

The Marine Sanitation System

Problems, their sources and some simple solutions

This document describes some common problems related to the marine sanitation system, tries to identify the sources and explain the causes behind the problems and finally, gives you some simple solutions. We can emphasize already here at the beginning:

A good maintenance is the key issue for a functioning marine sanitation system.

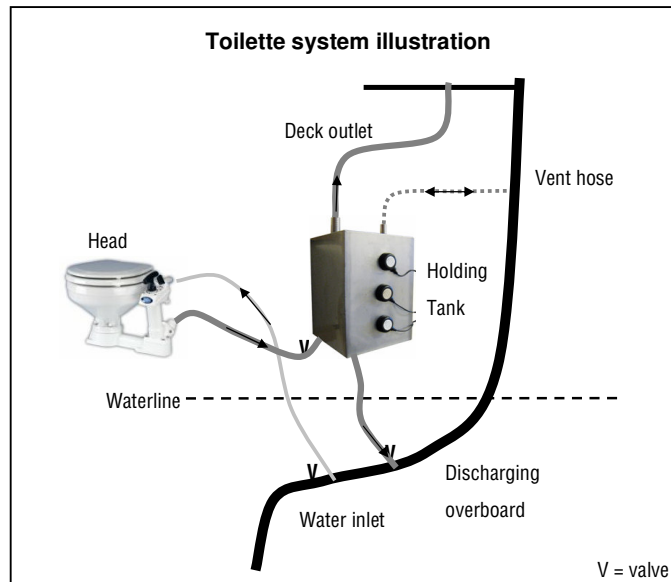


Illustration: Anders Meiton

The holding tank

The tank where the toilet waste is **temporarily** stored is called the holding tank. Tanks are made of plastic, aluminum or stainless steel. The tank volume should be sufficient for the crew to be able to spend several days onboard without emptying the tank. A recommended minimal volume is 40 liter. For systems with vacuum toilets a smaller volume can be used. As an extra environmental friendly approach, you can even connect KSW-water (Kitchen-, Shower- and Washing) to the tank. In this case, a bigger tank volume should be calculated accordingly.



A level indicator on the holding tank gives much comfort and security. No more “accidents” with overflow and awkward odors all over the boat. There are few things which make one so embarrassed and frustrated than a dysfunctional sanitation system or massive odors on the boat...

There are many “invisible processes” ongoing in your holding tank during the temporarily storage of the toilet waste. The holding tank is a “leaving machine” where a febrile bacterial activity and some chemical processes take place; natural processes much like that in a compost or in a wastewater treatment plant. Therefore, the best way to empty your tank is in land. The discharging should be made with a separate pump for this purpose. Discharging in land (in harbors) into special receiving tanks or through docking stations to the local sewer requires a deck outlet for your holding tank.

What is exactly we are flushing down the toilet?

Maybe you already heard about sustainable nutrient recycling or about reusing the nutrients from toilet waste as fertilizer? All this is about the nutrient content of the toilets ending up on a wrong place. Toilet nutrients should not be discharged to *aquatic environments*, because they are causing severe eutrophication there! Nutrients are for plants on land.

The nutrients we are talking about here are: N (nitrogen), P (phosphorus) and K (potassium).

NPK...Do you recognize it? Yes, it is a complex fertilizer used everywhere in agriculture. Of the NPK it is the N and P which is causing the most problems when they end up in our lakes or coastal waters.

Every time we are flushing our toilets the following amounts of nutrients are leaving our body (Ganrot, 2005):

- ca 12-15 g nitrogen (N)
- ca 0,7-1,2 g phosphorus (P)
- ca 90 % of the N and 55 % of the P originates from our urine and the rest is in the faeces

These amounts of nutrients are feeding about 1 kg of algae in the water...

These nutrients are also responsible for many technical and hygienic problems in our marine sanitation system. Why?

To be able to give you the answer to this question, let me guide you first in the biology and chemistry of the toilet waste nutrient compounds.

