

 **enteron** is entering your life

Our fully biological mini wastewater treatment plant for sailing and motor yachts, houseboats and large living and expedition mobiles uses natural digestive processes of microorganisms for the treatment of sewage polluted wastewater. For this purpose, the tract of mammals have been modelled as a centrepiece of our bioreactor - the use of natural processes for industrial processes, known as Bionic, is a new technology to make them more simple and effective.



 **enteron** is a fully automated multi-chamber water treatment plant, which combines the advantages of the activated sludge process with the use of effective microorganisms. These organisms form a bacterial film on a special hose, which provides an increased surface area for the biofilm. The system works like a bowel - the long hose with a corresponding surface and grown bacteria film draws especially the carbon from the wastewater. For this purpose, the bacteria is supplied oxygen from the outside air via a compressed air pump so that the minimum oxygen content of the liquid in the reactor for the survival of the culture is secured.

 **enteron**

Background

Would you have thought that the global computer industry would eventually agree on a data exchange standard? That everyone from schoolchildren to pensioners, even with smartphones and tablets are online at almost any time? That social networks are more important than real friends and their inventors would all be billionaires?

Anyone who would have bet 10 years ago that Germany would be one of the first nations to shut down its nuclear power plants, would at the very least been laughed at. The world is changing, quickly and comprehensively. No matter what your personal opinion is - the changes affect us all and are unstoppable.

When, nearly 15 years ago, I installed the outrageously expensive SUNPOWER photovoltaic modules on my yacht for the first time in order to supply the ship with self-produced energy, I was considered a dreamer. Today, after I have installed many peak kilowatts on yachts of all sizes, solar power has long been standard on long-liners. Today we even produce up to 1.6 kW of renewable energy while sailing. Two years ago, when I introduced "boot", the world's first commercial solar thermal solution for yachts, the doomsday predictions were of the same size; today many bluewater sailors produce hot water in this way and the first shipyard has installed the equipment as standard. Our electric cookers of the e-cooking-series were considered in January 2015 with scepticism - but the success speaks for itself: cooking takes place with self-produced electricity in many yachts, without gas and its dangers. Many of my clients can produce their own energy, convert seawater into drinking water, heating it and cooking with it emission-free and, above all, safely. Thanks to the advent of LED technology on yachts, the energy required for lighting has decreased, but comfort needs such as refrigeration and air conditioning have again increased. Today's sailors are very open to progress and innovative ideas and invest a lot in their self-sufficiency.

Therefore, it is now time to solve one of the last problems of life on board that people do not like to discuss: the disposal of excrement.

While at sea, far away from any coast, the input of faeces is negligible by yachts comfortable and surely has no measurable negative impact on the environment, but near the shore the situation is quite different. But it is precisely here, in beautiful harbours, bays and lagoons that people on long voyages gather. Most yacht enthusiasts are only really on the high seas 10% of the time. Where it is nice, there is something to see and discover, that's where the community is: there is simply no unexplored pristine corners any more - you can reach anywhere nowadays, if you want to. But the country infrastructure at hotspots are not up to this onslaught - some large Mediterranean marinas with thousands of moorings offers only a handful of toilets, often far away and dirty.

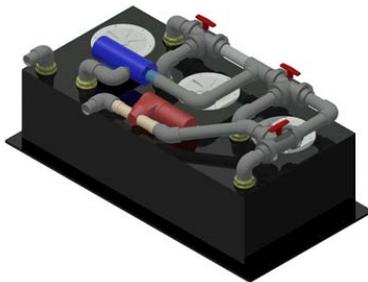
The result is immediately visible in midsummer: a brown, stinking cesspool. Anyone who has ever been to Cala d'Or in the summer knows what I mean. What was at best, still retained in the holding tank during the day, is forced overboard at night. The tanks that are always too small are often full in the evening. Draining, even if a functioning pump was available, would mean dropping anchor, and at worst loss of the berth. Of course, nobody does this.

What could be better than treating the wastewater directly on board ??

