THE OPERATION AND PERFORMANCE OF THE *BIOSEPTIC PERFORMA* 2000 AWTS

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Abstract

There are many books written about sewage treatment and a few papers written about aerated wastewater treatment systems (AWTS) in particular, but most have been written by academics for academics or engineers who deal with sewage treatment at a professional level. This paper is aimed at industry workers, cognitive buyers, geotechnical engineers and council officers who wish to increase their understanding of the operation of an AWTS and make a valued judgement of the comparative Performance of the various accredited AWTS available in Australia.

The operation of the *BioSeptic Performa* 2000 is discussed in relation to the conventional treatment of sewage in a municipal sewage treatment plant (STP). The paper highlights the advantages of the *Performa* and discusses why it produced the excellent results that it achieved in its re-accreditation by NSW Health in 2000.

The information displayed in the graphs shows the reduction of the pollutants in domestic sewage during treatment. Explanations of the various sewage terms are used throughout, using simple descriptions to explain the biological processes.

Keywords

aerated wastewater treatment system , AWTS, BOD_5, influent, NSW Health, TSS

1 Introduction

AWTS are compact sewage treatment plants contained in concrete or plastic tanks that treat all the wastewater from a domestic house by an aeration process to reduce pollutants in the water. The treated water is usually sanitised before disposal through surface or subsurface irrigation. The vegetation in the disposal area completes the water cycle by transpiring the water to the atmosphere and utilising the residual nutrients for vegetative growth.

AWTS have been available in NSW since 1982 and a little later in the rest of Australia. In 1998 the NSW Health Department published the AWTS Guideline for the testing of AWTS. This required all AWTS be re-tested at a STP. *BioSeptic* tested its *Performa* 2000 AWTS at the AWTS Manufacturers Association's test facility at Moss Vale STP. The test facility is described in Performance Testing of aerated wastewater treatment systems.

BioSeptic Pty Ltd was formed in 1993 when it received NSW Health department approval for the original *BioSeptic* AWTS. The directors have been involved in the industry since 1986. *BioSeptic* was a founding member of the AWTS Manufacturers Association Ltd. The Association's code of ethics requires members to manufacture AWTS according to their NSW Health accreditation.

2 The AWTS Performance Standard

Accreditation by NSW Health required *BioSeptic* to test the *Performa* using sewage from a municipal STP for six months and have 90% of the 240 samples comply with Section 11.7 of the AWTS Guideline 1998 as follows:

- BOD_5 of < 20mg/L, with no sample > 30mg/L,
- TSS < 30mg/L, with no sample > 45mg/L,
- thermotolerant coliforms < 30cfu/100/mL, with no sample > 100cfu/100mL,
- and all the following samples to have:
- dissolved oxygen (DO) of > 2mg/mL and
- free residual chlorine shall be > 0.2 mg/L and < 2.0 mg/L.

The following explanations define the terms used in the Performance standard:

BOD_5 – Biochemical oxygen demand in five days. This is the quantity of oxygen, expressed in milligrams/litre (mg/L) of dissolved oxygen, consumed by the bacteria to reduce the organic matter in the water at a constant temperature of 20°C in a dark environment.

TSS – Total suspended solids. This is a measurement of the organic and inorganic matter in the water that can be removed on a filter paper plus the dried residue in the filtrate.

Thermotolerant coliforms – these bacteria are indicator organisms used to measure the effectiveness of the disinfection process. They are measured as colony forming units per 100 millilitres (cfu/100mL) of water.

FRC – Free residual chlorine. This is a measurement of the free chlorine remaining after the disinfection process. It is assumed that by having a residual amount of free chlorine, pathogen kill will have been achieved.

