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SEWAGE TREATMENT UNITS (STU) IN OFF-SHORE OIL PLATFORMS AND REUSE OF THE TOTAL EFFLUENT.

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Resumo

La reutilización de aguas residuales procedentes de plataformas petrolíferas de alta mar es importante para prevenir la contaminación del medio ambiente merino, dado que la descarga de éstas al mar termina. Además, esta reutilización ayuda a preservar las fuentes de agua dulce y también a reducir los costes de transporte de la misma. Existen diferentes unidades de tratamiento de aguas residuales, siendo las más comúnmente utilizadas las biológicas y las electrolíticas.

Abstract

The reuse of sewage from off-shore oil platforms is important to prevent the contamination of the marine environment because the discharge of effluent into the sea finishes. Furthermore, this reuse helps to preserve fresh water sources and also to reduce the transportation costs of it. There are different sewage treatment units and the most commonly used are biological and electrolytic.

1. Introduction

Off-shore oil platforms use seawater and fresh water for their daily activities. The seawater is used mainly for cooling and flushing toilets. Fresh water is used for bathing, washing clothes, preparing meals, washing dishes and pots and preparation of the drilling fluid. An off-shore oil platform that has on average 120 people on board, uses about 30 m3 of fresh water per day which is all sent to the STU.

2. Sewage Treatment In Offshore Platforms

The sewage treatment systems on offshore platforms treat both gray water (bath water, washing hands, clothes and galley utensils), and black water (water from toilets and urinals flushing). After proper treatment of sewage, the effluent can be discharged into the sea, once meets the local legal requirements. The legislation in all countries describes the various aspects related to the form of sewage treatment on the platforms and vessels and the limits of the concentrations of substances that may be present in the effluent. The sewage treatment units most commonly used are biological and electrolytic.

3. Electrolytic Sewage Treatment

The electrolytic units operate based on the generation of sodium hypochlorite using the seawater electrolysis. The sea water mixed with the affluent is nothing more than a dilution of sewage. This dilution reaches 100% of the affluent volume because this process uses an amount of sea water approximately equal to the affluent volume.

The chlorine as sodium hypochlorite generated in the electrolytic cell is mixed with the affluent to oxidize the organic matter [1]. The drawback of the generation of chlorine is its high concentration in the unit outlet. The available chlorine concentration in hypochlorite solutions produced by electrolytic systems is in the range of 1000 to 2500 ppm [2].The RAN (Royal Australian Navy) condemned the use of electrolytic units due to this problem [3]. According to the report of the RAN, the electrolytic units produce effluents with an average residual chlorine concentration of 50 mg/l. Trihalomethanes concentrations were around 0.1 to 0.2 mg/l and the total organohalide concentration was estimated to be up to 2.3 mg/l. At these levels, electrolytic units effluents can be expected to cause localized disturbances due to high residual chlorine levels. However, rapid dilution will significantly reduce this disturbance. The trihalomethanes and other organohalides produced will add to the load of organohalides already present in the marine environment where they will add to a growing environmental problem. The exact extent of this impact is difficult to predict but the political and regulatory pressure on chlorine use and discharge is expected to increase worldwide.

De-chlorination to a 0-chlorine residual must be carried out before chlorinated water is dumped so it will not destroy the existing marine ecological systems. There is a way to reduce the chlorine concentration in the electrolytic units, but must be added a complementary treatment called dechlorination.

The dechlorination unit uses a mixture of food grade sodium sulfite and seawater to effectively remove the chlorine produced by the electrolytic process, before the effluent is discharged to sea. This option is required when the effluent discharge cannot contain chlorine or the effluent discharge point is into sensitive waters. This option provides the user with an off-skid mixing tank and dechlorination control panel. This system automatically injects a measured amount of sodium sulfite into the effluent discharge line. To satisfy this option it is necessary to purchase a drain pump, a mixing tank and a control panel. Furthermore, it is necessary to monitor more frequently by an operator the concentrations of chlorine output, besides the purchase of chemical that can not be absent and an extra consumption of electricity.

The cost of a dechlorination system is about US$ 75,000.00 which has a capacity of treating 28,390 liters/day.

The electrolytic units have high maintenance costs (mainly the replacement of the cells, which have no guarantee) and its operational complexity which depends on factors that can not always be met, compromising the stability of its operation.

The dilution of the sewage effluent is made by electrolytic units is contrary to the Brazilian legislation that considers this dilution illegal as can be seen in CONAMA Resolution 357 Article 30 which says the following: "In the conditions control of release, it is forbidden to dilution purposes before its release, the mixture of effluent with water of better quality, such as water supply, sea and open cooling systems without recirculation."

In the reaction of the generation of sodium hypochlorite in the electrolytic cells is produced hydrogen as a byproduct at a rate of 0.35 m3/kg of chlorine as the following equation:

$$NaCl + H_2O + 2e \rightarrow H_2 + NaClO$$

or

Salt + Water + Electricity = Hydrogen + Sodium Hypochlorite.

