PASS-THE-PFAS-PARCEL: MAKING PERMANENT PFAS DESTRUCTION ECONOMICALLY VIABLE

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ABSTRACT

For more than two decades, the water industry has played an expensive game of pass-the-PFAS-parcel. Granular activated carbon (GAC) and ion exchange (IX) can remove PFAS from water, but the contaminant is transferred into spent media and associated residual streams that still require lawful disposal and management. This paper presents a ten-year screening analysis based on the treatment options bench-tested for two Northern NSW Shire Council bores. At 6 ML/d, 21.9 GL would be treated over ten years. Applying the measured total PFAS concentrations gives an estimated 1.6-2.1 kg of PFAS in that water; the 2.4 kg value used in the accepted conference abstract is a conservative screening allowance. Using an illustrative 20 t replacement mass and the reported media service lives, annualised spent-media throughput is approximately 608 t for GAC, 261 t for IX at 280 days and 152 t or less for IX at a service life of at least 480 days. These are comparative estimates, not final engineering quantities. The paper contrasts adsorption with a proposed Magnetic Particle Extraction (MPE) pre-concentration pathway designed to reduce the residual mass presented for destruction. The central finding is that removal alone is not the end-point: treatment design should be judged by contaminant capture, residual mass, recoverability and the credible route to permanent destruction.

1.0 INTRODUCTION

PFAS substances are highly persistent synthetic chemicals. Their resistance to conventional degradation is useful in products but problematic after release. Water treatment therefore tends to separate PFAS from water rather than destroy it. Adsorbents such as GAC and PFAS-selective IX resin are proven separation tools. However, the treatment decision creates a second decision about spent media, washwater, backwash, protective equipment and other contact wastes.

A recent public tender by Narrabri Shire Council in Northern NSW provides a useful case study because the source water and bench-test results are publicly documented. ECT2 tested bore water from Tibbereena and Killarney for the NSW Department of Climate Change, Energy, the Environment and Water. PFOS and PFHxS accounted for more than 70% of the measured total PFAS. Both media produced water compliant with the 2025 Australian Drinking Water Guidelines during the trial. The projected service life was approximately 120 days for a properly sized GAC system, approximately 280 days for SORBIX PURE LC5 IX resin on Tibbereena water, and at least 480 days for the same resin on Killarney water [1].

The practical question is broader than whether a technology can meet a water-quality number. How much secondary material is generated over the plant life, what is its PFAS loading, and can it be economically taken to an end-point that destroys rather than relocates PFAS? This paper develops a transparent screening model and identifies the information still needed before procurement or design decisions are made.

2.0 METHOD

2.1 Basis and boundaries

The model assumes continuous treatment at 6 ML/d for 3,650 days. It uses the raw-water results in Table 1 and the ECT2 service-life projections. No allowance is made for plant downtime, seasonal blending, bore duty split, concentration variability or future guideline changes. Total PFAS mass is calculated as concentration multiplied by treated volume. Media throughput is annualised as operating days divided by service life, multiplied by an illustrative 20 t replacement mass.

Table 1: Source-water PFAS concentrations reported by ECT2 [1]

Analyte	Tibbereena (µg/L)	Killarney (µg/L)
PFBS	0.0037	0.0056
PFHxS	0.0211	0.0314
PFOS	0.0341	0.0372
PFOA	0.0018	0.0023
Sum PFAS (n=28)	0.0714	0.0943

The 20 t value is not supplied by ECT2. Independent review found that it is credible for one lead GAC vessel or routine GAC vessel change-out at this flow. A representative two-vessel GAC system could contain approximately 45-48 t in total. For IX, 20 t may be a conservative total installed inventory, but the available information does not establish that 20 t would be removed at each routine change-out [2]. Lead-lag configuration matters because the lag vessel may move into the lead position while only the spent lead vessel is replaced.

