Technology to suppress malodor at the watersides from bottom mud dredging

Yukio KOGURE

SO-EN CO.,LTD 1665-1 Shinbo-machi Takasaki Gunma 370-0018, Japan
e-mail : soen.net@gmail.com URL : http://so-en.net/index-e.html

Abstract : When bottom mud has accumulated on water areas, it will reduce the flow rate and the reservoir capacity. It will also hinder with the ship navigation. When organic matter has accumulated, the bottom mud will detoriate and will become sludge, the nutrient salts eluted will increase the growth of blue-green algaes that will cause contamination of the water and will generate a malodor. And to prevent the generation of malodor from the sludge, dredging the bottom mud is required. Organic bottom mud is where the malodorous substance is and the malodor generates during dredging. The retrieved soil from dredging generates a malodor too and it will also hinder with the dredging work. The construction cost for environment countermeasures and re-use will be enormously expensive. The most effective and economical way to process the bottom mud is by solid-liquid separation dredging process by MSC. The MSC method makes the separated water and soil without malodor.

Key Words : Dredging, Bottom mud processing, Organic sludge, Turbid water treatment, MSC method

1. Introduction

Over the years the inflow of sediment and sewage on rivers, lakes, marsh, dams, inner seas and etc. has accumulated on the bottom part of the water areas. This is called bottom mud. The accumulated bottom mud will not only interfere with the flow rate amount but it will also decrease the level of water storage. It will hinder with ship navigation. During summer, as the water temperature rise, nitrogen and phosphorus will increase, that leads to eutrophication.

Moreover, the massive outbreak of algal bloom due to photosynthesis causes water contamination and releases a bad odor causing environmental destruction.

As a countermeasure on bottom mud, dredging is being carried out conventionally. Dredging refers to digging across a large area of the bottom water and it is different from a local underwater excavation construction. With dredging, the water depth will increase so as the water flow cross-sectional area. The lakes, marsh, dams and etc. reservoir water volume will increase too. It will ensure the route for ship vessels. In addition, dredging has been carried out in the recent years as a countermeasure to remove sludge and organic bottom mud containing hazardous substances.

The bottom sludge from dredging is used for landfill because it contains hazardous substances and generates a malodor, it can not be re-used. And since the bottom sludge contains many organic matter, the malodor generates during dredging construction. The consideration of environmental aspects has become difficult. The sludge will be discharged with large amount of water and will need an enormously large space for the mud to dry. It will also require longer period of time with the malodor in the air that has a large environmental impact.

In the recent years , the maintenance of river and sewerage has progressed. The outflow of untreated wastewater to the sea has reduced and the bottom mud that has malodor has reduced as well. However, on plains, urban areas, closed areas such as park ponds, moats and etc. the discharged of non-specific source of farmlands, organic matter and nutritive salts has accumulated. Furthermore, the nitrogen oxide contained on the exhaust gas from factories and automobile will eventually flow with the rain, bottom mud accumulation will progress and the water quality will detoriate. With the increase of nutritive salts, it will be the nutrient source of the phytoplankton in the water and the growth of blue-green algae will increase that will generate malodor.

Stopping the inflow of contaminants and the accumulation of the bottom mud is the best countermeasure, but complete prevention is practically impossible. Therefore, it is necessary to carry out direct purification and dredging. Water management to maintain environmental protection and biodiversity. However, dredging work construction by the conventional method in urban areas has become difficult because the construction cost needs a lot of money to process the bottom mud from the water, the malodor during construction work and its large impact on the Ecosystem.

This article will describe and introduce the efficient bottom mud treatment by the MSC method technique as a countermeasure to suppress the malodor on the watersides during dredging.

2. Dredging Overview and Issues

Dredging is a method of digging into the bottom water, done by using a dredging pump for the suction of the mud (Figure-1), backhoe dredging by a shovel to scoop up the mud (Figure-2) and grab dredging to grasp the riverbed sediment (Figure-3). Generally, on shallow waters such as rivers, lakes, marsh and etc. pump dredging and backhoe dredging is oftenly used. On the sea with deeper and larger scale water areas, grab dredging is used.

