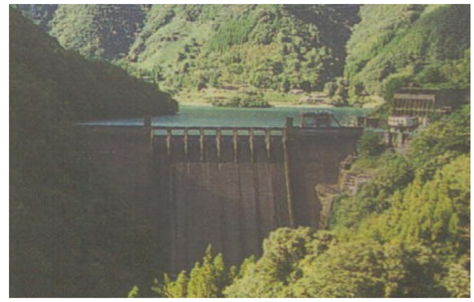

Key Issues: **5- Water Quality**

Climatic Zone:
Cf : Temperate humid climate

Subjects:
- Development of ship for treating freshwater red tide

Effects:
- Reduction in size and duration of the generation of red tide

Project Name: Tsukabaru Dam
Country: Miyazaki Prefecture, Japan (Asia)

Implementing Party & Period
- Project: Kyushu Electric Power Co., Inc.
1938 (Completion of construction) -
- Good Practices: Kyushu Electric Power Co., Inc.
1993 (Commencement of operation) -

Key Words:
Freshwater Red Tide, Ultraviolet Ray Irradiation, Automatic Control System

Abstract:
Kyushu Electric Power Co., Inc. has successfully developed a treatment ship which equips an automatic control system that can kill the red tide by ultraviolet ray irradiation. This ship has been used in the Tsukabaru reservoir and can always get about 100% of algae killing rates.

1. Outline of the Project

The Tsukabaru Dam is a concrete gravity dam for electric power generation, built in the Mimi river flowing between mountains in Miyazaki Prefecture. It has a total storage capacity of 34,326×103 m3. The location of the Tsukabaru Dam is shown in Fig.-1 and its specifications in Table-1. In its upstream basin, cultivated land amounts to 1% or less, mountain forests and wasteland occupying more than 95% of the area. There are a colony with a population of 4,500 or so and two dams in the area.

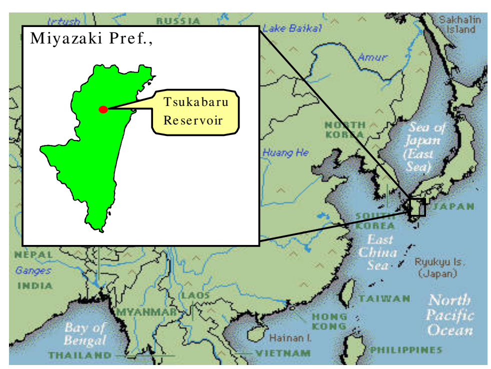

Fig.-1 Location Map

Although it is not clear when the red tide began to occur in the Tsukabaru reservoir, an outbreak was confirmed in the latter half of the 1970's. Around 1990, the red tide was seen almost each year. It appeared mainly in spring and autumn and was observed at the upstream end of the reservoir in the beginning. Then it grew to cover the entire surface of the reservoir. The species that formed the red tide was Peridinium bipes of dinoflagellates. The red tide hardly caused any direct problem except detrimental scenic effect. The freshwater red tide, which discolored the surface of the reservoir to cause a sense of incompatibility to viewers and gave out a foul smell, became a problem with respect to the hydrophilicity and the establishment of some means to eradicate it was in demand. Such methods of treatment as cyclic aeration, treatment after collection, and the use of ozone were discussed, and a conclusion was reached led to adopt the ultraviolet ray irradiation method, which had been used to purify tap water. Thus, a ship for treating the red tide by means of ultraviolet ray irradiation (Fig.-2) was developed.

