

# Fluctuations of Dissolved Organic Matter in River Used for Drinking Water and Impacts on Conventional Treatment Plant Performance

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Natural organic matter (NOM) in drinking water supplies can provide precursors for disinfectant byproducts, molecules that impact taste and odors, compounds that influence the efficacy of treatment, and other compounds that are a source of energy and carbon for the regrowth of microorganisms during distribution. NOM, measured as dissolved organic carbon (DOC), was monitored daily in the White River and the Indiana-American water treatment plant over 22 months. Other parameters were either measured daily (UV-absorbance, alkalinity, color, temperature) or continuously (turbidity, pH, and discharge) and used with stepwise linear regressions to predict DOC concentrations. The predictive models were validated with monthly samples of the river water and treatment plant effluent taken over a 2-year period after the daily monitoring had ended. Biodegradable DOC (BDOC) concentrations were measured in the river water and plant effluent twice monthly for 18 months. The BDOC measurements, along with measurements of humic and carbohydrate constituents within the DOC and BDOC pools, revealed that carbohydrates were the organic fraction with the highest percent removal during treatment, followed by BDOC, humic substances, and refractory DOC.

## Introduction

Natural organic matter (NOM) in surface waters is composed of a vast array of molecules, most of which have not been identified (1). Within this complex pool of organic molecules

are compounds responsible for taste and odor (2), disinfection byproduct formation (3), and bacterial regrowth in distribution systems (4). Our particular interest in NOM concerns those molecules that provide energy and carbon for bacterial regrowth, including environmental variables that might be useful in predicting concentrations of biodegradable dissolved organic carbon (BDOC) entering a treatment plant and treatment variables that impact BDOC reduction during treatment. While there are advanced techniques to control BDOC concentrations in finished drinking water such as ozonation followed by granular activated carbon filtration (5) and vacuum ultraviolet irradiation (6), many existing water utilities rely on conventional treatment to control NOM and its BDOC component. Knowledge of environmental variables that affect DOC and BDOC concentrations entering treatment plants as well as information on the efficacy of various conventional treatment steps in reducing these concentrations would allow plant operators to plan and adjust treatment in anticipation of changes in water quality.

Regulations promulgated by the U.S. Environmental Protection Agency are aimed at reducing the levels of disinfection byproducts in drinking water and focus on monitoring organic carbon concentrations in raw and finished water (7, 8). Studies that attempt to understand the variation in DOC and BDOC in raw water and changes through treatment typically involve sampling over weekly or monthly intervals (8), yet changes in DOC within a watershed can be far more dynamic (9–11). Here, we take advantage of a data set involving daily monitoring of DOC concentrations in drinking water before and after treatment (12) to develop predictive models of DOC in the source water and following treatment. We also have generated new data involving BDOC concentrations in raw and finished water as well as the impact of various treatment steps on these parameters. We present those predictive models and provide novel information about the composition of DOC and BDOC and changes through conventional treatment.

## Materials and Methods

**Source Water.** The White River in Muncie (Indiana) has a drainage area of 625 km<sup>2</sup> within the Tipton Till plain hydrogeomorphic region (13). The bulk of the land in the drainage basin is in active row crop agricultural. A few communities are located along the White River upstream from the treatment facility. The average annual river flow is 130 MGD (5.7 m<sup>3</sup>/s). Flow in the river can be augmented by releasing water from a 2.7 × 10<sup>7</sup> m<sup>3</sup> reservoir located 6 miles upstream from the treatment plant. Average annual precipitation is approximately 890 mm.

**Treatment Process.** The Indiana-American Water Company water treatment plant is a conventional treatment facility that involves pretreatment with powdered activated carbon for micropollutant removal during spring and summer. Treatment also includes prechlorination, coagulation based on ferric chloride and a cationic polymer, flocculation, sedimentation, and dual media filtration consisting of 61 cm of granular activated carbon (GAC) and 15–20 cm of sand. Posttreatment amendments include chlorine and ammonia to form chloramines, fluoride, and orthophosphate for corrosion inhibition. The GAC was implemented in March of 1997. Since the spring of 1999, 50% of the GAC has been replaced with reactivated/virgin GAC on a yearly basis. Plant production averaged 11 MGD (42 000 m<sup>3</sup>/day).

