SUSTAINABLE DEVICES FOR SEWAGE WATER MANAGEMENT ON SHIPS

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Abstract: Sea water pollution is one of the serious problems of these days. Sewage treatment system on ships are designed to purify sewage water before dumping it from the ship to the surounding water. To save environment, shipping companies are testing and installing sewage water purification systems that is the higest technology standards of today. These marine wastewater treatment systems are designed to gain effluent discharges that are of a higher purity. Advanced treatment systems (AWT) systems are still at the development stage. Comparing different manufacturers products and different working principles of this devices we got different results and diffferent drawings of working principles. Generally speaking AWT utilize enhanced aerobic digestion with physical filtration to clean and process sewage water on ships. AWTs generally provide improved screening, biological treatment, solids separation (using filtration or flotation), and disinfection (using ultraviolet light) as compared to traditional Type II MSDs. Advanced treatment systems (AWT) systems is in developing process and each new models gives better results of effluent purity. Therfore thosy systems are widely used on cruise vessels than on cargo vessels with less people onboard.
Keywords: sewage, advanced sewage treatment system – AWT, sewage treatment, , marine sanitation device - MSD.

1. INTRODUCTION

Sewage waste water produced on board ships is different by its retention time and lower water content than sewage waste water from the shore installations. Sewage water is less diluted (it has higher concentration) due to less use of water for sanitary flushing devices. The amount of sewage generated on board ships, depending on the number of people who reside on the same. Thus, vessels that have a smaller number of people, such as boats generate less sanitary sewage from yachts, commercial or passenger ships. (Hanninen and Sassi 2009)

Most of ships has an sewage treatment system, which is removing pollutants from sewage water before releasing processed waste water from the ship to the sea. Primary sewage treatment mainly removes solids by means of physical process. Secondary sewage treatment using bacteria to decomposes organic matters. Third stage is final stage where chlorination is used for sterilization of effluent before it is released to environment. "Advanced sewage treatment" (AWT) is a generally term covering treatment designed to remove any of harmfull substances. A variety of types of Advanced Waistwater Treatment Systems are available. Some are better proven than others and some are more complex and expensive, depend on their size and design.

Manufacturers of Sewage Treatmant Plants for ships, has been improved in last 10 years, and continue to upgrade existing and producing more complex Sewage Treatmant Plants with beeter quality of effluent.

To define the properties of waistwater and wastewater treatment equipment, the following indicators usually are used:

- **Biochemical oxygen demand in five days - BOD5,** [5]
- **Coliform bacteria** [6]
- **Suspended Solids** [7]

2. MATERIAL AND METHODS – LEGAL REQUREMENTS

The issue of retention and discharges of sewage waste water from ships, equipment and certification of ships, are governed by international rules and regulations, and rules and regulations of certain coastal states. From equipment monitoring sewage discharges vessels must be equipped with one of the following sewage treatment units:

[5] Quantity of oxygen that organic substance uses for its metabolism during five days.

[6] Bacteria whose numbers are generally used to show the presence of sewage substance and microorganisms that can harm human. Coliform bacteria is the family that live in human intestines. Number of coliform bacteria is easily determined in laboratory tests, on the basis of what can be known how many fecal waste is present in the wastewater.

[7] geometric means of concentrations of suspended solids in wastewater determined on 40 samples. It is measured by filtration of the sample through a previously weighed asbestos tiles, that is then dried and weighed again. Suspended particles are usually invisible, and eventually can cause siltation.

- Equipment for processing sewage of this type approved by the Administration that they comply with the standards and test methods elaborated by IMO.
- The system for macerating and disinfection approved by the Administration and shall be equipped with means for storing sewage waste water when the ship was closer than 3 nautical miles from the nearest land, or
- Sewage wastewater storage tank for sewage water, capacity to the satisfaction of the Board, for the retention of all sewage and must have the means for indicating the amount contained in the tank.

If the vessel has a sewage treatment device, then the standards for the quality of effluent from the device are aplied, which can be seen from Table 1.