Existing wastewater treatment plants for ships are large, energy- and maintenance-intensive and unsuitable for use on a private yacht. There are also the high prices and especially the space requirement. So energy-intensive preparation was not an option as a solution. Looking for a different, simpler method nature came to my rescue: why not try to replicate the natural digestive system? As a mechanical engineer and medical technician I worked on this idea until I found the right solution. Together with students from the Beuth University Berlin, the prototype was built and tested. A bioreactor, simulating the intestines of humans and animals, undertakes the treatment by means of microorganisms, which are based on an enlarged surface. This bacterial culture is specialized in faecal recycling and is held alive by the entry of the faecal matter and by oxygen. Upstream and downstream separation tanks and automatic pumps ensure the disintegration and the prevention of sludge.

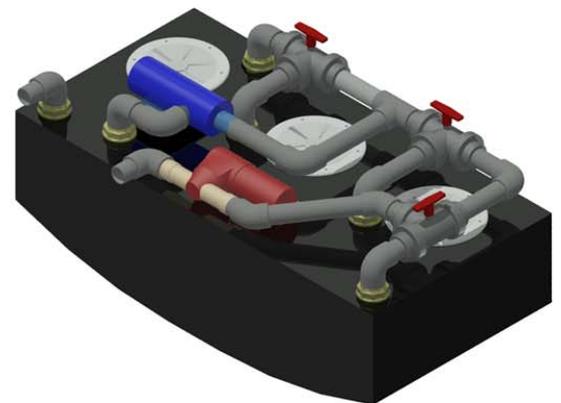
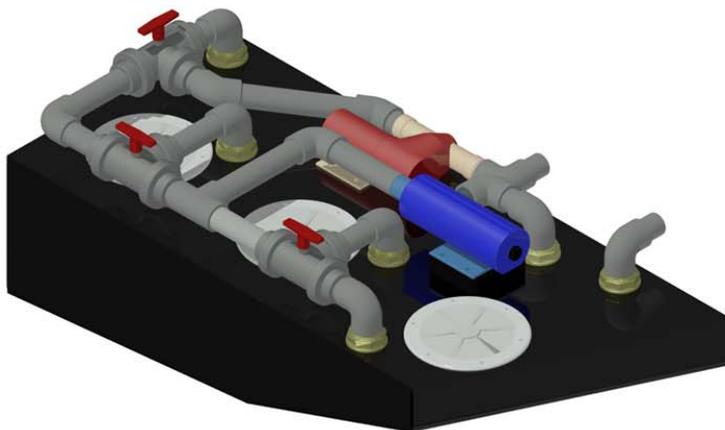
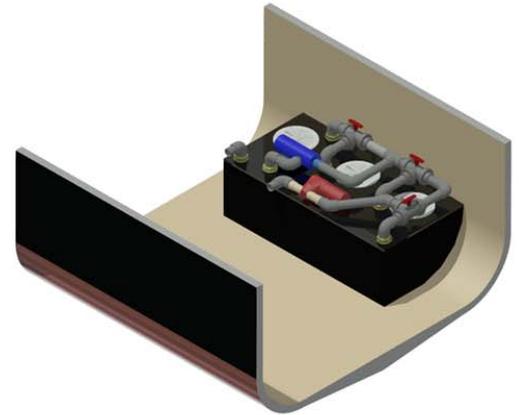
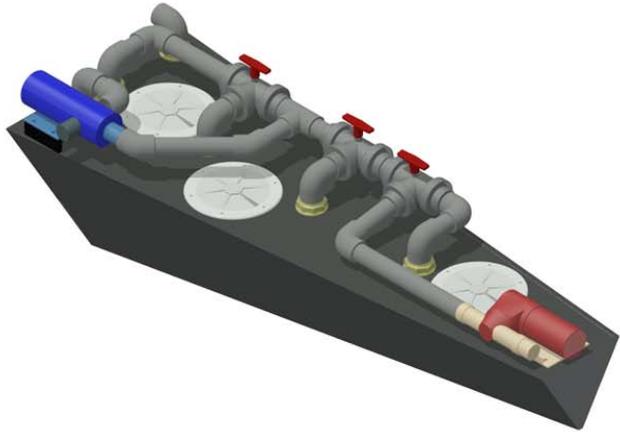
The demand was to build a fully automated, largely maintenance-free, but also energy-efficient and quiet system, ideally not noticed by the user.

Fundamental problems with conventional small systems, such as overloading and underloading as well as seasonal operation, had to be solved. It is not without pride that I am able to present this new technology today; financed and developed entirely privately, which will no doubt ensure some scepticism and discussions, but, on the other hand, finally represents a solution to a well-known problem.



