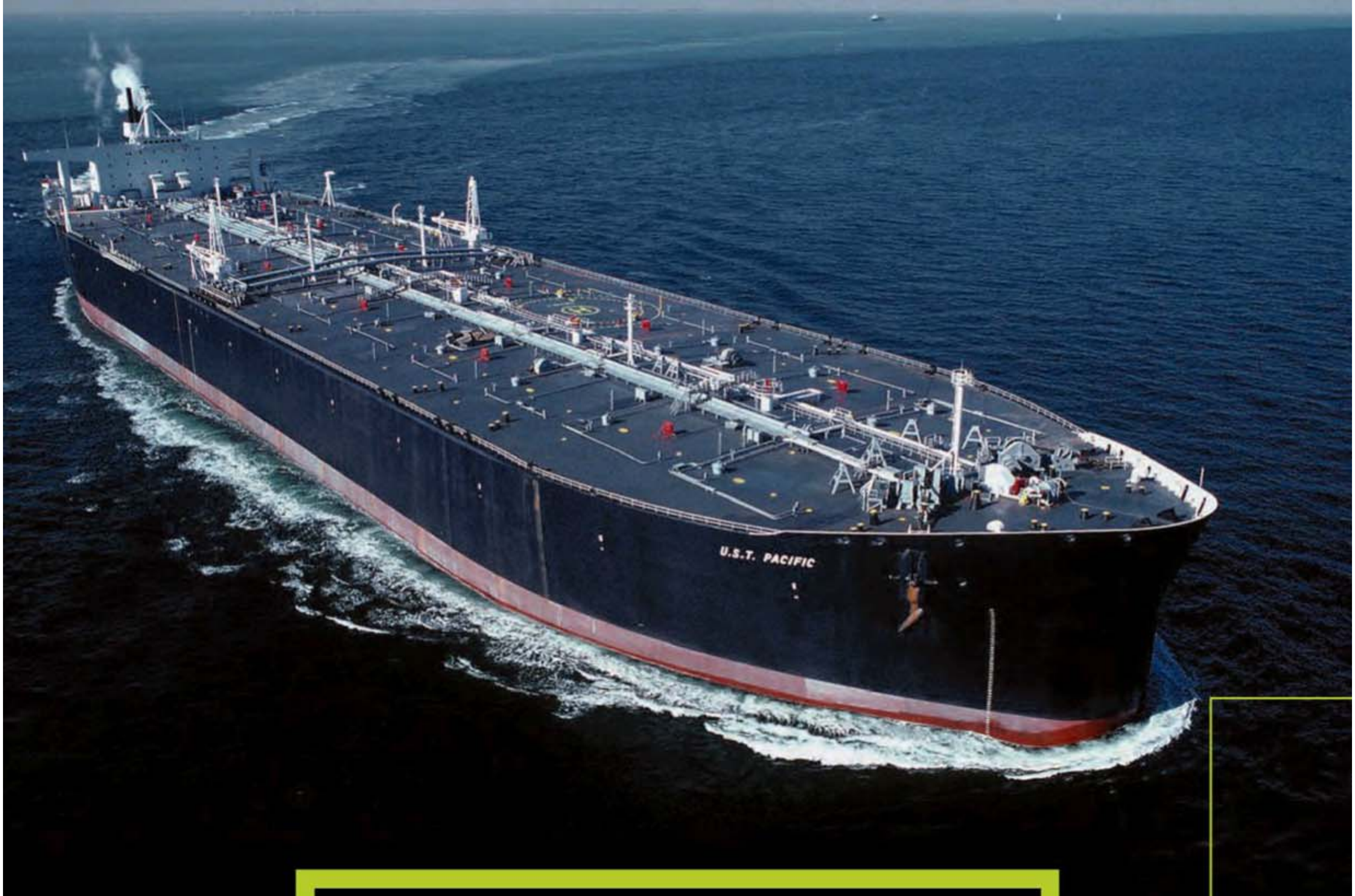

THE RIGHT MIX

The supertanker UST *Pacific*, built in 1979 at Newport News Shipbuilding, is equipped with a FAST model 40D4 treatment system.