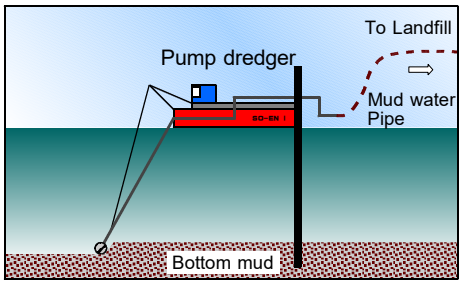


Figure-1 Pump dredge

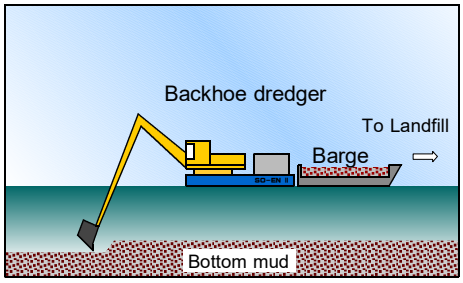


Figure-2 Backhoe dredger

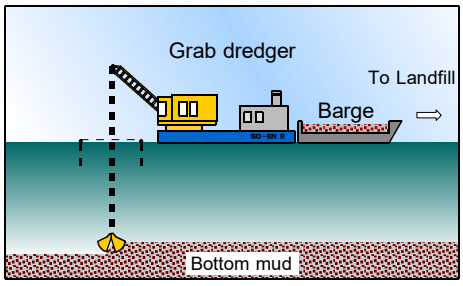


Figure-3 Grab Dredger

In pump dredging, the sucked bottom sludge in the pump is sent to the landfill. In backhoe and grab dredging, shovel and grab is used to dig the bottom mud and sludge is transported by a carrier vessel called barge. Depending on the situation, there are cases when the bottom sludge in the pump passes through an air pressure machine before it is sent to the landfill. Besides using the bottom mud for landfill, it is necessary to dehydrate and dry to a constant moisture content for transport and for re-use. In pump dredging, bottom sludge is sucked with large amount of water, normally the sludge water soil rate is 5~20% so it must reduce its water rate in the precipitation facilities. With the backhoe dredging, the soil rate is usually 60~80% but for re-use and for it to be transported into the land for final disposal it needs solidification process. In either ways, all these dredging methods for bottom sludge for re-use or final disposal, it is necessary to dehydrate, dry and solidify.

Therefore, with dredging construction, problems are as follows:

① Needs extensive grounds to provide space for large-scale plants, large-scale heavy machinery and sediment processing equipment.

② Needs countermeasures to suppress malodor that will generate from the organic bottom sludge

③ Bottom mud with high-content water rate needs solidification process for short term disposal because it is not hydrophobic.

④ The alumina-based flocculant and cement solidifying agent used for solidification process will need to be transported as industrial waste, it will require a lot of expenses for transportation and disposal costs.

⑤ Drilling by the large heavy equipment will cause the aquatic organisms in the bottom mud to die, destroying the Ecosystem of the fishes and other aquatic organisms as well by hoisting the bottom mud, it will make the water turbid.

⑥ The transportation of the bottom mud, solidification process and disposal cost as industrial waste is expensive, the entire construction costs is uneconomical.

3. The cause of the generation of malodor from the bottom mud

The cause of bottom mud accumulation is the direct inflow of sediments and/or the inflow of contaminated water containing organic matter and nutrients. The organic matter and nutrients after the inflow will continue to repeat dilution and diffusion, the bottom mud is then accumulated through precipitation. With elution and hoisting, some contaminated particles will regress back in the water. During this time, organic water is degraded by the aerobic bacteria that lives in the bottom of the water. Organic matter is then mineralized to nutrient salts (inorganic nitrogen and inorganic phosphorus state) and etc. In addition, the nutritive salts and carbon dioxide produced from mineralization will be absorbed by the phytoplankton and the growth of blue-green algae will progress thus contaminating the water quality. The dead bodies of phyotplankton through precipitation will accumulate in the bottom parts of the water, the accumulation of such organic matter and nutrient salt detoriates the bottom mud into bottom sludge.