**Chemical and Physical Parameters.** DOC concentrations in the raw, settled, filtered and plant effluent waters were measured in triplicate on a daily basis, using a portable TOC

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**TABLE 1. River Water Quality Data over the Entire Study Period<sup>a</sup>**

parameter	mean ± STD	range
UV absorbance (per cm)	0.104 ± 0.088	0.037–0.830
river specific UV absorbance (L/(mg m))	2.70 ± 0.95	1.40–10.51
true color (color units)	10 ± 7	2–66
river turbidity (NTU)	9 ± 27	1–344
alkalinity (mg/L as CaCO <sub>3</sub> )	256 ± 40	92–370
river pH	8.0 ± 0.2	7.4–8.5
temperature (C)	13.2 ± 6.7	2.2–26.7
river stage height (ft)	2.44 ± 0.45	2.08–7.28
river flow (m <sup>3</sup> /s)	4.0 ± 9.2	0.3–128.3
river DOC (mg/L)	3.86 ± 1.19	2.15–11.90
dissolved organic carbon flux (kg/day)	587.0 ± 6490	55.8–36 048.2

<sup>a</sup> Geometric means were calculated for data showing a log-normal distribution.

**TABLE 2. Mean (and Range) DOC and BDOC Levels in Raw, Settled, Filtered, and Plant Effluent Water over the Entire Study**

water type	DOC (mg/L)		BDOC (mg/L)	
	geometric mean ± STD	(range)	geometric mean ± STD	(range)
river water	3.86 ± 1.19	(2.15–11.90)	1.00 ± 0.32	(0.49–1.65)
settled water	2.55 ± 0.51	(1.56–4.45)	0.47 ± 0.17	(0.14–0.82)
filtered water	2.27 ± 0.47	(1.30–4.17)	0.36 ± 0.15	(0.10–0.68)
plant effluent	2.23 ± 0.47	(1.27–4.11)	not determined	not determined

analyzer (Sievers Model 800 with an inorganic carbon removal module, Ionics-Sievers Instruments, Inc., Boulder, CO). Monitoring was conducted from Aug. 28, 1998 to June 13, 2000, with grab samples taken until Feb. 1999, when it was automated with a multistream sampler (Sievers, Model 800/810/820 MS) to collect daily measurements from four sample streams (12). River water was filtered through precombusted (500 °C/4 h) glass fiber filters (Whatman GF/F) for grab samples and other chemical analyses listed below. An inline, 3- $\mu$ m stainless steel membrane filtering system (Collins Products Co., Model 9700 Livingstone, TX) was used upstream of the analyzer when monitoring was automated. A series of 20 samples for DOC analyses were split and filtered through both filter systems for comparison. BDOC concentrations were measured on a bimonthly basis, using plug-flow biofilm reactors constructed of paired chromatography columns (0.6 L total volume) filled with sintered borosilicate particles (14). The bioreactors were protected from light and fed at 4 mL min<sup>-1</sup> in the upflow mode with White River water, which was filtered through a two-stage (1 and 25  $\mu$ m) high-temperature cured glass fiber cartridge system (Balston). The filters removed large particles but allowed the suspended bacteria to pass, so that the filtrate was the source of nutrients and indigenous bacteria for bioreactor colonization. The bioreactors were colonized on the filtered river water for 6 months and then maintained with a constant flow of dechlorinated effluent from the treatment plant GAC filters. BDOC concentrations were determined from changes in DOC concentrations between the reactor inflow and outflow with bioreactors equilibrated to the test water so that DOC uptake was an overwhelmingly biological process (15). The DOC not metabolized in the bioreactors was defined as the nonbiodegradable or refractory DOC (RDOC). Humic substances were measured by macroreticular XAD-8 resin chromatography (16). The concentration of humic substances was calculated as the difference between the DOC concentration of the sample prior to acidification (pH 2) and the effluent from XAD-8 resin. Total dissolved carbohydrates were assayed with high-pressure liquid chromatography and pulsed-amperometric detection (Dionex DX 500) following acid hydrolysis of filtered (0.2  $\mu$ m) samples (17).