Material and equipment are key in meeting practical and regulatory sewage treatment requirements

BY ALAN FLEISCHER

When it comes to marine sewage treatment, a lot has changed over the past several decades. At the same time, a lot has not changed—the underlying microbiology of sewage treatment, for example.

In 1973, St. Louis Ship Division of Pott Industries occupied the same ground on which James Eads built ironclads for the Union Navy during the American Civil War. We were our own guinea pigs, installing and monitoring equipment on our own towboats, then equipping those of our towboat customers and gradually expanding into other classes of vessels and offshore structures. We have experience with sewage treatment for more than 2,000 commercial marine and offshore systems, and more than 40,000 land systems. These range in capacity from harbor tugs to cruise ships, and from single homes to small cities.

We have provided sewage treatment systems over the years for cruise ships, naval vessels, and some private yachts. However, our major interest and experience have been in workboats, other commercial vessels and offshore structures—those applications without large engineering departments or highly trained operators.

Before 33CFR159, there were no uniform federal standards for marine sewage treatment. Individual states applied their own regulations.

Between St. Paul, Minnesota and St. Louis, Missouri there were (and still are) 27 locks and dams on the Mississippi River. State rangers enforced "no discharge" regulations by going onboard towboats transiting these locks and verifying that overboard discharge valves were chained and locked in the closed position. During the grain harvest, this presented a real problem, as no pumpout facilities were available for the length of the Mississippi River. Our FAST treatment system originally was developed to permit multiple recycling of sanitary water to flush toilets so that the vessels could operate "no discharge" for up to three months at a time.

When the vessels came down below lock and dam 27 at the Chain of Rocks, they could pump out their holding tanks into the Mississippi.

The prototype system was installed aboard the Federal Barge Lines towboat M/V *Missouri* in 1969. It was successful and was followed by commercialization.

The Water Pollution Control Act of 1970 (amended in 1972) authorized the Environmental Protection Agency (EPA) to develop standards for marine sewage treatment, and the United States Coast Guard (USCG) to promulgate regulations. EPA originally specified no discharge on the basis that the required technology for marine sewage treatment was not sufficiently developed.

In 1975, the USCG issued 33CFR159, insisting upon "flow through" treatment on the basis that commercial competition would be the spur for industry to develop the required technology. Unlike land regulations, only human waste was regulated and graywater could be discharged without treatment.

Type Certifications

Unlike land regulations that require periodic testing to verify performance, 33CFR159 provided "type certifications." That is, once a system had passed a ten-day test and was otherwise qualified for this use, no further sampling of effluent was required. A similar ten-day test and type certification applied to MARPOL regulations.

To the author's knowledge, the ten-day test period was based upon the time required for a vessel in international trade to enter territorial waters, offload and/or take on cargo, and leave territorial waters. The vessel could then pump out holding tanks or treatment units. This, of course, did not address the situation of vessels operating for longer periods in territorial waters such as the Great Lakes, Great Rivers, or Intercoastal Waterway. A unit therefore could be designed and certified to operate for a ten-day period and then be placed in continuous service without violating 33CFR159.

Just as had been envisaged by USCG, competition was and has been fierce. Manufacturers marketed and still market units that meet the minimum requirements of the ten-day test. This, unfortunately, has created a misunderstanding that persists to this day. Some vessel operators sample effluent even though not required by 33CFR159 and have difficulty understanding why their measured results might not be within the limits specified in the regulation. The reason, of course, is that a unit will have some solids storage ability so that these solids do not enter the effluent during a ten-day test period. But, with the vessel and sewage treatment system in continuous operation, the storage volume is not sufficient to maintain the effluent quality.

A larger unit can be employed, one with significant sludge storage capability. But, this requires additional cost, size, weight, and provisions for separate sludge disposal.

In 1977, Canada issued regulations for vessels on the Canadian Great Lakes. In some ways, these represented a maximum interpretation of the then current MARPOL regulations—they required continuous monitoring of effluent chlorine residual. Under subsequent revisions to the Canada Shipping Act, Transport Canada now accepts MEPC.159(55) certification as evidence of compliance with Canadian rules.

