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Simultaneous realization of water quality improvement and sludge sediment elimination in the aquatic environment by the continuous addition of a novel bio-catalyst, *Waterkeeper*

Introduction

Waterkeeper is a selective bio-catalyst which has a capability to activate effective microorganisms and bacteria living in the environment, mainly in the aquatic environment, and is made from a complex of the bromeline enzyme extracted from pineapple superior to anti-oxidation and anti-bacterial function by an original technology of *Minaki Advance Co. Ltd.*, Japan. Besides, *Waterkeeper* can control or suppress the growth of corruptive and miscellaneous bacteria living in polluted surface water areas and sedimentary sludge by its anti-oxidation and anti-bacterial function, and accordingly, can selectively activate the microorganisms which are useful for the decomposition of organic matters. *Waterkeeper* is a bio-catalyst for effective microorganisms and bacteria, i.e. a typical selective catalyst. The main components of *Waterkeeper* are 1) Bromeline enzyme possessing anti-oxidation and anti-bacterial function, 2) Fermentation-suppressed modified yeast which especially enhances the decomposition of sedimentary sludge, and so on. In this presentation, improvement stages of water quality by the continuous addition of *Waterkeeper* into a typical aquatic sphere will be outlined first. Next, main field test results in the countries mentioned above on the purification of the aquatic sphere and the effluents from municipal sewage treatment works and industrial treatment works, will be introduced.

Typical water-polluted area – Before addition of *Waterkeeper*

Oxygen in the atmospheric sphere is absorbed into the surface water to result in the formation of aerobic region. The width of the aerobic region (i.e. the depth from the surface of water area) is reduced with increasing degree of water pollution there. For the dissolved oxygen (DO) is consumed more by microorganisms and bacteria which can decompose organic compounds, as the degree of pollution is increased. Under the aerobic condition, the organic compounds are completely oxidized to produce CO₂, nitrate (NO₃⁻), phosphate (PO₄³⁻) and sulfate (SO₄²⁻). If nitrogen in organic compounds is not oxidized to NO₃⁻, ammonia (NH₃) is generated. And if NO₃⁻ exist at DO=0, the nitrification bacteria decompose organic compounds using NO₃⁻ as the H acceptor to finally produce N₂ (termed denitrification).

Both the aquatic sphere lying below the aerobic region and the sedimentary sludge are in an anaerobic state, where the organic compounds which have not been decomposed in the aerobic region, are decomposed to produce carbon dioxide (CO₂), methane (CH₄), ammonia (NH₃) and hydrogen sulfide (H₂S). NH₃ and H₂S among these are bad odor gases. In the highly polluted area, the sunlight cannot reach the anaerobic area because of its turbidity. Accordingly, phototrophic bacteria, both green sulfur bacteria and purple sulfur bacteria, cannot take place the photosynthesis. Thereby, H₂S as the electron donor is not consumed through the photosynthesis. Bad odor H₂S as well as NH₃ generating in the anaerobic area, result in diffusion into the aerobic region in what they are. If nitrification bacteria and sulfur oxidation bacteria named *thiobacillus thiooxidans* live in the aerobic region, NH₃ and H₂S will be converted to

odorless NO₃⁻ and SO₄²⁻, respectively. However, they are not so numerous and active, because the width of the aerobic region is suppressed. Therefore, both bad odor NH₃ and H₂S gases result in the evolution into the atmospheric sphere without reducing their concentrations. CH₄ generating in the anaerobic area tends to evolve into the atmospheric sphere in what it is.

