

Advances in the characterization of the polarity of DOM under ambient water quality conditions using the polarity rapid assessment method

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ABSTRACT

Dissolved organic matter (DOM) is a mixture of compounds that are found ubiquitously in natural waters. The characterization of DOM is important in order to understand its effect on environmental processes and during treatment systems. Of all the properties usually measured with relation to DOM, the polarity is of critical importance since it will directly influence different processes. Recently, a new method has been developed for the characterization of DOM under ambient conditions, called the Polar Rapid Assessment Method (PRAM). The PRAM allows characterization and temporal and spatial comparisons under environmentally relevant conditions of pH and ionic strength. This study first modifies the PRAM method to 3 probes for high sample throughput by using a subset of the SPE sorbents to interpret DOM polarity by DOC and UV detection. Then the modified PRAM is compared to the XAD resin polarity method and finds a similarity in hydrophobic assessment but different results for the hydrophilic DOM. This study then evaluates the use of PRAM as a tool to evaluate water treatment processes and the character of size fractions of DOM. The PRAM is shown to be a very useful tool to evaluate and thus optimize treatment efficiency and removal of DOM.

Key words | natural water, polarity of DOM, polar rapid assessment method, treated water

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INTRODUCTION

Dissolved Organic Matter (DOM) is a mixture of compounds of varying molecular weight and polarity that are found ubiquitously in natural waters. DOM is formed by the natural breakdown of biological material in soil that then reaches water bodies through runoff events. DOM is also formed in water bodies as part of the biological activity in the water column. DOM can be further degraded in a water body, changing its physicochemical properties. The characterization of DOM is important in order to understand its effect on the environment and during treatment systems.

Of all the properties usually measured with relation to DOM, the polarity is of critical importance since it will directly influence different processes, including membrane fouling and formation of disinfection by-products. Recently, a new method has been developed for the characterization

of DOM under ambient conditions. This method, called the Polarity Rapid Assessment Method (PRAM), allows characterization and temporal and spatial comparisons under environmentally relevant conditions of pH and ionic strength (Rosario-Ortiz *et al.* 2007; Rosario-Ortiz *et al.* 2007). Analysis under ambient conditions takes into consideration the effect of ionic strength and pH on the configuration of the DOM, avoiding changes in configuration as a result of changes in these two parameters (Ghosh & Schnitzer 1980). This type of analysis can be done in less than one hour, allowing the development of an accurate and precise characterization of numerous samples. Characterization by PRAM is based on the preferential adsorption of specific DOM fractions onto solid phase extraction (SPE) sorbents. The sorbents included non-polar (C18, C8, C2),

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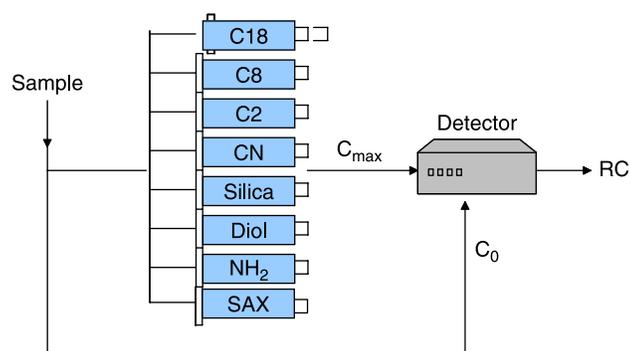


Figure 1 | PRAM analysis setup. Detection is commonly done using TOC and UV₂₅₄.

polar (CN, Silica and Diol), and anion exchange (weak and strong). **Figure 1** presents the experimental set up. The SPE cartridges are used in parallel, therefore allowing the characterization of multiple sites on the DOM. During typical applications, all eight sorbents are used in order to characterize different degrees of polarity.

The mechanisms involved in the characterization of DOM using PRAM are shown in **Figure 2** and summarized below in terms of the specific sorbents used.