With the increase of large amounts of organic matter inflow and phytoplankton growth, the oxygen in the water is consumed causing the decrease of dissolve oxygen. The areas near the water surface can take oxygen from the open air but in the bottom parts of the water, where there is no oxygen circulation will make the bottom in an anaerobic state that will cause the growth of anaerobic bacteria. The organic matter with the action of the anaerobic bacteria will become a malodorous substance such as hydrogen sulfide (H_2S) and ammonia (NH_3). (Figure-4)

Hydrogen sulfide is formed when the bottom part becomes anaerobic, it is contained on the accumulated bottom mud. Soluble in water, with weak acidity and its malodorous substance characteristic is a strong pungent odor similar to rotten eggs. And since it is trapped inside the bottom mud in a stationary state it hardly diffuses into the atmosphere

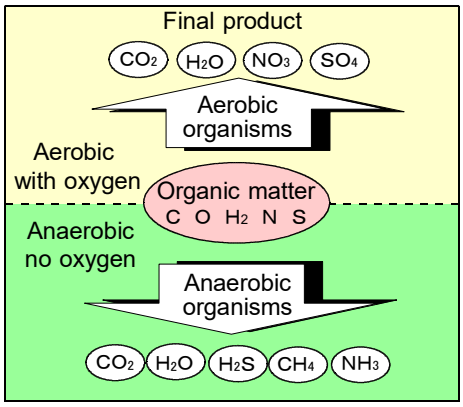


Figure-4 Decomposition of organic matter

stationary state it hardly diffuses into the atmosphere but once it takes an impact from the outside it will diffuse. With pH 7~8 in the water, the equilibrium concentration of hydrogen sulfide in the atmosphere is 1 mg / L relatively against the atmosphere of 20 to 100 PPM. The toxicity is strong, so there is a criteria provided by the Industrial Safety and Health Act with its concentration on the atmosphere.

Ammonia is not only being formed by organic matter decomposition, it also flows directly as ammonia nitrogen（NH_3 or NH_4）from untreated sewage.

Ammonia nitrogen when in water, if there is dissolve oxygen in the water it can be changed into nitrite（NO2）to nitric acid（NO_3）by the nitrification action of the aerobic bacteria. But in the bottom part areas which has small amount of dissolve oxygen and without nitrification, ammonia stays as it is. In addition, nitrogen oxides such as nitric acid（NOx）with large amount of flow from the outside from unspecified sources will accumulate and when oxygen（O）is deprived, it will make the bottom part areas in an anaerobic state and it will also end as ammonia contained in the bottom mud. Malodorous substances such as hydrogen sulfide and ammonia is contained sealed in the bottom mud and as long as they are in the bottom mud they will not diffuse into the atmosphere, but when it takes an impact from dredging and released in the atmosphere it will stink.

4. Locations that generates malodor on dredging construction

The dredging + the transport of bottom mud, pump dredging + mud water pipe, backhoe dredging or grab dredging + barge transportation method or air pressure transmissionsystem pipes

With dredging work on the water surface, the pump dredging will not generate a bad odor because the bottom mud is sealed through the pipes but with backhoe and grab dredging, the bad odor comes out as soon as the sludge emerges out of the water and out into the atmosphere. Bad odor occurs even at the time of loading the sludge into the barge and transport.

The sludge from the barge and the pipes are sent to a landfill, where it will be dehydrated and dried to a certain moisture content. However, since both the soil particles and the water are negative charge, it is difficult for them to separate, so it takes a lot of time to dry naturally and in the meantime, the bad odor will continue to occur. Locations where bad odor occurs on each of the process（Figure-5）

With the pump dredging method, the bottom sludge is sucked into the pumps and sent to the landfill sealed so it does not have a bad odor. Considering from the point of view on the odor control, it is the appropriate dredging method. But still, the bad odor will occur when the sludge is released on the landfill. Bad odor countermeasures on the landfill is required.

With backhoe and grab dredging method, the bad odor occurs on each of every location of dredging, transport and unloading. It is necessary to take thorough countermeasures against bad odor. But it is extremely difficult to take countermeasures on each of the location with this method. It is known as an inappropriate dredging method of organic bottom mud because of the bad odor that it generates. And at the same time, it is not suitable for dredging in close proximity to densely populated areas that requires environmental countermeasures. Barge navigation, landfill management and reclamation work is difficult to be carried out with the environmental countermeasures.

