

The Rocky Hill Water Facility.

Section 8. PFAS Remediation and related issues.

The PFAS contamination in the Rocky Hill water source and the removal of all PFAS contaminants with the Rocky Hill Water Facility is the immediate and critical issue facing the Rocky Hill community at this time, and which forms the content of this **Section 8.**

The previous **Section 7** describing the duty cycle operation of the Rocky Hill Water Facility is a necessary preface to this **Section 8.**

The Rocky Hill PFAS contamination problem was essentially resolved over a year ago with a relatively small amount of scientific investigation and literature search, and a PFAS remediation system design for Rocky Hill was described in **Section 3** on the website www.rockyhillwater2020.com

The design is based on the simple addition of two ion exchange filter units to the existing aeration stages of the Rocky Hill water system, and this is done at quite low cost. The use of PFAS selective anion exchange resins was presented as being the only viable method at present of totally removing all PFAS contaminants from the water.

Although the PFAS selective anion resin technology is quite new, the science of ion exchange is firmly established. The previous **Section 7** has described in some detail that ion exchange is an electrostatic process in which contaminant anions from solution are **exchanged** with mobile anions and are trapped on fixed positive charges embedded in the ion exchange resin. The process is fast and is a form of chemical reaction with a related stoichiometric equation. The important details of all this are further presented below.

There were two major scientific investigations that provided the basic information confirming the exceptional performance of modern PFAS selective ion exchange resins and demonstrated their role in total removal of PFAS from water.

One investigation was undertaken by a group at the University of British Columbia (Dixit et al.) studying PFAS capture by selective anion exchange resin in Canadian river water. This was only published in June of last year (2020).

It was a detailed laboratory study, simulating column adsorption, and is briefly described in **Section 3 (page 2).**

They found (among many other things) that **all** the PFAS contaminants were totally eliminated, that the presence of dissolved organic matter (DOM) in the water was a very important inhibiting factor in the PFAS capture process (as expected) and that in the absence of DOM (using distilled water) the PFAS capture efficiency of the resin was estimated to be extremely high, exceeding an indicated 100,000 BV (bed volumes) to breakthrough. [This defines the volume of water that was processed in terms of the number of volumes of the resin “bed” and relates the breakthrough of contaminant to the number of bed volumes processed.]

The second investigation was a two-year pilot study of PFAS removal by a PFAS selective anion exchange resin in a municipal water facility at Horsham, Pa. This is described extensively in **Section 2** on the website. The group from Purolite Corp. confirmed that all PFAS contaminants were removed by ion exchange (over a working period of almost two years) with the use of their PFAS selective anion exchange resin, PFA 694E.

The level of DOM (dissolved organic matter) content in the aquifer water in the Horsham study was measured at 200 ppb (parts per billion) that is a typical level for aquifer water. They were able to determine a bed volume (BV) number of 329,000 from their data for PFAS breakthrough. This was very important, specific, experimental information from a working system under realistic conditions.

Most laboratory studies using ion exchange resin columns have used water spiked quite heavily with PFAS contaminants to stress the resin and obtain quick results. This naturally leads to short breakthrough times and low BV (bed volume) numbers as the capacity of the ion exchange resin is finite, and the more PFAS that is added the shorter the breakthrough time will be. Also, of course, these very high PFAS contaminant levels are not truly representative of the typical real world PFAS contamination situations. So their numbers do not directly relate to real situations.

The Horsham study on the other hand demonstrated the ion exchange removal of PFAS contaminants in real world conditions of low level (100 ng/L = 100ppt) PFAS contamination in a Municipal well situation, and provided actual measurement of the bed volume number and time to PFAS breakthrough, over a working time of almost 2 years. There are very few actual measurement situations of this type, and since the Horsham well #10 water chemistry is very similar to that of the Rocky Hill aquifer, the experimental data from the Horsham study are taken to be quite definitive, and to be directly applicable to the Rocky Hill situation.

Of major interest in the work of the Dixit et al. group was an investigation of the release of the Chloride exchange anion. Through this they clearly demonstrated that the electrostatic forces dominated the ion exchange process when working at low levels of PFAS contamination.

In the ion exchange process the mobile exchange anion (Cl⁻) is being replaced by the functional group anion of the PFAS contaminant, and they found a 1:1 correlation between PFAS capture and the production of Chloride in the effluent water.