- (1) Non-polar sorbents, including C2, C8 and C18. These sorbents are commonly used for the extraction of non-polar analytes from water matrices and are used in PRAM to quantify the hydrophobic character of the DOM. The main mode of interaction is via van der Waals forces. Previous work has shown correlations between the capacity factors for a set of probes and hydrophobic descriptors (Rosario-Ortiz *et al.* 2007), which allows the use of these to characterize the non-polar fraction of the DOM.
- (2) Polar sorbents, including Diol, Silica and CN. These sorbents are mostly used for the separation of polar

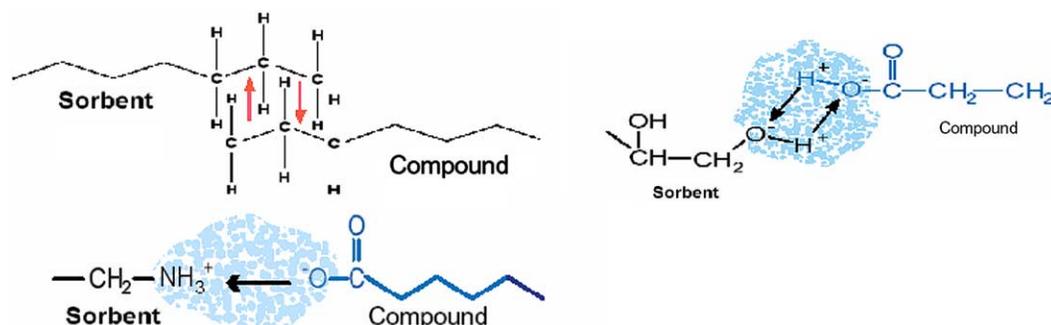


Figure 2 | Proposed interaction mechanisms between DOM and non-polar (top right); polar (top left); and weak anion exchange with an acetate anion (bottom).

analytes from non-polar and aqueous matrices, however applications have been developed for the extraction for polar analytes from aqueous matrices (Schlusener *et al.* 2003). During PRAM analysis, these sorbents are used to characterize hydrophilic character. The interaction between these sorbents and DOM will also be influenced by the relative affinity of water to these sites, although results have shown that some adsorption of DOM occurs (Rosario-Ortiz *et al.* 2007; Rosario-Ortiz *et al.* 2007; Gerringner *et al.* 2008; Rosario-Ortiz *et al.* 2008).

- (3) Anionic sorbents, including NH² and SAX. For these sorbents the primary mechanism is anion exchange, which has been well documented for the use with DOM, see **Figure 2c** (Hongve 1989; Hongve *et al.* 1989; Croue *et al.* 1999). Use of these sorbents allow the characterization of the anionic character of the DOM. (Rosario-Ortiz *et al.* 2007).

The main objective of this paper is to present additional development of PRAM for the analysis of environmental samples. Specific objectives include:

- (1) Development of a modified PRAM method for high sample throughput by using a subset of the SPE sorbents to interpret DOM polarity.
- (2) Comparing the PRAM method to the XAD resin methodology by completing XAD analysis and PRAM in parallel and in series at pH < 3 using UV and DOC detection. This study will help define the similarities and differences between both methods and will also allow subsequent comparisons between PRAM and XAD results. This information can then be used to decide on the most appropriate method to

assess the polarity variation of DOM in natural waters for a specific purpose e.g. to optimize water treatment processes.

- (3) Running the PRAM in parallel and series at the samples' ambient pH as well as at a pH lowered to below 3 and assess the information that can be found by comparing these results.
- (4) Showing applications of the PRAM to indicate its versatility. Applications include the characterization of treatment systems (including size to charge ratios), environmental samples and evaluation of DOM reactivity.

EXPERIMENTAL METHODS

Pram

The specific details regarding the application of PRAM have been discussed previously (Rosario-Ortiz *et al.* 2007; Rosario-Ortiz *et al.* 2007). Briefly, each SPE sorbent was first cleaned by passing 20-30 mL of Milli-Q water to ensure the removal of any UV absorbing impurity or around 3 liters to lower DOC impurities. After cleaning, samples were loaded onto the cartridges. Ambient sample flow through each SPE cartridge was maintained at 1.2 mL/min using a syringe pump (KD Scientific, Model 100, Holliston, MA, USA) for 8 minutes. The effluent from each cartridge was collected between 4–8 minutes (after initial breakthrough) and the absorbance at 254 nm was determined (UV Lambda 45, Perkin Elmer Corp., Boston, MA, USA or a UV 1700 Pharma Spec, Shimadzu). Retention coefficients (RC), defined as $(1 - C_{\max}/C_o)$, (where C_{\max} is the maximum absorbance of the samples after breakthrough has occurred and C_o is the absorbance of the original sample)

were calculated for all samples. The RC described the fraction of the total material (as determined by UV absorbance) that was retained by each SPE sorbent. The PRAM experiments are performed in triplicates for each of the chosen cartridges. All error bars correspond to the standard deviation of the mean of 3 replicate analyses.

