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A Desktop Assessment of Ozone Micro-Nanobubble Technology for Algae and PFAS Removal from Surface Water Bodies Using Open-Source Water Quality Data

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Abstract: Ozone is an excellent oxidant and helps in breaking down both organic and inorganic compounds; this effect is further enhanced when it decomposes into hydroxyl radicals. Several studies confirm the good performance of ozonation and micro-nanobubble technology in eradicating algae and per- and poly-fluoroalkyl substances. However, very little is known about the application of ozone micro-nanobubble technology in small-scale treatment; hence, this research aims to assess the potential of this technology. A survey was performed to obtain the water quality parameters of some selected water bodies via relevant open-source databases. The water quality was compared against the Environmental Protection Authority (EPA) guidelines to identify those that did not meet the criteria and it was identified that 18% of the surface water bodies were below the recommended guidelines. The identified water sources were then used for the treatment simulation, which applies the literature-reported % removal of water quality parameters to predict the effectiveness of ozone micro-nanobubble technology for the selected water sources in this study. Furthermore, the time (dose) that is needed for the treatment using this technology was estimated based on the surface area of the water bodies. The scalability study was conducted to assess how many water bodies could be treated within a day using a 50 m^3/h flow rate, which yielded a value of 27%. It was concluded that ozone micro-nanobubble technology can treat algae and per- and poly-fluoroalkyl substances in surface waters as part of their treatment process by reducing treatment frequency and environmental impacts. By observing the benefits of ozone micro-nanobubble technology, there is a considerable chance that the surface water bodies in the City of Salisbury and, therefore, other small-scale water treatment plants, will be healthier after undergoing this process. This study demonstrated the advantages of applying open-source water quality data as a quick approximation of the evaluation of new treatment techniques, which will help engineers to better predict the performance of the designed field trials.

Keywords: ozonation; micro/nanobubble; poly-fluoroalkyl; perfluoroalkyl

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1. Introduction

Only 2.5% of the total water on the earth is freshwater that can be used for sustaining life [1]. Water demand is increasing along with the increasing population across the globe, causing high amounts of wastewater production [2]. Wastewater is generated from sources like households, industries, mining, and agricultural activities [3]. Nontreated wastewater is harmful to the eco-biosphere and human health [3]. Despite the global recognition of the importance of wastewater treatment to society, 44% of the produced household wastewater in 2020 did not pass through efficient treatment plants [4]. The construction and operation of wastewater treatment plants (WWTPs) is a serious challenge in some developing and even developed countries. Small-scale treatment plants are called by different names in different parts of the world [5]. In South Australia, the name Community Wastewater Management System (CWMS) is used.

Water services, generally covering both water and wastewater treatment, have been broadened to include water recycling. A total of 63% of the generated 359.5 billion m^3 of wastewater is collected, and only 52% of the generated wastewater goes through the treatment process before discharging into the environment [6]. Considering the high volume of the generated wastewater and increased demand for water, the reuse of the treated wastewater for purposes like watering gardens, toilet flushing, industrial uses, irrigation, firefighting, and maintaining river flow is of interest [7]. As an emerging and important part of water services, management of water bodies, such as natural and man-made lakes, are increasingly operated by urban and regional councils as service providers to ensure a well-sustained livable environment for local communities. Increased turbidity, organic loading, and nutrients in water present serious challenges for these operators. Natural and synthetic organic compounds, nitrogen and phosphorous, pathogens, inorganic chemicals, microplastics, sediments, radioactive compounds, oil, heat, and emerging contaminants, such as UV filters, fire retardants, plasticisers, pesticides, and per- and poly-fluoroalkyl substances (PFASs), are the instances of the contaminants in wastewater streams [3]. Moreover, the presence of pollutants, especially nitrogen, phosphorous, and organic matter in water bodies, causes eutrophication, which consumes oxygen and produces hypoxic and anoxic conditions [6]. With eutrophication, algae grow exponentially, causing algal blooms [6]. In harmful algal blooms, the growth of algae is out of control, and they excrete toxins that are harmful to both humans and animals. While the illnesses produced by harmful algal blooms are rare, they can be debilitating or fatal [8].

Emerging contaminants, PFASs in particular, are major concerns. They have been in use since 1950 for metal plating, in firefighting foams, and for making waterproof fabrics. They can be harmful to embryonic development, learning and behavioral development in children, reproduction in adults, hormonal balance, and liver function [9]. Considering the importance of PFASs and global awareness about their potential hazards, finding efficient ways to remove PFAS compounds from surface water bodies is regarded as an incredibly significant priority. The hydrophobic and oleophobic properties of PFASs [10] make them useful for various applications like aviation, automotive, construction, energy, firefighting, food processing, medical, textiles, packaging, electronics, and domestic product industries [11–13]. PFOS (perfluorooctane sulfonate) and PFOA (perfluorooctanoic acid) easily move in an aqueous environment and conventional treatment methods cannot treat them [14]; therefore, they are serious threats. Some PFASs like PFAAs (perfluoroalkyl acids) are resistant to oxidation [15]; however, the application of granular activated carbon and methods such as reverse osmosis, nanofiltration, and electrochemical techniques can be useful in PFAS removal [16]. Yet, the disposal of these used contaminated filters is a serious challenge [14]. This project aims to develop and test the capability of an innovative technological solution for the degradation and safe removal of PFASs and other emerging contaminants in order to obtain a sustainable water environment. Water treatment process control and quality monitoring are two vital aspects of water quality management systems to provide optimal operational controls and preventive measures.