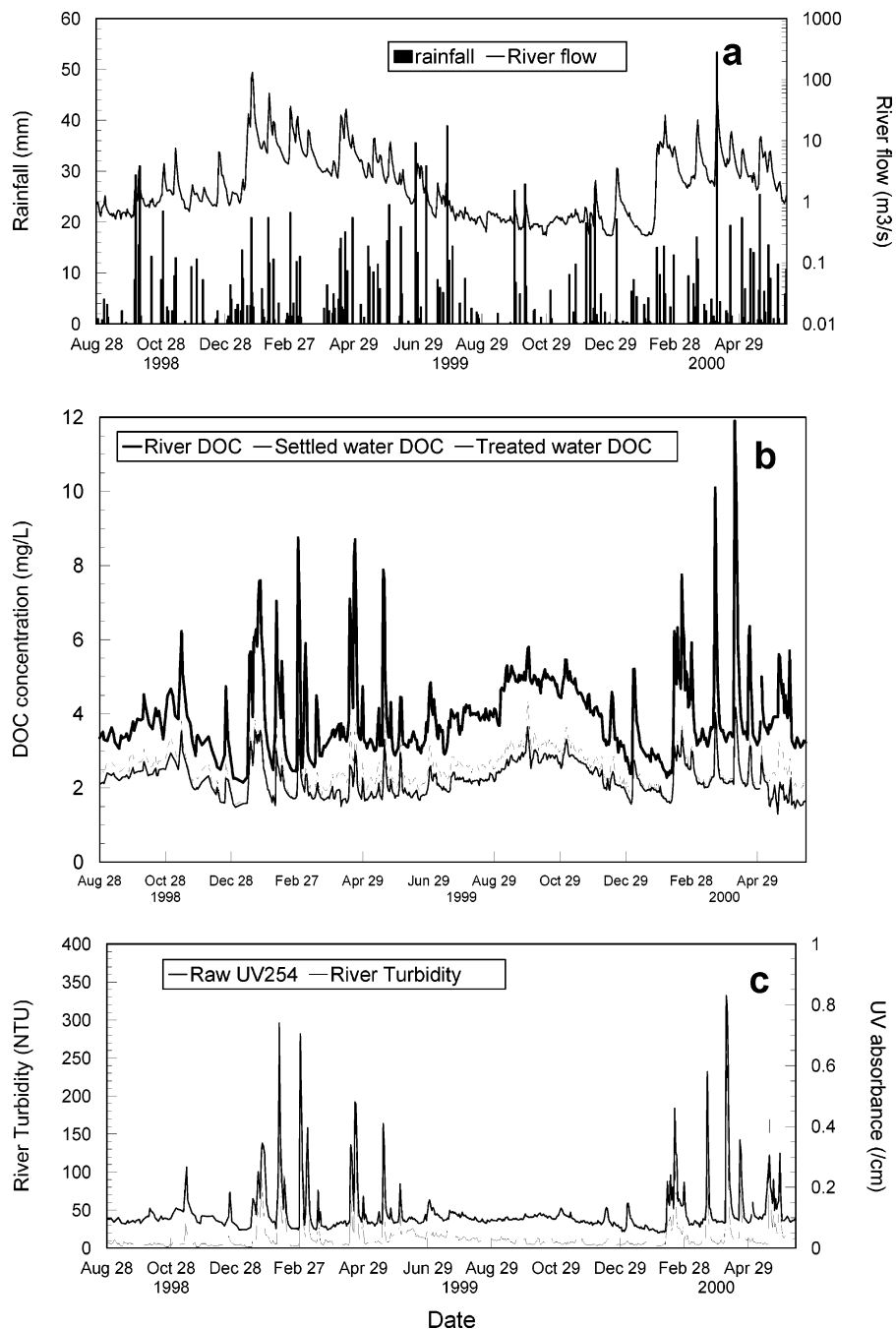
UV absorbance at 254 nm (UV<sub>254</sub>, in cm<sup>-1</sup>) and true color (platinum-cobalt color units) were determined with a

spectrophotometer (model DR 4000, Hach Company, Loveland, CO), and turbidity (NTU) was measured with an online surface scatter turbidimeter (model SS6 SE, Hach Company that was calibrated every 4 h (18)). Specific UV absorbance (SUVA, in L/(mg m)) was calculated as the ratio of UV<sub>254</sub> and DOC concentration (SUVA = UV Abs<sub>(cm-1)</sub> × 100/DOC<sub>(mg/L)</sub>). River discharge and stage height were recorded continuously at the U.S. Geological Survey gauging station 03347000 on the White River at Muncie. Water temperature was measured daily with a calibrated thermometer and daily precipitation was measured with a calibrated rain collector.