XAD Resins

Water samples are first acidified to a pH below 3 and then passed through an XAD – 8 resin followed by an XAD – 4 resin. The method followed is described in detail by Singer *et al.* (2007). The portion of DOM absorbed to each resin is then desorbed using 0.1 M NaOH. The XAD – 8 desorbed fraction is called the hydrophobic DOM. The XAD – 4 desorbed fraction is called the transphilic or slightly hydrophobic fraction and the fraction that was not absorbed by the resins is called the hydrophilic DOM. Samples were run in duplicate.

Calculations

The equations used for the analysis are shown here. The calculations are the same for C18/Diol as they are for the XAD – 8 /XAD – 4 resins as the two methods were set up in the same manner.

XAD Hydrophobic fraction

$$= \frac{(\text{DOC}_{\text{raw}} - \text{DOC}_{\text{XAD 8 effluent}} - \text{DOC}_{\text{XAD 8 leaching}})}{\text{DOC}_{\text{Raw}}}$$

PRAM Hydrophobic fraction = RC_{C18}

$$= 1 - \frac{\text{DOC}_{\text{C18 effluent}}}{\text{DOC}_{\text{raw}}} = \frac{\text{DOC}_{\text{raw}} - \text{DOC}_{\text{C18 effluent}}}{\text{DOC}_{\text{raw}}}$$

$$\text{XAD Transphilic fraction} = \left(\frac{\text{DOC}_{\text{XAD 8 effluent}} - \text{DOC}_{\text{XAD 4 effluent}} - \text{DOC}_{\text{XAD 8 leaching}} - \text{DOC}_{\text{XAD 4 leaching}}}{\text{DOC}_{\text{raw}}} \right)$$

$$\text{PRAM transphilic fraction} = \text{RC}_{\text{C18+diol}} - \text{RC}_{\text{C18}} = \frac{\text{DOC}_{\text{C18+diol effluent}}}{\text{DOC}_{\text{raw}}} - \frac{\text{DOC}_{\text{C18 effluent}}}{\text{DOC}_{\text{raw}}} = \frac{\text{DOC}_{\text{C18+diol effluent}} - \text{DOC}_{\text{C18 effluent}}}{\text{DOC}_{\text{raw}}}$$

XAD Hydrophilic fraction

$$= \frac{(\text{DOC}_{\text{XAD 4 effluent}} - \text{DOC}_{\text{XAD 4 leaching}})}{\text{DOC}_{\text{raw}}}$$

PRAM hydrophilic fraction = $1 - \text{RC}_{\text{C18+diol}}$

$$= 1 - \left(1 - \frac{\text{DOC}_{\text{C18+diol effluent}}}{\text{DOC}_{\text{raw}}} \right) = \frac{\text{DOC}_{\text{C18+diol effluent}}}{\text{DOC}_{\text{raw}}}$$

Water samples

Two natural waters, one DOM standard (International Humic Substance Society (IHSS) isolate from the Suwannee River) and one DOM type - chemical probe (rutin trihydrate) were used during testing. The rutin and IHSS isolate solutions were made in 0.01M phosphate buffers at pH 2 and 7. The natural source waters were kept at ambient pH. Natural samples were filtered with a 0.45 μm membrane filter and their pH was subsequently lowered to below 3 with a solution of concentrated HCl. Table 1 shows the summary of the water quality data for the samples presented in this paper. The SUVA is calculated as the UV_{254} value over the TOC of the sample times 100. The SUVA value can be used for analysis of DOM and gives information on the relative aromaticity of the sample (Weishaar *et al.* 2003).