Ozonation is a known technique in water and wastewater treatment and is effective in algae treatment as a pre- or post-oxidation agent. Different water sources show a range of quality parameters—for example, their pH ranges from 7.1 to 8.7, and they have been treated using various methods like ozonation, ozonation + activated carbon, and ozonation + permanganate. The majority of the investigations were conducted in laboratories; however, some field works [17] have been conducted, too. It has generally been concluded that no ideal ozone dose has been found for algae treatment in all water bodies. The needed dose depends on the quality of the water; even in some water bodies with similar quality and using the same technology, different treatment outcomes have been observed. Ozone micro-nanobubble technology (MNBT) for algae treatment has been used during the past 5 years; however, the removal of PFAS using this technology is not readily available in the literature. This research aims to utilise a desktop study using historical water quality parameters via open-source water quality databases and treatment efficiencies via a literature review to assess ozone MNBT as a potential treatment option for the removal of algae and PFAS. The objective is to make use of the Internet of Things (IoTs) to provide a preliminary but reliable assessment to guide the experimental design to obtain the specific operational data needed to optimise the treatment process. Ozone and MNBT are able to oxidise contaminants like PFASs and algae seed through direct oxidation by ozone molecules or generated non-selective very active OH radicals, therefore assisting in improving water quality and mitigating the environmental and health burdens.

In this paper, first introduced was the geographical site of the study where the water sources of interest are located. Then, the surface water bodies in the introduced site were identified. Ozone-based treatments of surface waters with any water quality parameter in the range of the selected parameters of water bodies of the chosen geographical site were searched in the open-source literature and the results were retrieved. Afterwards, the process of collecting open-source quality data of the water bodies under study was performed and their useful quality parameters were selected to make a comparison. The water bodies not complying with the Environmental Protection Authority (EPA) guidelines were distinguished and the treatment efficiencies of the literature's ozone-based water treatment methods were used to calculate the predicted quality of those unhealthy water resources after similar treatment. The scalability of the proposed treatment was also studied.

2. Methodology

2.1. Case Study Site

The City of Salisbury (CoS) is one of the 68 South Australian councils and provides essential services and facilities to the communities. Located 25 km north of Adelaide, South Australia, it is home to a population of 147,602 and covers 158.1 km^2 [18], the boundary of which is shown in Figure 1. The climate in the region is considered typical Mediterranean, with cool, wet winters, and warm to hot, dry summers [18]. CoS via Salisbury Water, a business unit of the CoS, is continually trying to enhance and improve environmental sustainability. Salisbury Water monitors and maintains over 40 wetlands [18]. Being a water service provider that recycles and distributes non-drinking water around the city, it provides water for flushing toilets, washing cars, filling ornamental ponds, and irrigating plants, as well as other industrial uses [18].

The two key factors that led us to choose CoS as the location for this case study were as follows: First, due to the proximity of the two airfields, Edinburgh RAAF base and Parafield Airport, where firefighting foam was used regularly [19,20]. Although the long-chained PFAS foam has been banned for further use, traces of this material can still be found in the surrounding bodies of water, including both surface and groundwater. The second reason was a small-scale water treatment project similar to the CWMS scale operated by Salisbury Water. Furthermore, certain locations have aquifer storage and recovery (ASR) programs to store the collected and treated stormwater from the wetlands and utilise it when the wetlands are dry [2].

2.2. Data Collection

Step 1—Identifying surface water bodies.

The first step of conducting this desktop study is the identification of surface water bodies located within the Salisbury Local Government Area (LGA). To identify these locations, different databases/websites were used, including:

- City of Salisbury.
- Google Maps and Google Earth.
- Nature Maps—Department of Environment and Water.
- Geoscience Australia.

While using Nature Maps, the LGA was filtered to show Salisbury only, by choosing ‘Administrative boundaries > Administrative > LGAs’ in the Layers Table. Then, the Draw Tool was used to draw a polygon following the LGA boundary line, and the ‘Water bodies’ and ‘ ‘Watercourses’ boxes were checked under ‘Surface water’. In the next stage, the Query function was used to set the Data Source as either ‘Water bodies’ or ‘Water courses’, and ‘All Polygon Drawings’ was chosen as the Map Area. To extract watercourse data, the ‘Feature Type’ was selected, and ‘Type’ was chosen to obtain water body data. Lastly, by entering the search function, the results for the chosen polygon were obtained, which was equal to the Salisbury LGA.

Figure 1. The boundary of the City of Salisbury (Source: NatureMaps).

Step 2—Obtaining water quality parameters.

