Why Media Matters and Empty Bed Residence Time does not

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This is a paper about the importance of Biofilter Media to the success and effectiveness of a bioreactor system in reducing pollution and odour nuisance.

In the 90's biological systems were all based on organic biofilter media. The systems installed were basically a "black box" that contained a variety of organic media, e.g. wood mulch, cocos fibre, composted bark, or a mix.

The design of these systems were both practical and limited.

Media suppliers were agro-companies that found a market for their rest products. The media qualified was based on the air flow and the capacity was expressed in m3 of air per hour per m2 meter of material. Although the height of the media material fluctuated its average was 1.5 meter (5 feet). The allowed loading rates were 35 to 100 m3/m2.

Engineering Firms specified the type of organic media they thought best and kept the design on the safe side by keeping the loading rates limited and contact times long.

In reality there were many more criteria but they were hardly considered in the design. Some of those were:

- Media pressure drop starting around 1,000 Pa and increasing to levels as high as 3,500 Pa;
- Media shrinkage, which created air leakage at the side of the system;
- Prevalent air flow as a consequence of cracks in the media;
- Media life time.

Overall, the performance of the system was reasonable but never excellent. And that only for a short period of time.

Some parties tried to optimize the systems by mixing robust and fine media that had already been composted to improve the media life and reduce the pressure drop. However, the processes inside the filters were still more or less a "black box". The basic buffer capacity, nutrients and bacterial life reduced the organic pollution in the air and the odour of it.

Applications were many: From Composting Facilities, Paint Companies, Rendering Plants, Sewer Systems. Although the presence of Sulphur and Nitrogen limited the lifetime of the media it did work.

This changed in the mid 90's due to the development of a completely different concept: Biotrickling Systems. The organic "black box" with its natural buffer cap, nutrients and biology was replaced with a synthetic media (SSM wPUR) without natural buffer and nutrients, which was placed inside an (often) impressive looking, high-tech bioreactor.

Suddenly much more knowledge was required to design a system. This knowledge development started off huge innovations in biological air abatement.

Although several types of media were tested one invention became leading: Structured Synthetic Media with Polyurethane Foam. Especially the application of reducing Odour and Sulphur Emissions was very successful.

The loading rate per m3 of the structured synthetic media was substantially higher than that of the organic media. In addition, great improvements were made in efficiency, lifetime and pressure drop.

To understand this difference it is important to look at the physical difference in the media. The organic media was and is based on natural resources present in the media. There was a buffer capacity, nutrients and living organisms. Synthetic media has none of these natural resources. It is plastic. This means that all necessary process components need to be brought in in a way that an effective environment for a long-living biological process is created and maintained.
In this paper we will not discuss the parameters and criteria to create this environment. We will focus on the different aspects of the bioreactor, being the physical characteristics of the media and its effect on the reactor design.

It was necessary to create the optimum environment inside the bioreactor and within the synthetic media to allow for the best

exchange between pollution and biology so that biological oxidation can take place.
Contact between the pollution and the biology is key for the efficiency of the system. To optimize the exchange and allow for biological oxidation two criteria are key in a biological system:

- Contact surface (Biological Exchange Area (BEA));
- Contact time.

The contact surface (BEA), is the surface area of the media that holds a biological film that is in contact with the air flow. The contact time is the time that the air flow is inside the media and in contact with the biology. This is not the Empty Bed Residence Time (EBRT) but the true contact time, which is depending on the void volume in the media. Therefore, the void volume is a deciding criterion in the design of the bioreactor.

In the organic filters the design criterion of m3 of air per m3 of volume was a derivative of the contact time. It was based on the understanding that a certain amount of contact time was necessary to allow the biological process to take place. It is what later became known as the Empty Bed Residence Time or in short: EBRT.

The real decision making parameters are the void volume and the BEA. Depending on the BEA and the void volume a certain EBRT can be achieved.

To illustrate the effect of the void volume and the BEA on the EBRT that is necessary to build an effective biological system we have compared the EBRT of various in the table below. The difference is significant:

Location	Media Type	Air Treated	EBRT
VAM - Composting System	Compost based media	Composting waste air	36 seconds / 0 gram H_2S/m^3
Smilde - Rendering Plant	Compost based media	Rendering process air	43 seconds / 0 gram H_2S/m^3
Dordrecht WwTP	Compost based media	Sewer waste air	55 seconds / 4 gram H_2S/m^3
Anheuser Busch - Brewery	Permapac (SSM wPUR)	Groundwater stripping	8 seconds / 28 gram H_2S/m^3
South Walton WwTP	Permapac (SSM wPUR)	Sewer waste air	28 seconds / 3 gram H_2S/m^3

This significant reduction is a consequence of the media choice. The SSM wPUR has a much higher void volume per m3 of media and a much higher BEA. Over time, when the organic media deteriorates under the influence of acid and biological process, the void volume will reduce and the difference will be even bigger.