The technique developed by me can be realized in various tank sizes and shapes, so that the space necessary for installation can be provided in the keel area (as ballast replacement), for example, and under bunks and benches. On catamarans, the often empty bow sections can be used.

Variants



Each system consists of a circulation, an oxygen and a drain pump, an activated carbon filter for the vent line, up to three separate tank areas and manual valves for maintenance and decommissioning. A mechanical level sensor monitors the level, and an electronic system (12-24 volts) controls all relevant processes. At night there is a restriction of the system to avoid pump noise. In case of overload (more persons on board), the owner can easily adjust the controller. The function check is carried out visually; the pumping of treated wastewater can take place automatically or manually. The best results can be achieved with electric and vacuum toilets and thin toilet paper.

What is the situation today ??

Effluents on yachts and houseboats should only be discharged untreated into the open sea outside the 12 nautical mile zone. In increasing numbers of sea territories discharging is forbidden (Turkey, Netherlands, Sweden) or there is simply no 12-mile zone without direct contact with the neighbouring country (Baltic Sea). Resulting waste water must be collected in holding tanks and pumped ashore. The tanks used for this are often much too small, especially for



the number of persons on charter boats. Many guests on board are not very familiar with sea toilets and use them as they would on land - too much paper is used and the required flushing creates 8-12 l of wastewater, which completely overwhelms a 40 l waste tank. The pumping ashore is usually impractical, the network of pumping stations too thin. Many pumps do not work.

Many crews therefore dispose their untreated faeces into the sea !!

The odour produced in the tank systems, particularly in the summer are attempted to be suppressed by a variety of chemicals. This only adds more polluted wastewater to the sea. In inland lakes and rivers, discharging is prohibited, meaning that certain houseboats need a functioning wastewater treatment.

Existing wastewater treatment systems for ships are very large and expensive and time-consuming to manage and maintain, meaning they could not prevail in the field of recreational boating. The system developed by me is based on the technology of conventional, fully biological sewage treatment plants. This concept has been scaled down accordingly and is designed for the ship's rocking motions to have no effect on the function. The use of electronic systems has deliberately avoided, since these require regular maintenance and calibration.

The energy requirement of an average of 20 Ah can already be ensured by a 100 Wp photovoltaic module. Different loads can be easily adjusted by the operator controlling the system (persons on board, seasonal use, weekend operation). A timed programming allows the reduction of pump functions during the night.

The system is available in different sizes - the design can be adapted to the requirements on board. An additional sewage collection tank is unnecessary.

Of course, all the surfactants contained in modern detergents and cleaning products, additives, fragrances and dyes are harmful to the environment somewhere. This wastewater can unfortunately not be entirely avoided on a yacht or a houseboat - the collection tank would be too big, and too costly would be the treatment on board. In faeces and toilet paper, however, the entry of solids and the resulting water turbidity and pollution is undeniable and visible to everyone. Many sewage constituents float up and when emptying a holding tank the brown cloud clearly shows the pollution. That's why many tanks are likely to be disposed of during the journey or at night. Many a holding tank suction has never been used.



Here my thoughts moved to developing a suitable on-board mini WWTP, which would simply process the created toilet effluents quickly and reliably. Here some conditions had to be considered:

- Fully automatic operation
- Reliable treatment performance even in overload and underload
- Low energy consumption
- Safe even in intermittent operation (weekend use)
- Maintenance; no sensitive sensors in the system
- Suitable setup for all types of boat and crew size

The users of our plants should not be burdened with unnecessary monitoring or control tasks, yet we wanted to make use of complex electronic sensors. Therefore, the plants had to be dimensioned according to the respective crew size, and the basic settings of the control electronics take over the standard operation – the fully automated and safe treatment of waste water.

In underload (minimal use) the death of the bacterial colony may occur in the bioreactor . This can then be adjusted when re-starting the plant through the addition of a so-called concentrate. The inexpensive bacterial culture is simply pumped via on-board toilet into the facility.

Give us one per cent

Even for only 1-2 per cent of the average price for a new a modern cruising yacht we can deliver a fully automated yacht treatment plant, which makes you independent of pumping stations and land-based disposal. Stinking holding tanks, chemical additives against bad odours, worries about overcrowded tanks, constant demands of the crew - all this belongs to the past. And additionally, you make a significant contribution to keeping the oceans clean. For existing yachts, we are planning to replace the holding tanks with such a facility (as long as there is enough space for it).