Table-1 Particulars of Tsukabaru Dam reservoir

Item	Particulars
Type of Dam	Concrete gravity type
Year of Completion	1938
Dam Crest length × height	215.00 × 87.00m
Catchment Area	410.6km^2
Reservoir Area	1.14km^2
Total Storage Capacity	34,326,000m^3
Effective Storage Capacity	19,555,000m^3
Mean Depth of Water	26.01m
Frequency of Lake Water Replacement	About 40 times/year

Fig.-2 Red tide treatment ship

2. Features of the Project Area

The Mimi river with the Tsukabaru Dam rises from the Kyushu mountain range. This area is abundant with dams; two in its upstream and three in the downstream. The Kamishiiba Dam in its uppermost stream, is the Japan's first arch dam, built in 1955. The Tsukabaru Dam, the second largest in scale in this river, following the Kamishiiba Dam, was constructed in 1938 by using then the most advanced civil engineering technology. It was the first full-scale dam for electric power generation in Kyushu.

3. Major Impacts

The temperature characteristic for proliferation of Peridinium bipes, which mainly generated in the Tsukabaru Dam, test culture of restrictive nutritious salts, lake flow of the reservoir, distribution of germinated cysts, distribution of planktons and the quality of water were investigated. The results of the investigations suggested that in the Tsukabaru Dam, the freshwater red tide was not caused by the so-called eutrophication, or abnormal proliferation of planktons due to a high concentration of nutritious salts; the following factors were assumed for its generation:

1) That a stable cyst accumulation area as a nursing place of freshwater red tide was formed;
2) That there was accumulation of red tide cells on the surface layer due to their phototaxis as well as the accumulation mechanism leading red tide cells toward the upstream end of the reservoir together with lake flow; and
3) That the above factors constituted a continuous cultivation system for Peridinium at the upstream end of the reservoir.

4. Mitigation Measures

Based on the findings mentioned above, and by referring to existing literature and actual cases, effort was made to select an optimum measure for freeing the Tsukabaru Dam reservoir of the freshwater red tide. As a result, the ultraviolet ray irradiation method was selected in view of its economic efficiency, treatment capacity and novelty. As ultraviolet ray treatment equipment, it was decided to use a mobile, ship-form treating system in consideration of drifting of red tide accumulation in the direction of a wind and frequent heavy floods in the Tsukabaru Dam Reservoir.

Following the decision, the effect of the treatment was confirmed through experiments by the field mesocosm. The experiments were executed from Nov.1989 to Mar.1993. In the area treated by means of ultraviolet rays, all cells were killed and precipitated in two days. After stopping the treatment, swimming red tide cells were not observed. To know the relation between the amount of irradiated ultraviolet rays and the rate of killing the cells of Peridinium bipes, laboratory tests of the ultraviolet ray treatment were carried out. From the test result, it was known that a minimum amount of ultraviolet ray irradiation was 2,400 μ W/cm2 for 45 seconds.

With the above findings taken into account, a freshwater red tide treatment ship was developed. It was in the form of a catamaran, about 12.3m long and 3.6m wide. In the center portion of the ship, two treatment tubes having a diameter of 0.6m were provided. In the treating operation, the treatment tubes are immersed in water and the red tide was sucked from the front inlets and introduced into the tubes. After leaves and other litter were removed, the red tide was treated by ultraviolet rays irradiated from 40 lamps (main wavelength: 253.7nm).

The treatment ship is capable of killing waterweeds at a rate exceeding 90% in a 50 seconds or longer retention time in the tubes (i.e., the duration of irradiation) in case more than 10,000 cells of red tide is contained in lake water of 1ml. When the number of cells is between 5,000 and 10,000/ ml, the rate rises to 95% or higher for a 30 second or longer retention time. It can kill almost 100% of cells in 20 or more seconds if the umber is less than 5,000/ ml. Once treated, the majority of red tide cells ceases to move, precipitates and resolves.

One of the distinctive features of the treatment ship is that it is equipped with a system for estimating the number of freshwater red tide cells in the water, with the turbidity as an index, on the basis of data of the number of cells, treatment time and the rate of algae killing, and controlling the rpm of an underwater motor in each treatment tube. In other words, the ship has an automatic control system that can attain a stable killing rate by adjusting the duration of ultraviolet ray irradiation correspondingly to the density of the red tide. Fig.-3 is a schematic diagram of the control system for red tide treatment.