The water quality information of these water bodies was obtained by first identifying the databases followed by extracting the water quality parameters. The databases used are introduced below:

- Goyder Institute.
- Water Connect.
- Water Data SA.
- Nature Maps—Department for Environment and Water.
- Green Adelaide.
- EPA Aquatic Ecosystem Condition Reports.
- Reports on the Parafield Airport and Edinburgh RAAF Base.

Step 3—Literature review of PFAS and algae control.

This section identifies the journal articles, reports, case studies, and databases that used MNBT or ozonation for algae or PFAS removal from surface water bodies. Both laboratory and on-site studies were included, and the following databases were used to retrieve the necessary information:

- University of South Australia Online Library.
- Google Scholar.
- Goyder Institute.
- Water Connect.
- Case studies conducted by commercially available micro-nanobubble generators.
- Literature Review.

Step 4—Identifying comparable parameters.

The span in which the water quality data were distributed was found through the comparison of the relevant data found in Stage 2. The literature review showed that the efficiency of MNBT and ozonation processes is a function of dose, pH, temperature, dissolved organic matter (DOM), and dissolved oxygen (DO) [21–23]. The following parameters were selected as scope:

- DO in mg/L.
- pH.
- Temperature in °C.

2.3. Data Analysis

The collected data were first analysed to distinguish the water bodies not complying with the EPA guidelines for 'healthy' water bodies, i.e., those with high nutrient concentrations and algal bloom formation potential. Since not all surface water bodies had water quality parameters, an assumption was necessary to assimilate the percentage of 'unhealthy' water bodies from the known locations in the entire CoS. The literature review data were used for the next analysis. All documents found via Step 3 involving studies that were conducted on the surface water in the lab or in the field and that had any water quality parameter in the range of the above parameters of CoS surface water bodies were included in this study. In this set of conditions, the assumption was made that approximately the same removal efficiencies that were found in the literature documents could be seen if the same treatment methods were applied to CoS water bodies. A statistical analysis was run to explore if a correlation can be found between the quality of water in CoS water bodies and the case studies from the literature review.

3. Results and Discussion

3.1. Overview of Water Bodies in the City of Salisbury

Rivers, creeks, wetlands, and lakes form the surface water bodies of the CoS area. Little Para River is the major river in the LGA; Cobbler and Dry Creeks are two creeks [2]. Furthermore, it includes 46 wetlands [2], 135 water bodies (including wetlands), and 306 watercourses, 136 of which are unclassified watercourses and the remaining are channels, canals, drains, and ditches [24]. The CoS website has not identified the type of wetland, that is, perineal, intermittent, or dry. Therefore, Google Earth and Google Maps were used to find if these wetlands were dry; however, this was redundant due to the unavailability of information regarding the quality of water (Step 2) in these wetlands. The water bodies identified by Nature Maps were perineal. CoS lakes are divided into three categories: ornamental, natural, and permanent lakes. Both ornamental and permanent lakes use groundwater for topping up; however, natural lakes mainly use stormwater runoff for this purpose. Natural lakes contain stormwater runoff and can be dry or wet. Salisbury's groundwater is brackish; however, databases like Water Connect and Goyder Institute do not contain information on CoS water bodies. The water bodies have areas ranging from 56.49 m^2 to 366 337.7 m^2. Figure 2a,b show the water bodies described by Nature Maps and watercourses on Nature Maps, respectively.

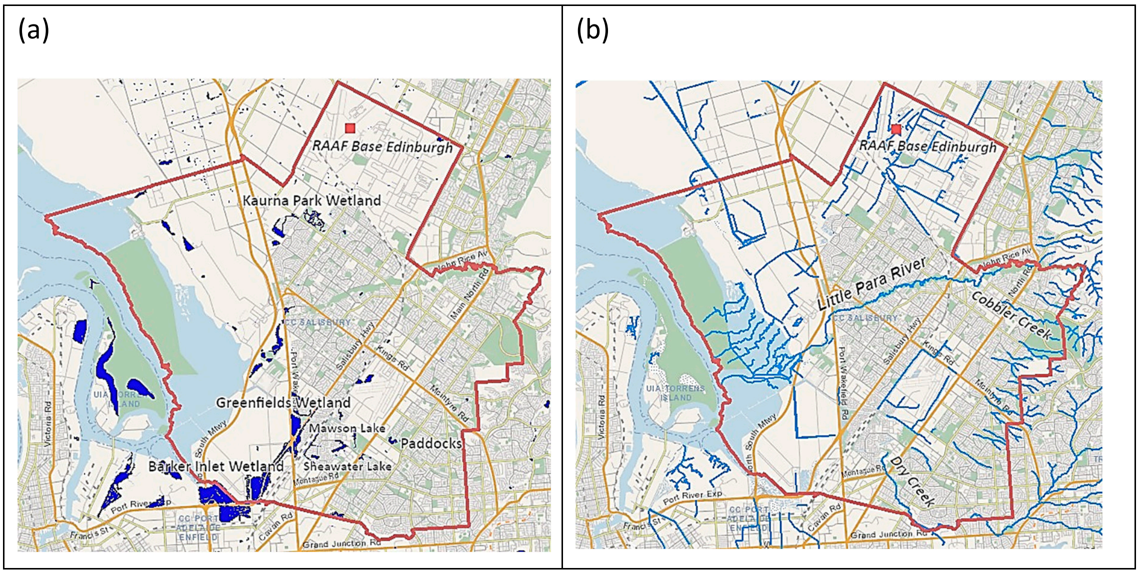

Figure 2. (**a**) The surface water bodies and (**b**) watercourses in the City of Salisbury (blue areas) [24].