MEPC.159(55) and NVIC 1-09

MEPC.159(55) tightened the earlier effluent requirements for five-day biochemical oxygen demand (BOD5), total suspended solids (TSS), fecal coliform, and residual chlorine. As was the case with 33CFR159, it superseded previous standards and was also a type approval.

Because the United States had not ratified Annex IV of MARPOL, USCG issued Navigation and Vessel Inspection Circular No. 1-09 as a means for U.S. vessels to comply with MEPC.159(55) and for U.S. manufacturers to obtain certifications for sewage treatment systems from USCG.

In some respects, NVIC 1-09 is more stringent than MEPC.159(55) and some manufacturers who had previously obtained MEPC certification from classification societies found that their certifications did not meet USCG requirements. However, 33CFR159 remains in effect for vessels in U.S. waters.

In general, sewage treatment accelerates the natural process whereby biodegradable wastes are oxidized and returned to their state in nature before human use.

It is worth noting that MEPC.159(55) and NVIC 1-09 are written for vessels. But, it is common for offshore operators to specify these requirements for fixed platforms, possibly because compliance with NVIC 1-09 implies compliance with the associated electrical, piping, safety, and structural requirements. However, the marine regulations do not address the very important question of sludge disposal to maintain the specified effluent quality. A fixed platform cannot simply pump its tanks at sea after leaving territorial waters.

Currently, USCG considers graywater to be sewage for vessels operating on the Great Lakes. Otherwise, the legal definition of sewage comprises human body waste in 33CFR159 with the addition of wastewater from medical dispensaries in MARPOL regulations.

Most of the vessels we deal with are not passenger ships. They are equipped with marine sanitation devices certified under 33CFR159 and are therefore not subject to this requirement. However, passenger vessels are subject to VGP 2013 and the requirements are comparable to, and are in fact a bit stricter than, those for MEPC.159(55).

MEPC.227(64) and dilution

Scheduled to take effect in 2016, MEPC.227(64) addresses issues specific to passenger ships and vessels operating in the Baltic Sea. Of particular interest is the fact that it addresses the use of dilution in meeting certification testing requirements. A number of certified units do just that—use dilution to achieve the effluent concentrations required to pass the test. The extra water may ostensibly be intended to backflush filters or to produce chlorine by electrolysis.

However, we call them "cheater" units because they really don't remove the contaminants from the wastewater and as a result, they can be very compact and light in weight. There is nothing inherently wrong with using additional water in a process, but the added water should be accounted for in evaluating the test results. Such a provision is incorporated in U.S. EPA standards for industrial wastewater. It just never made it into USCG or MEPC test requirements.

Graywater

Adding graywater to blackwater substantially increases both organic and hydraulic loading for any given number of persons and also introduces other concerns regarding application and operation of the sewage treatment system. The increased loading can be handled, of course. But one area requires special

SUMMARY OF MARINE REQUIREMENTS						
Regulation	BOD5 (mg/l)	COD (mg/l)	TSS (mg/l)	Fecal Coliform (MPN/100 ml)	Residual Chlorine (mg/l)	Test Duration Days
33CFR159	n/a	n/a	150	200	n/a	10
Canadian Great Lakes 1977	50	n/a	50	250	0.5	10
MARPOL 73/78	50	n/a	50	250	0.5	10
MEPC.159(55)	25	125	35	100	0.5	10
MEPC.267(64)	25	125	35	100	0.5	10
VGP 2013	30	n/a	30	20	0.01	30
	45	n/a	45	20	0.01	7

Notes:

1. BOD5 is a 5 day biochemical oxygen demand, the amount of oxygen that the effluent will deplete from the receiving waters during a 5 day period.
2. TSS is total suspended solids.
3. MPN/100 ml is the most probable number of coliform bacteria per 100 ml sample.
4. Residual chlorine is total residual chlorine, which includes chloramines in addition to free available chlorine.
5. VGP is the EPA Vessel General Permit Rules 2013.
6. VGP requirements are for testing in service, others apply only to certification testing.

attention and that is the temperature of the wastewater.