**Data Analysis, Model Development, and Validation.** Data were analyzed using a spreadsheet program (Lotus 123, Lotus Development Corp., Cambridge, MA), a graphing program (Harvard Graphics, Software Publishing Corp., Santa Clara, CA), and a statistical analysis program (Statgraphics, STSC, Rockville, MD). Data were transformed (decimal logarithm) to achieve a normal distribution. Stepwise linear regression models were run with Statgraphics. Significant differences were determined with an error level of  $p = 0.05$ . Model validation for river DOC and plant effluent DOC was performed with monthly data collected from the same sites between 2001 and 2003 on a routine basis as part of the EPA enhanced surface water treatment rule compliance testing.

## Results and Discussion

**Factors Impacting River Water Quality.** A total of 536 samples were obtained from the White River over the 2-year sampling period (Tables 1 and 2) and showed that DOC, UV<sub>254</sub>, and turbidity increased during storms (increased precipitation and flow) and then declined during the return to baseflow (Figure 1a–c). There was good agreement between the DOC concentrations of split samples filtered with the GF/F or the Collins filter ( $r^2 = 0.99$ , slope = 0.91), suggesting that little DOC was present in the 0.7–3.0  $\mu$ m size class. UV<sub>254</sub> is influenced by elevated NO<sub>3</sub> concentrations, but NO<sub>3</sub> did not exceed 1 mg N/L in the White River, and was diluted during storms when SUVA values increased. All of the water quality parameters fluctuated widely, and with the exception of pH, varied over 1 or more orders of magnitude (Table 1). Such drastic variations in quality after storm/runoff events are typical in flowing waters (19, 20). For the White River, UV<sub>254</sub> varied directly with DOC but with a higher



**FIGURE 1. Changes in water quality over the study period.**

magnitude, increasing as much as 12-fold during storms, while DOC increased a maximum of 5.5-fold (Figure 1b,c). This led to an increase in SUVA values under high river flow conditions, indicating an increase in the contribution of aromatic-C, probably associated with humic substances. The presence of humic material was also suggested by true color values, which increased as much as 8-fold during storms (data not shown).

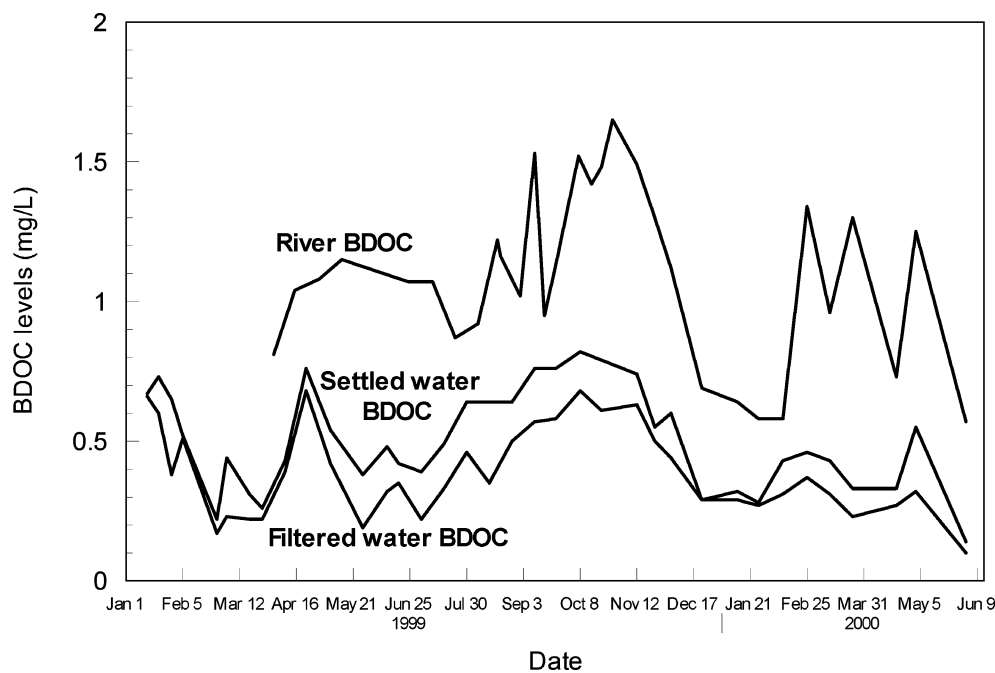
These observations indicate a shift not only in the quantity but also in the composition of NOM following precipitation and suggest that runoff leached humic substances from the upper soil horizons. Soil and hydrology affect NOM, as hydrologic conditions define the flow paths that water takes in transporting DOC to streams and rivers, and interact with soil horizons of differing mineral and inorganic character (21). UV<sub>254</sub> is a reasonable surrogate for DOC concentrations, not only in natural waters (22), but also in other environments such as sediment pore waters (23). However, the strength of