This was a stoichiometric release of chloride (following the ion exchange equation) and indicated that the exchange process under these conditions was essentially totally electrostatic interaction with no significant molecular adsorption (which would not have released Cl⁻) and was based on the exchange of anions on the resin. **The long range electrostatic forces were totally predominant in ion exchange at low PFAS contaminant levels.**

Previous work on the removal of inorganic anions and anions from natural dissolved organic matter by anion exchange resins had also shown that the

removals followed ion exchange stoichiometry (Boyer et al. Univ. N.C. 2008 - Environ. Sci. Technol. 2008, 42, 19, 7431–7437).

The electrostatic removal of inorganic anions and DOM anions is therefore directly competitive with the electrostatic removal of PFAS by anion exchange resins.

In summary:

Anion exchange resins provide an optimum electrostatic process for anion contaminant removal from solutions with contaminants at low levels.

The above conclusions are intuitively obvious.

As described in **Section 7** the anion exchange resin initially has an enormous number of fixed, embedded, positive charge cations that are associated with an equal number of linked Cl⁻ anions that were introduced at the resin “activation” to obtain charge neutrality. When water is introduced these linked cations and anions would dissociate and become mobile ions. However the fixed embedded positive charged cations are not mobile, and remain as fixed positive charges although the Cl⁻ anions are mobile and can move away in solution.

The fixed positive charged cations then electrostatically attract any mobile anions from external solution as a result of the relatively long-range electrostatic forces. These anions would enter the resin bead and, to maintain charge neutrality, a mobile Cl⁻ anion would leave the bead and enter the external solution. This is the mechanism of anion **exchange** that is described in more detail below.

With the introduction of water (having PFAS and other mobile anions) to the ion exchange resin this anion exchange process becomes fully activated.

Anions from the external solution can then be trapped into the PFAS selective ion exchange resin. There is also the existence of possible molecular adsorption by the resin polymer, but at low levels of contaminant there are only random situations of the very close molecular contact with the resin that is required for the molecular adsorption process to occur.

The electrostatic anion exchange therefore dominates at low contaminant levels.

The anion exchange process would continue working until the resin is anion saturated, at which point there would be detected PFAS breakthrough in the effluent.

What severely limits the ion exchange performance in regard to PFAS anion capture is the competitive background presence of anions from inorganic and organic dissolved material in the water.

With the DOM level of 200ppb in the Horsham study this represented 200,000 ppt of DOM anions competing with 100 ppt of total PFAS anions. That is why the anion exchange resin becomes saturated, not with PFAS anions but with all the other anion content in the water. Reduction of the background DOM anion load is crucial to obtaining effective long-term operation of the ion exchange resin. Unfortunately this is not an easy task. The usual methods of removing DOM are molecular adsorption using GAC, ion exchange, and **aeration**.

If the anion load could be halved, the operating time of the resin might be doubled.

In spite of this, the 200 ppb level of DOM was considered to be acceptably low (especially when compared to river water). In actual terms it is indeed very low (200 parts per one thousand million) and the Horsham data indicated total PFAS removal for almost 2 years, while using only 20 cu ft (150 gallons) of PFAS selective resin – demonstrating the extremely high ion exchange capacity of the Purolite resin.

How anion exchange actually works.

It is useful to introduce details of the mechanism of the ion exchange process to better appreciate what is actually going on; that it is a fast process, and that it has direct relevance to the Rocky Hill duty cycle operation and to the PFAS remediation issue.

The Rohm and Haas article referenced in **Section 1, page 7** is very good in providing an overview of the ion exchanger (resin bead) structure. The resin is water insoluble and consists of small beads that each have a linked network (backbone) structure into which fixed, chosen, cation functional groups are incorporated. These fixed (positive charge) cations are electrically neutralized with counterions (which are mobile exchange anions) that can pass in solution through the resin bead membrane, and Cl⁻ is the generally used mobile exchange anion. The anion exchange resin is initially “activated” by neutralizing all of the fixed positive charges with mobile exchange anions Cl⁻ (using brine solution saturation). External anions from external solution can diffuse into the bead and exchange with a counterion (Cl⁻) that leaves the bead. Only anions are exchanged. Any cations in the external solution would be repelled by the fixed positive charges in the bead and cannot enter the resin bead, so only anions can be exchanged in this type of (anion) exchange resin.

The openness of the resin bead structure depends on the water content and the swelling of the porous gel beads, and more active volume and ion exchange capacity is obtained by using very large numbers of small beads of less than 1mm diameter.

The ion transport in the ion exchange process involves an external anion in solution diffusing through the thin barrier layer film (membrane) at the interface between the external solution and the interior of the resin bead, and entering the resin bead. There is then diffusion of the anion towards a fixed positive charge in the bead and (to maintain charge balance) the displacement of an exchange anion, which is mobile in the bead volume and diffuses through the membrane into the external solution. This constitutes an anion **exchange** cycle.