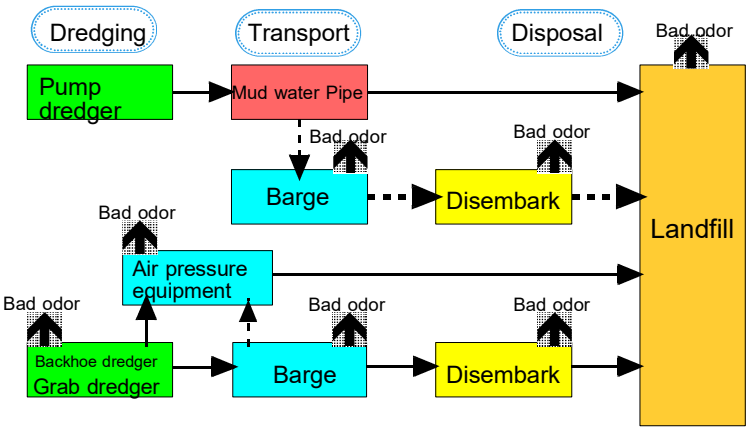


Figure-5 Locations where bad odor occurs on a dredging construction work

5. Bottom mud treatment and odor control by MSC method

5-1 Overview of the MSC method

The MSC method has iron salt and metal salt as its main components, this method is carried out by using an inorganic coagulant made out from rare earth elements called "MSC" for bottom mud treatment and water purification technology. As hydrophobing dehydration treatment and soil stabilization additive, MSC facilitates dredge bottom mud precipitation and consolidation fast, as well as purify the separated water. It allows the bottom mud to be transported faster, the re-use of the separated soil is made possible, shortened the dredging construction period, there is no adverse effect on the Ecosystem and the environment, a very safe and economical bottom mud treatment and turbid water processing method.

The structure of sludge consists of fine particles which aggregates to mineral particles. The spaces between fine particles will be filled with water and air, these soil particles usually have negative charge and it is difficult to separate.

By adding MSC, MSC electrically neutralizes the negative charge of soil particles because MSC is a positive ion substance. During this time, capillary water combined with soil particles is separated. Then, interstitial water and a film of absorbed water will become free . By this hydrophobing phenomenon, soil particles will adsorb each other and the particle diameter becomes bigger, that leads to sedimentation. By adding the polymer flocculant, the diameter of the flock will get bigger and it will settle down very fast.
(Figure-7)

The formed coagulation soil has large hydraulic conductivity and because there is no re-mudflow it enables to conduct effective dehydration and improves the soil quality.

The process by the MSC method is the same as the coagulation-sedimentation reaction in wastewater treatment but it is a complete reaction in a series of systems that it does not require large-scale equipments such as mixing tank, flocculation sedimentation tank and etc. that is being used in wastewater treatment. And because of its high hydrophobicity to separate soil, it does not require mechanical dewatering machine, making it an extremely compact equipment.

Characteristics of the bottom mud treatment process by the MSC method is as follows:

① Flocculation sedimentation velocity with MSC is several times faster than conventional flocculant. (Figure-8)

② Flocculation separated soil becomes hydrophobic and interstitial water rapidly drains. The frame of soil particles itself is easy to be compressed and shows large coefficient consolidation .
(Figure-9)

③ Suspended substances (SS) and organic matter (COD) in the water are separated by flocculation sedimentation and the separated water will be purified as clean treated water.
(Table-1)

④ Flocculation separated soil quickly becomes hydrophobic making it a transportable water content ratio.