2.2 Equations

For a concentration C in µg/L and volume V in litres, PFAS mass (kg) = C × V ÷ 10^9. For media replacement mass M in tonnes and service life L in days, annualised ten-year media throughput (t) = (3,650 ÷ L) × M. Annualised throughput includes the proportional use of media remaining in service at the end of year ten; whole-event dispatch totals may therefore be slightly lower.

2.3 MPE comparison

MPE is being developed by NTS as a pre-concentration process. Functionalised magnetic nanoparticles are dosed into water to bind a target contaminant, then recovered in a magnetic separator. The intended value is not simply another removal mechanism: it is the ability to recover the binding material into a substantially smaller residual stream that may be practical to transport and destroy. For this screening paper, 20 t over ten years is treated as an NTS design target, not as a demonstrated full-scale PFAS residual yield. Validation requires independent PFAS analyses, nanoparticle mass-balance and recovery data, hydraulic performance, contaminant loading capacity, regeneration or disposal characterisation, and destruction trials.

3.0 RESULTS

3.1 PFAS mass in the treated water

At 6 ML/d, the ten-year treated volume is 21.9 billion litres. If all water had the Tibbereena concentration of 0.0714 µg/L, it would contain approximately 1.56 kg of total PFAS. At the Killarney concentration of 0.0943 µg/L, it would contain approximately 2.07 kg. The 2.4 kg figure in the accepted abstract corresponds to a deliberately conservative screening allowance above the two reported results. This distinction should be maintained: source-water concentration and bore duty determine the actual mass load.

Table 2: Ten-year screening comparison at 6 ML/d

Scenario	Service life	Assumed mass/event	Annualised media/residual
GAC	120 days	20 t	608 t (≈610 t)
IX - Tibbereena	280 days	20 t*	261 t
IX - Killarney	≥480 days	20 t*	≤152 t
MPE design target	n/a	n/a	≤20 t target

*The 20 t removed-per-event assumption for IX has not been confirmed by ECT2 and should not be used for final design or procurement.

3.2 What the comparison means

On the stated assumptions, GAC generates approximately 29 kg of spent media for every gram of source PFAS. The 280-day IX scenario generates approximately 13 kg/g and the 480-day scenario approximately 7 kg/g. These ratios do not imply poor removal performance; they show the physical consequence of using bulk media to capture trace concentrations. They also exclude water retained in wet media and other ancillary residuals, so dispatch mass may be higher.

Relative to the 608 t GAC screening case, a 20 t MPE residual target would represent a 96.7% reduction in residual mass requiring downstream management. Relative to the two IX scenarios, the reduction would be approximately 92.3% and 86.8%. These percentages compare gross residual

mass, not demonstrated lifecycle performance. They should only be used as a testable target until matched, full-scale data are available.

4.0 DISCUSSION

4.1 Removal is not destruction

The Narrabri bench trial answers an important first question: both tested media can remove PFAS sufficiently to meet the applicable drinking-water guideline during the modelled service period. It does not answer the final question: what happens to the captured PFAS? If spent media is stored, landfilled or transferred to another facility without destruction, the risk has changed form and location, but the fluorinated compounds remain.

Australian PFAS guidance emphasises prevention of further spread and risk-based management of PFAS-contaminated materials [3]. In NSW, waste must be characterised and classified, transported by appropriately authorised parties where required, and accepted by a facility lawfully able to receive it [4]. PFAS contact residuals should not automatically be labelled hazardous waste; classification depends on their characteristics and the applicable regulatory framework. Equally, a treatment proposal should not assume that an off-site destination is a permanent end-point merely because the material leaves the water plant.

4.2 Residuals beyond spent media

A whole-of-process assessment should include iron and manganese pretreatment sludge and filter backwash; spent cartridge, bag or other prefilters; GAC backwash and initial flush water containing carbon fines; IX commissioning rinse water; vessel drain-down, media transfer and washdown water; and contaminated PPE, absorbents, liners, hoses and containers [2]. The ECT2 memo also notes iron and manganese challenges and recommends considering pretreatment to optimise whole-of-service-life cost [1]. Pretreatment can extend adsorbent life, but it also introduces additional solids and water streams that require management.