The rate of the process (interaction time) is limited only by the rate at which anions can diffuse in and out of the exchanger structure, through the membrane.

For PFAS contaminant molecules, the functional group “head” of the molecule is the anion. Therefore, in the case of PFOS for example there is the sulfite anion (SO₃⁻) dragging along the heavy PFOS molecule through the membrane, as one scenario. On the other hand, the carbon chain PFOS molecule body is completely saturated

with bonded Fluorine atoms, is totally hydrophobic (water repellent) and there are no dangling bonds to hinder its water mobility. This is the opposite scenario.

In the literature it is stated that the anion exchange process is generally fast as there are no actual electron pairing bonds that are broken, but little information is given on the specific interaction times.

In the A. K. Pandey. (2008) thesis presentation to Oklahoma State Univ. on the topic **Kinetic Study of Ion Exchange Columns**: a value for anion Mass Transfer Coefficients (MTC) is cited as > 200 microns per second and MTC is defined as the rate at which ions move from bulk solution to the exchange site – predicted from column hydrodynamics.

(https://shareok.org/bitstream/handle/11244/9655/Pandey_okstate_0664M)

The next requirement is an estimate of the membrane thickness.

This can be derived from studies on the manufacture of anion exchange membranes for alkaline fuel cells in which a range of membrane thicknesses from 30 microns to over 100 microns is cited. PhD thesis: Richard de Villa Espiritu, 2017. Newcastle Univ. U.K.

(<https://theses.ncl.ac.uk/ispui/bitstream/10443/3702/1/Espiritu%2C%20R%202017.>).

Taking an average value of 65 microns for membrane thickness, and an anion mobility above 200 microns per second, the interaction time would then be of the order of 320 milliseconds or less. This indicates that the electrostatic anion exchange process is indeed quite fast – faster than seconds, even when assuming a rather thick (65 microns) bead membrane.

The ion exchange process is also chemically reversible, so that a captured PFAS anion can in principle be exchanged back into solution and replaced by a returning Cl⁻ mobile exchange anion under suitable conditions (such as excess concentration of the mobile exchange anions – as employed in regeneration procedures).

However, in regard to reversibility, in this previously mentioned anion exchange example with a PFOS anion, once it is linked to a fixed positive charge on the structure of this PFA 649E resin, that PFOS anion and molecule are not going to be exchanged again and released without a fight.

Anion exchange resins can exhibit “affinity” for certain anions over others.

There is a table of general anion affinities, and the Chloride anion (Cl⁻) is quite low on the list, below nitrates (NO₃⁻) and sulphates (SO₄⁼). That is why Cl⁻ is such a commonly used mobile exchange anion.

Ion exchange resins can be chemically engineered for high selective affinity, and the Purolite anion resin PFA 694E is a PFAS selective resin.

Such selective resins are considered to be only for single use, and non regenerable. The PFAS functional group anions are very firmly captured by these resins.

When the anion exchange resin becomes anion saturated, and PFAS breakthrough is observed, there is actually very little PFAS contaminant trapped in the resin because the initial PFAS concentration level in the water was extremely low (parts per

trillion). The expensive anion exchange resin becomes saturated by all the anions from DOM and dissolved inorganic material, outnumbering the PFAS molecules by factors of thousands to one.

The ion exchange process with duty cycle system operation.

This situation is most easily addressed by initial comparison to GAC and the adsorption process with the short range, weak, molecular forces that require extremely close contact between the molecule in solution and the adsorbent material (activated carbon) in a duty cycle system.

If close molecular contact is not met, an efficient level of adsorption will not occur. The flow rate and the volume of filter material are then related empirically by the EBCT (empty bed contact time) parameter. For GAC the required contact time for efficient molecular adsorption is 10 to 20 **minutes**.

The situation for GAC in systems that are operating under duty cycle is then quite clear. It is required to have an efficient adsorption process during the duty cycle operation, and therefore the GAC filter volume has to be based on the duty cycle pumping rate (not on the time averaged flow rate) – exactly the same as if it were a continuous pumping system at that high pumping rate. So, for a duty cycle system pumping at 200 gpm and with an EBCT of 10 minutes, a very large GAC filter volume of 2000 gallons (minimum) is needed. That is for the GAC molecular adsorption process – due to the required contact time.

The molecular adsorption process cannot accommodate duty cycle system operation, because the required GAC volume always has to be based on the maximum duty cycle flow rate.