Water index	Removal rate
SS	80～99%
COD	50～80%
TN、TP	50～80%
Heavy Metals	50～90%

*The effect depends on water quality and condition

Table-1 Water purification effect by MSC

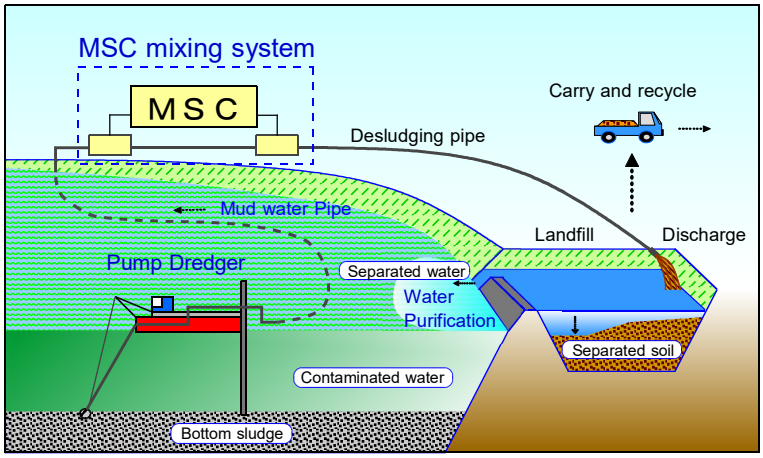


Figure-6 Construction image of the MSC method

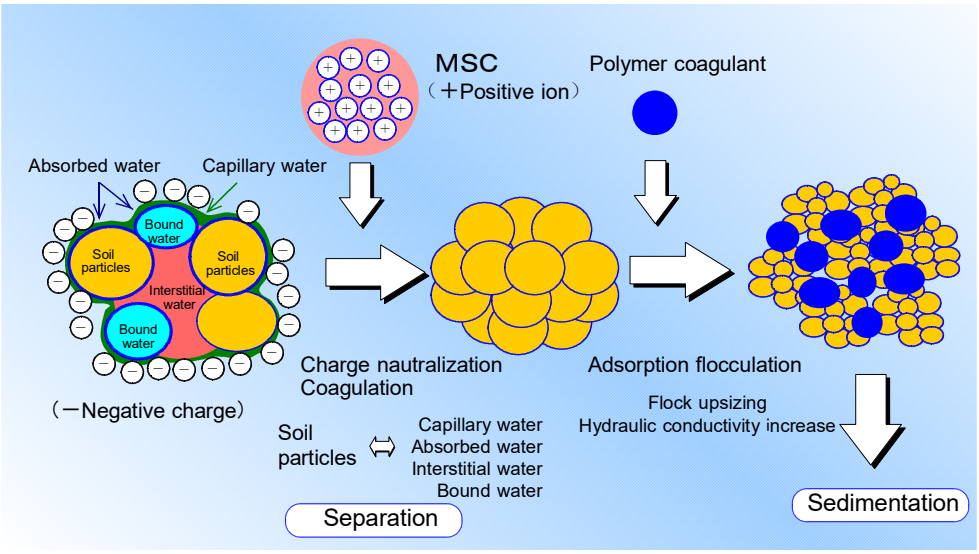


Figure-7　Mechanism of MSC method

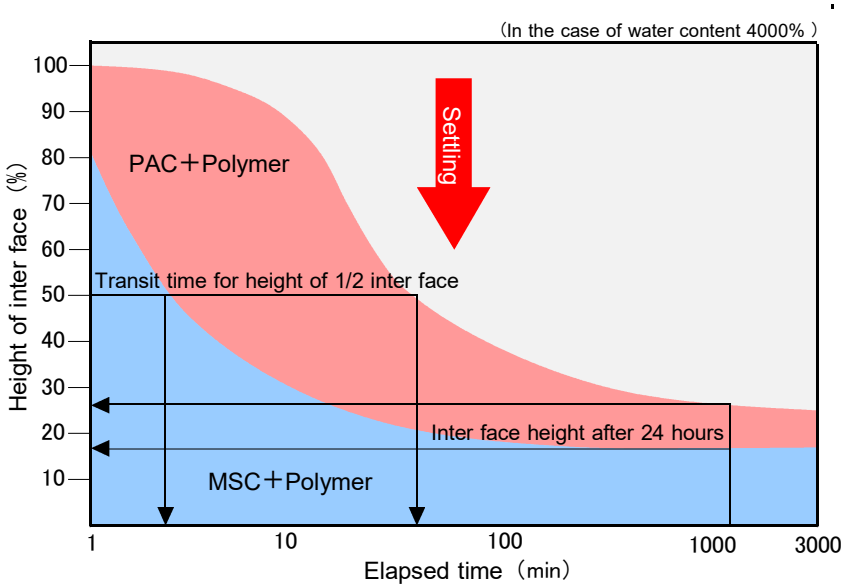
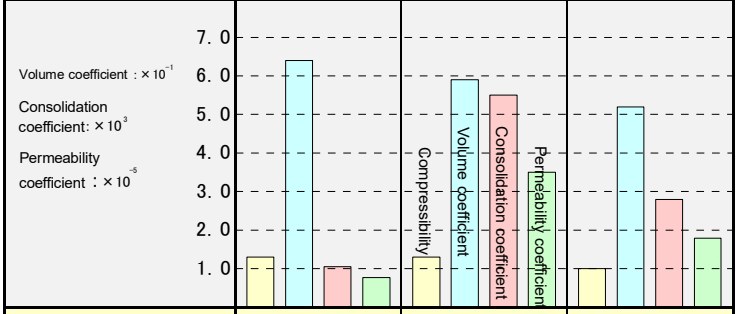