Improvement stage I of water quality accompanied by the continuous addition of *Waterkeeper* termed Phase 1

When *Waterkeeper* is continuously added to the aquatic area to adjust the concentration there at 8 ppm, both the activation of effective microorganisms and bacteria (named catalysis) and the deactivation of corruptive and miscellaneous bacteria leading to the putrefaction and contamination (named negative catalysis) are caused owing to *Waterkeeper's* synergism. The activation of effective bacteria for decomposing organic compounds, nitrification bacteria, sulfur oxidation bacteria named *thiobacillus thiooxidans*, denitrification bacteria, etc. tend to induce complete decomposition of organic compounds, conversion of NH₃ and H₂S to NO₃⁻ and SO₄²⁻, respectively, generation of N₂, etc. Accordingly, the turbidity in the aerobic region is reduced. Besides, *Waterkeeper* can activate organics-decomposition bacteria and phototrophic bacteria such as green sulfur bacteria, purple sulfur bacteria and purple non-sulfur bacteria living in the anaerobic area. Both green sulfur bacteria and purple sulfur bacteria under irradiated sunlight begin to take place the photosynthesis to consume H₂S (as an electron donor). The purple non-sulfur bacteria also begin to take place the photosynthesis to consume organic materials (as an electron donor). The decomposition of sedimentary sludge is promoted as well through the synergism of organics-partial decomposition anaerobic bacteria and fermentation-suppressed modified yeast, and subsequently, lumps of disintegrated sedimentary sludge begin to float. It should be emphasized that the increase in the amount of DO which is consumed by effective aerobic bacteria activated by *Waterkeeper*, can be compensated by the decrease in that of DO which is consumed by corruptive and miscellaneous bacteria leading to the putrefaction and contamination.

Improvement stage II of water quality accompanied by the continuous addition of *Waterkeeper* termed Phase 2

Both the activation of effective microorganisms and bacteria living in the aerobic and anaerobic areas and the deactivation of corruptive and miscellaneous bacteria leading to the putrefaction and contamination are promoted more by the continuous addition of *Waterkeeper*. The complete decomposition of organic compounds is enhanced. Thereby, the aerobic region is expanded and at the same time, the turbidity is decreased more. Accordingly, the activity of phototrophic bacteria in the anaerobic area is increased more, leading to the promotion of hydrogen sulfide consumption and organic compound consumption as the electron donor. At this stage, the concentrations of bad odor NH₃

and H₂S sulfide evolving into the atmospheric sphere markedly decrease enough not to feel bad odor for us. The evolution of CH₄ still continues, and N₂ gas bubbles are vigorously generated through the denitrification. The decomposition of sedimentary sludge is promoted more, and thereby the floatation of lumps of decomposed and disintegrated sludge is observed frequently. At the latter half of this phase, algae begin to live in the aerobic region, and through the oxygenic photosynthesis taking place in algae, oxygen gas is generated and the DO level markedly rises.

Improvement stage III of water quality accompanied by the continuous addition of *Waterkeeper* termed Phase 3

In order to maintain a favorable aerobic state, *Waterkeeper* must be continuously added to the aquatic area to adjust the concentration there at a level of 3 to 8 ppm, depending on the degree of imposed pollution load. At this stage, the aquatic system is in a state where the activity of effective microorganisms and bacteria is increased more and correlative and miscellaneous bacteria leading to the putrefaction and contamination are restricted more. The growth of algae is promoted, and through the oxygenic photosynthesis (i.e., generation of oxygen) taking place there, the DO level is increased dramatically. Thereby, organic compounds can be completely decomposed, and the turbidity markedly decreases. The sedimentary sludge gradually decreases. The sedimentary sludge is in a state of aerobic - anaerobic coexistence, but even if NH₃ and H₂S are generated under the anaerobic condition, they can be converted to odorless nitrate and sulfate, respectively, by nitrification bacteria and sulfur oxidation bacteria named *thiobacillus thiooxidans* living in the aerobic area. As the sedimentary sludge decreases, the generation of methane is reduced and finally the sedimentary sludge disappears. Accordingly, any CH₄, NH₃ and H₂S are not generated at all. The natural ecosystem is recovered, and as a result, aquatic organisms return and live.