RESULTS AND DISCUSSION

Optimization of PRAM for Multiple Analyses

Previous studies used up to seven different sorbents for PRAM analysis (Rosario-Ortiz *et al.* 2007; Rosario-Ortiz

et al. 2007; Rosario-Ortiz *et al.* 2008). These cartridges measured the hydrophobic fractions (C18, C8 and C2), hydrophilic (Diol, Silica and Cyanide) and the anionic fraction of the DOM. A subsequent study on different natural and treated waters indicated that for a general picture of polarity, three cartridges could be used (unpublished data). Specifically, the C18 cartridge was chosen as most representative of the hydrophobic group of cartridges as it has been shown to have the most interaction with the hydrophobic structures with its longer aliphatic chain (Rosario-Ortiz *et al.* 2007). The Diol was preferred to the silica and cyanide for the same reason: its affinity to the hydrophilic fractions appears higher based on previous results. Finally the NH^2 sorbent was preferred to the SAX for the opposite reason: less adsorption was observed onto this sorbent than for SAX. However, the NH^2 did show more differences between waters than the SAX. This choice of cartridges is important as it shortens the method for the purpose of characterizing differences between waters. Exemplary runs of the 3 types of cartridges versus other cartridge of that type are shown in Figures 3a and 3b

The C8 and Silica cartridges were run in triplicate for confirmation of the C18 and Diol cartridge results and to observe if other PRAM columns needed to be run. Previous PRAM data usually shows that the C8 SPE cartridge would have an RC value lower than the C18 as the aliphatic chain is shorter on the SPE cartridges (Rosario-Ortiz *et al.* 2007; Geringer *et al.* 2008). Figures 3a and 3b show the C – 18 and C – 8 PRAM results were similar for the samples. Figures 3a and 3b show the Diol and Silica PRAM results were the same. These results confirm that the C – 8 and Silica PRAM analyses are not critical for the study. It is recommended that a 3 probe parallel PRAM system be used for multiple analyses and other SPEs can be used for verification.

Table 1 | Water quality data for natural waters

sample	Natural water 1	natural water 2	plant 1 influent	plant 1 effluent	plant 2 influent	plant 2 effluent	plant 3 influent	plant 3 effluent
TOC (ppm)	3.4	13.4	2.2	1.2	3	1.7	2.4	1.4
UV_{254}	0.0800	0.3500	0.0577	0.0223	0.0863	0.0288	0.0602	0.0196
SUVA	2.4	2.6	2.6	1.9	2.9	1.7	2.5	1.4
pH	7.2	7.3	7.3	7.2	7.2	7.1	7.1	7.2
IS ($\mu\text{S}/\text{cm}$)	58	47	88	93	105	109	139	149

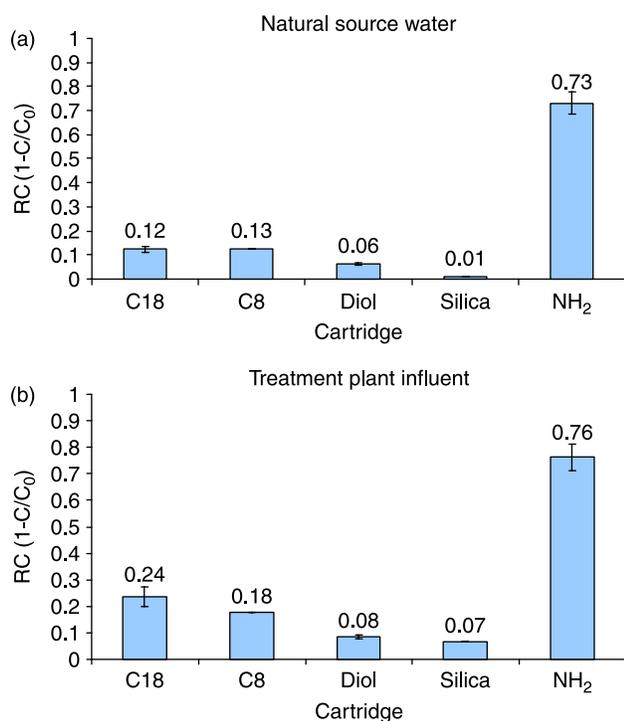


Figure 3 | a and b. UV PRAM on natural source water and water treatment plant influents.