3 The *BioSeptic Performa* 2000

3.1 The Septic Tank

The *Performa* receives all the wastewaters from the toilets, bathrooms, laundry and kitchen of a house. The *Performa*'s primary tank is a 3575 L baffled septic tank. This exceeds NSW Health's standard requirement for ten people (3050L) to ensure excellent primary settling. A concrete baffle divides the tank into a primary chamber that is twice the size of the secondary chamber. The baffle makes the tank into a giant grease trap and prevents the overflow of scum from the tank. The wastewater (influent) from the house flows into the septic tank through an inlet square junction. The square junction is a vertical pipe that directs the influent down to the middle depth of the tank, preventing splashing that will disturb the surface crust.

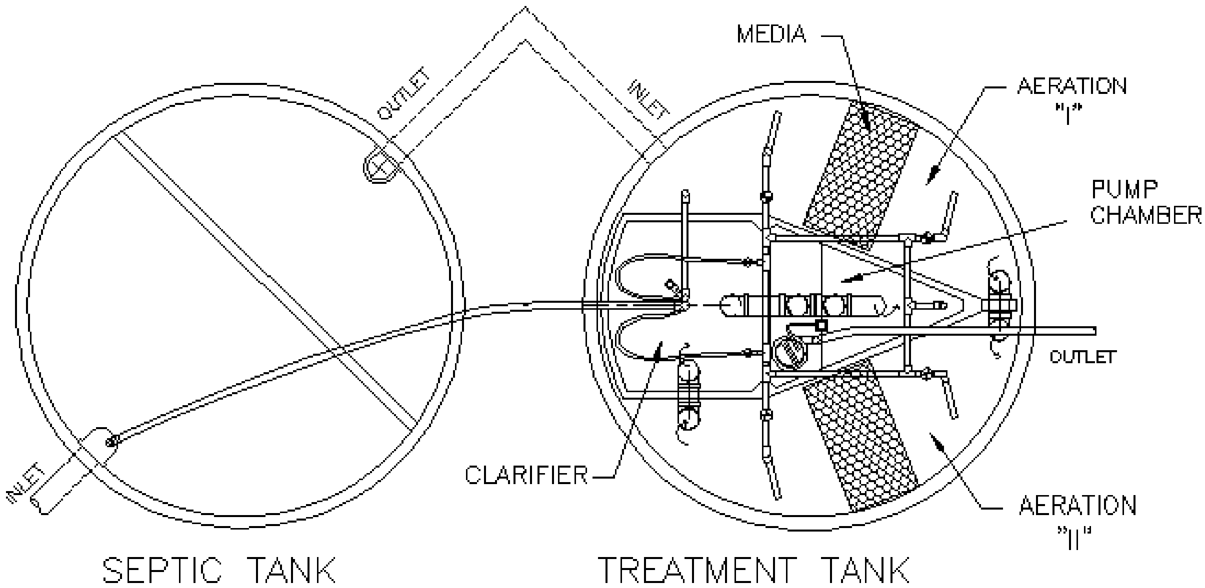
The heavier fraction of the waste sinks to the bottom of the tank and the lighter fraction, oils and fats, floats to the surface to form an air tight scum to exclude the transfer of atmospheric air into the water. An anaerobic condition develops in which anaerobic bacteria commence the degradation of the organic matter that settles out of the influent. Anaerobic bacteria are slow acting that digest the complex organic compounds in the waste, in the absence of free oxygen, into simple soluble compounds that are used by the bacteria for energy and food. The process can be described in simple terms as:

Organic matter + anaerobic microorganisms →
anaerobic microorganisms + water + carbon dioxide
+ methane + nitrogen & phosphorous compounds

A septic tank that is working effectively will build up a community of bacteria (single celled organisms) that will support a symbiotic community of lower order multi-cellular organisms, including insects and worms.

The settled sludge forms a uniform layer across the bottom of the two chambers. The floating scum is retained on the inlet side of the baffle. The baffle is not sealed and water passes through holes to the second chamber where further settling occurs. On the advice of Professor George Tchobanoglous *(pers. comm.)* a polypropylene filter was fitted in the outlet square to trap any suspended particles overflowing to the secondary treatment tank. This is for the very simple reason that if waste does not enter the treatment tank it does not need to be treated.