the relationship diminishes under changing hydrologic regimes, suggesting that sources of DOC and their quality change with hydrology. For example, in the Shingobee River in northern Minnesota, samples collected during the spring snowmelt revealed a doubling of DOC concentrations, while UV<sub>254</sub> tripled (21), demonstrating the limitation of using UV<sub>254</sub> to predict DOC concentrations (24).

In the White River, our ability to predict DOC concentrations with UV<sub>254</sub> was improved with consideration of flow, turbidity, and alkalinity (Table 3; relationship #1,  $r^2 = 0.87$ ,  $p < 0.05$ ). Suspended sediment concentrations in rivers during storms typically follow a clockwise hysteresis, with higher concentrations on the rising limb of the hydrograph. Turbidity in the model may be a surrogate for differences between the rising and falling limbs of the hydrograph. Similarly, alkalinity is low in precipitation compared to groundwater, so alkalinity in the model may indicate changes in the proportion of discharge deriving from groundwater

**TABLE 3. Predictions Using Simple and Stepwise Linear Regressions**

relationship	dependent variable	variables in model in order of inclusion and with <i>R</i> -squared value in []	equation	<i>R</i> -squared	<i>N</i>
#1	river DOC (mg/L)	UV absorbance (cm <sup>-1</sup> ) [0.68], alkalinity (mg/L) [0.77], flow (Cuft/s) [0.86], and turbidity (NTU) [0.87]	$\log \text{DOC}_{\text{river}} = 1.55 + 0.485 \log \text{UVabs} - 0.074 \log \text{flow} - 0.028 \log \text{turbidity} - 0.001 \text{alkalinity}$	0.87	536
#2	plant effluent DOC (mg/L)	river DOC (mg/L)	$\log \text{DOC}_{\text{effluent}} = 0.645 \log \text{DOC}_{\text{river}} - 0.039$	0.68	536
#3	plant effluent DOC (mg/L)	river alkalinity (mg/L) [0.42], river flow (Cuft/s) [0.52], river UV absorbance (cm <sup>-1</sup> ) [0.64], river turbidity (NTU) [0.69], river pH [0.72], water temperature (°C) [0.73], river color [0.74]	$\log \text{DOC}_{\text{effluent}} = 1.62 + 0.247 \log \text{UVabs} - 0.075 \log \text{flow} - 0.075 \log \text{turbidity} + 0.076 \log \text{color} - 0.036 \log \text{temperature} - 0.001 \text{alkalinity} - 0.065 \text{pH}$	0.74	536
#4	DOC removal (%)	river turbidity (NTU) [0.43], river DOC (mg/L) [0.52], pH [0.57], flow [0.59], alkalinity [0.61], temperature [0.63], color [0.65].	$\text{DOC removal} = -77.268 + 5.851 \log \text{turbidity} + 54.909 \log \text{riverDOC} + 7.163 \text{pH} + 4.601 \log \text{flow} + 0.067 \text{alk} + 5.114 \log \text{temp} - 6.702 \log \text{color}$	0.65	536
#5	river BDOC (mg/L)	river DOC (mg/L)	$\log \text{BDOC}_{\text{river}} = 1.433 \log \text{DOC}_{\text{river}} - 0.830$	0.80	26
#6	effluent BDOC (mg/L)	effluent DOC (mg/L)	$\log \text{BDOC}_{\text{effluent}} = 1.492 \log \text{DOC}_{\text{effluent}} - 0.950$	0.51	26
#7	BDOC removal (%)	DOC removal	$\text{BDOC removal} = 1.457 \text{DOC removal} + 3.780$	0.52	26