Application of *Waterkeeper* technology to sewage treatment works

The sewage treatment works based on an activated-sludge process and a rotating plate process can be improved by the continuous addition of *Waterkeeper* into an aeration basin or the inlet of the works; (1) Improvement of water quality, (2) Reduction of excess sludge to zero, while a prescribed amount of sludge return is maintained, i.e. no need of sludge disposal, leading to an energy saving. In the aerobic area, the activation of effective bacteria such as organics-decomposition bacteria, nitrification bacteria, sulfur oxidation bacteria named *thiobacillus thiooxidans*, denitrification bacteria (facultative anaerobic bacteria), phosphorous assimilation bacteria, etc. results in the promotion of complete decomposition of organic compounds, conversion of NH₃ and H₂S to NO₃⁻ and SO₄²⁻, respectively, generation of N₂, capture of P, etc. In the anaerobic area of suspending sludge floc, the activation of organics-partial decomposition bacteria and phototrophic bacteria though trace leads to the promotion of coagulated sludge in the activated-sludge floc. Subsequently, the reduction of excess sludge to zero can be achieved. CH₄ generating in the anaerobic area and N₂ generated through the denitrification evolve into the atmospheric sphere. NH₃ and H₂S generated in the anaerobic area can be reduced by the nitrification bacteria, sulfur oxidation bacteria and anaerobic phototrophic bacteria activated by *Waterkeeper*. Both bad odor gases evolve into the atmospheric sphere at their lower concentrations, resulting in decrease in bad odor.

Typical field test results

1. Doi River (Sakai, Osaka-Pref., Japan) in accordance with the tidal action of Osaka Bay; After 9 months' addition of WK, water transparency reached more than 100 cm from 10 cm.
2. Shichibu and Ura River (Ohita-city, Japan); After 7 months' addition of WK, marked decrease of sedimentary sludge and improvement of water quality were achieved.
3. Rongtan River (Quanzhou, China); By WK addition from Jun. 1, 2001 to Apr. 30, 2003, decomposition and disappearance of sedimentary sludge by 180 to 200 cm a year and improvement of water transparency were brought about.
4. Geiho Pond (Suzhou, China); By WK addition from Oct. 17, 2002 to Mar., 2004, simultaneous improvement of water transparency and elimination of sedimentary sludge were achieved.
5. Soubuchi Pond (Hyogo-Pref., Japan); By WK addition from Jul. 27, 2006 to Nov. 30, 2006, the microorganisms activated by WK living in the benthic sludge layer in winter could suppress the generation of the water bloom the next year.
6. Residential (Hongkong) Sewage Treatment Works based on Conventional Rotating Plate Process; By WK addition from Apr. 2003 to Mar. 2004, simultaneous improvement of water quality and elimination of excess sludge were achieved. *E-coli* actually died without any sterilization agents added. Only clarified water which contained WK, was discharged into the aquatic environment. WK could activate the microorganisms living there. Sedimentary sludge can be decomposed by WK's synergism.
7. 5th Sewage Treatment Works based on Activated-Sludge Process (Kunming, China); By WK addition from Apr. 9, 2005 to Aug. 2, 2005, the excess sludge reduced to zero while a prescribed amount of sludge return was maintained, after its 3 months' addition. The effluent which contains WK, was discharged into the aquatic environment, where sedimentary sludge could be decomposed by WK's synergism.
8. Treatment Works of Livestock Waste Water based on Activated-Sludge Process (Quanzhou, China) Simultaneous improvement of water quality, CODCr < 70 mg/L, NH₃-N < 7.5 mg/L and reduction of excess sludge to zero could be achieved. An energy saving by 30 to 50% reduction of electricity due to an alteration of intense to weak aeration, reduction of sludge transportation energy due to no excess sludge, etc. could be achieved. The effluent which contained *Waterkeeper*, was discharged into a river, where microorganisms could be activated and the sedimentary sludge could be decomposed.

Conclusion

By the continuous addition of *Waterkeeper*, the simultaneous realization of water quality improvement and sludge sediment elimination in the aquatic environment or the simultaneous realization of water quality improvement and no excess sludge while a prescribed amount of the sludge return is maintained in the activated-sludge process, can be achieved. Furthermore, the effluent from the treatment works which contains *Waterkeeper*, is discharged into the aquatic environment where *Waterkeeper* can activate microorganisms living there, and subsequently, the sludge sediment can be decomposed and eliminated.