Figure-8　Change of interfacial height through time (Sedimentation Velocity)

（In the case of water content 4000%）

	Free additive	MSC	P A C
Compressibility	1.3	1.3	1.0
Volume coefficient cm²/kgf	6.4 ×10⁻¹	6.9 ×10⁻¹	5.2 ×10⁻¹
Consolidation coefficient cm²/d	1.05×10³	5.5 ×10³	2.8 ×10³
Permeability coefficient cm/sec	0.78×10⁻⁵	3.5 ×10⁻⁵	1.8 ×10⁻⁵



（Consolidation weight：0.1kgf/cm）

Figure-9　Consolidation Comparison

5-2 The advantages of MSC method

The MSC method treatment of sludge and contaminated water is carried out in a step by step process from the pumps that sucked the mud water then into the pipes that is connected with a continous stirring device in the line mixer and direct input of MSC polymer flocculant. The stirring and mixing will cause chemical reaction in the pipes, the immediate solid-liquid separation is performed at the time of release.

With its fast solid-liquid separation, it is possible to make the construction of the downflow distance short and with small content, thus it can discharge more bottom mud into the landfill, has excellent workability and reduces the dredging construction cost. The initial sedimentation of the dredging separated soil is self-weight consolidation that it can be carried out in a normal dump truck in a shorter period of time than the conventional method. And since it has high compaction strength, the landfill used in the dredging construction can be used early even without performing ground improvement work.

The MSC method prevents the bad odor during dredging construction. The malodorous substances such as hydrogen sulfide and ammonia in the bottom sludge is decomposed by the chemical reaction of the MSC, the bad odor does not occur in the landfill as well as the separated water and soil. The separated soil in the landfill can be used as fertilizers and soil conditioners because of the components included in the MSC (iron, potassium, calcium) and nutritive salts (nitrogen, phosphorus) by the microorganisms, the separated soil can be effectively re-used as an agricultural soil.

The advantages of MSC method are as follows.

① The aggregation and sedimentation of the soil particles is fast, early initial subsidence, the separated water is purified.

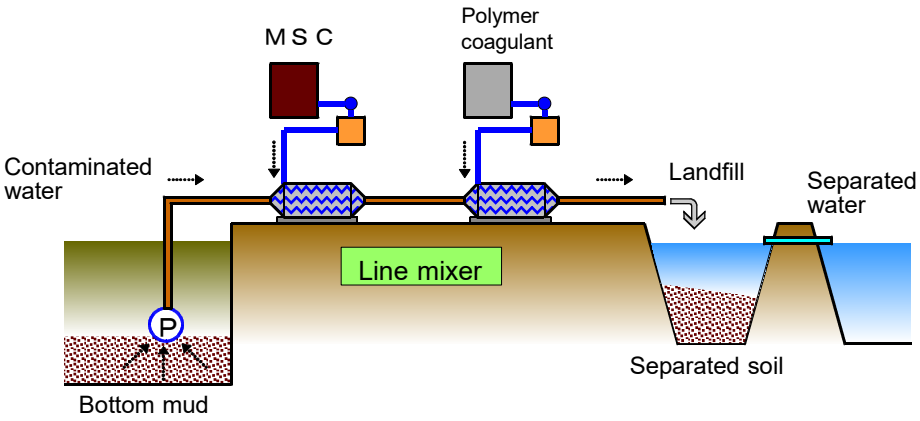
② Hydrophobically improved, with large coefficient consolidation, large amount of separated soil can be accomodated in the landfill processing area.