**FIGURE 2. Seasonal changes in BDOC concentrations for river and treated waters.**

versus direct interception of precipitation or overland flow. The model accurately predicted river DOC concentrations for data collected between 2001 and 2003 (Figure 3, relationship #1). Others have used linear equations (25) or nonlinear and hyperbolic equations (20) to describe the relationship between carbon levels and runoff, but with lower accuracy.

The flux of DOC in the White River, estimated from the product of river flow and DOC concentrations, shows that a large proportion of the DOC export (75%) occurred during the runoff events, even though baseflow conditions prevailed 87% of the time. The annual DOC flux of the White River was 1.15 g m<sup>-2</sup> yr<sup>-1</sup>, well below the 2.8–3.1 g m<sup>-2</sup> yr<sup>-1</sup> reported for larger rivers in China and the former USSR (20, 26).

**Organic Matter Removal after Conventional Treatment.**

The concentrations of DOC in the treatment plant effluent followed the fluctuations of the river DOC, declining, on

average, 42.0 ± 7.7% (range 17–73%) during treatment, with roughly 80% of that reduction occurring during settling (Figure 1b). The DOC removal (%) was predicted (Table 3, relationship #4) and the model was verified (Figure 3). Plant effluent DOC could be predicted as a linear function of river DOC concentrations (*r*<sup>2</sup> = 0.68), but prediction was improved (*r*<sup>2</sup> = 0.74) by a multiple linear relationship that included the same variables as the model for river DOC, plus temperature, pH, and color (Table 3, relationships #2 and #3). The importance of alkalinity to the model is understandable, given that flocculation and coagulation are pH dependent. The reduction in DOC concentrations during treatment was higher at low alkalinities. For DOC levels between 4 and 8 mg/L, average DOC removal was 47.9 ± 8.2% for an alkalinity range of 60–120 mg/L versus 38.4 ± 6.1% when alkalinity was above 120 mg/L (significant difference, *p* < 0.01). Settling

