PFAS AND WASTEWATER: WHAT CAN BE DONE?

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ABSTRACT

Per- and poly fluoroalkyl substances (PFAS) are persistent chemicals that are widely used in developed countries. They are present in many consumer goods and industrial processes, and as a result they inevitably find their way into wastewater. Although the environmental and health impacts of PFAS is yet to be fully understood, there is increasing regulatory interest in controlling PFAS in our environment.

This paper will bring together recent research into:
- PFAS in wastewater, recycled water and biosolids
- How PFAS behave in wastewater treatment plants, and
- How PFAS can be treated or removed.

This paper also considers how the waste hierarchy and source control can be applied to managing PFAS in wastewater, recycled water and biosolids. The focus will be to provide a useful understanding of PFAS in wastewater treatment plants and what are reasonably practicable control measures.

1.0 INTRODUCTION

Effective management of the impacts of PFAS on wastewater treatment plants (WWTP) can pose significant challenges because by design, these facilities are 'receivers' of waste streams. Their purpose is to accept domestic sewage, septage, and industrial and commercial waste streams, any of which may contain PFAS. As biosolids and recycled water can be applied to land and discharged to surface water (recycled water only), it is imperative to evaluate and manage the risks to human health and the environment associated with PFAS exposure. This paper brings together the current state of knowledge for PFAS in wastewater and options available for it to be controlled, removed or treated.

2.0 DISCUSSION

It is useful to understand some of the key properties of PFAS, in order to understand how they get into wastewater treatment plants and what happens to them once they are there. PFAS are an added to products and protective coatings because of their 'surface-active' behaviour. They are able to repel both oil and water, and form a thin, wet film across a large surface area, which is why they have been used in fire-fighting foams. Because of these properties, they are very useful and have many applications in manufactured goods.

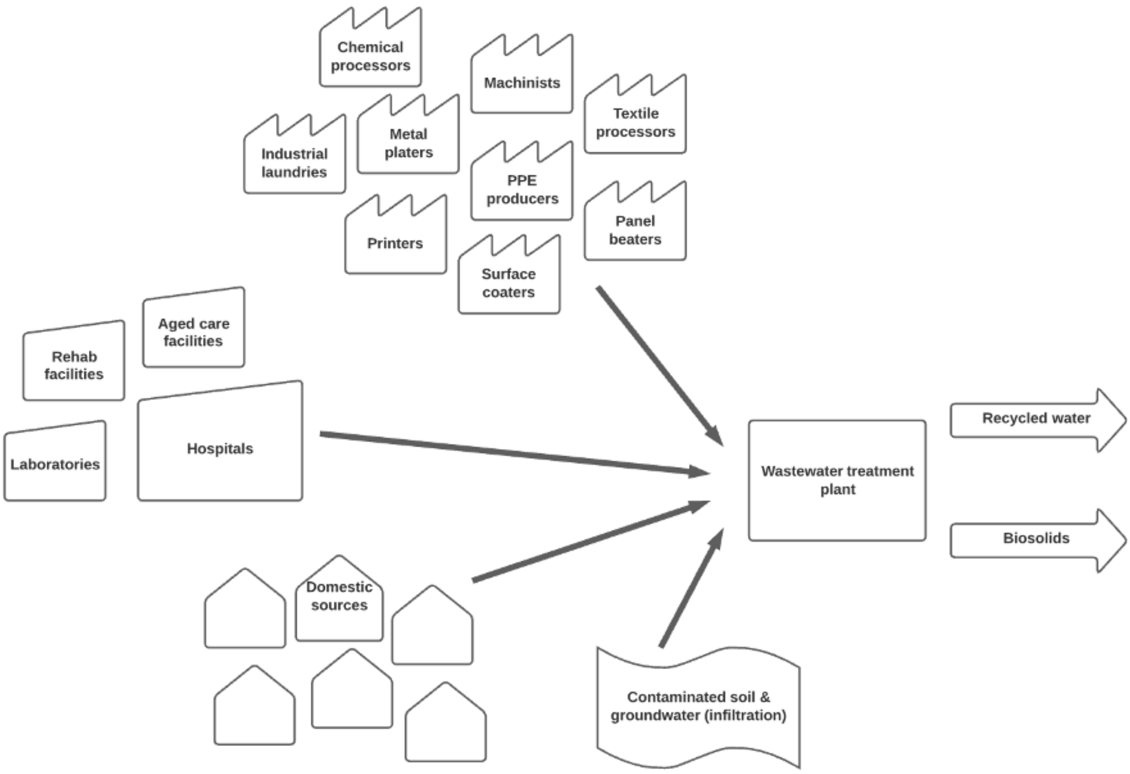
Chemically, PFAS have a chain of carbon atoms that are bonded to fluorine. This bond is one of the strongest chemical bonds and therefore PFAS are resistant to degradation and take considerable energy to break down.