Figure 1: The *BioSeptic Performa* 2000



The *BioSeptic* Treatment Tank

The aeration process: Introducing air increases the dissolved oxygen (DO) in the water. Aerobic bacteria use the oxygen to oxidise the complex compounds in the organic matter to simple compounds that are used as energy and food for their survival. The aerobic process does not generate the noxious gases such as methane that are produced in the anaerobic process. (The reduction of the organic matter is also known as BOD_5 reduction). The process can be described in simple terms as:

Organic matter + aerobic microorganisms →
aerobic microorganisms + water + carbon dioxide
+ nitrates & phosphorous compounds

The bacteria are commonly called growths, activated sludge or biomass. A good example can be observed in nature by touching rocks in a stream, the side that is opposite to the stream flow will be covered with a thin slippery film of bacteria. The bacteria feed on the passing organic matter; in this way rivers reduce their organic loads as they flow. The domestic and industrial effluents of modern society have sometimes overloaded the river's natural biomass' capacity to reduce the organic load resulting in the eutrophication (pollution) of the river. The use of a system such as the *Performa* will allow waste to be treated and recycled at its source rather than be transported to a municipal STP where it has historically been partially treated and discharged to a river or the ocean.

Systems that utilise bacteria that oxidise organic matter while suspended in the water are known as suspended growth systems. Their drawback is that the growths can be washed through the system if there are high flows, such as a bath or washing machine discharging to the system. Systems that provide a substrate (bacteria support media) on which the bacteria can grow are called attached growth systems. Sheets of corrugated plastic are glued together to form a rigid honeycomb matrix to provide a large surface area. However, a chamber of sufficient size to contain the media for the bacteria required to reduce the organic load from a house would be too small to accommodate peak flows. There needs to be sufficient hydraulic retention time (HRT) for the biomass to work efficiently. The *Performa* solves this problem by being a hybrid system.

Figure 1 shows that the *Performa*'s aeration chambers contain large quantities of media for the attached growth and a larger area to provide capacity for HRT and the suspended growth.

Sewage treatment can be performed in

a) a completely mixed process, where each part of the process is completed before moving to the next process such as in a sequential batch reactor (SBR), or
b) a plug flow system, where the process gradually occurs as water flows though the system

The former are either square or round, while the latter have narrow and long flow paths.

It can be seen in Figure 1 that the media is placed transversely to the flow path so that the water must pass through the media for treatment by the biomass. It is important that there is no opportunity for the water to bypass the biomass. The media divides each aeration chamber into two sections with each section containing an air diffuser to provide good oxygen transfer to the water. Most BOD_5 reduction occurs in the first aeration chamber, before it overflows to the second chamber. The media placement and shape of the *Performa*'s sequential aeration chambers combine the completely mixed and plug flow methods used in traditional STP.

Air Supply

A 100 L/minute air blower provides the *Performa*'s air supply. The quantity of air needed to reduce the organic load is much less than 100 L/minute. However, air is also required to mix the water to prevent dead spots forming anaerobic conditions and creating odours. The air also operates the sludge and skimmer returns that waste and recycle the activated sludge.

The small additional cost of a larger blower than the industry standard of 80L/M and the negligible change in the running costs for the additional 20 watts, is a benefit that provides a margin of safety. The larger blower provides adequate air to maintain the biomass and operate the recycling system. Anaerobic conditions caused by air starvation are thus avoided in the *Performa* aeration chambers.

The average influent BOD_5 during the six months of the Moss Vale test was 160g/m^3; this was reduced in the effluent to 4.79g/m^3. The *Performa* achieved BOD_5 reduction of 97%.