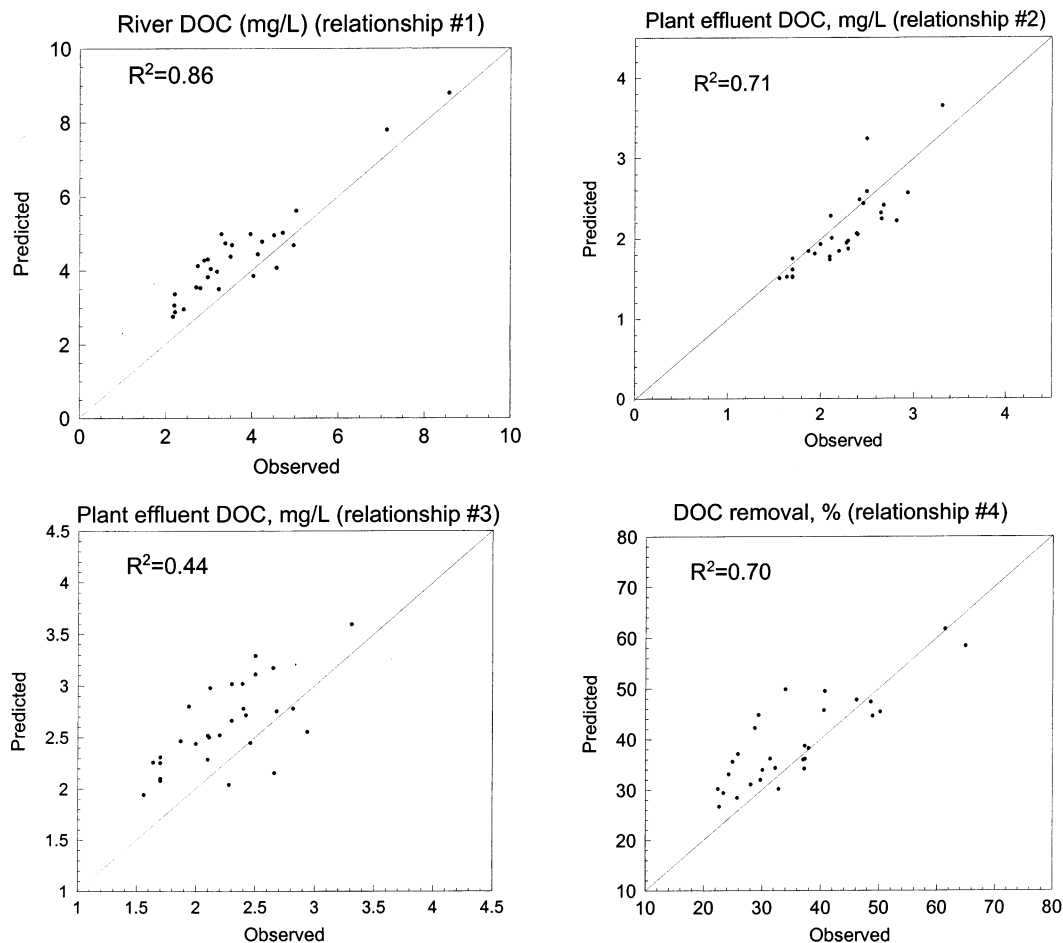


FIGURE 3. Predicted and observed data after model verification (the line of equivalency,  $y = x$ , is shown).

efficiency also depends on organic matter quality and concentration, inorganic ions, design of the sedimentation basin, and coagulation conditions, including coagulant type, dose, and temperature (7, 27, 28), and we observed that organic removal increased significantly ( $p < 0.01$ ) with increasing DOC concentrations in the river. Others have observed that DOC removal during treatment is usually higher for waters with elevated DOC concentrations that contain high molecular weight organic molecules and a high content of humic substances (high SUVA) and that low molecular weight DOC with low SUVA values is poorly removed by coagulation (27, 28). Water samples from various rivers with DOC concentrations greater than 4 mg/L exhibited an average DOC removal of 55% versus 31% for water with DOC below 4 mg/L (29), and NOM removals as high as 90% have been reported for acidic waters from the southeastern United States with TOC concentrations  $> 10$  mg/L (30). A test of our model for plant effluent DOC with data from 2001 to 2003 showed good predictive capability (Figure 3, relationships #2 and #3).

**DOC Quality and BDOC Concentrations.** Operation of the bioreactors allowed us to quantify the biodegradable and nonbiodegradable DOC in river and treated waters (Table 2). The BDOC measurements represent the mean of two bioreactors, and previous analyses of BDOC in raw water showed that outflow measurements from four replicate bioreactors on six different dates over a 4-month period had an average coefficient of variation (cv) of 5.5% (14). Like DOC, BDOC concentrations in the river followed a seasonal trend with lower concentrations ( $0.60 \pm 0.19$  mg/L) in winter when the temperature was  $< 10$  °C compared to concentrations ( $1.11 \pm 0.34$  mg/L) when water temperatures were  $> 10$  °C (significant difference,  $p < 0.01$ ). Seasonal increases in BDOC

concentrations have been observed during spring snowmelt or summer algal blooms (31, 32), even though the sources of BDOC associated with these phenomena differ, with soils and allochthonous carbon contributing during snowmelt and autochthonous algal exudates and lysates contributing during phytoplankton blooms. During algal blooms, BOM would be produced from excretion of low molecular weight and labile compounds and algal cell lysates. Treatment plant effluent BDOC concentrations, with a geometric mean of  $0.36 \pm 0.15$  mg C/L, tracked river water BDOC fluctuations. BDOC concentrations in both river and plant effluent waters were a linear function of DOC concentrations in these waters (Table 3, relationships #5 and #6,  $p < 0.05$ ), though the prediction of river BDOC ( $r^2 = 0.80$ ) was considerably better than the prediction of plant effluent BDOC ( $r^2 = 0.51$ ).