3.2. Overview of Surface Water Quality and Other Parameters

Now that the available surface water bodies have been identified, the corresponding water qualities should be studied. The RAAF interpretive report (2020) [25] was the main information source that presented the PFAS amounts in locations surrounding and inside the base. The problem was that the water quality parameters were only reported for April and August and no data were provided for summer months in which algal blooms arose. EPA aquatic ecosystem condition reports (2011) and the water monitoring station downstream of Adams Creek were other information sources.

Surface water quality in CoS is shown in Table 1. As can be seen in this table, DO ranges from 0.35 to 9.3 mg/L, EC varies between 82.5 and 781 μS/cm, pH is in the range of 6.21–8.36, and the temperature is between 11.1 and 37.7 °C. As previously mentioned, the information retrieved from the Edinburgh RAAF base (2020) only covers the data of surface water in April and August, which are related to the lower temperature values, while station A5051022 has monitored the temperature throughout all months of the year.

Table 1. Water quality parameters of surface water bodies within CoS.

Location	DO (mg/L)	EC (μS/cm)	pH	Temp (°C)	Reference
North of (off-base) Edinburgh RAAF Base	1.35–6.5	155–301.4	6.21–7.44	11.2–18.9	
Edinburgh RAAF Base	3.88–8.2	113–318.6	6.34–8.36	11.1–20.8	[25]
South of (off-base) Edinburgh RAAF Base	0.35–9.3	103.3–454.2	6.73–8.15	13.0–22.2	
Kaurna Park Wetland	2.09–7.2	82.5–586	6.65–8.07	13.8–22.1	
Little Para River, Burton	8.35	781	7.61	18.7	[26]
Little Para River, Salisbury Downs	6.05–7.49	285–340	7.05–7.45	11.45–24.0	[26]
A5051022—Adams Creek d/s	-	-	-	6–46	[27]
Range	0.35–9.3	82.5–781	6.21–8.36	6–46	
Required Standard	>3	150–500	6.5–9.5	-	[28]

Both locations in the Little Para River pass the DO conditions, which should be higher than 3 mg/L for healthy freshwater and over 6 mg/L in ideal conditions [29]. Inside or near the RAAF base, the lower concentration limits indicate hypoxic conditions, i.e., less than 3 mg/L [29], and the higher concentration limits indicate the healthy conditions of the water bodies. The overload of contaminants generates hypoxic conditions [6] and prepares the environment for algal bloom. Healthy watercourses with acceptable DO concentrations were seen in both locations of the Little Para River and the problem was mostly seen in ponds and lakes. Considering the enhancement of algal bloom in stagnant water, this makes sense [6]. The DO concentrations of different locations are shown in Figure 3 in which the minimum requirement has been shown with a red horizontal line. This figure shows that six out of thirty-two locations have DO concentrations less than that of healthy water. The information retrieved for the RAAF base and locations surrounding it was recorded in two different seasons of the year; the low DO levels were recorded in April while the data recorded in August in the same place were higher than the threshold value of 3 mg/L. It is possible that the warm conditions in April enhanced the algal bloom and consequently reduced oxygen concentration, but as a result of treatment, DO levels increased later in August.