In addition to the EBRT there is another parameter that needs to be taken into account in case of higher H2S applications. This is the breakdown capacity of the H2S per m3 media. In case of high H2S this design parameter might be higher than the normal contact time needed for efficient performance.

Based on the breakdown capacity of H2S a larger volume of media is required based on normal contact time. In this case the BEA is the decision making parameter. For illustration see the two projects below where this is the case.

Location	Media Type	Air Treated	EBRT
Heineken - Brewery WwT	Permapac (SSM wPUR)	UASB waste air	136 seconds / 26 gram H_2S/m^3
Aviko - Potato Processing	Permapac (SSM wPUR)	UASB waste air	51 seconds / 77 gram H_2S/m^3

Since SSM wPUR has a much larger void volume than the randomly dumped (organic) media, a higher efficiency of the gross volume is the result.

At the same time there were also developments to use standard chemical scrubber materials. Fillings like Jaeger Balls and Saddles were also used as Bio Media. Unsuccessfully. Although the Jaeger Balls created a huge amount of void volume, they had a very low BEA. The Saddles had low void volume and very reasonable BEA it seemed, but the biology mass did not stick to the saddles and the biology flushed out, which resulted in a very low, real BEA.

In the beginning of the 00's the SSM wPUR was the most successful media available and all Engineering Firms started to specify this material. The general understanding was that the PUR foam was the driving force in the reactors. Based on this belief a new development started Random Dumped Foam Cubes.

The Foam was easy for the biology to attach to with a high void volume and a large BEA. For a short time this seemed to be the new next step. But it became clear that the Foam Cubes were not the answer.

The reason for this is a consequence of the growth of the biomass. The Foam was not the mythical driving force in the success of the SSM wPUR. The outside surface area of the Foam was!

The Foam itself became a completely clogged part of the system. The Foam was holding water and biomass and prevented the air from passing through.

This was found both in the foam from the SSM wPUR (where the supplier who had started initially with a foam thickness of 20 mm already was reducing the thickness of the media layer in the system) and in the Randomly Dumped Foam Cubes. The Cubes lost their void volume and BEA because the inside of the cubes did not have more available surface area and the volume was reduced to the small space between the cubes and the only surface the biology could attach to was on the outside of the Cubes. The Cubes collapsed under the weight of the biomass and the water and the system then failed.

Here you clearly see the difference between dry void volume and BEA and the Operational Void Volume and BEA. To allow a long and effective lifetime of the media the media will need to maintain an Operational high Void Volume and BEA.

The very successful Permapac (SSM wPUR) changed over time without communicating this with the market. Was the Foam about 80% of the media in the beginning, over time the thickness of the Foam media was reduced and the spacer material between the media enlarged and in the end less than 50% of Foam was used.

An example of the most optimized Permapac was the installation delivered to Melbourne Water, an Odour Control Facility for 126,000 m3 of air coming from a sewer trunk manhole. In 18 seconds EBRT the odour efficiency was over 98% and the outgoing concentration was an average 700 OU/m3.
An example for H2S removal is As Samra in Jordan, with a contact time of 40 seconds and a removal capacity of 200 g/m2.

At the Melbourne Western Treatment plant the odour concentration was up to 50,000 OU/m3, which was reduced by 99.8% to around 1,000 OU/m3 in the outlet. This all at a contact time of 18 seconds. This is about half of the contact time from the traditional organic filters, and generating a much more solid performance. The system is now running for 10 years and has had no downtime. During the whole period just one single valve in the water line broke. Traditional organic media would have been replaced 3 times by now. The pressure drop of the system is still under 700 Pa.

In 2008 the next big step in media development was taken: Structured Synthetic Media without PUR Foam called Spacious Wire Pac (SWP). This SWP does not have any PUR Foam any more, but exists of material that has the surface characteristics of the foam but does not need the thickness of it. This step was the latest and greatest revolution in the Bio Media.

Compared with the Permapac the Spacious Wire Pac doubles the BEA and the Void volume. In essence it almost doubles the capacity. The reactor with SWP reduced the EBRT once more. This time by 35 - 50%!!!!