The hydrogen is produced at the cathode of the electrolytic cell and is transported to the tank with hypochlorite. Hydrogen is not saturated with water such as air, so it is easily detached and it is one of the lighter gases and with high risks of fire and explosion. Hydrogen has a wide range of explosion of 4-75%.

Hydrogen production requires dilution with air to reduce its concentration. For this, the electrolytic units using the air compressor from platforms. Unfortunately, it may have malfunction of the compressor or the air injection valve, avoiding sufficient air from reaching the gas to perform the necessary dilution, allowing increased concentration of hydrogen and an imminent risk of fire and explosion if the hydrogen inside reaches its explosive range and an ignition sources on the platform.

Another important aspect is that the effluent contains a high concentration of chloride ions, sodium, calcium and magnesium which prevents its use for certain purposes.

There is another type of sewage treatment plant which uses hypochlorite as well, but does not make the electrolysis of the seawater. These units mix sodium hypochlorite ready directly into a affluent of STU with the same goals of electrolytic units.

4. Biological Sewage Treatment

For over a century, the technology of biological treatment of sewage is a much used worldwide, both on land and on ships and platforms. We can divide the units of biological sewage treatment platforms in two types: with and without sludge return. The units which return sludge have a aeration tank, a tank of clarification, a disinfection tank, a blower, a chlorinator and a disposal bomb. In units with return sludge, this is done by air lifting systems, releasing the excess sludge from the clarification tank in the first tank (aeration tank). In a clarification tank biological film is formed by retaining the particles in suspension. After this stage, the treated sewage is sent to the chlorination. After the effluent has been chlorinated, it is sent directed to the disinfection tank, where it remains there for the time necessary to increase the effectiveness of chlorination. Then the effluent is discharged at sea.

The biological units without sludge return are the most effective and do not have the limitations that the previous unit does. It is composed of the following parts:

a) Aeration tank, the tank also called Media, where the microbiota adheres to it and makes the biological degradation of sewage;

b) A blower that supplies oxygen sufficient to maintain the microorganisms under aerobic conditions, generating only CO2, water and small amounts of biomass;

c) A chlorinator that doses the amount of chlorine needed to minimize the concentration of microorganisms in the water;

d) A disinfection tank to provide a greater contact time of chlorine with the effluent;

e) A disposal pump of effluent that turns on every time the level of the contact tank reaches the limit fixed in the project [4].

In these units, the lowest acquisition costs, effectiveness, high removal rates of BOD (Biological Oxygen Demand) and TSS (Total Suspended Solids), operational simplicity, high reliability for continuous operation and the generation of a stable effluent and according to USCG and IMO requirements make them preferred for recycling work, which it is the target of this work. Moreover, maintenance costs are negligible. The STU that uses this biological treatment has removal rates equal or higher than 85% reaching a BOD of 30 mg / L and TSS of 30 mg / L. This facilitates the post-treatment of the effluent.

In this paper, we consider only the biological treatment plants without sludge return for being the only one that guarantee continued operation with minimal human interference and have no limitations as the electrolyte units have regarding high concentrations of chloride ions (19.841 ppm) , sodium (11.035 ppm), calcium (418 ppm) and magnesium (1.330 ppm).

5. Water Transportation

One of the main reasons for hiring tugs (supply boats) by platforms is to provide fresh water. Fresh water is transported by tugs (supply boats), traveling regularly to take it up the platforms. The water supply for the platforms is so critical that on some occasions, they have had to stop drilling the well due to logistical problems that causes the lack of water for the production of drilling fluid. Bad weather is one of the reasons that preclude the tug (supply boat) to sail, and thus, to discharge water in the platform.

A supply boat cost 30,000 to 120,000 U.S. dollars per day, depending on the type of vessel. Whereas each supply boat has many different uses and many of them are used for various platforms, we can say that, on average, each platform would need one supply boat exclusively for its use.

When the water landing on the platform it takes approximately three hours and two people are dedicated exclusively to this task. The time spent in this operation during one year is equivalent to the work of one person for 26 days (12 hours / day).

With the reuse of effluent water this time could be used for other tasks.

The frequency of the supply boat trip to bring water to the platform is on average once a week but can get up to three times when the drilling fluid is producing at maximum capacity. In an offshore oil rig, the largest volumes of freshwater are used in the preparation of drilling fluids.

6. Water Based Mud

Water is the main component of the drilling fluid water based and it is also present in the fluid organic base. Historically, the drilling industry has used primarily water-based muds (WBMs) because they are inexpensive. The used mud and cuttings from wells drilled with WBMs can be readily disposed of onsite at most onshore locations. WBMs and cuttings can also be discharged from platforms in many U.S. offshore waters, as long as they meet current effluent limitations guidelines, discharge standards, and other permit limits. WBMs do not present environmental problems for organisms living in the water column or widespread problems for organisms living on the sea floor.