Comparison of XAD and PRAM

As part of the development of PRAM, and in order to be able to compare the results with the great wealth of data on the polarity of DOM done using the XAD resin method, a direct comparison between both methods was completed. The comparison of the resin and PRAM methods was done at pH < 3. At pH < 3, the charge on the mixture of DOM molecules is neutralized by protonation, therefore the DOM molecules become less polar and are able to sorb more readily onto non-polar sorbents. C18 SPE cartridge from the PRAM method was compared to XAD – 8 resin and the diol SPE cartridge was compared with the XAD – 4 resin. Finally the anionic exchange PRAM cartridges are anionic sorbents used to assess the negative charge of the DOM. These anion exchangers are only used in the PRAM approach at natural pH as the DOM in natural water at neutral pH is negatively charged. At pH < 3, the DOM would be protonated and the NH₂ cartridge would not give any relevant information.

Both methods were run in series on four different samples: rutin as a known probe, an IHSS isolate and two natural waters used for drinking water of low and high

DOC. The results are shown in Figure 4. Not all material can be recovered from the resins and the calculations for TOC include the percentage not recovered; this percentage ranges from 6 to 12% of the total material. It is noted that the DOC leached by the XAD – 8 column seeps into the influent of the XAD – 4 column and it is impossible to know whether or not this DOC is captured by the XAD – 4 column or partially or totally goes through. The same situation exists for the series C – 18/diol SPE cartridges.

For the PRAM measurements with UV₂₅₄, the leaching can be controlled to an absorbance value of 0.0025 for C18, glycol and NH₂. The TOC for the PRAM and resins analyses was controlled to a value below 10% of the value

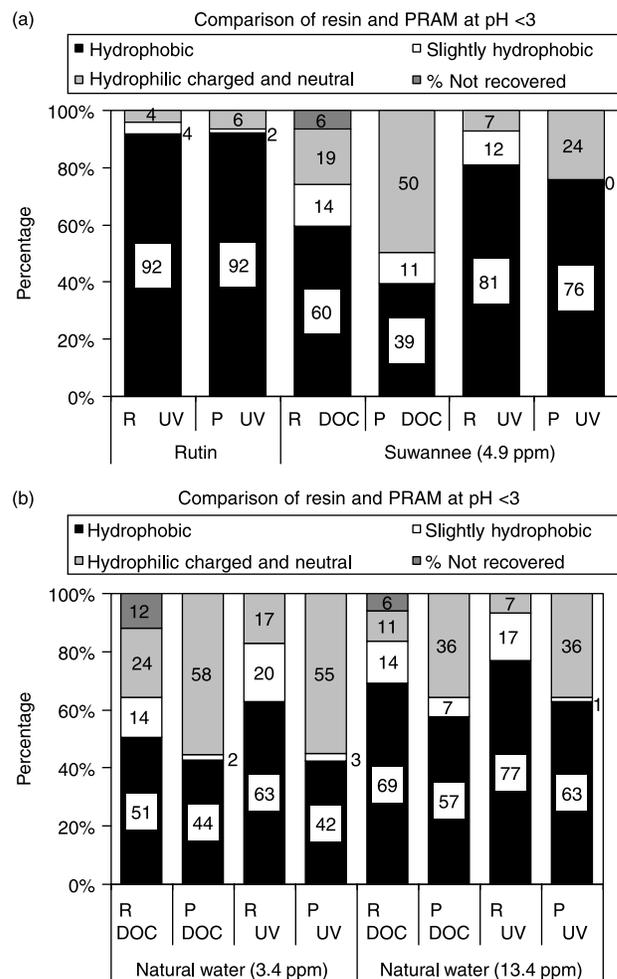


Figure 4 | a and b. Comparison of PRAM and resin methods for four samples (R = resin, P = PRAM). Both methods are analyzed for TOC and UV and comparison is made according to the hydrophobic, slightly hydrophobic or transphilic fractions.

of the original sample for good quality assurance. The XAD columns leached less than 0.3 mg/L DOC after cleaning, thus, the DOC values were adjusted for the calculation of the analytical results. The DOC adjusted values for the resin method were calculated by removing the leaching of the column to its respective effluent. The PRAM was also run at natural pH and at low pH to more closely compare with the resin method. Also, the PRAM was run in parallel as well as in series (C – 18/Diol), for comparison purposes. Some UV and DOC comparisons are made between methods.