The beneficial microorganisms that treat sewage originate in the human body at a temperature of 37°C. Treatment efficiency drops rapidly at temperatures above 37° C. and discharges from laundry and automatic dishwashers can easily cause wastewater temperature to rise well above 37°C. We are aware of one installation with vacuum toilets where the laundry and dishwashers used 90°C. water rendering treatment of the sewage impossible. There is no easy fix and skin coolers or other means may be required to make treatment possible.

It is worth noting that certification testing is normally done at municipal sewage plants where the wastewater is cooled to a typical ground water temperature of 20°C. Certification is therefore no guarantee that the treatment system will actually work onboard the ship.

In the U.S., we are accustomed to in-sink garbage disposal units. But, it is worth noting that graywater as defined in marine sewage treatment does not include ground food waste from the galley. That is covered in Annex V of MARPOL versus Annex IV for sewage. However, if ground food waste is mixed with sewage, then it must be treated to the same standard and the increase in organic loading to the sewage treatment system is out of all proportion to the additional hydraulic loading. It is in fact somewhat greater than the organic loading from the blackwater.

Over the past 40 years, the volume of water required for toilets (water closets) has been significantly reduced and the development of freshwater generators has also been significant. The combined result has been that freshwater can be used instead of seawater for sanitary purposes, and the greatest effect has been reduced corrosion problems with sanitary pressure piping.

The change has had some effect upon sewage treatment processes, but not as much as might be imagined. Reduced volume means greater concentration of contaminants and, to achieve a certain effluent concentration such as 25 mg/l BOD5 for MEPC.159(55), a larger removal percentage is required. However, for a given size bioreactor, the detention time is also increased by the reduction in volume permitting the larger removal percentage to be achieved. That is why aerobic bioreactors are typically rated in terms of applied BOD5 per unit reactor volume, lb/1,000 ft^3.

Terminology and Processes

In general, sewage treatment accelerates the natural process whereby biodegradable wastes are oxidized and returned to their state in nature before human use. In addition to its benefits to public health, treatment of sewage reduces its "oxygen demand" and prevents depletion of much needed oxygen in the receiving body of water. The term generally used to describe this is five-day biochemical oxygen demand (BOD5), the amount of oxygen that the wastewater will deplete from the surrounding water over a five-day period.

Other terms frequently used are chemical oxygen demand (this includes both the biodegradable and the non-biodegradable fractions) and total suspended solids (TSS), an indicator of the turbidity of the water.

Aerobic processes employ microorganisms that thrive only in the presence of

This FAST Model D-4V is a special skid mounted unit manufactured for an offshore oil platform in Mexico. It was designed to provide secondary treatment, chlorination, and dechlorination for blackwater and graywater from up to 73 persons.

oxygen. Aeration maintains a level of dissolved oxygen in the wastewater. Although there is an economic and energy cost associated with aeration, aerobic processes are easier to control than anaerobic processes, produce higher quality effluent, and are more practical for most applications in other respects as well.

Anaerobic processes employ microbes that thrive only in the complete absence of oxygen. Byproducts are organic acids and methane.

Primary treatment is designed to remove gross, suspended, and floating solids from raw sewage.

Secondary treatment removes the dissolved organic matter (soluble BOD5) that escapes primary treatment. It is normally achieved using aerobic processes. Byproducts are carbon dioxide, water, and a residual sludge resulting from less than perfect digestion of the wastewater.

In a suspended growth process, the microbes and sewage solids are submerged and are kept in suspension by the agitation associated with aeration. The contents flow out through a clarifier or sedimentation tank and the clear supernatant can be disinfected and discharged to the sea. The suspended solids settle in the clarifier and are returned to the aeration tank. These increase the concentration of microbes in the aeration tank and accelerate the process. Eventually, however, some of the sludge in the aeration tank must be separately discharged and dealt with to prevent it from being discharged with the effluent.

A membrane bioreactor (MBR) is a variation of the suspended growth process. A membrane prevents suspended solids from escaping the aeration tank and the effluent is typically of very high quality, much better than required by the regulations. Sludge must be separately discharged and dealt with to prevent an excessively high solids concentration from prematurely fouling the membranes. MBRs also can be very compact when other means are available to deal with the resulting sludge.