Table 1. Demanding purity of effluent from sewage treatment unit according to MARPOL Annex IV

INSTALLED EQUIPMENT	COLIFORM BACTERIA QUANTITY / 100 ML	SUSPENDED SOLIDS QUANTITY MG/L	BIOCHEMICAL OXYGEN DEMAND IN 5 DAYS (BOD5) MG/L	PH
For devices installed prior January 1st 2010.	250	50 (100)*	50	---
For devices installed after The 1st January 2010.	100	35	25 Chemical Oxygen Demand - 125	6,0 - 8,5

Note: * 50 mg / l if the device is tested on land, 100 mg / l if the device is tested onboard
Source: (elaborated by author)

The states of the European Union are signatories of the MARPOL Convention, therefore the provisions and limitations on discharges of sewage wastewater from a boats are applied. (Ćorić at al 2008)
The Republic of Croatia is a party to of MARPOL Convention. In addition to of MARPOL, the problem of protecting the sea from discharges of sewage wastewater to the sea in Republic of Croatia, has regulated with a series of laws and regulations such as:
• **Maritime Code** (Pomorski Zakonik)**,**
• **Law on Environmental Protection** (Zakon o zaštiti okoliša),
• **Regulations on the Protection of the marine environment in a protected ecological and fishing zone of the Croatia** (Pravilnik o zaštiti morskog okoliša u zaštićenom ekološko-ribolovnom pojasu Republike Hrvatske)
Croatian Register of Shipping (CRS) its rules for the construction and supervision of ships, like all other class societies, based on the provisions of the Convention and the IMO Resolutions, (the MARPOL and SOLAS). Thus, equipment, devices and certificates for treating sewage wastewater must be in accordance with the MARPOL Convention. CRS require another limitation for chlorine. Namely, if for disinfecting sewage wastewater or effluent using chlorine, free chlorine content in effluent that is discharged into the sea can not exceed 0,5 mg/*l*.

3. MATERIALS AND METHODS - SEWAGE TREATMENT UNITS ON A VESSELS

Marine systems and equipment for processing and treating sewage, should be simple, small, reliable and not too expensive. Also, the system should meet the quality standards of discharged effluent after device, according to international regulations. What kind of system for sewage treatment will be installed on a ship depends on many factors such as: number of persons residing on board, their retention time, the area of sailing, the time of the ship in port and during navigation, the quality (purity) of effluent, i.e. standards to meet the effluent.
Smaller yachts and pleasure boats are usually not equped with sewage treatment unit, but having a collection tank for sewage water, which contents can be pump out directly into the sea or through the pump-mill for grinding while sailing on the permissible distance from the coast.
Commercial ships with a standard number of crew (persons onboard) of twenty persons, usually have smaller biological-chemical devices, which does not hold sewage water, than treated water (effluent) is discharged immediately, and it can be said to have flow-through type. The quality and purity of the discharge meets the requirements of MARPOL's Annex IV.
Passenger ships - ferries, have a complex device for sewage treatment and sewage collection tanks. Depending on the area of navigation, the collection tanks collect and hold sewage wastewater until it is pumped from tank directly overboard when the ship is in an area where such discharges are allowed. Or, if such ships can not be far enough from shore, that such discharges can not be applied directly, then it uses the sewage treatment devices for the treatment of sewage wastewater.

Passenger cruise ships (cruisers) have the largest number of people on board, so the production of sewage waste water is of the highest compared to other ships. Because of that, these ships are equipped with the most complex sewage treatment plants systems, that can meet much higher requirements than are the requirements of international legal legislation. Beside of a sewage water treatment system have a system for the disposal of sewage sludge, but also a number of tanks for collecting sewage waste water and tanks for storage of processed (purified) sewage water. Sewage wastewater treatment includes a series of operations and procedures in order to remove from water different floating substances, suspended solids, dissolved substances, or substances that change properties of waste water. (Bupić and Milić 1998.) Sewage waste water treatment process means reduction of those pollutants to the quantity or concentration that treated sewage discharged into natural aquatic systems, they become not harmful to human health and life and do not cause unwanted changes in the environment.

4. RESULTS AND DISCISSION

Sewage water can be treated on three basic principles: mechanical, chemical and biological. Treating sewage waters in practice is usually a combination of these basic principles, such as mechanical and chemical, mechanical and biological, and chemical biological.

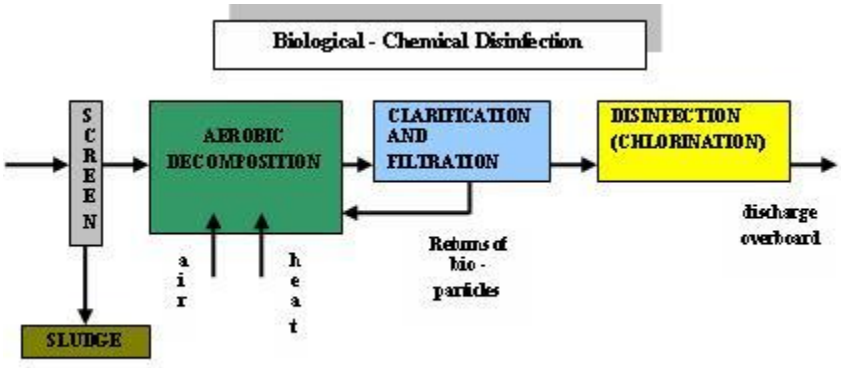
Treatment of sewage water on the ships include the following processes:

1. collection and management of sewage water
2. Pre-treatment of wastewater
3. oxidation of wastewaters
4. clarification and filtration of waste water
5. disinfecting wastewater
6. treatment and disposal of sludge

Pre-treatment of wastewater protects the following stages of purification. Sewage contain enough solids and grease that can cause problems in later stages of the process. Pre-treatment reduces the amount of solids in the effluent. Effective pre-treatment reduces the need for oxidation in the later stages of the process. Pre-treatment is a mechanical nature and consists of a filter screens and settling parts. Sewage water first passes through the grinding pump before the entrance to the screen, in order to produce less sediment in that degree of purification.

Biological treatment is a system in which microorganisms use organic impurities from sewage water for their food. There are several types of biological processes, of which is the most common system for treatment with activated sludge, where sewage is mixed with active sludge in the tank with continuous air ventilation. The efficiencies of the process depend on the amount of active biomass and living conditions for bacteria. It is not necessary to add additives to the biological oxidation, and the amount of sediment is small. Disadvantages are the long period of time for starting system and sensitivity to external interference, such as chemicals that get into and destroying bacteria, or bacterial mortality due to lack of oxygen if ventilation is not working.

Figure 1.: Simplified schematics diagram of the biological - chemical treatment of Sewage wastewater and disinfection.

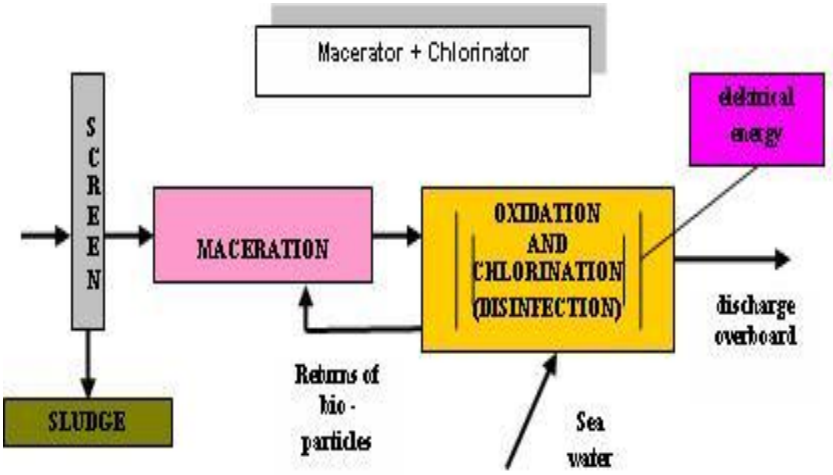


Oxidation is a process where the remaining organic particles after filtration must be oxidized either chemically or biologically. Certain chemicals such as chlorine, hydrogen peroxide, ozone, can be added for oxidization of organic dirt in the sewage water.

Chemical oxidation is used in sewage waters treatment systems with chlorination and maceration. This system reduces the amount of particles by bio-oxidation of, dilute treated water with salt water and disinfecting sewage water with use of electro-catalytic process. Electro-catalytic process produces sodium hypochlorite from seawater, which has disinfecting action to the sewage water. Some operators also add to the chlorine to the contact tank to ensure complete disinfection. This results in excessive high concentration of chlorine in the discharged effluent, which is fatal for marine organisms.

The advantages are the simplicity of the process and the possibility of using sea water for flushing toilets. The disadvantage is that it is necessary to add chemicals or salt tablets if a ship sailing in the area of low salinity of sea water or fresh water rivers and lakes. Water quality at the exit of such systems is not of very high purity.

Figure 2.: Simplified schematics of the processing sewage water from maceration and disinfection by chlorination



Clarification and filtration is the separation of active biomass, sludge particles and bacteria from water, and this is a critical phase of the treatment. After oxidation, sludge is separated in the sedimentation tank and returned to the aeration tank. The process of clarification and filtration, which is used on the ship is a membrane filtration, dissolved air flotation and settling. Flotation of dissolved air system relies on the injection of microscopic air bubbles in the jet of water supply, causing the particles to afloat to the surface of the pool with sloping sedimentation surface, from which surface floating particles are continuously removed along with the wastewater stream.