On-board toilet today

In all newly built yachts today corresponding faeces collection tanks are present, where the toilet wastewater ends up. In many districts their presence and use are even prescribed by law. To some extent there is an absolute ban on the discharging of waste water into the sea and the corresponding outwardly leading seacocks must be securely locked to prevent accidental opening. The pumping out of the tanks must then be done at the next port. All marina operators are advised to keep appropriate pumping stations available. Here the skipper can then dispose of their faeces at a charge. Depending on crew size, use of toilets, toilet systems (pump toilets require a large electric vacuum toilets and little rinsing water), a tank can be full after just one day. Here's an example:

Typical 10m class cruising yacht widespread on the Baltic Sea , an on-board toilet, crew size of 2 persons, tank size 40 l. The manual pump toilet needed for rinsing 5 l seawater. With only three toilet uses per person and day, the tank is full no later than the next morning. That would mean that after a day trip or each day before anchoring the crew members must set a course for a port for disposal.

What is the reality?

Many crews cannot avoid emptying their holding tanks at sea, even within the 12-mile limit, into the sea. Because if the tank is overfilled, toilet paper remnants and faeces present in the wastewater would soon clog the tank vent line. This disposal is certainly problematic. There are also other, installation-related problems: due to a lack of space on board often rectangular connectors for the plumbing hose are found on the sea cocks.

This right angle often leads to blockages, which the crew then combats with drain cleaner or other harsh chemicals. This means more, sometimes extremely polluting effluents get into the sea. The skipper consoles himself with the fact that there are very few water sports enthusiasts and the majority of pollution today is caused by land and freight and passenger shipping.

But even those who want to behave properly are often faced with defective or unfavourably placed pumping stations. We ourselves have found in our tests on the Baltic coast, very few functioning stations no matter where we were travelling. Most are likely pure tokenism. Because if this system was really working, there would have to be long lines on Fridays and Sundays at these pumping stations: returning charter yachts or weekend sailors who surely cannot all have been outside the 12-mile zone, would have to sometimes wait a long time, as the following example shows:

Landing/mooring	2 min
Connecting pump	1 min
Pumping	3 min
Removing pump, dropping	2 min
Overall, at least 8 minutes at optimal operation	

This means that even for an experienced skipper who can easily put on and remove and knows the pump, this requires at least 8 min. Until the next is applied, another 2 minutes are likely to have passed. Add to this a skipper who is still uncertain, charter guests that are not familiar with the pump, strong winds or just missing coins, the maximum number of yachts per hour is limited to 4-6. In many marinas where the pumps were installed later in a corner, they are either not found or are not steered towards out of convenience.

While researching the topic of disposal of excrement we have observed the pumping-out behaviour in several large marinas on the Baltic coast on different weekdays and weekends. All ports examined there were partly large charter fleets. Pumping processes could not be observed and in some cases the staff on site were unable to operate the pumps. Some showed very distinct traces of years of disuse.



How do you deal with wastewater yourself?

Sure you can argue about whether so-called gray water (dishwater, rinse water, shower water) is heavily polluting or not. This wastewater is not our subject.

Imagine how nice it would be simply to have to think no more about the subject of toilet wastewater. Using the toilet as you are accustomed to do at home, no lengthy explanations to passengers on board and no thoughts of clandestine disposal or the port

with the next pumping station.

The operation of our mini sewage treatment plant on board yachts and houseboats ensures complete independence from land-based waste management systems and makes only a few demands on you as a user:

Depending on the system, it is advantageous to the bioreactor used by us to use the thinnest possible toilet paper. All aggressive cleaners and chemicals, which may be contained in scent enhancers and toilet accessories, remain a threat to the cultures of bacteria settled in the bioreactor. Therefore, you should stop using them altogether. If the toilet is clean, cleaning with water is just fine. If necessary, you can wipe the toilet seat with a cloth moistened with alcohol detergent tabs (window cleaner or alcohol, lemon or vinegar cleaner). This affects all germs.

Should unpleasant odours occur, something is wrong with the treatment plant. In most cases, the bacteria in the reactor are dead (for example they simply starved after a standstill for lack of use of the system). The re-introduction of a bacteria solution helps against this, which also constitutes the only resource of our system. The electrical energy necessary for plant operation is taken from the vehicle power supply and can be produced inexpensively and carbon-neutrally by photovoltaic, wind and hydro generators. The consumption of a standard system, designed for two people, is about 17 Ah (the energy demand of the onboard refrigerator is approximately 40-60 Ah). The required energy can be generated reliably even with a single 100 Wp photovoltaic panel.