Fixed growth processes employ microbes growing on fixed surfaces rather

The situation is much more difficult for a fixed platform than for a ship, as the platform doesn't have the opportunity to pump out to a municipal sewer or to open ocean.

than suspended in water and they provide different process characteristics. These microbes include not only aerobes but also anaerobes and facultive microorganisms as well (facultive microorganisms are switch hitters—they can operate with or without oxygen). This more complex biota also includes higher ordered microorganisms, such as sludge worms that predate upon the simpler life forms and substantially reduce the net rate of sludge accumulation.

The fixed film processes produce less sludge, provide faster startup and transient responses, and are relatively unaffected by wide variations in hydraulic and organic loading. That means that they can provide more consistent treatment in the variable marine environment without the intervention of trained operators.

Disinfection

In general, land treatment systems do not employ disinfection unless they are discharging into waterways associated with beaches, boating, fisheries, and so forth. However, marine systems invariably are required to provide disinfection of the effluent, probably because no one knows exactly where the vessel will be at the time of overboard discharge.

The most common method of disinfecting effluent is chlorination. It is widely used because it is simple, economical, and effective. However, chlorine compounds tend to persist in effluent and they are known to be mutagenic and carcinogenic. The chlorine residuals specified in MEPC.159(55) and VGP 2013, 0.5 mg/l and 10 µg/l respectively, are not sufficient to ensure reliable disinfection of the effluent in everyday service. So, if chlorine is used for disinfection, the higher concentrations needed must be removed before discharge.

If the MBR membranes are suitably selected, they will filter out the bacteria measured in the certification test and ultraviolet disinfection can be employed if the optical qualities of the effluent permit.

It would be impossible to ignore improvements in materials and equipment in recent years. However, the underlying processes used to treat the sewage have been around for some time and knowhow is a major consideration in the design of marine treatment systems.

Sludge

Any process capable of providing secondary treatment or meeting the requirements of MEPC.159(55) produces a residual sludge. Theoretically, if all sewage is uniformly biodegradable and doesn't contain any non-biodegradable solids, it should be possible to biologically oxidize all of the organic material to produce carbon dioxide, water, and nothing else.

Unfortunately, different biodegradable materials have different reaction rates, some much slower than others. In addition, marine wastewater in the real world can contain river silt, drilling mud, rust, and so forth. To meet secondary treatment requirements with tanks of reasonable size, something less than 100% removal of biodegradable materials is standard practice. The residual sludge is separated from the effluent, is stored, and is then processed separately.

Now, this is true whether the process collects only secondary sludge or a mixture of primary and secondary sludge. That is, some processes separate primary sludge from the raw sewage before secondary treatment. Others perform secondary treatment on the raw sewage without that pretreatment.

The situation is much more difficult for a fixed platform than for a ship, as the platform doesn't have the opportunity to pump out to a municipal sewer or to open ocean. Recall that this sludge is nothing more or less than digested and partly digested organic material plus some non-biodegradable solids.

There are at least two ways to deal with this sludge. One is denial—simply refusing to admit that any such sludge exists. This can be explained on the basis that it didn't show up during a ten-day certification test. Even in longer periods of operation the amount of sludge produced is really pretty small compared with the main sewage flow. If the unit burps a little bit every once in a while (and it will) and you don't see it at that moment, you can claim that it doesn't exist.

Another way to deal with the sludge is digestion and concentration. Because the volume of sludge produced is so small, it can be subjected to long detention periods in an aerobic digester of reasonable size and further digestion and dewatering will substantially reduce its mass and volume. The remainder can be bagged or incinerated for disposal as solid waste, or incinerated or disposed of as liquid waste. Each approach has advantages and disadvantages. However, one big advantage of dealing with the sludge as a liquid is that it can be contained in tanks and piping so that operators don't have to come into contact with the sewage or sewage sludge. **MT**

Alan Fleischer *is with the Scienco/FAST Division of Bio-Microbics, Inc., a manufacturer of sewage treatment systems and associated product lines.*