The water supply for the preparation of the drilling fluid is considered the highest priority among the activities carried out on a platform. In other words, the need for water is highly critical.

To drill an oil well, besides the specific equipment, it is used a drilling fluid which is a mixture of clay, chemical additives, water, etc. They are injected into the well by pumps. The main objectives of the use of drilling fluid are:

1. Providing hydrostatic pressure to prevent formation fluids from entering into the well bore;
2. Carrying out drill cuttings and suspending the drill cuttings while drilling is paused and when the drilling assembly is brought in and out of the hole.
3. Maintain the mechanical stability of the well;
4. Keeping the drill bit cool and clean during drilling;
5. Transmit force to the hydraulic drill;
6. To limit corrosion.

Although there are drilling fluids which use sea water, the drilling fluid using fresh water is the most used. For using sea water in WBMs, it is necessary to apply chemicals in the water to neutralize undesirable ions as calcium, magnesium, etc. This chemical application increases the drilling final costs.

7. Reuse Of Sewage Effluent

Due to high transportation costs of fresh water and the difficulties inherent in this activity, we brought about a form of using the total effluent of the sewage treatment system in offshore platforms (black and gray water). The effluent in the biological treatment plants for sewage contains a low concentration of TSS, BOD and COD. The disinfection with hypochlorite tablets made destroys fecal coliforms, but there are still some microorganisms resistant to chlorine [5], which must undergo further treatment to be eliminated allowing the effluent being used without any risk of biological contamination, as the organic base drilling fluids are biodegradable.

8. How To Avoid Microorganisms

Ozone is a highly oxidizing agent that has the ability to eliminate any microorganisms in the water. Ozone is widely used in Europe in order to destroy microorganisms in drinking water before consumption. This treatment will provide further reduction in BOD, TSS and COD.

To meet the technical requirements of recycled water coming from the effluent is further recommended to use a system for filtering and an ozone system for sterilization, since certain biological contaminants are resistant to chlorination, which is used in sewage treatment plants, but not to ozone. These microorganisms should be eliminated, since the drilling fluid organic base is biodegradable. The use of ozone will reduce the consumption of biocide applied to kill microorganisms in the water used for drilling.

9. Deozonization

When installing the ozone disinfection systems it is necessary to use a process of deozonization to prevent ozone escaping into the environment [6]. The deozonization can be achieved by installing a UV lamp dimensioned for this purpose.

The amount of water/day required for producing drilling fluid is variable. So, the reuse of effluent will have three different situations, as follows:

a) If the well needs less water than disposed in the effluent of the STU, the platform may store the water for later use.

b) If consumption is equal to the effluent, the platform does not need to be supplied by tugs.

c) If the drilling operation needs more water than the effluent, the platform will use only additional water that comes from the industrial water tank, thus reducing yet the need of supply.

10. Advantages Of Reusing Effluent

The main advantages of the effluent recycling system for the preparation of the drilling fluid are:

1. Reduce the need of water transportation by supply boats.
2. Do not dispose of any effluent into the sea.
3. Do not depend on weather conditions to have a water supply.
4. Do not run the risk of stopping the drilling process for delay or impossibility of transporting water by supply boats.
5. Minimize the risk of biological contamination of the organic base fluid.
6. Use the time saved in downloads of water for other activities.
7. The use of water from the effluent represents a savings of approximately 30 m3/day of water in an offshore platform with up to 120 people. In other words, 900 m3/month.
8. Significant reduction in transportation costs of fresh water.

11. Calculating Water Economy

Based on the reuse of 210m3/week (30 m3/day) of the effluent water and that this will provide a reduction of one trip of supply boat each week, we have an annual savings of approximately US$ 4,000,000.00, if the platform uses supply boat which costs from US$ 30,000.00/day to US$ 120,000.00/day.

We can also use the following mathematical formula to find the annual savings with the reuse of water from sewage treatment plant:

$$\text{Annual savings} = \frac{(Ve \times 365)}{VSB} \times Csb$$

Where:

Ve = volume of effluent per day in m3

Csb = Cost of the boat that carries water supply in dollars

VSB = volume transported by supply boat in m3

The investment in design and installation of the reuse of water vary between U.S$ 250,000.00 to $ 600,000.00 approximately, depending on the present sewage treatment unit, the number of people on board, the necessary adjustments to your implantation, etc.. The return of capital is between 1-3 months, or more precisely according to the formula:

$$\text{Pay Back 1} = \frac{250.000}{(V_e \times C_{sb})/ V_{sb}} \qquad \text{Pay Back 2} = \frac{600.000}{V_e \times C_{sb}) / V_{sb}}$$

Pay Back 1 for those who already have biological unit and Pay Back 2 for those who do not have a biological unit.

The preservation of the environment has been a primary goal of humanity and reuse of sewage effluent from the platform will prevent contamination of the marine environment, since there will be no further discharge of effluent into the sea. On the other hand will provide a significant preservation of fresh water sources and will bring a high reduction in transportation costs of fresh water.

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