Real time monitoring and controlling of Marine Sewage Treatment Plant Effluent

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Real time monitoring and controlling of Marine Sewage Treatment Plant Effluent

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Abstract:

As on date around 56,000 vessels are moving in the World shipping fleet and it is growing every day. All these vessels were manned by seafarers who spend on an average of 6 months on-board. Their continuous stay on-board required the basic hotel service such as food, climate controlled Accommodation and all lavatory facilities. On top of this thousands of passenger ferries and cruise liners floating on the oceans also providing similar facilities for nature-calls of passengers. Discharge of these wastes from sewage system affects the marine environment, particularly in the confined water bodies similar to Baltic sea. One of the important requirements as per MARPOL (International conventions for the prevention of Pollution from ships,1973) by IMO is maintaining sewage treatment plant (STP) onboard [1]. This part has been specified in detail as ANNEX-IV – Prevention of Pollution by Sewage from ships[1]. Standards for Sewage treatment plant placed on-board is evaluated basis on the contents in the effluent from the plant after all processes completed. This evaluation is not performed on every STP fitted in so many numbers of vessels in service today. As a part of pre- building exercise STPs were chosen from list of type approved systems available. This type approval is issued by marine administrators by sample evaluation of one of the plant in the factory environment.

This paper proposed the model STP in which the data from Real time monitoring the contents in the effluent can be used to regulate the air supplied to the plant. Different sensors such as microorganism detector, PH prob, Phosphorous sensor and Nitrogen detector of instant results types used for this purpose. To regulate the supplied air, frequency controlled motor is used in the supply–air Fan. This regulation of air will reduce the energy requirement of the overall process. Added with the regulation of air supply, real-time control on feed rate of dosing pump optimize the chemical use in the plant. Nitrogen and Phosphorus contents continues measurements and flowmeter readings from inlet and outlet of the plant ensure the effective performance of Full treatment module. This proposed model plant will be an energy efficient and real-time compliance to the international limitations stated in MARPOL.

***Key Words** :Sewage treatment plant, Effluent, Aerobic bacteria, MARPOL*

1. Introduction

Ships are the main backbone of economic activities all around the world. Around 80% of the world trade depends on sea mode. The environment on which crew members stay onboard influences the efficient vessel operations. As new automated inventions on different equipment including main propulsion engine keeps the crew members stress free. On the other hand new rules are developed by international regulatory every day. The compliance with these rules are placed on the shoulders of crew members including captain of the vessel. World over environmentalist debating much on the damage to the environment due to the developments of industrialization. This activity does not leave the maritime industry too. To overcome the ill-effect of developments, maritime regulator framed pollution prevention rules under MARPOL[2]. This convention explains the requirements of vessel operation to control different pollutants segregated as different Annexes. Sewage is one of the major pollutant to sea is described in Annex-IV. One of the requirement as per Annex-IV is fully functional Sewage Treatment Plant (STP) on board. For the efficient operation of STP, close monitoring of the effluent content and regulating their operational paraments are important[3]. This paper describes one of the methods to achieve this task.

2. Pollution

Pollution is an activity which affects the ecosystem and the living organism over there in change in rate of growth and reproduction of plant or animal species[4]. In some cases the pollutants are in the form of Energy such as heat and radioactive waves too. Although pollution can be caused by natural events, the majority of pollution is caused by human involvement. Any industrial process design makes at least slightest negative impact as environmental consequences[5]. The ability to keep away this unnatural damage makes the earth livable for all the creatures.

2.1.Marine Pollution

The most common sources of marine pollution are shoreline and recreational activities, ocean/waterway activities, smoke emission activities, and dumping at sea. Hydrodynamics, geomorphology, and human factors all have a strong influence on the geographical distribution of marine debris[6]. Significant amount of pollution due to maritime activity is Air pollution due to the combustible fuel emission which leads to warmer earth[7]. Any kind of discharge to sea within confined waters affects the local food cycle and, as a result, the living conditions of humans and other species there.

2.2.Sewage as Pollutant

Sewage from ocean-going ships is dumped directly into the sea. Because the ocean is vast, untreated sewage breaks down and becomes liquid after a long period of time in it[8].The sewage discharged to sea by cruise line industry only is in the range of 110,000 liters of blackwater and 970,000 liters of greywater [9].