Urine (pee) is a strong salt solution meaning that urine contains large amounts of Na^+ and Cl^- ions along with considerable amounts of K^+ (potassium), Ca^{2+} (calcium), Mg^{2+} (magnesium), SO_4^{2-} (sulfate), PO_4^{3-} (phosphate), etc. ions. In addition to these abundant ions, urine contains large amounts of urea (ca 25 g/l urine). Urea is a small organic molecule $[\text{CO}(\text{NH}_2)_2]$, which begin to decompose in contact with air and with the help of the enzyme urease (also in urine). Urea decomposition begins already in the toilet head and large amounts of N from urea are released in the urine solution. Ammonium ions (NH_4^+ , called ammonium-N) and carbonate ions (CO_3^{2-}) are the main result of this decomposition. Small amounts of ammonium ions are converted into ammonia (NH_3) which is gas smelling “typical animal manure”. During these processes the pH of the urine is drastically changed from an initial pH of ca 5, 8 to about 9 just after some hours after the toilet flush. This pH change has a big impact on several processes causing technical and hygienic problems in the sanitation system.

Another important ion in urine is the phosphorus which is always in phosphate form (PO_4^{3-}) called phosphate-P. This ion is very sensitive for pH changes in the urine and when the pH increases the phosphate ion easily combines with the existing positive ions in the solution, precipitating as solid salts, like Ca-phosphates, K-phosphate, Mg-phosphates, ammonium-magnesium-phosphate (called struvite), etc.

These salts form a thin layer in the hoses, pipes and on the bottom and the walls of the holding tank. With time, this layer became thicker and thicker, very hard to get rid of.

Summing up, after the urine had left our body a lot of natural processes begin and will change its composition resulting in increasing pH, salt precipitations, odor building and corrosive impact on the sanitation system.

We are also eliminating many other hazardous compounds via urine, like drug residues, hormones and preventive-pill residues. They are passing through the sanitation system without any change ending up in the marine environment. This type of environmental pollution will not be discussed here.

The faeces (poo) contain considerable amounts of phosphate-P. The nitrogen is mainly bound in organic form (not fully digested food), large



amounts of bacteria (from the guts) and partially digested food rests. We are also eliminating metals, heavy metals, pathogens, etc. via faeces.

In the holding tank urine and faeces is mixed together and the N-rich urine became directly available to the bacteria in faeces for further decomposition. Ammonium-N from urine is converted into nitrate (NO_3^-) and nitrite (NO_2^-) by the bacteria. However, bacteria need carbon-rich compounds for survival and the faeces + the toilet paper in the tank are sufficient carbon suppliers.

The bacterial decomposition and N conversion is a very important natural process, is the basis for all type of organic waste or wastewater treatment everywhere.

Odor free decomposition requires air

There are two main ways of bacterial decomposition for organic materials. One, which is odor free, is called *aerobic decomposition*. This process requires “oxygen loving” bacteria and produces carbon dioxide (CO_2) which is an odorless gas, heavier than air. This is the most effective decomposition process in nature and to work successfully, the bacteria need a lot of air. Therefore, it is of crucial importance that the tank ventilation is well functioning! The tank vent hose must be clean, permitting a good air circulation (oxygen rich air in - CO_2 out) to the tank.

Odors from the tank

The other decomposition process is called *anaerobic decomposition* and is due to the “oxygen hateing” bacteria. This process is slow producing very bad smelling gases. This type of decomposition will take over your tank when the ventilation is not functioning. Anaerobic bacteria produce a mixture of different gases (CO_2 , sulfur monoxides and dioxides and methane). Sulfur oxides are nasty smelling gases, methane is odorless, but flammable. We do not want either of them on the boat!

How to secure an odor free system?

Well functioning ventilation is the key for an odor free system for your boat. Check the vent hose often, and if it is clogged try to rinse it.

Today you can buy several types of “solutions-on-can” for the tank treatment:

- So called “bio-active” treatments containing living aerobic bacteria cultures or nitrates you can add to the tank to trigger the aerobic decomposition. They are working well, assuming that you have good

ventilation in your tank. But be aware...if the ventilation is poor or not working, the treatment will have a short effect.

- Different types of chemicals or solutions with enzymes, etc. Generally, without real effect. They are usually perfumed and only camouflage the odors with a more pleasant scent. The effect is short. Chemicals usually contribute to quick precipitation of urine salts and cementing of sludge on the bottom of the tank. Very difficult to remove.