4.3 Economics of concentration

Destruction cost is often quoted per tonne of material accepted, not per kilogram of PFAS destroyed. This creates an unusual economic effect: the carrier mass can dominate cost even when the contaminant mass is measured in kilograms. Because no verified disposal quotation was included in the source documents, Table 3 presents a sensitivity analysis rather than a claimed market price. Transport, characterisation, handling, minimum charges, water content and technology-specific acceptance criteria are excluded.

Table 3: Illustrative residual-management cost sensitivity

Residual mass	$500/t	$1,000/t	$2,500/t	$5,000/t
608 t GAC	$0.30 m	$0.61 m	$1.52 m	$3.04 m
261 t IX	$0.13 m	$0.26 m	$0.65 m	$1.31 m
152 t IX	$0.08 m	$0.15 m	$0.38 m	$0.76 m
20 t MPE target	$0.01 m	$0.02 m	$0.05 m	$0.10 m

The strategic implication is that pre-concentration can change the feasibility of destruction. A technology does not need to be the final destruction process to create value; it may serve as the bridge that converts a diffuse, high-volume residual into a smaller feedstock suitable for an approved destructive technology. The economic comparison must still include treatment energy, consumables, capital, labour, maintenance, verification sampling and all residuals.

4.4 Information required for a defensible full-scale comparison

Before the screening values are used commercially, suppliers should confirm design flow and daily operating hours; total bed volume and empty-bed contact time; number of treatment trains and lead-lag arrangement; media volume, density and mass per vessel; whether service life refers to lead-vessel breakthrough or final outlet breakthrough; the mass physically removed at each event; drain-down and wet dispatch mass; and the proposed transport and spent-media management route [2].

For MPE, the equivalent evidence package should report influent and effluent PFAS by a NATA-accredited laboratory; individual and total PFAS mass balance; nanoparticle dose and recovery; residual nanoparticles in treated water; hydraulic residence time and pressure loss; performance under

iron, manganese, organic carbon and turbidity variation; concentrate volume and solids mass; and independent destruction or disposal acceptance data. Claims should be based on like-for-like flow, source water, target guideline and operating duty.

5.0 LIMITATIONS

This is a screening analysis, not a detailed design. The ECT2 summary does not provide full-scale bed volume, media mass, vessel configuration, density, operating hours or change-out protocol. The IX throughput is particularly sensitive to whether 20 t represents total installed inventory or the mass actually removed during a routine lead-lag change. Wet dispatch mass cannot be derived from the memo. Service life may change with source-water variability, pretreatment, operating strategy and the treatment endpoint.

The MPE residual figure is an NTS development target and has not yet been demonstrated for Narrabri water at full scale. This paper therefore does not claim that MPE is presently a proven substitute for the bench-tested systems. It proposes the mass of secondary waste and the route to destruction as additional performance criteria that should be measured in future trials.

6.0 CONCLUSION

Narrabri's problem is not hundreds of tonnes of PFAS. It is approximately two kilograms of PFAS dispersed through 21.9 GL of water and potentially captured inside hundreds of tonnes of secondary material. GAC and IX can provide effective removal, but their value should be assessed alongside the mass and character of the residuals they create.

Using a transparent 20 t-per-event screening assumption, the ten-year annualised throughput is approximately 608 t for GAC and 152-261 t for IX. Those values are useful for comparing orders of magnitude, but they remain subject to supplier confirmation. An MPE residual target of no more than 20 t would materially change the downstream economics if removal, recovery and mass balance are independently validated.

The lesson for the water industry is simple: stop evaluating PFAS treatment at the clean-water outlet. A complete decision must follow the contaminant through capture, concentration, transport and a credible permanent end-point. The best treatment train may be the one that makes destruction practical, not merely the one that makes PFAS disappear from one sample bottle.

7.0 ACKNOWLEDGEMENTS

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8.0 REFERENCES

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