The Clarifier

After aeration has reduced the organic load, the water overflows into the clarifier. All aeration processes create a biomass known as activated sludge and this needs to be removed from the discharge water. The *Performa* has a 0.5 m^2 rectangular clarifier with a cone at the base to concentrate the settled sludge to a central pick up point. Its 500 L capacity allows 20 hours residence time for the average daily flow of 600 L from a four-person house. This is many times the recommended design rate for a clarifier and ensures that the activated sludge has sufficient time to settle and allow clarified liquor to overflow into the disinfection stage.

During the 2000 accreditation test, the influent flow to the *Performa* was 0.3 m^3/h and increased to 0.6 m^3/h for the last 30 minutes. The *Performa*'s clarifier was given a thorough testing of its ability to settle solids (the activated sludge), as it was tested beyond the average flow conditions, reducing the residence time to 1.6 h.

During the Moss Vale tests the *Performa* achieved a 98% reduction in suspended solids. The average suspended solids in the influent were 239g/m^3; this was reduced to 5.55g/m^3.

A water clarity test is used as a quick method to discover the probable BOD_5 reduction. Water is displaced from a clear Perspex tube until a black cross at the bottom is visible. Water clarity of >0.30m is usually regarded as having a BOD_5 of <20mg/L. Clarity checks were made on the test samples. As the flows increased during the test the water clarity decreased a little until the high flow after 2.5 hours gave the lowest result. At the conclusion of the test the flows were returned to 0.225 m^3/h. A reading taken thirty minutes later showed that the clarity had returned to the pre-test levels. Although the accreditation process does not test for it, the *Performa* has a very good ability to recover after a heavy load.

An airlift pump returns all of the settled activated sludge from the bottom of the clarifier hopper to the septic inlet. This is waste activated sludge and the anaerobic processes of the septic tank degrade it. The skimmer removes any floating biomass plus a portion of the clarifier influent water containing the activated sludge and recycles it to the inlet of the first aeration chamber. This is very important as it provides seed bacteria to increase the aeration process.

It is at this point that the advantage of the *Performa* can be seen over AWTS that do not have a septic tank to store the waste activated sludge. Aerating organically loaded water produces activated sludge and except in very lightly loaded systems, where the design exceeds the loading rate by many times, i.e. when there is only one person using a ten person system, the aeration process will always build up sludge. In the aeration basins of an STP the activated sludge is decanted to maintain the sludge residence time (SRT). AWTS without a septic tank or settling tank that can hold at least three years waste sludge need to have the excess sludge frequently pumped out and carted off site to avoid the overloading of the aeration chambers with sludge. One Queensland council makes this a condition of installation approval for such systems.

Disinfection Process

The final part of the process is to remove pathogens. The *Performa* uses the time-tested method of sanitising the water with chlorine in the form of 200 g tablets of sodium trichloroisocynuric acid. It is obviously not feasible to test the effluent for every pathogen that may be in the water and so a test is made to detect faecal coliforms (FC), these are bacteria present in the lower intestines of warm bloodied animals. FC are always present in sewage and if the FC are reduced or not detected, it is assumed that other pathogens that are susceptible to chlorine have been removed or reduced.