Blackwater is one type of sewage, which its main source from toilets and medical facilities. This usually contain harmful bacteria, along with viruses, pathogens, intestinal parasites, and harmful nutrients. Fish breeding is significantly affected with either bacterial or viral contaminations if untreated or inadequately treated water discharged to sea. This ultimately posing public health risks. Excessive algal blooms are promoted by sewage nutrients such as nitrogen and phosphorus, which deplete oxygen in the water. Loss of oxygen leads to the results of fish kills and the extinction of other aquatic species. The blackwater generation by one single cruise ship of 3000passengers and crew is estimated between 55,000 to 110,000 liters per day.[10]

Greywater is the next type of wastewater that is typically generated by non-toilet sources such as sinks, showers, food processing, cloth washing, and cleaning activities on board a ship. This water contains detergents, oil and grease, metals, organic compounds, nutrients, food waste, and coliform as a contaminants. Untreated waste water generated from cruise ships was found to have several times the amount of faecal coliform bacteria seen in untreated household wastewater, according to pollution detection tests conducted by maritime regulating authorities[8]. Greywater contains a high concentration of nutrients and oxygen-demanding stuff, which has the potential to harm the environment. The main source of liquid waste created by cruise ships is usually this (90 to 95 percent of the total). The cruise ship releases around 330,000 to 960,000 litres per day for a 3,000-person group. When calculated on a per-person basis, the results range from 110 to 320[10].

3. MARPOL Annex-IV

The MARPOL convention was adopted by the International Marine Organisation (IMO) in 1973 to limit pollution caused by maritime activities. This convention divided contaminants into six categories: oil, chemical in liquid form, chemical in package form, sewage, garbage and pollutants to air. Regulatory requirements to the Prevention of Pollution by Sewage from Ships is covered in Annex-IV of MARPOL.

This part of convention define sewage as

1. drainage and other waste of any form from toilets and urinals
2. drainage from medical premises
3. drainage from the space containing living animals
4. Other waste water when mixed with drainage defined above.[1]

Collection tanks are designed and installed to hold these drainages. When there is no approved STP onboard, these waste water is discharged to shore facility and performed the required treatments before discharged to any waterbodies. Holding huge volume of waste, particularly on passenger vessels is difficult. All the vessels on international voyages equipped with STP to compliance with discharge criteria.[1]

Special Area

Some geographical sea areas are defined as special area due to technical reason relating to their oceanographical and ecological condition including their sea traffic. In these areas stringent discharge requirements are followed to maintain their status as similar to unaltered condition. For example consider Baltic sea where only limited water is exchanged with other sea areas makes all the contents discharged in Baltic sea stay within it. To maintain flora and fauna of Baltic sea, special area status is assigned to this territory as per Annex-IV. [1]

STP

Performance of biological STP as shown in fig-3 is mainly depends upon the number of aerobic bacteria presence in the plant. The growth of these bacteria is based on the air supply to the aeration chamber in the plant. Quantity of air supplied to the plant also an important factor for energy efficient operations of the plant. The other factor of the evolution standard such as chlorine content as disinfectant if used is depends on the dosing rate of chlorine added in the effluent. Regular monitoring the disinfectant content and regulate the dosing rate also optimise the use of chemicals which are an environmental ill-natured component in the process[11].

New amendment of the approval standards for STPs evaluates BOD (Biochemical oxygen demand) and COD (Chemical oxygen demand) in the effluent[12]. At present these tests were normally conducted in the laboratory environment. Logistics involved with the sample delays the test results. The same conditions are applicable to other contents tested in the effluent such as nitrogen and phosphorus.

Effluent Standards

The performance of STP is measured based on the effluent discharged out from them. The marine environment protection committee through resolution MEPC 227(64) adopted guidelines on implementation of Effluent Standards and Performance Test for sewage Treatment Plants.

The following are testing standards[12]

(1) Thermotolerant Coliform Standard < 100 TC/100 ml
(2) Total Suspended Solids (TSS) Standard $<35Q_i/Q_e$ ppm
(3) BOD $<25Q_i/Q_e$ ppm
(4) COD $<125Q_i/Q_e$ ppm
(5) pH value ≈ 6 to 8.5
(6) Condition if Detected value is zero or less than limit.
(7) N Total < 20Qi/Qe ppm
(8) P Total <1.0 Qi/Qe ppm

Qi -Influent Quantity

Qe-Effluent Quantity

Water Quality Probe

Multiple parameters can be measured at the same time with this water quality sensor. This probe uses the fluorescence principle to measure several parameters.

They are as follows,

BOD,COD, TOC,DOC	Optical Brighteners	Ammonium
Dissolved Oxygen	Nitrate	Salinity/TDS
Pressure	Coliforms	Turbidity
Chloride	Tryptophan	Crude oil
pH	Temperature	Refined oil

Fluorescence is a type of luminescence that occurs over extremely short time scales (10-9 – 10-7s).This phenomena is not due to the heat radiation . Some molecules absorb ultra-violet light (short wave radiation) from the source and then emit longer wavelength radiation blue light[13]. Fluorophores are molecules that display this feature. A light emitter and detector, as well as various optical components for separating specific wavelengths of light, are necessary for observing and quantifying fluorescence.

A set of lenses and filters direct the light from the excitation source. The light is absorbed when it reaches the sample, and some of the molecules glow. The fluorescent (emission) light is directed to a detector after passing through a second set of lenses and filters/monochromator (usually a photodiode).