Duty cycle systems are forced into using unacceptably high volumes of GAC.

However, in complete contrast, the anion exchange process is not molecular adsorption. It is a completely different (electrostatic) process and there are no long contact time requirements. The anion exchange process is quite fast and is similar to a chemical reaction.

Ion exchange can therefore accommodate time variant flow rates with no change in the efficiency of the anion exchange process, which is not locked into any resin volume requirements based on flow rate. Anion exchange is fully compatible with duty cycle system operation.

What decides the volume of the ion exchange resin is the desired capacity, which determines the duration of the anion exchange process.

The anion exchange process has been shown to be entirely electrostatic at low concentration levels of PFAS and DOM contaminants, and Rocky Hill with relatively low values of DOM, and with PFAS contamination at levels of parts per trillion, certainly meets this condition.

This is extremely important, and determines everything. These low contaminant level conditions also applied to the Horsham situation.

One of the initial impressive results from the Horsham work was the fact that a relatively small volume of ion exchange resin completely eliminated PFAS contaminants for nearly two years, and removed any involvement or use of GAC.

Operational performance of the Rocky Hill PFAS remediation .

To determine the actual operational performance of the Rocky Hill PFAS remediation system it is appropriate and necessary to simply use the actual data experimentally obtained from the directly comparable system (Horsham) with the same general water conditions, and using the same known PFAS selective anion exchange resin.

The chemical analysis of the Horsham well #10 was very similar to that of Rocky Hill in almost all respects, especially in DOM content.

The PFAS contaminant level at Horsham well#10 was averaging 50ppt for PFOA plus PFOS, and 100ppt when including all other PFAS molecules, and these sorts of levels are expected also for Rocky Hill (where the other PFAS chemicals are not yet listed).

The data from the Horsham study gave a value of 329,000 bed volumes to the point of detected PFAS breakthrough with a bed volume of 20cuft of resin, which is 150 gallons. There were therefore 329,000 x 150 gallons of water processed until detected PFAS breakthrough (when the resin was anion saturated).

To increase the ion exchange capacity, it is proposed to increase the resin volume to 1000 Liters (264.3 gallons) for the Rocky Hill system. With this bed volume there would be an anticipated PFAS breakthrough at 329,000 x 264.3 gallons, namely at 86.95 million gallons. This is simply scaling the resin volume.

The Rocky Hill water system provides 26 million gallons per year, indicating that PFAS breakthrough would be observed after 3.34 years – as described in **Section 3**.

This is all based on the resin capacity (resin volume) and on the actual volumes of water processed. The Horsham experimental data have been directly applied to the equivalent Rocky Hill situation.

The anion exchange process operates up to the point of anion saturation of the resin, when PFAS breakthrough occurs, and this is detected from the first (lead) filter in the Rocky Hill dual filter system. Incidentally, an EBCT for a 264 gallon volume of resin at a 200 gpm duty cycle pumping rate is 1.32 minutes for each filter which is a definitely relevant contact time to permit slow uniform water dispersal through the resin medium.

The filter design is important to ensure optimum filtering efficiency, and the linear flow rate through the filter is controlled by the choice of the filter diameter.

This is presented in the following descriptions of two specific Waterco Micron filters, SMD 1400 and SMD 1200. The pressure drop across the filters needs to be kept low as the resin gel beads swell with water content, reducing the membrane thickness, and they are relatively fragile.

The Rocky Hill PFAS remediation system details.

To a casual observer the Rocky Hill PFAS remediation system of **Section 3** would be rather unimpressive, consisting only of two rather ordinary looking filter tanks interconnected with some PVC pipework and valves, and not “high-tech” at all.

There are no flashing lights or digital readouts.

The new technology is actually what is going on inside the filter tanks, with the magic of the anion exchange process and the special PFAS selective anion exchange resin that is being used.

a. The Filters.

Waterco is one of the largest manufacturers of filters and water treatment systems in the world, and their industrial and commercial filter units are designed for optimum filtering efficiency and performance. <https://waterco.us/water-treatment> Their line of Micron filter units is very suitable for the proposed Rocky Hill PFAS treatment system, and the SMD 1400 unit (and SMD 1200) are of appropriate sizing. <https://www.poolsupplyunlimited.com/pool/waterco-22501404101na-micron-smd1400-commercial-side-mount-deep-bed-sand-filter/177161p1>.

The working pressure of 58 psi for the SMD 1400 filter is more than adequate because the filter units are to be installed in the low pressure aeration stages of the Rocky Hill water facility, and are also required to be operated with low pressure drop to avoid damaging the resin gel beads. The bulkhead connections on the filters permit the use of standard quick connect PVC union couplings and standard PVC pipework and fittings.