Disinfection is the last stage in the process of purification and disinfection. Depending on previous methods of wastewater treatment, disinfection is an essential part of the purification process, which ultimately determines the quality of wastewater. When applied clarification and membrane filtration, then disinfecting using ultra-violet light (UV). If waste water is very unclear, the ultra-violet light is not suitable for disinfection. Other potential ways of disinfection been using chlorine radicals and ozone, which can achieve a higher purity of waste water.

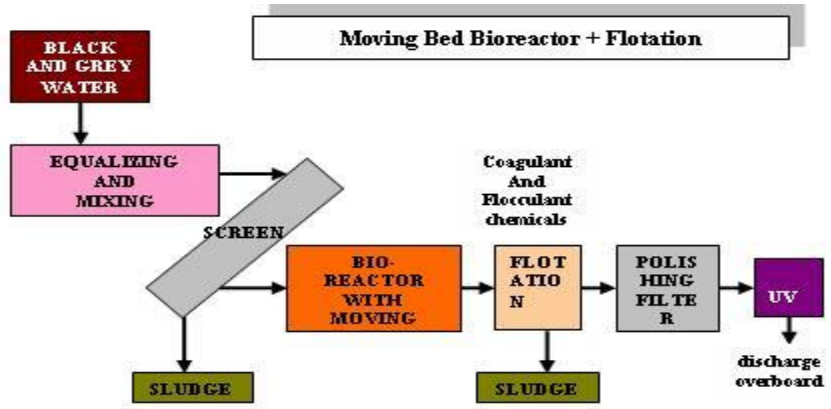
Sludge treatment depends of sewage water treatment process. Effective pre-treatment prior to the bio-reactor reduces sludge production and improves the sludge drying. Sludge that comes from the process, must be treated by centrifuge, dried on the steam, pressed or other treated by alternative processes for sludge in order to achieve sufficiently dry condition to be burned in incinerators.

Advanced Sewage waste water treatment plants

Some of the manufacturers of equipment for processing sewage waste water, have developed advanced equipment for processing sewage waters on ships, which achieve very high quality and purity of the treated water after those devices. Such achieved effluent quality after the device has no restrictions for discharge.

Moving Bed Bioreactor and Flotation.

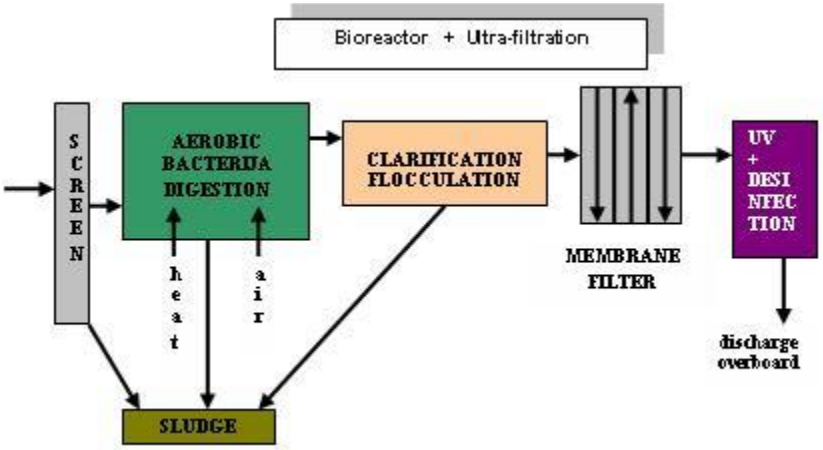
Figure 3.: Simplified schematics of processing sewage waistwater with moving bed bioreactor and flotation (Hanninen and Sassi, 2009.)



Bioreactor with a movable bottom plate contains a plastic surface, which increases the surface area on the which bacteria adhering. In the bioreactor with a movable bottom is not necessary to circulate sludge back into the process of biomass. Sludge is separated after the bio-reactor with flotation or by sedimentation. Separation of sludge requires use of large quantities of chemicals that help flotation or settling (sedimentation). After separation or sludge still has residual particles in the water which must be submitted to fine filtration prior to disinfection. The advantages of such bioreactors are easy to operate and low content of particles and microorganisms in the effluent.

Bioreactor and Ultra-filtration system has improved aerobic decomposition and filtering through a low-pressure membrane filters. Ultraviolet light is used for disinfection of effluent prior to discharge overboard. The system produces a sludge which must be properly handled and disposed it. The major problem is their membrane filter pollution and maintenance. Usually the filters clean with water flow in the reverse direction after a certain period of time.