Their usefulness and resistance to degradation mean that PFAS find their way into wastewater from diverse sources. Our homes are full of PFAS-containing goods such as:
- Water-repellent coatings on clothing
- Stain-resistant coatings on furniture and carpets
- Flame-resistant plastics and upholstery
- Non-stick baking paper and food packaging

- Detergents and cleaning products
- Cosmetics and sunscreen.

Of course, PFAS can also come from commercial and industrial sources, such as the manufacturing of PFAS-containing goods. They are also used extensively in personal protective equipment and clothing.

Therefore, as shown in Figure 1, PFAS can enter the sewer system from washing our clothes, washing ourselves, cleaning our homes, our excreta, trade waste connections, landfill leachate, laboratories and hospital wastewater. Groundwater contaminated with PFAS can also enter the sewer system and this has occurred where fire-fighting foams have been used extensively (Department of Defence, 2019).



<u>**Figure 1:**</u> ***Sources of PFAS in the sewer system and into wastewater treatment plants***

It is important to understand that PFAS is a "man-made" problem, with the scale of the issues proportional to the level of development and industrialisation. We are responsible for the manufacture and over-use of PFAS, and the corresponding widespread environmental pollution caused by their use. Although PFAS can be incredibly useful and play an important function in protecting people from acute risks such as fire, we must question the use of these environmentally persistent chemicals in products such as cosmetics, clothing and food packaging.

2.1 How PFAS behave in wastewater treatment plants

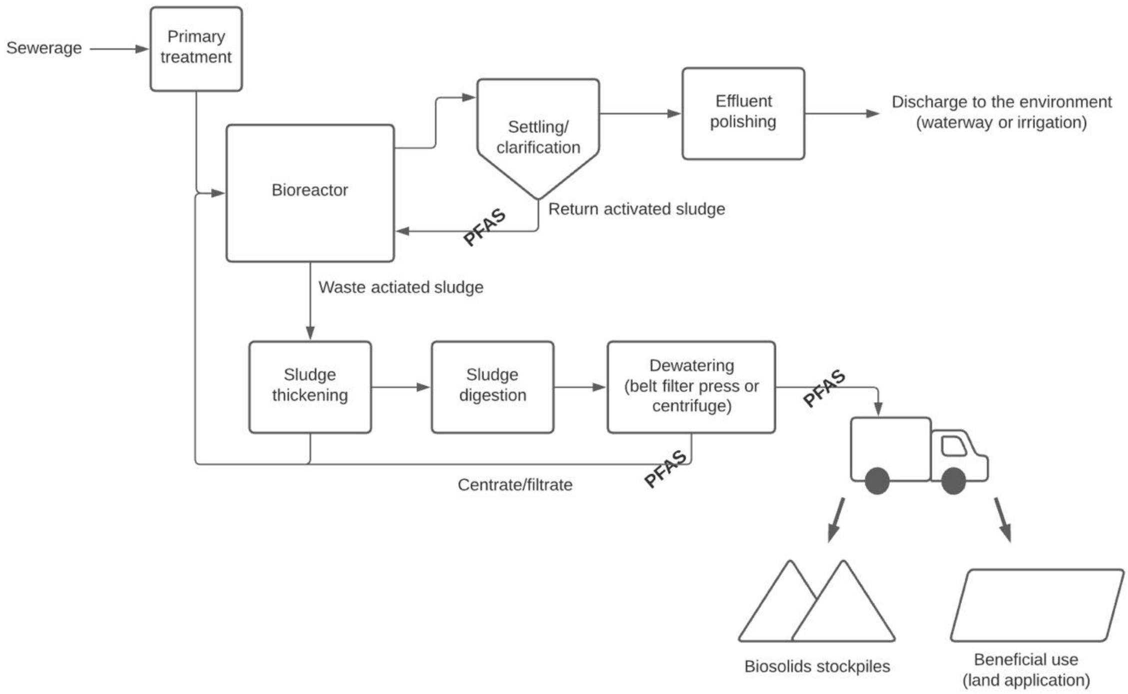
Essentially a 'soup' of PFAS enters wastewater treatment plants and we can make a few generalisations about how they behave. Although treatment plants are not specifically designed to treat or remove PFAS, some will be transformed into shorter-chain compounds and others can bond with sulphur-containing compounds to produce sulfonated PFAS. Whereas PFAS that are in the perfluorocarboxylic acid (PFSA) and perfluorosulfonic acid

