the hybrid generation system.

Power generating equipment used in this system consists of a 10.78 kW photovoltaic array, a 6.4 kW wind power generator and a back-up power supply consisting of a 25 kW diesel generator and 800 Ah/10h storage batteries.

In the daytime, the load equipment is powered by photovoltaic and wind power generation systems and simultaneously, excess power is charged into the storage batteries. At night, the load is powered by the wind power generation system and by the discharge of energy from storage batteries. If photovoltaic and wind power generation systems malfunction, the diesel generator may be activated by either an automatic or manual switch.

Fig.7 Landscape of the Southern Japan Alps Senjougatake refuge

Fig.8 Construction of Senjougatake refuge

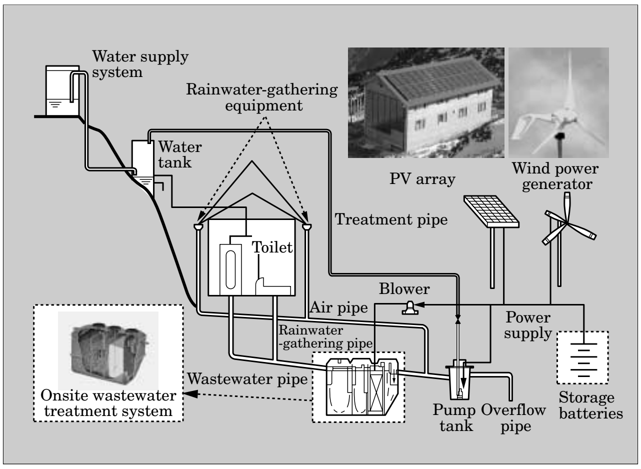


Fig.9 Structure of onsite wastewater treatment system

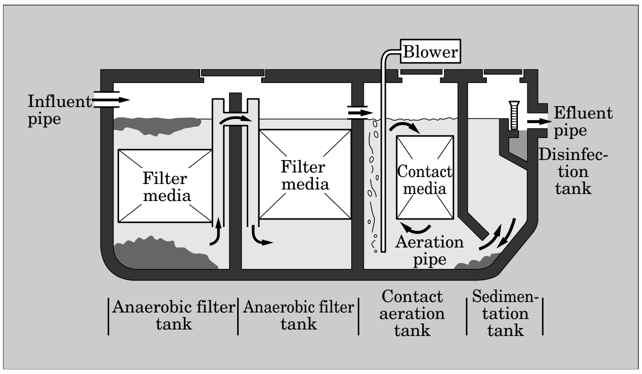
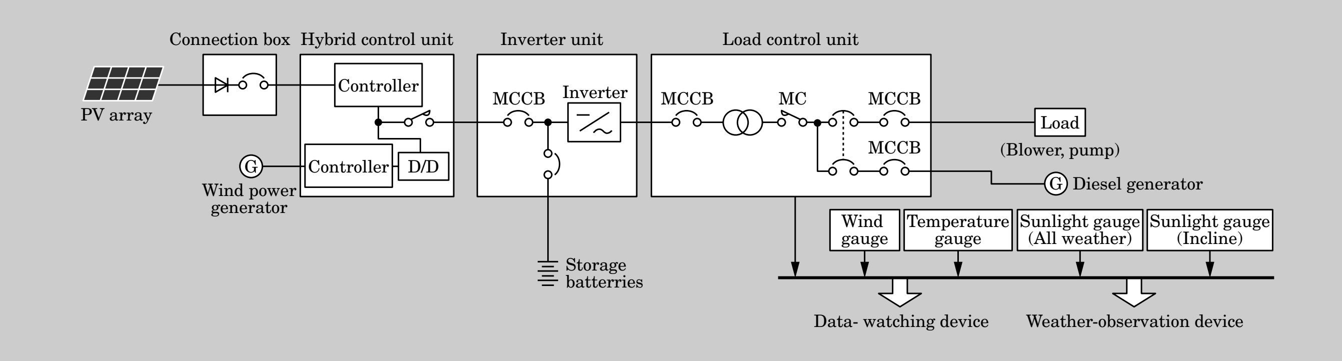


Fig.10 Construction of hybrid generation system



As depicted in Fig. 7, photovoltaic panels are mounted on the roof and walls of the refuge and 16 sets of windmill generators (400 W each) are installed around the refuge. During the summer mountain climbing season, generated power will be used to drive the mechanical equipment of the wastewater treatment system and to run the electrical equipment of the facility. While the refuge is closed for winter, the photovoltaic panels on the roof, windmill generators around the facility and indoor diesel generator will be dismounted and stored on account of the heavy snowfall. During the winter season, power supply to the heaters of the wastewater treatment tank is maintained by photovoltaic panels on the wall and by four sets of wind power generators.

As the technology of hybrid generation systems (photovoltaic and wind power) progresses there will undoubtedly be advances in the ability of these systems to generate high quantity and quality electricity, which is independent of the prevailing weather conditions.

By examining the data collected throughout the year on weather conditions and operating conditions of each generating facility, Fuji Electric researchers are committed to constructing the most suitable hybrid generation systems.

4. Conclusion

Unfortunately at present, our global environment may pose several threats to human and ecosystem health, such as endocrine-disrupting chemicals, the ozone hole, the greenhouse effect, etc. In fact, in the USA, quite often-electoral candidates must have strong environmental policies in order to be seriously considered for election. Likewise, the business community must take a firm stance on environmental issues and introduce measures such as environmental accounts. As such, Fuji Electric is dedicated to encouraging those research activities, which attempt to remedy our most pressing environmental problems, such clean water and energy facilities. Fuji Electric is pleased to have had the opportunity to present some of our recent developments in environmental research. Moreover, we pledge continued support to the further development of technologies designed to protect and enhance our environmental resources.

References

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