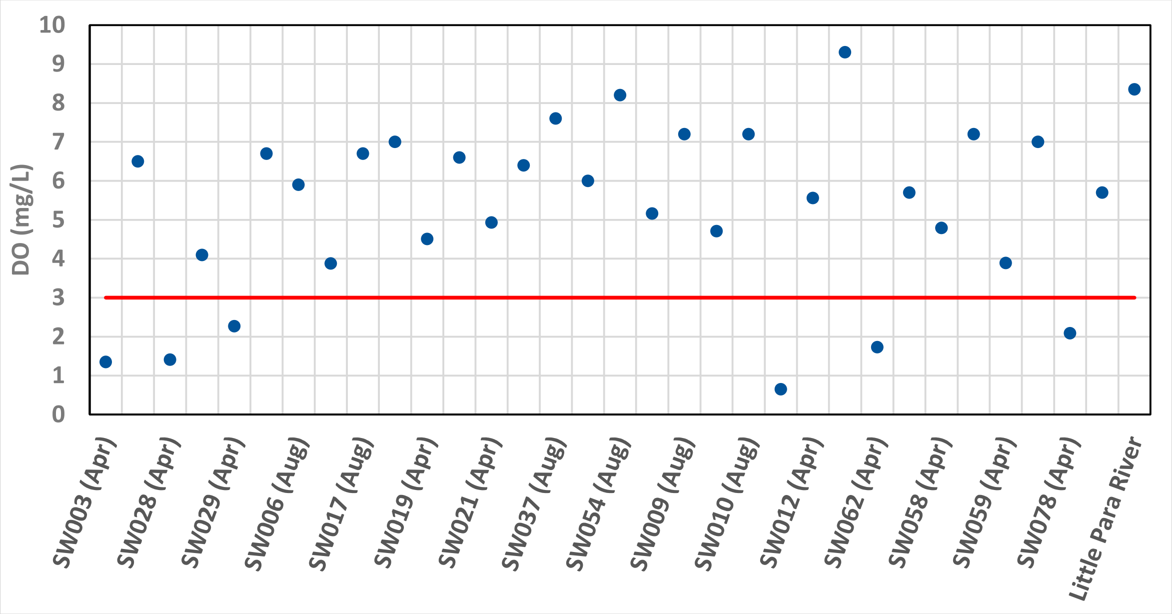

Figure 3. The DO levels of surface water bodies in CoS. The red line demonstrates the minimum DO level for a healthy water body.

Analysing water quality data showed that six bodies had lower DO values compared with the guideline value for healthy water; for pH and EC values, the number of such water bodies was four. Six out of thirty-two water bodies were below the minimum DO threshold values, which is equal to 18.2%. With the assumption that the calculated data can be used for the entire CoS area, 23 of the total 135 water bodies in this area had insufficient DO levels. The low concentration of DO means that the water body is going to start eutrophication with a high chance of algal bloom. Considering that algal cell count information was not accessible for this study, this comparison helps to find an alternative method for determining the water bodies with a high chance of algal bloom. It should be noted that the monitored DO values were mainly for April and August, with lower temperature values compared to the summer season; therefore, it is expected that more than 18% of the water bodies can suffer from algal bloom.

The concentrations of total PFAS and PFOS + PFHxS inside and surrounding the RAAF base have been demonstrated in Figure 4. The maximum allowable PFAS concentration is dependent on the type of water usage, i.e., drinking and recreation [30,31]. Considering human health, the maximum PFAS and PFOS + PFHxS concentrations are 10 µg/L and 2 µg/L, respectively, for recreational applications, but for ecological health to protect 95% of the species, the maximum allowed PFAS is 220 µg/L [31]. In Figure 4, the levels of contaminants in all locations except SW019 have been shown on the primary vertical axis, with the secondary vertical axis showing the contaminant concentrations of only location SW019, because PFAS and PFOS + PFHxS levels in all locations except SW019 were less than 2 µg/L. These concentrations were around 175 µg/L and 150 µg/L, respectively, in SW019. In addition, the SW003, SW028, and SW029 locations were north and upgradient from the base, while SW006, SW017, SW019, SW021, and SW054 were inside the base. Surface water bodies in SW009, SW010, SW011, SW012, and SW062 were locations of road drains off the base, and SW058, SW059, and SW078 were in the Kaurna Park Wetland, south of the RAAF base. Figure 4 shows that despite the low concentrations of PFAS, it is mobile and, therefore, is an urgent issue to be resolved.