Ventilation pump:	600 mA, if switched on for 50% of the time, 12 h x 0.6 A = 7.2 Ah
Transferring:	24 x daily 1 min A 10 A = 8 Ah
Pumping out:	6 x daily 2 min A 10 A = 2 Ah
TOTAL:	17 Ah

Our vision

With our mini wastewater treatment systems for yachts and houseboats we want to generate an entirely new environmental awareness and appeal to a subject that has long been taboo. No person should have a guilty conscience in the pursuit of their hobbies or just while living on the water on a houseboat or on their yacht due to a lack of disposal facilities of its on board excrement. A mini biological sewage treatment plant is the solution for small and medium-disposal needs, as it typically occurs on private vessels.

In one of two inhabited ships with an average of 4 toilet uses per day 24-40 litres of waste water is produced per day; the volume varies depending on the toilet system used. This amount needs to be cleaned within a further day and pumped out after separation of suspended solids. Therefore, the minimum size of this mini system is 120 l total volume capacity.

In short-term extra use by guests on board the pumped circulation and ventilation interval is changed; the same applies even with minimal use over a service life.

The functional principle - our treatment process

The waste is dumped into a first tank area where solid particles fall by gravity and floating substances accumulate on the surface. All solid components in the waste water are macerated by a chopper pump in the facility or the toilet, the remaining particles reach the liquid via the special hose. Here special bacterial cultures process the content of the wastewater - leaving only the treated liquid. This permeates through corresponding perforations out of the tube into the tank container and from there into the third collection tank. Here a discontinuation of any remaining solids occurs again (tiny particles, which have passed through the perforations). The resulting sludge is automatically pumped out and fed to the pre-treatment again. The resulting, now clear residual water is pumped through a filter into the sea. The emptying of the collecting tank can be controlled fully automatically via a level sensor or manually (especially for land vehicles). The upstream filter serves only to safely prevent the mixing of residual particles and pumped waste water triggered by heavy ship movements. This ensures only clear fluid can get into the environment. The system operates without any auxiliary or operating materials or chemicals, a small amount of effective microorganisms are required only for initial operation and after stoppages, which is simply flushed through the toilet. Thus, the system is ready for operation. Maintenance is hardly necessary, only for over or underload operations must the control electronics be switched by the user (overload with more people on board, underload during holiday mode or temporary closure).

In case of malfunction, which are easy to recognize thanks to built in viewing glasses, each tank can be pumped out individually. For example, blockages caused by the introduction of food waste, hygiene products or excessive toilet paper use can therefore be eliminated. The valves and pumps used are maintenance-free.

Easy handling

The user must set the facility after first operation according to manual or automatic emptying and the corresponding number of persons aboard. Each system is designed during construction for an average sized crew, which can be expected on board the yacht or the vehicle. This defines the size of the collection tank. Short-term use by guests on board can be compensated simply by reprogramming the pump control. For the underload operation or during absence, the system can be just as easily converted. Only the supply of oxygen must be maintained in order for the bacterial film not to die. Prolonged disuse, which can lead to their early death due to the resulting food shortage for the bacteria, means the plant must be started again with bacterial concentrate.

Advantages

- Sewage collection tanks including their discharge to pumping stations are replaced by the **enteron** system; it requires little additional space
- The energy requirement of the plant, which operates at 12 or 24 volts, is extremely low; a maximum of 15 to 25 Ah consumption per day is to be expected depending on system size.
- The follow-up costs by the microorganisms employed are low, currently 1 litre costs only €16 (there are an average of 200 ml required to start).
- The annoying pumping at pumping stations and the search for them, the secret emptying at sea or in harbours and bays are a thing of the past.
- The investment in **enteron** accounts for only 1-2% of the total cost of an average yacht cruiser and thus ensures more manageable costs wherever applicable to the holding tank. For new builds, the result is a saving effect.
- Our system can be adapted in all sorts of sizes and variants (geometries) to all installation requirements. The pumps and components used are industry standard parts from renowned manufacturers. Necessary spare parts are therefore easily available worldwide.