(PFCA) groups are stable terminal compounds and will not degrade further.

It is virtually impossible to do a mass balance of PFAS through a WWTP, as there are so many compounds and there are transformations of some but not others. In addition, the biomass is not an equivalent representation of the influent at a given point in time. Because the bulk of the biomass resides in the bioreactor (the sludge age), it essentially has an accumulated PFAS load, whereas the effluent passes through in a matter of hours.

There is certainly opportunity for further investigation into the relative concentration of PFAS within different wastewater streams. To date, research has primarily focused on PFAS in influent, effluent and biosolids. However, I believe there is the potential to reduce the concentration of PFAS circulating in wastewater treatment by targeted side-stream treatment. For example, the centrate from centrifuge dewatering could contain more concentrated levels of PFAS and treatment of this stream may be more practicable and cheaper than wholesale destruction of the total biosolids product.

Figure 2 shows internal streams that could be targets for side-stream treatment.



<u>Figure 2:</u> ***Potential concentration points of PFAS in wastewater treatment plants***

2.2 PFAS in recycled water and biosolids

By-products of wastewater treatment plants are primarily treated water and biosolids. As wastewater treatment plants are not designed to treat PFAS, what enters via the influent eventually leaves in either the treated water or the biosolids. As the solids stream (sludge or biosolids) is a heterogenous mixture of organic matter, there are more potential binding sites for a wider range of PFAS. Additionally, the longer the PFAS chain length, the stronger the attraction the hydrophobic tail has to solids. Therefore, short-chain PFAS tend to favour the effluent and long-chain PFAS favour the solids stream.

There are a number of key research papers that have investigated the concentration of PFAS in Australian biosolids. Gallen *et al* (2016) found PFAS in the biosolids of all 16 wastewater treatment plants that were sampled for the study. This study included plants that had used both mechanical and lagoon treatment, for a range of population sizes.

More recently, Moodie *et al* (2020) also found PFAS in biosolids from 100% of the 19 Australian wastewater treatment plants tested in this study. This research estimated that Australians contribute 6 mg per person of PFAS to biosolids, each year. In total, it was estimated that 85 kg of PFAS would be found in the 327,000 tonnes of biosolids produced annually in Australia.

Moodie *et al* also found:
- A consistent concentration of PFAS in biosolids, regardless of the size of the population, suggesting that a baseline PFAS concentration is contributed by residential sources.
- A positive correlation between PFAS and urban locations, indicating that PFAS is also contributed by industry.

2.3 Current regulations and policies

Regulations of PFAS are evolving and need to be understood to evaluate overall risks. Limited national guidance is in place that addresses the safe levels of PFAS in biosolids and recycled water. The long history of agricultural use of biosolids and recycled water in crop and livestock production raises health concerns at the end consumer level. Key pathways include the uptake by crops and animals, the potential for leaching of PFAS into groundwater, and the presence of PFAS in surface water from treated water discharges to waterways.

It is important that risk assessments for biosolids and recycled water continue to be updated with new information to evaluate whether there are unacceptable PFAS risks related to human health and the environment. For example, the Queensland Department of Environment and Science has now published the End of Waste Code Biosolids, which sets trigger limits for PFAS in soils where biosolids have been applied (DES, 2020).

In cases where there is an unacceptable risk of continued use of biosolids containing PFAS in certain land applications, the reuse of biosolids may require alternative management to remove or treat PFAS.