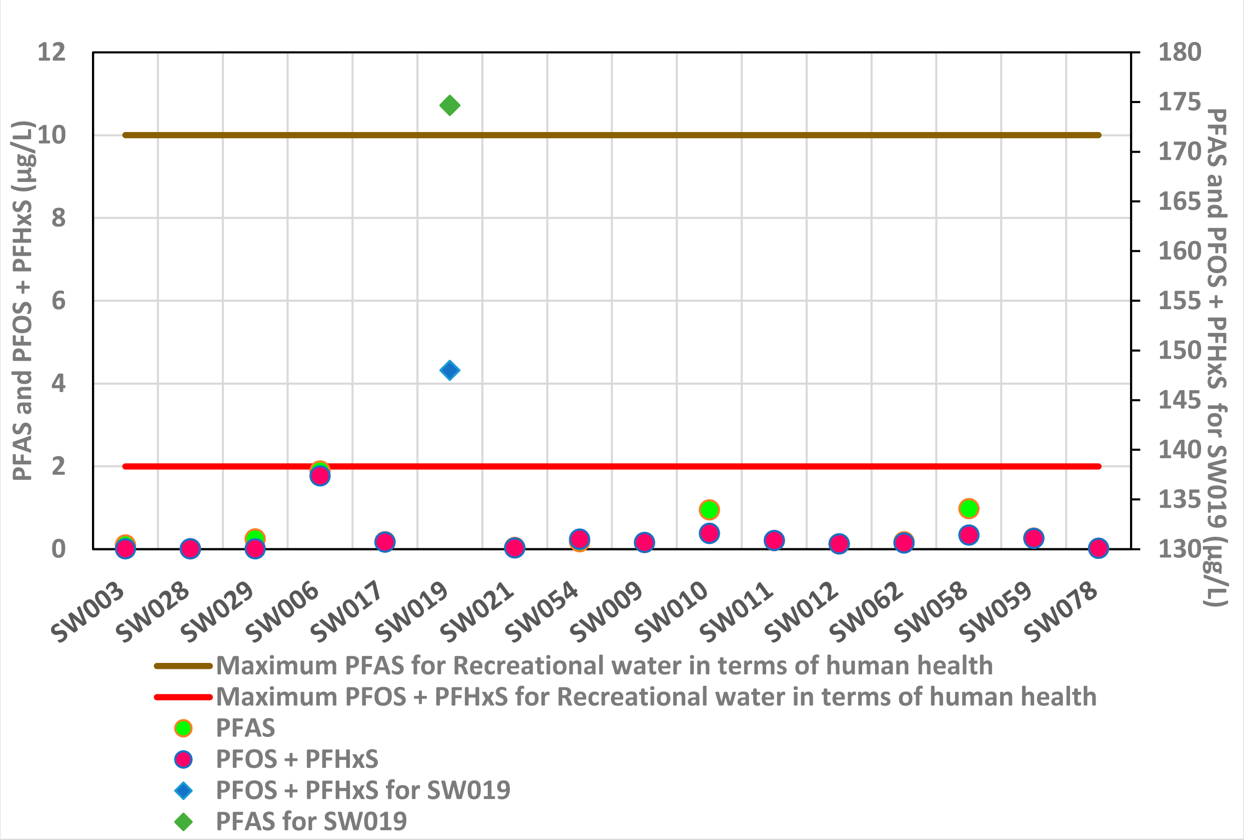

Figure 4. Total PFAS and PFOS + PFHxS of locations inside and surrounding the RAAF Air Base in Edinburgh. The horizontal lines represent the HEPA (Heads of EPAs Australia and New Zealand) maximum criteria.

3.3. Utilisation of Literature Case Study Results

After determining the range of water quality parameters for surface water bodies of CoS, the site studies or laboratory experiments (Table 2) performed within that water quality range were considered. For this purpose, studies based on ozonation and MNBT for algae and PFAS removal were analysed (Tables S1–S3). In the literature review of PFAS removal, only its removal by ozonation could be retrieved, and no documents related to its removal via MNTB were found.

Additionally, an investigation was conducted to find if there was a correlation between the pH and temperature values of CoS water bodies and those from the literature review studies. pH and temperature were selected since they were the most abundantly accessible parameters obtained from the case studies. As Spearman's rho correlation coefficient is suitable for non-parametric data, it was used to study the correlation, which yielded the correlation coefficients of 0.996 and 0.989 for pH and temperature, respectively, showing a very strong positive correlation. These strong correlations were expected since the case study values were within the range of the CoS water bodies. This statistical test further confirms that the comparison is possible.

Table 2. Summary of literature review results for algae and PFAS removal within the given water quality parameter range.

Algae Reduction Using Ozonation	Temperature (°C)	pH	DO (mg/L)	Reference
93%	16.6–31.3	-	-	[32]
95.9%	-	7.9	-	[17]
Algae Reduction Using Ozonation + MNBT	**Temperature (°C)**	**pH**	**DO (mg/L)**	**Reference**
96%	18.5–24.1	-	-	[33]
100%	15–28	6.5–9	4–12	[34]
DO increase from 4 to 6.1 mg/L	-	-	4	[35]
DO increase from 1 to 8 mg/L	26–32	-	1	[36]
PFAS Reduction Using Ozonation	**Temperature (°C)**	**pH**	**DO (mg/L)**	**Reference**
95%	22.5	-	-	[37]
77%	22	7.5	-	[38]

Table 2 shows that algae reduction as a result of only ozonation is less than 96%; however, it increases to higher than 96% when coupled with MNBT. For PFAS reduction, the efficiency of ozonation is more than 76%. The documents found in the literature review were considered in this study as long as at least one of their water quality parameters was in the range of CoS water quality parameters. The difference in reduction rates for similar technologies could be due to the conglomerate of parameters. Rositano et al. (2001) [39] and Zanacic et al. (2016) [40] showed that similar treatment processes for similar water qualities produced different reduction efficiencies. They also demonstrated that based on water quality parameters and location, each water body will show a unique treatment result.

Ozonation has been used in the wastewater industry during the past two decades but only as a disinfectant at the end of the process and not for the primary treatment of algae [41]. This is mainly because ozone is highly active and reacts with organic contaminants; hence, high doses of ozone are required if it is added in the primary steps of wastewater treatment. However, in some cases, ozone has been used for pre-oxidation to improve the coagulation process [32]. Considering the size of CWMS and small-scale water treatment plants, they will require much smaller doses of ozone. Furthermore, many surface water bodies within CoS have aesthetic applications or are used to capture stormwater, meaning that they are not intended (as of yet) to be re-used. These water bodies can benefit from ozonation, especially together with MNTB, to decrease the treatment frequency and improve the health of the water body and ecosystem.