The lateral manhole accessory would be very useful at the time of resin replacement, and the cost for this would need to be additionally evaluated.

The SMD 1400 with a filter area of 16.49 sq ft supports a 200 gpm duty cycle flow rate at a loading of 12.1 gpm/sq ft or linear velocity (LV) of 1.62 ft /min – which is a low velocity and within good design range for filters to permit slow uniform water dispersal through the resin medium without any channeling or tunneling effects. The pressure drop across the PFA 694E resin bed at 12gpm/sq ft would be 1.3 psi per ft., namely 2.8 psi for a bed depth of 2.14 ft. (1000 liters volume).

The SMD 1200 is of a smaller diameter (48 inches vs 55 inches) with a filter area of 12.56 sq ft, resulting in a loading of 15.9 gpm/sq ft. or linear velocity (LV) of 2.13 ft/min, which is still an acceptably low rate for uniform filtration. The pressure drop across the resin bed would be 1.8 psi per ft., namely 5 psi for a 2.8 ft. bed depth.

This was the filter originally selected in the **Section 3** Rocky Hill design.

On reflection, the SMD 1400 is preferred if the slightly larger diameter can be accommodated and the filter conveniently handled. The filters have the same height.

b. Why two filters in series ?

All of the anion exchange removal of PFAS occurs in the first filter, and the Rocky Hill design estimate is that a time interval of 4 years would occur before the filter medium would need to be replaced. Therefore, only one filter is basically needed. The estimate of 4 years is based on using the Horsham data with an assumed extra benefit of further DOM reduction by the Rocky Hill aeration system.

Two filters are used in practice so that the first filter can be removed, re-loaded, and replaced without disrupting the operation of the water facility.

It is generally accepted practice to run with two equal filters in series, one as the "lead" filter and the other as the "lag" filter. This is called "lead-lag operation".

All the filtration work is done in the first "lead" filter, and that is the one that is monitored for PFAS "breakthrough". When PFAS output is detected, valves are operated manually to bypass the lead filter and to close it off. The lag filter is then running on its own, and it becomes the new "lead" filter in the system.

The original "lead" filter can then be drained and decoupled from the pipework and removed. There is no urgency in this, as the water facility still operates normally.

The filter is then physically moved away to have the ion exchange resin replaced.

It is later returned and positioned into the system as the new lag filter. This filter exchange routine is repeated every 4 years, hopefully longer.

The lateral side manhole accessory on the filters becomes very useful for replacing the resin on site. The PFA 694E resin has the consistency of coarse sand, and bulk weight is around 42 lb/cu ft. For 1 cubic meter (35.3 cu ft.) of resin the weight is just less than 1500 lbs.

The resin is not dangerous as a result of the PFAS content. The amount of PFAS trapped in the resin is totally minuscule.

Assuming 50ng/L for PFAS in the Rocky Hill water (PFOA 10, PFOS 16, PFNA 2ppt) and 329,000 Bed Volumes to breakthrough and a resin bed volume of 1000 Liters, then the amount of trapped PFAS is $329,000 \times 1000 \times 50 \text{ ng} = 16.5 \text{ grams} = 0.58 \text{ oz}$. There would be less than 0.58 oz of PFAS trapped uniformly in the beads of 1,500 lbs of resin. This is firmly trapped in the resin beads. It won't rub off or wash out.

The removal and replacement of the resin is a procedure very similar to the routine removal and replacement of sand in a swimming pool sand filter – a 5 or 6 year standard procedure for some pool owners, and pool maintenance companies.

The whole idea of the filter shed (extension building) is to have enough room to be able to uncouple the filters and move them around easily on dollies, to allow for resin replacement on site – without disrupting the normal water facility operation. This provides considerable cost savings against having filters detached from fixed piping and removed and transported off site by flatbed, to be returned again and reconnected – all at additional expense. These are very significant recurring expenses that are unnecessary.

c. The extension building.

The extension building (or filter shed) is required because with duty cycle operation there are long times of stationary water in the filter units, with problems of freezing in cold weather. There is no room for the filters in the aeration area. The filter shed does not have to be climate controlled – other than keeping the ambient temperature in the 40–50 F range (above freezing) in the winter. The same situation exists in the aeration system area.

There are two viable locations for the filter shed. One is on the East side of the pump house – towards the water tower. The other is on the South side which is the site of the aeration building and has the problem that the South side has the large air intake filter – but it is still a location that is open for consideration.