The DOM type, chemical probe rutin is characterized mainly as a hydrophobic molecule (92%) and 4% hydrophilic by the resin method. This result is confirmed by the PRAM C18/Glycol SPE's run in series at pH = 2, hydrophobic (92%) and hydrophilic (2%) (by subtraction of C18 from C18-Glycol combination). The IHSS Suwannee River standard sample by the resin method is dominated by the hydrophobic fraction. The DOC results show this fraction to be 61% and the UV results show a much higher percentage (81%) is the hydrophobic fraction. This difference is then found to be about three times as much as for the hydrophilic fraction that is shown to be 14% for the DOC and 12% for the UV analysis. These results indicate that the UV fraction (aromatic and double bond chromophore) make up most of the DOC found. The UV results of the C18 PRAM run at pH = 2 (hydrophobic fraction) are 5% lower than the resin method results with the PRAM value of 76%. The PRAM for the DOC shows a different picture than the resin for the DOC fractionation. The PRAM results for DOC are 21% less than the resin, although the slightly hydrophobic fraction is low and close in both DOC and UV. The comparative results between the resin and the PRAM at pH < 3 indicate the same general fact of high hydrophobic, low hydrophilic content of the Suwannee River TOC and that the UV fraction (aromatic and double bond chromophores) makes up most of the hydrophobic fraction.

The natural water samples show again that the PRAM method appears to adsorb relatively less material on the C18 and diol cartridges than the XAD – 8 and XAD – 4 resins. The C18 cartridge and XAD – 8 resin show a similar picture both for UV and DOC, with the hydrophobic

fraction dominating the samples. The XAD – 8 adsorbs up to 14% more than the C – 18 PRAM cartridge. The slightly hydrophobic or transphilic fraction is lower for both methods but the resin method shows a much higher response than the PRAM.

The overall results indicate that the C18 cartridge appears to have a similar response to the samples as the XAD – 8 resin. The maximum difference is seen for the Suwannee IHSS isolate for TOC where there is 21% difference in hydrophobic fractions between both methods. The other measurements show a difference ranging from 0 to 14%. The diol cartridge, which followed the C18 cartridge, did not show response comparable to the XAD – 4 resin. The diol cartridge appears to not adsorb well the slightly hydrophobic fractions that the XAD – 4 resin remove. Both methods do show that this fraction is much smaller than the hydrophobic fraction. The diol and XAD – 4 cartridge do not appear to have the same effect on the sample.

PRAM in series at pH 7

An isolate from the IHSS Suwannee River sample was used to run the PRAM SPEs in series. Table 2 shows the results. The data shows that the order of the cartridges does not impact the results as the difference between the runs remains low and within the experimental error. The dual and triple runs with a plus sign add up the individual runs and compare it to the successive run e.g. C – 18-Diol. The results for the individual runs are always more than the successive runs. The % difference shown here is the difference with the sum of the single runs of the corresponding cartridges. This difference shows that the DOM in the isolate is composed of molecules that can often be found to have both hydrophobic and hydrophilic character.

Table 2 confirms that a molecule is not always completely polar or non-polar but can have functionalities that set it in both categories. This is the main value of running the PRAM both in series and in parallel. The parallel PRAM yields information on the overall hydrophobicity, hydrophilicity and charge of the DOM. A 20% retention on the C18 allows us to say that 20% of the DOM is hydrophobic. In a similar manner a 10% retention on the

Table 2 | Results of series run of SPE cartridges for IHSS isolate at pH 7

	SPE Cartridge	RC Avg. of 3 runs	% difference
Single runs	C18	0.09	
	Diol	0.03	
	NH ₂	0.93	
Dual runs	C18 RC + Diol RC	0.12	
	C18-Diol	0.11	12.1
	Diol-C18	0.11	9.2
	Diol RC + NH₂ RC	0.97	
	Diol-NH ₂	0.93	3.2
	NH ₂ -Diol	0.95	1.8
	C18 RC + NH₂ RC	1.02	
	C18-NH ₂	0.95	7.0
	NH ₂ -C18	0.94	7.8
Triple runs	C18 + Diol + NH₂	1.06	
	C18- Diol-NH₂	0.95	10.0
	CND	0.95	10.1
	DCN	0.95	9.6
	DNC	0.93	11.8
	NCD	0.91	13.5
	NDC	0.92	12.6

N = NH₂ RC; D = Diol RC; C = C18 RC.