The best solution is a well functioning ventilation of the tank and flushing the toilet as often as possible with drinking water. (About this see later on).

Some words about the toilet paper

We all know that a sparing use of toilet paper is best for a marine sanitation system. However, the quality of the toilet paper has a big significance! Toilet papers which are dissolving slowly can easily clog your system and they are not suitable for use in any marine toilet.

To find out whether any toilet paper is OK for use onboard, make this *simple test* on several types of toilet paper (from Peggy Hall):

- tear off a sheet of paper from a toilet paper roll and put it in a glass of water overnight
- check the glass next morning and stir the glass a little

If you see only fine pieces of paper (looks like snow) or the water is cloudy, then you found your marine toilet paper! If the paper is still intact or mostly intact, it is not suitable for any marine toilet. A very cheap flimsy toilet paper probably is as good as an exclusively labeled “marine” toilet paper (with an exclusive price!).

The head and the raw water pump

The toilet bowl is also called the head. The flushing can be manual or electricity driven. In both cases, the raw water pump takes the flushing water (raw water) directly from the lake or the sea and empties the flush water to the holding tank.

Odors from the head

Toilets that use raw water for flushing and are not rinsed properly from time to time with drinking water have odor problems. Why? The answer is simple: almost everywhere in the industrialized world drinking water is processed water with food grade quality. This water is also used in homes for toilet flushing and our toilets at home are not “smelling bad” even after several days/weeks of usage. For marine toilets we use raw water.

Why is this water so different?

Costal sea water and lake water are full of living organisms, dissolved salts, and suspended particles from sediment and mud. When this raw water passes through the head, particles of salt precipitates and particles of mud or sediment get stuck everywhere in the way in to the toilet and on the interior of the head. Small living organisms (like algae and plankton) also get stuck and begin to decay already in the head. This gives the typical “old, stale” odor of a badly maintained toilet.

How to get rid of the odor from the head

To avoid this problem the best solution is to flush the toilet as often as you can with some drinking water. Yes, this can be a dilemma on a boat, when you need to prioritize between drinking, cooking, washing and flushing the toilet...However, if you want to get rid of the odors from your toilet head, you may consider saving and using some drinking water for flushing from time to time.

If you use your boat only on weekends, a good thing to do is to make the last toilet flush with drinking water, before closing and leaving. From time to time is very good if you can rinse with some white vinegar (ca 1-2 dl). Do not flush after the vinegar. It is important that the vinegar is left in the system until next time you use the toilet.

Deck outlet for sewage discharge inland

From 2004, in Sweden, every new boat with toilet system (holding tank) must have a deck outlet for sewage discharge (with a pump) inland. Moreover, the tank must be equipped with at least one level indicator at $\frac{3}{4}$ -level.

Discharging overboard

You can discharge overboard trough a thru-hull discharge valve or with a discharge pump.

The direct sewage discharge into the water is not prohibited by law in Sweden. Other countries like Denmark, Finland, Germany, USA, etc. have restrictions in this area. Always check the law and the restrictions for those countries which territorial waters you are planning to visit.

For the toilets on sailing boats a water seal is necessary to avoid the siphon effect in the system.

The vent hose



To minimize the pressure in the holding tank and to ventilate odors a vent hose is installed between the tank and the hull above the waterline. Sometimes, on this hose an odor-filter is installed. To maintain well functioning ventilation this filter must be replaced by a new one at least once/season. Using chemicals for odor treatment or odor camouflage is not recommended.

All type of sanitation hose will fail (smell) with time...Even the holding tanks of stainless steel are ageing after some 10-15 years because the corrosive impact of urine during weeks or months of storage. The same is true for the other components of a sanitation system. Be careful when choosing these components. Only high quality components and a good maintenance can guarantee you a long-lasting safety.

Odors from hoses and pipes

To discover the odor source in hoses or pipes is a difficult detective work and not fun at all! Every boat has its unique installation way for the sanitation system because of a constant searching for the best place in the very limited space of a boat.