3.4. Scalability of the Proposed Treatment

The treatment durations required for commercial treatment plants with common sizes and flow recirculation for some water bodies in CoS have been shown in Figure 5. Nature Maps data were used to find the area of the surface water bodies. The depth of all bodies was assumed to be 1 m to calculate the volume of the water bodies. Nature Maps produced 135 results, of which only 15 had a name. Water bodies with the smallest surface area (water body 1), the largest surface area (water body 3), and those corresponding to one-day treatment time at three different flow rates were selected. The treatment duration of one day for the flow rates equal to 15 m^3/h and 50 m^3/h was seen for paddocks 8 and 5, respectively. Only one water body with a treatment duration equal to one day and a flow rate of 7.5 m^3/h was recorded (water body 2).

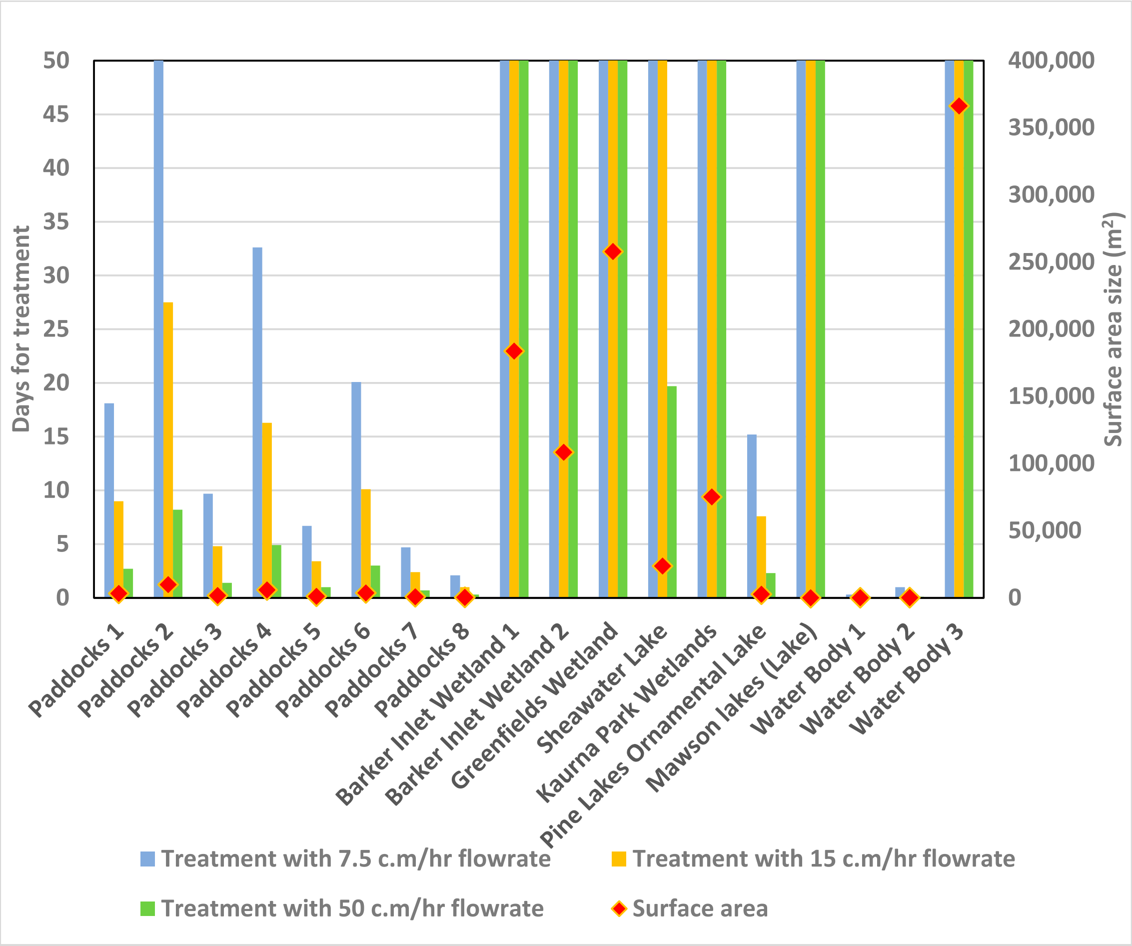

Figure 5. The treatment duration of the surface water bodies for commercially available MNBT equipment with flowrates of 7.5, 15, and 50 m^3/h. The names that were not provided in the database were identified as 'water body'. 'c.m' stands for cubic meters. The depth of all water bodies was assumed to be 1 m. The maximum treatment duration shown in the figure is 50 days.