Diol cartridge means that 10% of the DOM is hydrophilic. A series run of C18 followed by Diol will allow to find out what percent of the DOM has both hydrophobic and hydrophilic character. If a sample with a 20% C18 and 10% Diol yields a 25% C18 + Diol then 5% of the DOM has hydrophobic and hydrophilic characteristics.

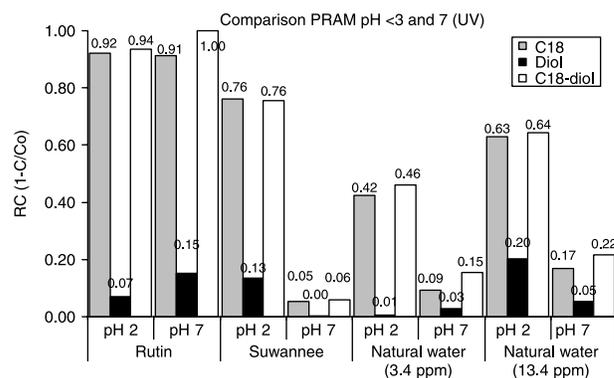
PRAM at different pH

The PRAM samples were run on the C18, Diol and C18 + Diol at both pH < 3 and pH 7 (ambient pH for the natural waters). The results in Figure 5 show that the adsorption to the cartridges is much higher at the low pH. This is expected as the DOM is protonated at that pH and loses its high charge which allows the molecules to more readily interact with the C18 and and Diol SPEs. The comparison of the two pH samples gives an idea of the amount of DOM protonated by lowering the pH.

The rutin probe is not affected by the pH, as the C18 already had a very high affinity to the molecule at pH 7. The pH < 3 samples show significant differences for the natural water samples and the IHSS standard: these samples are mixtures of countless molecules and the C18 and Diol cartridges do not have high retention coefficients at ambient pH. The main change is seen on the C18 cartridge with RC values that jump from the 0–10% to the 40–75% range. This shows the amount of hydrophobic molecules that get protonated is 40–65% more than at pH 7. Thus, the affinity to an anion exchanger overwhelms the hydrophobicity of DOM at pH 7.

Finally it can be noted that lowering the pH of the samples can be used to enhance very small differences of sorption at pH 7. If the ambient PRAM runs show small differences in RCs between samples it is difficult to assess the significance of this difference. Lowering the sample to a pH lower than 3 allows the samples to adsorb better and the differences between samples are then more significant. Thus, a quick PRAM analysis at pH < 3 may be able to compare the results to XAD historical data.

As described previously the comparison of the PRAM in series and parallel can yield more information. In Figure 5 we can see that the high TOC (13.4 ppm) natural water has a 17% hydrophobic fraction and a 5% hydrophilic fraction. The series run of C18 + Diol shows a retention coefficient of 22%. This result leads to the hypothesis that none of the DOM molecules carry both hydrophobic and significant hydrophilic characteristics.

**Figure 5** | Comparison of PRAM at pH 7 and pH < 3.

APPLICATIONS

Multidimensional characterization of water samples using Ultrafiltration (UF) and PRAM

An analysis of ultrafiltration fractions of the water treatment plant effluent of Figure 3b was performed using the C18 cartridge to evaluate the hydrophobic fraction. The results are shown in Figure 6. This is of interest to analyze the differences found between the UV analysis for these size fractions. It is assumed that the ionic strength does not change. The amount of DOC in each UF fraction is different and that can affect hydrophobicity. This is probably the reason that the RC increases in some fractions above the initial total sample value. The fractions are such that the > 10 K (kilodalton) retentate is the highest molecular weight fraction. The 5–10 K fraction is found in both the 10 K filtrate and the 5 K retentate. The 1–5 K is found in both the 5 K filtrate and 1 K retentate. And finally the < 1 K fraction is found only in the 1 K filtrate. The results show that high MW fractions >5 K contain the largest amount of hydrophobic UV 254 absorbing material (26–31%) over 10% more than the 1–5 K DOM. This method does show the significance of the non-polar fractions of the different size fractions.