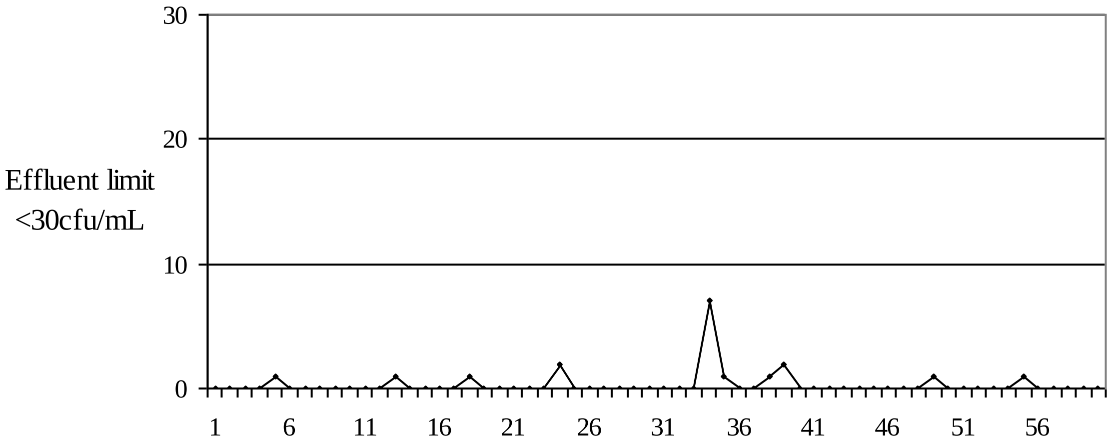
It has been suggested (Lustig T, 2001) that using chlorine has some drawbacks, because it may not kill the eggs of parasitic worms and it can produce dioxins, some of which may be injurious to our health. Chlorine has been the sanitiser of choice for many years and there have been no recorded instances of ill effects from chlorinated AWTS effluent in Australia. One alternative is not to chlorinate, but this would result in the discharge of pathogens many times more dangerous than any possible effects from chlorine.

The only alternative is Ultra Violet treatment. This requires a very low turbidity and good quality effluent so that the pathogens are exposed to the UV rays and not shielded by particles in the water. Unless the lamp is self cleaning, frequent manual cleaning is required to avoid build up of slime on the lens, which would otherwise reduce the effectiveness of the UV rays. At this time high efficiency UV treatment with low maintenance is not available. It should be noted that a little chlorine is often added to supplement the UV treatment in order to leave a residual disinfection in the effluent to ensure no recurrence of pathogens downstream.

Pathogen kill using chlorine is a combination of concentration and time, but unlike UV once the chlorine is in the water it will continue to kill pathogens until it is totally oxidised. It has been generally considered in the industry that a 0.5 h contact time between the pathogens and the chlorine will achieve an effluent of <30cfu/100mL. The lower the concentration the longer the contact time. The *Performa* has a 300 L chlorine contact chamber to ensure that there is sufficient contact time.

The accreditation test required that the 60 samples collected for bacteriological analysis had to be <30cfu/100mL. The *Performa* achieved this easily with no FC detected on fifty days, 1cfu/100/mL on seven days, 2 cfu/100mL on two days and 7cfu/100mL on only one day. The 99.99% removal rate proved that the *Performa* is very effective at killing faecal coliforms and therefore other pathogens. Published results from a AWTS using UV show that it achieved an average FC concentration of 1.60cfu/mL, the *Performa* chlorinator achieved a five times better result of 0.30cfu/mL. The unpublished Australian Standard for AWTS has reduced the pathogen level to <10cfu/110mL. The *Performa* in its present form will meet this standard.

Figure 2: Faecal Coliform Reduction = 99.99%



4 Nutrient Removal

Accreditation by NSW Health does not require the reduction of nutrients only the reduction of the pathogenic and organic loads. However, the *Performa* significantly reduced the nitrogenous content of the wastewater. When the requirements of the NSW On-Site Disposal Guidelines are applied to a land application area the nitrogen concentration in the effluent is most often the limiting factor.

However, it is important to consider whether it is desirable to remove all the nitrogen from the effluent before disposal. Nitrogen is an important nutrient for plant growth; it is readily applied as a fertiliser to gardens and farm pasture all over Australia. Nitrogen is required for protein synthesis to facilitate plant growth. There is little point in applying nutrient free water to vegetation and expecting them to transpire the water if they die from malnourishment.