Equation (1) was used for the calculation of treatment duration (h). By dividing this value by 24, the treatment duration in terms of the number of days was calculated. For example, water body 3 with a flow rate of 50 m^3/h requires up to 10 months for complete treatment, while water body 1 with a flow rate of 7.5 m^3/h needs only 7.5 h.

$$\text{Treatment hours} = \frac{\text{Volume of water body}}{\text{Flow rate in m}^3/\text{hour}} \tag{1}$$

According to Table S3, the largest water body with algae removal in the literature had a volume of 123,348 m^3. The removal of algae in small and medium-scale water bodies was effective [42]. Only three water bodies out of one hundred and thirty-five, i.e., Barker Inlet Wetland 1, Greenfields Wetlands, and water body 3 were larger than that. This indicates that the rest of the lakes have small enough sizes to be treated for algae removal using ozone MNBT. Treatment time depends on the flow rate and the number of units used. A total of 27% of the total water bodies (37 bodies) can be treated within one day using the flow rate of 50 m^3/h. This confirms that mobile treatment plants can treat a lake within a day and then travel to the next site to treat it during the next day. This makes the treatment process more efficient. NBs can survive up to two months in water, which reduces the treatment frequency and the cost of algae removal. Furthermore, determining the water bodies that can be treated in one day helps with being proactive against algal blooms instead of reacting after the occurrence of a bloom. According to Moleaer [36,42], only one treatment is necessary using ozone MNBT compared with five to ten treatments using algaecide. The authors stated that during a two-week treatment, they saved approximately USD 1000 on algaecide but not equipment and maintenance costs. Using ozone MNBT compared with only ozonation needs less dosage and less contact time to achieve a higher reduction rate [43,44]. It is concluded that MNBT ozonation will help in reducing the cost of algae and PFAS removal. As already mentioned, CoS conducts Aquifer Storage Recovery (ASR) programs. MNBT ozonation can help in groundwater treatment [45] and, due to the long stability of NBs, they can be transferred to groundwater after being utilised for surface water treatment; this can be beneficial considering groundwater treatment.

Based on the strong correlation of water quality parameters between the case studies and CoS surface water bodies, it can be concluded that almost similar algae reduction values can be achieved using ozonation and MNBT. In spite of the unavailability of studies conducted using ozone MNBT for PFAS reduction, analysing PFAS removal rate using ozone, and given the enhancing effect of MNBT on the efficiency of oxidation and degradation of the contaminants while demanding lower concentrations of ozone, led us to this conclusion that reduced treatment frequency and cost would be necessary for PFAS treatment using ozone-filled nanobubbles. Since the CoS has a small-scale water treatment plant, like CWMS, it can also be projected that similar reductions of PFAS and algae can be achieved provided the similarity of the range of water quality parameters. However, due to the sensitivity of ozone to the quality of water mixtures, exact removal rates of algae and PFAS cannot be provided without conducting lab or field studies. Zhao et al. (2019) [46] undertook a similar study, investigating the reduction of algae using coagulation, and discovered the optimal conditions for algal reduction based on the dose, pH, and densities of the initial algal cells. These parameters were utilised to formulate a regression equation and an artificial neural network to find optimal conditions for algae removal. A similar approach for a few surface water bodies in the CoS could achieve a trend and provide a multi-regression analysis to discover the optimised conditions for the removal of the given quality parameters. Later, this could be further expanded to other CWMS or small-scale treatments in South Australia; however, in order to achieve this, land use, climate, and rainfall patterns will all need to be accounted for.

In this study, the most considerable limiting factor was acquiring publicly available data. Databases such as Water Connect and Goyder Institute did not have any data corresponding to surface water body qualities of the CoS. The acquired data had limited information with no indication of total nitrogen (TN), total phosphorous (TP), algal counts, and summer water temperatures. Therefore, some correlations between the parameters of water quality for the CoS and the case studies were based on picking and choosing from different case studies of the selected water quality parameters within the range, as not all the case studies contain the exact same water quality parameters in the dataset as per the CoS water body.

4. Conclusions

According to this study, it was identified that 18% of the surface water bodies were not meeting the required EPA guidelines. Temperature and pH showed a high level of correlation of over 0.98 between CoS water bodies and those from the literature review studies, and based on this, it was assumed that ozonation and ozone MNBT applied to the case studies should produce similar reduction rates in the CoS. Further, a scalability study was performed to assess how many water bodies could be treated within a day using a 50 m^3/h flow rate, which yielded a value of 27%. Identifying these water bodies early on will facilitate a proactive approach to prevent algal blooms rather than reacting when algal blooms form. From these observations, it was concluded that PFAS and algae could be reduced using ozone MNBT; however, since the efficacy of this method is dependent on water quality parameters, the reduction rate could widely vary. From the correlation, it can be comprehended that although reduction will occur, its rate and scale cannot be precisely investigated without laboratory or field studies. That said, by observing the benefits of ozone MNBT, there is a considerable chance that the surface water bodies in the CoS and, therefore, other small-scale water treatment plants, will be healthier and have reduced levels of PFAS and algae after performing ozone MNBT. A validation study is required to obtain information about the feasibility of using ozone MNBT for surface waters impacted by algae and PFAS within small-scale water treatment plants in South Australia.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su16020668/s1, Table S1: Lab or on-site studies conducted using ozonation for algae treatment in surface water entities.; Table S2: Lab or on-site studies conducted using ozonation for PFAS treatment in surface water entities.; Table S3: Lab or on-site studies conducted using ozonation and/or MNBT for algae treatment in surface water entities. References [47–52] are cited in Supplementary Materials.

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