Characterization of treatment systems

The PRAM was run on the influent and effluent of three traditional water treatment plants that used different source waters from the same watershed. The three plants used coagulation and chlorination. Figure 7 shows that the water treatment facilities completely remove the hydrophobic

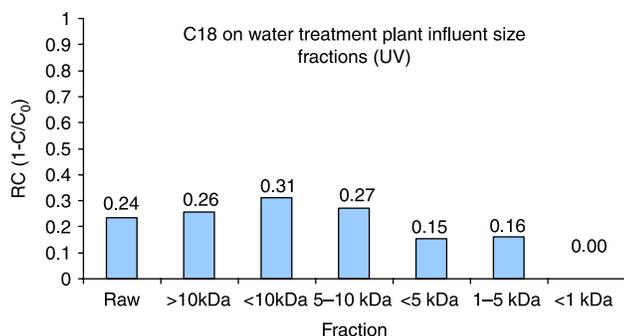


Figure 6 | PRAM results for size fractions on WTP influent (Fig. 3b) by UV analysis.

fraction represented by the C18 cartridge. All three treatment plants saw different amounts of hydrophobic fractions in their effluents but even high values of 22% were completely removed from plant 1. This shows that the water treatment process of the facilities worked very well on the hydrophobic fraction.

The Diol cartridge, representing the hydrophilic fraction shows that this fraction is the one treatment has the most trouble with: two of the facilities see this fraction increase. The hydrophilic fraction is harder to remove and it is unclear why one plant could remove that fraction while the other two could not as they used similar treatment trains. The increase of the hydrophilic fraction could be due to the water treatment process itself: the lack of removal of the hydrophilic fraction increases its relative amount that is shown in the effluent RCs.

Finally the NH² cartridge shows an important decrease in the charged fraction. This is important as it shows how effective the plants are at removing the DOM. More specifically this can be used to assess the effectiveness of the coagulation process that relies on the neutralization of the charges to create interaction between particulate matter in suspension. The three different plants had different efficiencies with plants 1 and 2 removing 40–50% of the charged fraction while the third plant only removed about 20%. The difference in processes can then be analyzed to improve treatment of the source waters.

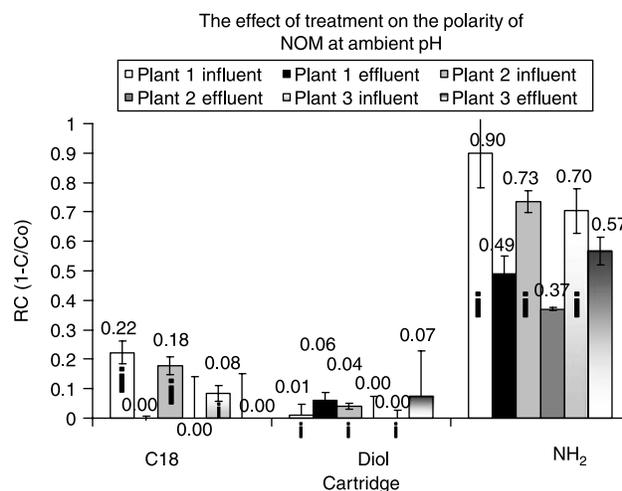


Figure 7 | PRAM run on influent and effluent of three treatment plants.

CONCLUSION

This study has shown that PRAM can be a useful and fast tool for the assessment of the polarity of DOM as well as for the evaluation of water treatment processes. The PRAM has been made more efficient for multiple samples by decreasing the number of cartridges used from 7 to 3. The comparison of PRAM with the XAD resin method has shown that the C18 can be used as a direct surrogate for the XAD – 8 resin but the Diol and XAD – 4 did not compare very well. However the relative importance of the fractions was well represented in both methods.

When analyzing water for its DOM content PRAM can be used at both ambient pH as well as a pH lower than 3. The PRAM can also be run in parallel or in series. The combination of these methods leads to different information being obtained about the DOM. Comparison of parallel and run series allows to estimate what percentage of the sample has multiple characteristics or not: hydrophobicity and hydrophilicity centers.

The PRAM can also be used alongside other methods such as ultrafiltration to find more information on the DOM of interest. The estimation of the polarity of the different size fractions of a sample can lead to a better understanding of the overall structure of the DOM.

Finally, the PRAM was used to evaluate the impact of water treatment processes on multiple treatment plants. The PRAM showed that the hydrophobic fraction was totally removed by all the facilities and the charge fraction also saw an important decrease. However the hydrophilic fraction appeared difficult to treat. This analysis of water treatment impact clearly shows the potential for PRAM to help optimize such processes as coagulation.

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