③ Permeability coefficient is large, the landfill processing area will dry fast, secondary construction can start early.

④ Separated soil is highly drained and it is a fertile soil that it can be re-used as agricultural soil.

⑤ It prevents bad odor during construction, no bad odor on the landfill processing area and the separated soil and water is odorless.

⑥ Blue-green algae and harmful substances such as heavy metals are removed, environmental improvements of the water is obtained.



By line mixer arranged in a pipe, each agents are mixed together.

Figure-10 MSC Line Mixer Method Concept

5-3 The malodor prevention by the MSC method

The hydrogen sulfide (H_2S) and ammonia (NH_3) contained in the bottom mud is unpleasant to human beings, these are the malodorous substances specified in the Offensive Odor Control Law. These malodorous substances are formed from organic matter with anaerobic bacteria, the more organic matterin the bottom mud means more hydrogen sulfide and ammonia.

The organic matter in the water is determined by measuring the indices of Chemical oxygen demand (COD) and Biochemical oxygen demand (BOD) that can confirm that the bottom mud is organic.

The main components of MSC are iron salt (mainly referred to as iron chloride(III) (ferric chloride): $FeCl_3$) and metal salt (aluminum sulfate: $Al_2(SO_4)_3$) strong acidic substances.

These susbstances will react with the malodorous substance thus preventing the occurrence of malodor.

Malodor prevention mechanism of MSC are as follows.

① Hydrogen Sulfide

Hydrogen sulfide reacts with the aqueous solution containing metal ions, a property resulting in precipitation of the metal sulfide. Hydrogen sulfide is soluble in water, the aqueous solution is weak acidic, the precipitation product of sulfide, depends on the solubility product of the pH and sulfide. From these chemistries, the removal of hydrogen sulfide, oxidation and the metal salt treatment has been effective.

MSC has metal ions with acidic substance, the hydrogen sulfide by oxidation action of chlorine ions as iron chloride（III）（Cl）is oxidized and decomposed, iron ions（Fe_3^{+}）will react with hydrogen sulphide sulfur ions（$S2^{-}$）, will become iron sulfide（FeS） insoluble and precipitate.

With these chemical reactions, the hydrogen sulfide in the bottom mud will be decomposed and removed, prevents the occurrence of malodor.

② Ammonia

Ammonia is soluble in water, the aqueous solution of the alkaline substance pH changes its concentration. On Neutral range of pH7 ~ 8, ammonia is 1 ~ 2mg / L, with pH10, it will rise up to 20 ~ 30mg / L.

These will make ammonia react in water and ables it dissociate $NH3 + H2O \rightarrow NH4^{+} + OH^{-}$, by its acid that neutralizes alkaline, it will suppress the generation of ammonia.

MSC has strong acidity, by adding it on the mud water it will neutralize alkaline, it will prevent the occurrence of ammonia malodor.

③ Musty odor

The musty odor found in detoriated water areas are caused by blue-green algae. The main causative agent of the musty of odor are the substances such as diosmin and 2MIB（methyl isoborneol）that is formed by the blue-green algae and actinomycetes. Algae uses the nitrogen and phosphorus in the water as their nutrient source, they will grow with the photosynthesis from the sunlight, by removing the nutritive salt, the occurrence of algae can be prevented so thus the occurrence of malodor.

Dredging by the MSC method will suppress the elution of nutritive salt by removing the sludge.

The dredging that will suck the bottom mud along with the contaminated water, will also remove the nutritive salt in the water. In addition, it will also directly remove the blue-green alage and the suspended solid, returning clear water. With the MSC method in water areas whereas the malodorous substance is removed, water environment is regenerated with high water transparency and without malodor.

6. Continous malodor prevention on water areas

The MSC method is the countermeasure to prevent malodorous substances such as hydrogen sulfide, ammonia and etc. and it also prevents the musty odor caused by the blue-greean algae.

But with water areas with contionous inflow of organic matter and nutritive salt and as the time/years pass by the bottom mud will accumulate again over time. When the bottom mud accumulates, the elution and winding up of nutritive salt will be high, the growth of blue-green algae will occur, contaminating the water quality and making the waterside environment detoriate.