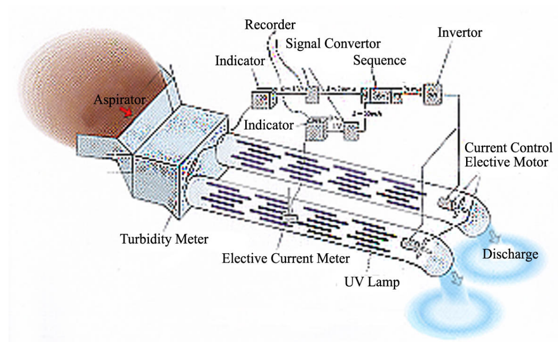

Fig.-3 Red tide treatment control system

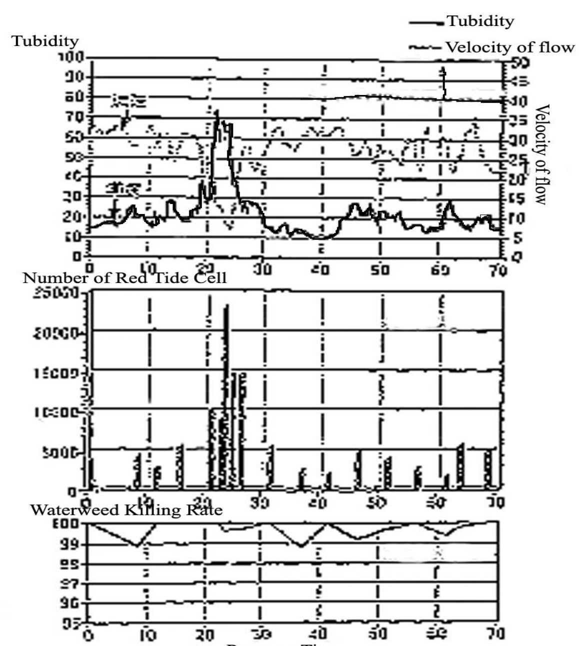

Fig.-4 Process of red tide treatment

5. Results of the Mitigation Measures

The introduction of the red tide treatment control system into the treatment ship made it possible to attain nearly 99% or even higher rates of algae killing through automatic adjustment of the duration of ultraviolet ray treatment on the basis of data of the quantity of ultraviolet rays and the rate of killing freshwater red tide. The ship being capable of treating about 800m3/h of water maximum, when the red tide grew in an area of approximately 20,000m2 in this dam reservoir, its disappearance was observed after treated for five hours or so. Fig.-4 shows a process of red tide treatment. As a result of repeating the treatment in an early stage of the generation of freshwater red tide since 1992, its growth has been successfully reduced both in size and time from previous levels.

6. Reasons for Success

The following items may be cited as reasons for success:

1) Initial cost is less and the capacity of treatment is larger than other methods of treating.
2) Unlike the treatment using chemicals, there is no discharge of a substance which may cause secondary pollution to the environment.
3) The power to kill phytoplanktons accumulating near the water surface is high.
4) The ship in a catamaran form can move about a wide range of water area at a high speed.

7. Outside Comments

1) Denki Shinbun (July 17, 1997 issue)
   "The method costs far less than conventional filtration methods and the capacity of treatment is more than ten times larger. As an achievement of unique, unprecedented development, the ship attracts a large number of inquiries and requests for information. Inquiries are being received from not only electric power companies having the same problem but also government offices, prefectural and other local autonomous bodies as well as foreign countries such as Korea and Israel.

8. Further Information

8.1 References

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2) Yasushi ISERI, Zenichiro KAWABATA, Kenji FUJIMOTO and Michiharu ITOU: Suppression of Algal Bloom by Ultraviolet Radiation, Water for Use and Waste Water, Vol.1, No.4, 1996

8.2 Inquiries

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