Generally, shorter and straighter hoses and pipes are the best options for the ventilation and throughput, and of course, against clogging and odors.

However, bad material quality and ageing of hoses is also a source. With time, small hoses will be clogged because of salt precipitation from urine or because of stocked solid waste and toilet paper. Be aware especially for those hose areas where the waste can collect and the water is stagnating (called "low spots"). Too scarce flushing or flushing with too little water is both contributing factors.

How to get rid of odors from hoses and pipes

If you suspect that the odor is coming from "somewhere from the hoses", there is a simple way to detect exactly where. Odors are always strongest at their source and the permeating section of a hose can be identified by:

- clean off the outside the "suspected" section of the hose (to remove any odors which may come from other sources around),
- wet a clean rag in hot water, wring it out and wrap it around the section. When the rag has cooled, remove it and smell it. If the rag smells, then the hose is permeated there. The only solution is to replace the hose with a new one.

Flushing often with drinking water and giving a white vinegar treatment to your toilet from time to time or after a weekend on the sea are not just solutions for the head. These methods are also important protective steps to keep your hoses and pipes free from salt precipitation and clogging.

Other problems related to the toilets...

Pumps getting stiff

The most likely source is salt precipitation in hoses and pipes. When the layer of salts is increasing during longer periods of time, the diameter of hoses and pipes are reduced and you can notice that is “harder to pump”. Another source may be an almost clogged hose or pipe. When the toilet is used sporadically (during weekends) the pump can easily dry. Precipitated salts + a dry pumps makes that when you will use the pump next time, it will be stiff. It needs lubrication...

Solution: Flush several times with drinking water or use the white vinegar treatment as described earlier. Check the lubrication. If the pump is dry, try to lubricate with some drops of cooking oil. Please note: this is an acute fix and not a permanent solution! Cooking oil is easily flushed out into the head and the hose contributing to more sticky surfaces where bits of paper and solid waste will easily trap. The best solution is a real lubrication with thick Teflon based grease as soon as possible. This lubrication will also prolong the life of your pump.

The pump is squeaking

A pump is squeaking when it needs lubrication. The most likely reason for this is a dry pump. Valves can easily get dried and the seals worn away, especially when a boat (toilet) is used only over weekends.

Solution: A real lubrication once per year (when winterizing) with a proper Teflon based grease is the best you can do for prevention and good maintenance. In this way you can avoid a rapid aging and hard wear of the pumps. Again, cooking oil is just an acute fix, hiding squeaking for a moment!

There is stop somewhere in the toilet system

The sources are numerous...It can be any or many of the earlier described ones and the solutions are different, depending on the cause. The most important thing is to not get panic!

Acute solutions:

- Don't force the system! Pumps can break; the holding tank can implode with very nasty consequences, etc.
- Use another, temporary solution as “substituting toilet” until you are capable to make a systematic search for the cause of the failure.
- *If it's possible* (the stop is not at the waste discharging equipment) empty the system overboard or inland.
- A regularly check of the level indicator usually helps to avoid “suddenly” filled tanks or sewage overflow on your boat. Especially in connection with many visitors or parties onboard...
- Check regularly the vent hose and the vent fitting. Keep this clean, rinse if necessary.
- Stiff pumps or squeaking can be fixed with cooking oil and carefully turned in use again.
- If the holding tank is not full, flush the toilet several times with drinking water. If you have white vinegar or citric acid (even a little environmental friendly hand-dishwasher can be used) flush with these several times. Use small amounts at a time and after 30-40 minutes flash again with drinking water. This steps can be repeated several times, but be aware to not cause tank overflow!

Lasting solutions are those which prevent problems and contribute to a good maintenance of the sanitation system:

- annual control of pumps with lubrication, change of permeating hoses, worn seals and, valves, etc.
- to prevent salt precipitation flush with drinking water as much as possible, use some white vinegar from time to time when flushing
- to prevent clogging in hoses and pipes: rinse, choose a proper toilet paper (how to test was described above), flush often and preferably with drinking water, check that the pipes and hoses are installed in a correct way (without “low spots” where waste can collect).

Finally,

Have a good time, enjoy your boat and life out on the sea!

Take care of you and others!



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