The accumulation of bottom mud can not be completely prevented because there is also a sediment flow caused by natural disasters but the accumulation of organic mud can be prevented by appropriate countermeasures. The most important countermeasure is to stop the inflow of organic matter and nutritive salt, there is also the flow from non-specific sources, so it is necessary to perform direct countermeasures in the water.

It is also important to increase the natural purification function of the water. Hydrogen sulfide and ammonia is the methamorphosis of the anaerobic bacteria. The organic matter and nutritive salt that flowed into the water is decomposed and removed by the action of the aerobic bacteria. Thus it is necessary to activate the microbial environment to prevent the generation of hydrogen sulfide and ammonia from the organic matter. Natural purification function depends on the plants that grow in the water and the indegenous bacteria.

But when the amount inflow of organic matter increases, it exceeds the natural purification capacity. By placing CarbonFiber water purification material in the water, it will serve as the carrier of microorganisms in the water, an effective reinforcement to water purification effect.

It is also important to increase the dissolve oxygen on the bottom parts of the water and by not letting it go to an anaerobic state. Water areas like rivers, waterfalls, rapids and etc. that has a flow, natural aeration is performed and oxygen dissolves in the water, plain water areas with gentle flow is prone to be in an aerobic state, it is necessary to provide an engineered drop structure for aeration. Closed water areas such as lakes, dams, park ponds and etc. should be made to circulate the flow of the water and in some cases it will require aeration from an aerator or fountains. In big dams and lakes, it is necessary to establish an intermittent air pumping cylinder to move large amounts of water with small energy, it will be effective for water circulation.

7. Conclusion

Water is the source of life, including the human race. The life and its works is made up by the benefits of water. For the human race, water is not only for drinking, it is also essential for agriculture, industry, economic activity and a very important source for power generation. Landscapes with water is beautiful and gives people comfort, serenity and peace. Enjoying water sports will keep us active and relaxes our daily life.

Water that has so many benefits to us, yet, it is contaminated by us, by allowing the accumulation of the bottom mud. From the accumulated bottom mud, comes the elution of nutiritive salt, promoting the water pollution contamination, spreading the malodor, becoming the vicious cycle of environmental pollution. If the water pollution contamination worsens, not only the malodorous substances like hydrogen sulfide and ammonia will occur but also methane. The organisms living in the water will die, the water will turn black, we

can not use our water resources and it will also affect the people's health.

As an environmental countermeasure, it is necessary to carry out the suitable bottom mud removal to remove the malodor and causative agents that causes the water contamination. It is also important to create a sustainable society. The removal of the bottom mud by the conventional method will cause malodor during dredging construction.

With the bottom mud processing of the MSC method, it will prevent malodor during construction and it will eliminate the bad smell in the water and soil after treatment, the treated soil can be re-used effectively. By using this method in rivers, lakes, ponds and stagnant water areas in the city where bottom mud has accumulated, it will improve the water quality, it is an effective countermeasure. In addition, this method can process organic sludge discharged from sewage treatment facilities and can be applied to a variety of areas. It is possible to reduce sludge waste disposal costs and along with achieving environmental improvement.

With Japan aiming to be a tourism country, many foreigners visit Japan in search for beautiful and nature scenery. But if bottom mud will accumulate and detoriate the water areas, the foreigners who came to visit will be discouraged. Tourist spots in the urban areas, like castles
that has landscapes with ponds, moats and etc. has become a common problem. In the coming

Tokyo Olympic Games of 2020 to be held in Japan, many athletes will come to Japan including tourist too, the beauty of the waterfronts should be the pride of Japan and it will be an issue for environmental improvement.

It is necessary to conserve the beautiful waterfront. In order for us to live comfortable with the water areas, we should remove the bottom mud from the contaminated waters. Use an economical, high treatment technology without the malodor to treat the bottom mud. It is necessary to aim further for environmental improvement.

■ REFERENCES

1）*The National Research and Development Institute for Public Works : Bottom mud countermeasure technology on closed water areas research*（2006）

2）*Lakes/Marsh Technology Workshop bottom sediment working group: technical documents related to bottom sediment*（2009）

3）*General Foundation of Construction Engineering Research Center: Rivers earthwork manual*（2009）

4）*NPO）CarbonFiber Make Water Method Association: CarbonFiber technology for water use guidelines - Water environment edition*（2009）