Assuming a location on the East wall, the space is limited. This restricts the footprint to probably around 15 ft x15ft maximum.

There are underground pipes to the storage tank from the well house, and excavation for foundations should be avoided. The 15ft x 15ft dimension is characteristic of a medium sized room, or medium large garden shed.

Modern steel prefab construction is favored for the main reason that construction of this type is based on bolted tie-down assembly to a solid concrete slab, with pre-fabricated interlocking bolted panels. The structure is durable and lightweight and essentially “open area”. A 10ft ceiling height is easy to achieve. There are several contractors in the local area that deal with prefab structures of this type.

The procedure is to outline the general requirement and ascertain what could be provided to meet it, and the related cost. Specific additions are then introduced, such as glass blocks in sections of the wall for natural light, instead of windows, and a steel security door at the N side or NE corner, either sliding or two sided, with 6 ft opening and 8 ft height, locked from the inside. Also, addition of thermal insulation and outside trim (stucco, brick veneer, etc.,) and basic electrical supply wiring, lighting fixtures, some power outlets, and plumbing details.

Constructing a prefab steel shed of this type is not a difficult undertaking.

The concrete floor slab continues outside through the door as an external working apron or service/loading pad.

At a connection area to the wall of the aeration building, two PVC pipes enter the filter shed through holes in the aeration building East wall. One is the entrance pipe from the aeration mid-stage pump, the other is the return line to the second aeration column. The two filter units face each other with these pipes running between them as supply and return manifolds. The filters and control valves have detachable union couplings and they connect to the manifolds.

There is also a steel door installed in the East wall of the aeration building connecting to the filter shed, closed from the aeration side. The aeration building is maintained as a secured area. An electrical power line is introduced through a non metallic conduit above the door.

There is no pumping equipment in the filter shed.

The above description outlines a suggested construction of the extension building.

d. The PFAS Remediation System Cost.

Description.

The proposed PFAS remediation system for Rocky Hill, as outlined in **Section 3**, and presented in this **Section 8**, consists of the two filter units with the ion exchange resin, and with the filter shed (extension building) to house the filters. There are no other additions, and no changes to the water facility operation.

The cost of the filters was quoted last year in **Section 3** as \$4500 each for a total of \$9000 and this still seems to generally apply. The filter description and links to on-line suppliers have been presented above. The cost of mentioned accessories (lateral manhole) is not known at this time – estimated at \$1500 (\$750 each filter). The cost of the PFA694E resin has increased.

The original cost of around \$8000 per 1000 Liters, quoted in the Horsham study 4 years ago, is now closer to \$12,400 according to an article by American Water Company entitled “Advantages of Ion Exchange for PFAS removal” which gave some cost information, 8 months ago, on systems using PFA694E resin.

If we allow for further increases to as much as \$13,500 per 1000 liters, the total resin cost might now be around \$27,000 as a high estimate.

There are a number of ball valves, union couplings, PVC adapters and 4 inch PVC pipe, and other PVC incidentals that should cost around \$4000.

This gives total hardware cost at around \$41,500 – mainly the cost of the resin.

As stated in **Section 3** the major cost item will be the extension to house the filters. This filter shed has been described in some detail, and should be a reasonably straightforward job. An estimated cost, based on the listed work, could be within \$100,000. This gives a sum total of **\$143,500** when adding a separate plumbing cost (2-day labor) of \$2000. The plumbing would be the main assembly work needed for the filter pipework. There will be additional small items costs.

It is customary to add a 20% contingency for budget purposes (\$29,000) and, for example, to allow for shipping and other related expenses.

This should provide a total of **\$ 172,500**. Of course it is necessary to get actual quotations for the costs to be more firmly established.

In Summary:

Cost of resin	\$13,500 x2	\$27,000	Cost of resin replacement
Cost of filters	\$4500 x2	9,000	(4 year recurring cost)
Filter Accessories	\$750 x2	1,500	\$ 13,500
PVC valves, couplings, etc.		4,000	
Contracted plumbing labor		2,000	
Pre-fab building extension		100,000	
SubTotal (estimate)		\$ 143,500	
20% contingency		29,000	
Total.		\$ 172,500	

The simplicity of the system, using standard commercial filters and parts, means that it is not possible to deviate very far from the estimated cost figure. The major component costs and ion exchange resin costs can be verified.

The cost of the filter shed could be inflated further without much overall impact. When related to the revenue stream being generated from the working water facility, this is a relatively inexpensive system construction.

Conclusion.