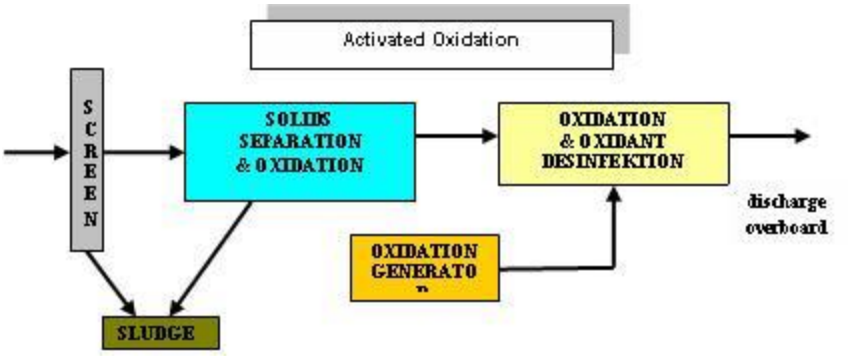
Figure 4.: Simplified schematics of the bio-reactor and ultra-filtration



Activated Oxidation is a process that contains primarily screen, separating the primary particles and oxidizing system, a secondary oxidation tank and device for the generation of oxidation. Due to oxidation, which is produced by electrical means, no need chlorine disinfection. Sludge is removed from the effluent by using polymers.

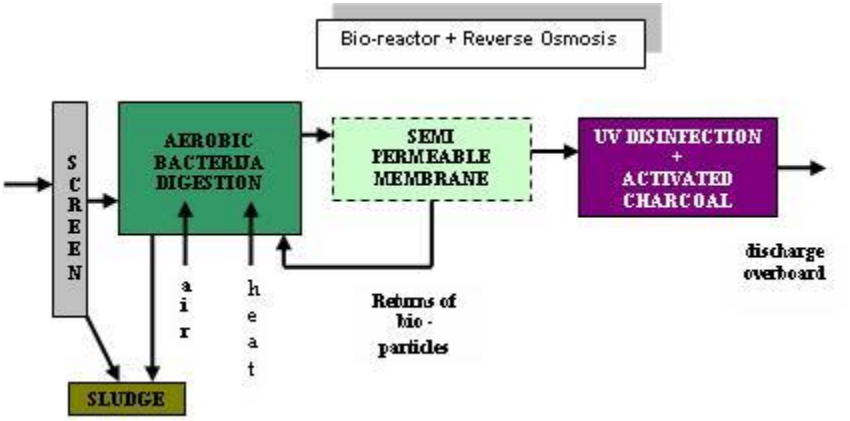
Water can be extracted from the sludge, so that dried sludge can burn in incinerators onboard. The disadvantage is that ozone is produced as a by-product and sludge disposal requirements. This process results in high effluent quality, and is less harmful to marine life because it does not use chlorine and ozone remains disappear quickly.

Figure 5.: Simplified schematics of an activated oxidation



Reverse osmosis filtration is usually used for purification of gray water. After the aerobic bacterial decomposition, gray water passes through a semipermeable membrane in pure water, and after membrane passes ultraviolet light disinfection. Prednost sustava je u proizvodnji ispustne vode visoke kvalitete (čistoće). The advantage of the system is in production of high quality effluent (purity). Disadvantage is maintenance of the filters (membranes), and the necessary disposal of sludge, usually by drying and incineration onboard, or dropping into the sea where it is allowed, or by landing at the shore receiving devices.

Figure 6.: Simplified schematics of bio-reactor and reverse osmosis



5. CONCLUSION

Maritime traffic has always influence on the sea and coastline. Negative impacts on marine and coastal environment, created by the routine operations of maritime transport are rising, where a variety of pollution causing losses in natural habitats, and the economy of coastal areas. Regardless of whether the various pollution caused by accidents or it is result of ordinary operations, always have a negative impact on the ecosystem. Aware of these facts, the international community was forced to engage in a demanding and difficult job of the legal regulation of these issues in order to adequately protect the marine environment, human health, which is also often threatened by pollution due to sewage and wastewater.

Preventing sea pollution requires the cooperation of the industry and the public sector in which science has to contribute in the understanding and solving problems. Methods for improving and maintaining environmental standards that protect the marine environment, should help the shipping industry, but also for improving and maintaining standards of internationally agreed minimum. In addition to the standards, it is necessary to increase capital investment and insist on the further development of technology. Solutions to reduce pollution must be applied in the terms of execution and control, and achievable in today's technical and technological level of development.

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