2.4 How PFAS can be removed or treated

Due to the strength of the carbon-fluorine bonds along the PFAS chain, PFAS are extremely resistant to degradation. Although their stability is one of their many useful characteristics, the downside is that they last for decades and even centuries. Most of the PFAS that has ever been manufactured is present somewhere on the planet. This includes in landfills, landfill leachate, soils, groundwater, surface water, stockpiled biosolids, our homes, cars and also stored within our bodies. It is this persistence that is of concern to regulators, even though the impacts to human health and the environment from different types of PFAS are not fully understood.

To reduce the amount of PFAS that is manufactured and ends up in our bodies and the environment in the future, there are three options available: source control, treatment, and containment.

Source control – as water utilities are not regulators, the creation and enforcement of regulation rests with the federal and state governments. Some national and international regulation already exists, including the Stockholm Convention, however the federal government has only assessed the risk of about 200 PFAS (there are at least 4,000 PFAS in use).

However, regulatory source control can be extremely effective. An extensive study was undertaken by Ulrich *et al* and assessed the concertation of PFAS in wastewater sludge samples from more than 1,100 treatment plants in Germany. These samples had been collected between 2008 and 2013, during which time regulations were enforced to limit the use of some PFAS. The study showed a clear correlation between regulatory controls and reduced PFAS in sludge; they saw a 90% decrease in the measured PFAS in sewage sludge, from a total of 17 tonnes in 2008 to 1.5 tonnes in 2013.

Treatment – wastewater treatment plants are not designed to remove or break down PFAS. Therefore, additional unit processes would need to be added on to complete this task. As shown in Figure 2, there are accumulation points for PFAS in wastewater treatment plants, and therefore targeted treatment of these streams would be a sensible starting point. However, the treatment options are very limited. Due to the strength of the carbon-fluorine bonds, a lot of energy is required to break down PFAS, with thermal destruction being the only technology capable of doing so at scale.

For primarily water streams (such as treated water and centrate/filtrate), PFAS can be reduced by adsorption with activated carbon or separated using reverse osmosis. Activated carbon adsorption does not destroy the PFAS and it creates a PFAS-contaminated waste which would then require disposal or treatment. Separation using reverse osmosis would also produce a waste retentate with a higher PFAS concentration and would require considerable energy to do so.

Due to the heterogeneous nature of wastewater sludges and biosolids, there is no technology that can extract the majority of the PFAS and separate it from the biomass. Therefore, the preferred option is thermal treatment (incineration) which results in the destruction of virtually all the beneficial components of the biosolids, including the organic matter and nutrients.

Several emerging sludge treatment technologies exist that could meet the goal of reducing biosolids disposal costs and PFAS mitigation. Emerging technologies include pyrolysis, gasification, supercritical water oxidation and ion exchange resins, however these are not yet available at municipal scale.

Containment – wastewater solids could be temporarily or permanently stored, as an alternative management option. However, due to the high volume of biosolids produced daily, huge storage facilities would be required. Stockpiling in open areas does not provide sufficient environmental protection, as PFAS can still be transferred into the environment via dust, contaminated rainwater/leachate, birds, animals and insects.

The cost of treating or containing wastewater streams with low concentrations of PFAS is very high and it would be difficult to justify that the cost is in proportion to the risk. These control methods do not reflect the waste hierarchy or solutions which are reasonably practicable for most of the water industry. The most effective management option is therefore source control.

3.0 CONCLUSION

PFAS are a large group of chemicals that are used extensively by industry and in consumer products. The strength of the carbon-fluorine bond makes them extremely resistant to degradation and wastewater treatment plants are not designed to treat or remove the PFAS that enters via the influent.

The widespread use of PFAS in consumer products and industry provides many sources of PFAS into the sewer system. After passing through wastewater treatment plants, PFAS will bind to either the effluent (shorter-chain PFAS) or the solids (longer-chain PFAS). Our options for managing the PFAS once it is in these streams is limited and for biosolids, would result in the thermal destruction of the entire mass.

Management and treatment of PFAS in wastewater should be commensurate to the risk, and so it is important that a thorough risk assessment of PFAS and its potential to harm human health and the environment through treated wastewater and biosolids use is undertaken to inform management options.

Source control through regulations to limit the manufacture, use and importation of PFAS has been shown to be a highly effective way to reduce PFAS in recycled water and biosolids across a whole population. This is reflected in the waste hierarchy and offers the water industry hope that the burden of managing PFAS in wastewater does not rest solely on them.

4.0 REFERENCES

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