1. Cronulla WwTP compared to Melbourne Water WwTP - Odour Removal;
2. Ajman WwTP Upgrade compared to Ajman original - Odour Removal and H2S Reduction;
3. Casing (Viscose) Production Company expanding its capacity - CS2 and H2S Removal (and doubling capacity).

Re. 1 - Cronulla vs. Melbourne

Cronulla is a WwTP in Sydney (AUS) and has foul air with more or less the same characteristics as Melbourne with the only difference being the amount of flow.

In Melbourne SSM wPUR is used and the gross EBRT is 18 seconds. The results is a very well-performing system that has been running for 10 years. The pressure drop is still below the guaranteed 700 Pa, and the outlet odour is reduced to around 1,000 OU/m3.
The Cronulla system on the other hand is running on SWP (no PUR). In this system the contact time is only 12 seconds, which makes the EBRT 50% less than Melbourne. The Cronulla outlet air is around 300 OU/m3 and the pressure drop is around 100 Pa.

Both systems perform better than the guaranteed value, except that Cronulla has a 50% more flow per m3 of media and the pressure drop is significantly lower.

Re. 2 - Ajman WwTP upgrade, compared to original

Around 2007 an Odour and H2S emission control plant was built based on a copy of Permapac. With ingoing concentrations of over 1,200 ppmv and a flow of 45,000 m3/h the system was built with 8 towers, each containing 4 meter of copied Permapac media. The result was devastating: the system only performed in the beginning. Pretty soon the system was clogged-up and performance dropped off the radar. The customer found that the system was clogged with Biomass and Sulphur and decided to take the media out and clean it. They could keep the system running if media was taken out for cleaning on a bi-monthly basis. The system reached its best performance at around 85% removal efficiency of H2S.

Ultimately the media was replaced by SWP. The removal efficiency went up to 99.9% and the pressure drop stayed under 100 Pa. No media needed to be taken out for washes anymore.
The flow over the SWP was 35% higher; The contact time more than 75% lower than the original design and not only excelled the SWP in performance, also the energy costs based on the pressured drop dropped significantly.

Re. 3 - Casing (Viscose) Production Company expanding its capacity:

In 2003 a Sulphur Emission Control System was delivered to a company manufacturing viscose products. The emissions were CS2, COS and H2S. The system was designed to remove about 4.8 kg of Sulphur per tower. The system functioned well and met the design criteria most of the time. The design removal for H2S was 80% and for CS2 65%. In 2010 the company needed to expand. Instead of expanding the amount of towers it was decided to replace the SSM wPUR with the new SWP. The new capacity was guaranteed for 10 kg of Sulphur reduction per tower. The removal efficiency was guaranteed for H2S at 95% and for CS2 at 85%.

The system is currently outperforming the guaranteed values largely: The overall Sulphur removal is around 15 kg per

tower and the H_2S removal is around 99%, CS_2 removal at 90%.
The total capacity of the new SWP about tripled compared with the SSM wPUR.

Location	Contact Time	Emissions Out	Remarks
Melbourne	18 sec.	avg. 700 OU/m3	
Cronulla	12 sec.	300 OU/m3	
UASB Process Air - Permapac Copy	38 sec.	failing	systems clogging / bi-monthly cleaning needed
UASB Process Air SWP	28 sec.	100% (0 H2S out)	
Viscose Process Permapac	4.8 kg / tower	H2S: 80% CS2: 65%	
Viscose Process SWP	15 kg / tower	H2S: 99% CS2: 90%	

CONCLUSIONS:

As this paper demonstrates, great progress has been made over the last 20 years in the Biological Air Abatement Technology.

From an organic "black box" we have come to an engineered, predictable and controllable technology that is the most economical solution in Emission Control.

As the results demonstrate, the development of the media on which the biology grows, has made it possible to expand the applications, the efficiency and the systems.

But it is also a sophisticated technology. A technology that cannot be specified by simply using criteria as EBRT. The technology supplier needs to be knowledgeable and the choice of media material is crucial to the design parameters, lifetime and pressure drop over the system.

The impact of media is all-encompassing. Without the right type of media one cannot build the optimal process and reach the incredible results.

With the right media, the system will be guaranteed for up to 20 years, the downtime is none and flexibility great. No redundancy is needed in these system and no carbon back-up is needed anymore to achieve the desired low odour emissions.

EBRT is an unacceptable design parameter for these systems. It is the Media that does matter!!!