This **Section 8**, as well as the previous **Section 7**, was necessary to develop the basic understanding of the ion exchange (ix) process and to be able to critically relate it to adsorption and GAC. The Horsham study was impressive because it showed that huge amounts of GAC could be replaced by quite small amounts of ix resin in that situation. The common misapprehension is that ix resin is simply some sort of super adsorption material, better than GAC. Many published studies are still centered around this. The main point however is that, at Horsham, another process had been introduced into the game – namely electrostatic anion exchange. At very low levels of contamination (such as in the Rocky Hill aquifer – and also in well#10 at Horsham) there is low probability of PFAS contaminant initiating the required conditions of close contact for adsorption, so the PFAS extraction efficiency is low in spite of the large amounts of adsorbent. Electrostatic anion exchange becomes the dominant process in this situation, with a PFAS selectivity, and the volume of ix resin depends only on the required anion exchange capacity.

It is very difficult to extract impurities at parts per trillion without some method of identifying and isolating them. The adsorption process does not isolate or identify anything, it is totally indiscriminate and GAC can adsorb any type of molecule, even charged ones. It has trouble however adsorbing molecules that are highly soluble. Ion exchange only deals with ions in solution. PFAS molecules are soluble in water, and therefore ionize. Anion exchange only deals with anions. The PFAS chemicals have functional group anions. So now we are getting some identification and PFAS isolation. It is next required to reduce the background of extraneous anions to improve PFAS anion selectivity. That is largely done by the Rocky Hill aquifer, which introduces a massive amount of adsorption and reduces all dissolved anion content from milligrams/liter (parts per million – river water) to parts per billion, a factor of 1000 reduction, and then we add aeration to reduce DOM further. That is the Rocky Hill situation, and then we use the new PFAS selective ix resin. We do not need large volumes of adsorptive material, we simply need an appropriate volume of PFAS selective ion exchange resin, and a procedure based on the electrostatic anion exchange process. This has been described in **Section 8**.

Actual construction details for the Rocky Hill PFAS remediation system have been fully described in this **Section 8** and they are quite easily restructured as a feasible community system proposal that is based on utilizing the considerable advantage of the Rocky Hill Water Facility in having an integrated aeration stage. The details present a very simple PFAS remediation system that can be constructed at relatively low overall cost.

Outside Proposals received and loan applications made.

Outside proposals or estimates have been received recently and have reportedly formed the basis for a Rocky Hill application for a \$2.3 million loan from the US Dept. of Agriculture – for PFAS remediation, Firm Capacity, and some infrastructure work.

The full details and basis of the loan application have not been disclosed.

It is also not known to what extent the implications of the duty cycle operation of the Rocky Hill Water Facility have actually been understood and appreciated, especially in view of Firm Capacity appearing as a listed major component of this \$2.3 million loan application.

It is relatively easy to obtain municipal loans in the present environment of active infrastructure spending. However these are loans, not grants, and they relate to long-term million dollar municipal debt, and they require payback.

It can be considered fiscally irresponsible to involve the Borough in millions of dollars of long term debt if it is poorly applied, not well thought out, and especially if it is not actually needed.

It is simply not necessary to require millions of dollars of spending to remove trace parts per trillion level PFAS contamination from the Rocky Hill water.

The Rocky Hill Borough historically, with deliberate effort, has successfully maintained itself essentially debt free – which has contributed significantly to its success and independence. Many small communities fold because of fiscal debt. To illustrate overall concerns on this loan and expenditure issue, without involving names, an example of a recent contractor proposal that is now being considered (and which was relevant to the loan application) should be introduced.

The outside contractor proposal involved attaching two ion exchange filters in series, having an EBCT of 3 minutes each, to the output of the Rocky Hill well pump at 250 gpm.

This is immediately seen to be treating ion exchange resin just like a molecular adsorption material and requiring 750 gallons of resin (which is 2,840 liters) for each filter.

At a resin bulk density of 700 gm/L this is 1,988 kg or 2.19 US tons of resin for each filter. For both filters the amount of anion exchange resin is then 4.38 US tons.

This is a ludicrously large amount of ion exchange resin, totally inappropriate.

The above filters are located on the high pressure output from the well pump and are specified as being high pressure carbon steel vessels with connecting pipework of cement lined carbon steel.

These filters are not installed in the low pressure aeration section of the Rocky Hill Water Facility, where they can be commercial fiberglass filters and the valves and pipework and the hardware can be PVC – as already used in the aeration section.

This makes an enormous difference in system cost.