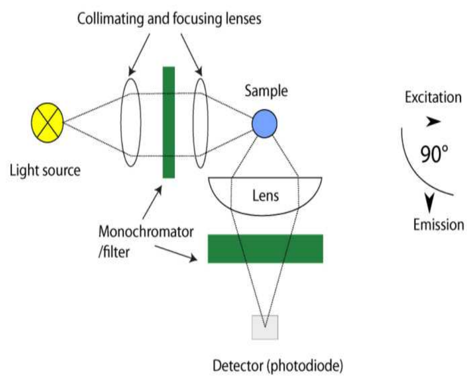

Fig-1.Water quality sensor- fluorescence principle.

To limit the possibility of erroneous readings caused by stray excitation light reaching the detector, this photodiode is generally positioned at 90 degrees to the incident light beam.

When activated by UV radiation, a considerable part of chromophoric (light absorbing/colored) organic matter becomes luminous. Different fluorescence peaks have been detected using laboratory fluorometers that scan the whole spectrum of excitation and emission wavelengths[14]. For example, humic-like fluorescence (Peaks A and C on Fig. 2) may be traced back to terrestrial production by vascular plants, but protein-like fluorescence (Peaks T and B; Figure 2) is mostly associated to in-stream production by algae and bacteria. Strong relationships between conventional water quality parameters and fluorescence peaks have been identified of particular interest are the correlations between: (i) dissolved organic carbon and humic-like fluorescence (A and C) and (ii) biochemical oxygen demand (BOD) and tryptophan-like fluorescence (Peak T).

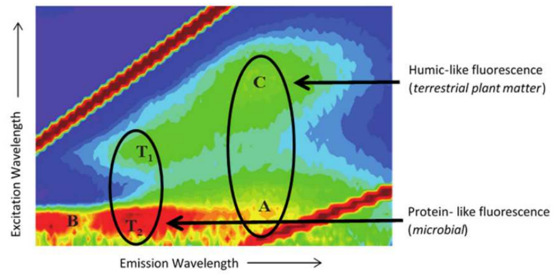

Fig-2.Image from Excitation Emission Matrix spectroscopy

4. Proposed Monitoring Method

I choice is ACOMARINE ACO Maripur NF membrane type waste water treatment system for this project. This system is not regularly monitored onboard, despite the fact that it is permitted to achieve the requisite outcome of Resolution 227 (64).

During on-board operation, an aerobic reaction occurs, which decomposes the solid particles in the waste water into effluent and reduces BOD and COD levels. The optimal amount of air supply is essential to maintain efficient aerobic operation.

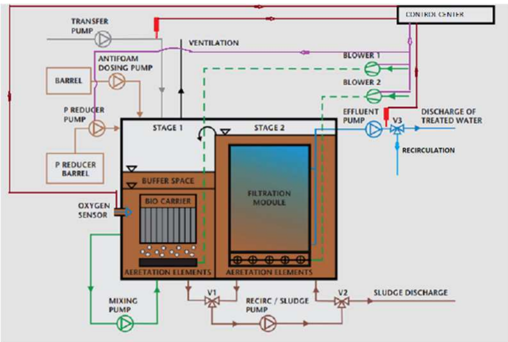

Fig-3. Biological sewage treatment plant

The flow of waste water and effluent is continuously recorded and relayed to the control centre by flow sensors installed at the inflow and output. Water quality probes for BOD, COD, Thermotolerant coliform, Total Nitrogen, Total Phosphorus, and PH were also added to the flow stream. All of these readings are also sent to the control centre.

The computations are done in the control centre using data from various sensors installed at the inflow and outflow points. This estimated result is compared to the database's set of acceptable norms. If the value is less than the required standards, the final exit three-way valve towards overboard is opened based on the comparison with the database. The three-way valve directs the effluent back to the system as return if the value exceeds the standards.

The air supply to the aeration chamber was appropriately adjusted to boost the STP's efficiency. If the measured property values (BOD, COD, and TC) at the effluent output are significantly lower than the criteria, the air supply to the plant can be lowered. The frequency-controlled motors that drive the air supply fan will do this. The control centre provides the signal to modify this frequency.

In terms of phosphorus reduction, the majority of phosphorus in wastewater comes from human excrement as well as phosphorus in household detergents. The P-Total level in the STP influent is determined by the amount of detergent used and the number of people on board at any given time[15]. The final P-Total result is controlled by the quantity of dosing chemical added in the treatment plant. Metal salts are generally added in chemical phosphorus precipitation method to react with soluble phosphorus and generate solid precipitate. The extra dose if any will be thrown away along with the sludge. The dosing pump's timer and stroke control function control the supply rate. The control signal for optimum dosage is calculated using the sensor's phosphorous measurement value and compared to the standards data.

5. Conclusion

The above-mentioned model eliminates the possibility of polluting the sea as a result of a malfunctioning STP onboard. Furthermore, the plant's operational efficiency will be improved by making the best use of power to regulate the air supply. Even though this efficiency boost is tiny, it will be useful as ship operations move toward decarbonization. Chemical pollution in the water and on land (when sludge discharged to shore) is reduced by regulating total phosphorous concentration by optimising dosing rate

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