Nitrogen in the different stages of wastewater is found in the forms of ammonia (NH_3), total Kjeldahl nitrogen (TKN), nitrates (NO_3^-) and nitrites (NO_2^-). Ammonia is an oxygen-depleting compound and should be limited in its discharge to water. In soil the ammonium ion (ammonia in water) is immediately available for plant uptake and can be held on the exchange sites. Ammonia is oxidised to nitrite and then to nitrate. In the form of nitrate, nitrogen can be taken up by the plant roots for growth. TKN is the organic waste that has not been degraded and if discharged to a land area may be degraded in the presence of air by the microorganisms in the soil. If the nitrogen content of the water can be changed to the oxidised form then a supply of liquid fertiliser, in small doses, is available to the vegetation in the land disposal area.

Nitrification: It has been shown that the *Performa* can easily reduce carbonaceous matter (BOD_5 reduction) but it can still provide excess air to oxidise ammonia as shown below:

Ammonia + oxygen + *Nitrosomonas* bacteria $\rightarrow$ nitrite + hydrogen gas + water

Nitrite + oxygen + *Nitrobacter* bacteria $\rightarrow$ nitrate

The nitrifying bacteria are slower acting than the carbonaceous bacteria and are easily inhibited, they also require nearly four times the quantity of oxygen to oxidise 1 kg of ammonia than is needed to oxidise 1 kg of BOD_5, so the *Performa*'s larger air blower is beneficial at this stage.

During the Moss Vale tests, the *Performa* removed 79% of the ammonia when the average influent strength was 46 g/m^3 NH_3. In the final test period, the effluent BOD_5 was reduced to <2g/m^3 and the nitrification of the ammonia increased to a removal rate of almost 100%, with an average value of 0.17g/m^3 of NH_3. Random sampling of *Performa*s installed in the Silverdale area of NSW reported ammonia effluent concentrations below detectable levels.

Similar removal rates were experienced with TKN. The Moss Vale tests showed 69% reduction from an average influent of 49g/m^3 to 15g/m^3. The Silverdale sampling showed a range between 3.6 – 7.6g/m^3.

Denitrification: In this final step, denitrification occurs when the nitrate is reduced to nitrogen gas and lost to the atmosphere. Whereas nitrification is an aerobic process, denitrification is an anoxic process, and requires a carbon source in the form of organic matter (BOD_5) to occur. It is shown as:

Nitrate + carbon + hydrogen $\rightarrow$ protein + nitrogen + carbon dioxide + water

The Moss Vale test results showed that the *Performa* effected a 45% reduction in TN by reducing an influent TN of 46 g/m^3 to 26.75 g/m^3. When more favourable BOD_5 conditions occurred, as they would in an average household, the reduction increased to 57%.

The *Performa* does not use a quiescent period to increase denitrification. It is questionable whether it is really necessary to denitrify? In order to achieve denitrification more components, such as timers have to be included, which means that as the AWTS age there will be more components to break down and be replaced. As long as good nitrification is achieved, then the small amount of nitrogen that remains is more of a benefit to vegetation in the disposal area than it is a threat to the environment. It also means that at higher strengths and flows, the organic reduction and therefore the pathogen kill rate may be less if aeration is curtailed to achieve denitrification. *BioSeptic* considers that it is more important to consistently provide good organic and pathogen reduction.

7 Conclusion

The *Performa* is a robust and relatively simple AWTS built on the KIS principle, "keep it simple". It is manufactured from good quality durable components that have the necessary specification to consistently produce high quality effluent. Its all-concrete construction means that it will last for many years; it will not float out of the ground in heavy rain, and it will not melt in a bush fire like a plastic tank.

Independent service technicians have reported that it is an easy system to service and maintain in order to produce good water quality.

Its large chamber sizes, bacterial support media, air supply and complex chamber pattern ensures that it has more than adequate capacity to treat wastewater from the largest household and allow it to do it in a consistent and reliable manner. Its chlorinator, which is unchanged since 1993 and imitated by many other AWTS today, ensures that it will reliably kill indicator pathogens.

The *Performa* has been vigorously tested at the Moss Vale test site and proven to produce one of the highest quality effluents of the AWTS that are accredited for sale in NSW.

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