There is no mention of a building extension or filter shed to house the filters. Many contractors would require a building extension to be provided for them. Others would not mention a filter shed, but propose that the system would be housed in trailer units, that can be towed away or flat-bedded – as in this case. The replacement of spent resin would involve the removal and subsequent return of a trailer unit – involving significant additional recurring expenses. None of these cost details appear to be presented. There are a lot of TBD items and it is all considered to be an estimate.

There is nothing conceptually wrong with a system approach based on trailer units when intended for pressurized systems running at continuous pumping with multiple wells, and which are generally the systems of larger towns and large communities. The capacity of such systems can always be increased by adding more banks of filters, and adding more trailer units as required.

Also, such communities have a much larger customer base than Rocky Hill and can probably tolerate the ongoing costs associated with the trucking around of trailer units on a regular appropriate basis.

However, the Rocky Hill system is a duty cycle system with a different type of operation and additionally has an aeration unit – and the ion exchange filters should be incorporated into the aeration unit. Aeration is one of the few ways to reduce the DOM and inorganic anion content of the water – **Section 3, page 3.**

Very few municipal water systems have an integrated aeration unit.

Overall, the above contractor proposal is simply based on their routine use of trailer based packaged water filtration systems operating under continuous pumping at pressure. It is certainly not a proposal that is designed around the Rocky Hill type of duty cycle system as we require, and in addition the cost would be totally prohibitive and unacceptable.

Unfortunately, contractor proposals will probably all be very similar to this one and based on established systems familiarity over many years with GAC molecular adsorption filtering, and based on the routine EBCT approach.

The use of the ion exchange process in applications like PFAS remediation is very new, and anion exchange resin will be considered simply as an alternative molecular adsorption medium similar to GAC. Also, a municipal water facility running under duty cycle operation and including an aeration system would represent an extra unknown quantity.

In Summary.

The proposal example (as outlined above) is obviously not at all based on the needs of the Rocky Hill community and on compatibility with the Rocky Hill water system. These should be basic requirements for all proposals submitted for Rocky Hill consideration.

If Rocky Hill Council persists in going ahead with the \$2.3 million loan request based on the type of proposal just described, then at least they should make some attempt to fully explain and justify the rationale to the Rocky Hill Community for doing so. This is especially required in view of the many times that the alternative approach of **Section 3** (based on the Horsham study) has been presented and explained, and which must be taken seriously.

In this **Section 8** this PFAS remediation system has all been presented again in much greater detail to illustrate that it is scientifically well grounded and thought out, and is totally viable.

In addition to providing a relatively low cost and effective solution, it uses the aeration system to extend resin operation time (to estimated 4 years, and perhaps longer) and so reduce the impact of recurring expenses.

The system cost is also fully compatible with the level of revenue generated by the water facility itself, to facilitate a self-funding approach.

If Rocky Hill Council feels uncomfortable about fully understanding the situation and is unable to handle the responsibility, or lacks the capability or expertise to construct a filter shed and install ion exchange filter units as described in this **Section 8**, they should perhaps consider the possibility of hiring an independent Engineer/Project Manager to review the task as described and to handle the details for them. At least that would perhaps represent a positive step in the right direction.

Regarding the needs of the Rocky Hill community, that is an issue which is not very clear since the community overall seems to be largely unaware and unconcerned about all the aspects and the implications of the existing PFAS contamination of the water supply. Perhaps it is just a problem of missing communication.

A citizen resident does not have the authority to advocate for the community.

It is not appropriate or realistic.

Community groups and Citizen groups are normally required and expected to function as community centers to develop community interest and participation in perceived matters of common importance and concern.

The possible commitment of the Borough to millions of dollars of long-term municipal debt would seem to qualify as a topic for serious community concern, yet the Rocky Hill Community and Citizen groups appear to be equally as dormant as the overall community on the matter.

It is perhaps necessary for Community and Citizen groups to revisit their core missions and *raison d'être*. The issuance of long-term megadollar debt on Rocky Hill residents should be too important a matter to ignore.

It is hoped that this **Section 8**, as well as the preceding **Section 7**, provided adequate information and content for Rocky Hill residents to be able to fully dissect and analyze the various proposals on PFAS remediation systems that may be coming along.

Any possible long-term loan applications and what they are to be used for need to be made fully available to residents and need to be very transparent.

The situation should make proper sense, and be fully understood and acceptable. The final decisions will need to be Rocky Hill community decisions – since Rocky Hill residents end up paying for it all, probably for many years to come.

It should not then be possible to say that: “we didn’t know” or “nobody told us”. There should be no valid grounds for any such excuses.

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Ivor Taylor. Dec. 10. 2021.