On the average, BDOC levels in the river were reduced by  $62.1 \pm 11.4\%$  (range: 35.8–82.5%) after conventional treatment, with approximately 82% of that reduction occurring during settling. The higher percent removal for BDOC compared to DOC suggests that BDOC was selectively removed by the settling process. Few studies have assessed BDOC removal by coagulation, but our data fall within the range of 38–88% for BDOC removal by ferric chloride and alum (33) and the range of 50–86% reported for a full-scale treatment plant using alum and no preoxidation (34). Laboratory-scale coagulation experiments conducted on various water types and under different coagulation conditions revealed that BDOC removal varied between 0 and 74% and was a function of BDOC quality, source water origin, and coagulation conditions (29).

Settled water BDOC concentrations were reduced a further  $23.2 \pm 12.1\%$ , on average, after GAC/sand filtration, and BDOC levels were consistently lower (significant difference,

**TABLE 4. DOC, Humic Substance, Total Dissolved Carbohydrate (TDCH), and BDOC Levels before and after Treatment**

date	sample type	DOC			River BDOC <sup>a</sup>		
		total mg/L	humic substances mg/L (% of DOC)	TDCH $\mu$ g/L (% of DOC)	total mg/L (% of DOC)	humic substances mg/L (% of BDOC)	TDCH $\mu$ g/L (% of BDOC)
5/2/2000	river water	3.79	1.62 (42.7)	258 (6.8)			
	settled water	2.31	0.91 (39.5)	78 (3.4)			
	filtered water	2.21	0.99 (45.0)	72 (3.3)			
	river water BDOC reactor outflow (= refractory DOC)	2.61	1.35 (51.6)	24 (0.9)	1.17 (31)	0.27 (23.0)	234 (20.0)
6/2/2000	river water	3.26	1.48 (45.3)	111 (3.4)			
	settled water	2.17	0.96 (44.4)	38 (1.8)			
	filtered water	2.08	0.92 (44.4)	33 (1.6)			
	river water BDOC reactor outflow	2.65	1.36 (51.2)	18 (0.7)	0.61 (19)	0.12 (19.5)	93 (15.3)
6/13/2000	river water	3.08	1.49 (48.6)	150 (4.9)			
	settled water	2.24	1.00 (44.5)	69 (3.1)			
	filtered water	2.03	0.85 (41.9)	41 (2.0)			
	river water BDOC reactor outflow	2.52	1.31 (51.9)	21 (0.8)	0.56 (18)	0.18 (32.0)	129 (23.0)

<sup>a</sup> River BDOC values are derived from the difference between DOC data and BDOC reactor outflow (or refractory DOC): BDOC = DOC – RDOC.

$p < 0.01$ ) in the GAC filtered water (Figure 2), while the refractory DOC concentrations were similar in the settled and filtered waters. However, the removal of BDOC within the Indiana-American conventional GAC filters was not as high as that reported for biological filters (up to 60%, (35)), because of shorter contact times (<5 min), mass transfer limitations for the transport of BDOC to the biofilm from accumulating floc (36), and frequent backwashes with chloraminated water that reduce biological activity.

**Chemical Fractionation.** The contributions of humic substances to the DOC in river, settled, and filtered water over 3 different days from May to June 2000 ranged from 39.5 to 48.6% (Table 4). There was no consistent pattern to the change in humic content over the three dates, and these values are low compared to many streams and rivers (37), but the data are consistent with the low SUVA values for the White River. The analyses for humic substances were single samples passed through XAD-8 resin columns, but previous work with replicate columns showed an average cv of 3% for this method (Kaplan, unpublished data). There was a consistently higher humic substance content of the refractory DOC (bioreactor effluents averaged 51.4% humic-C), indicating a selective metabolism of nonhumic substances by the bioreactors, and humic substances accounted for 42.7–48.6% of the river DOC but only 19.5–32% of the river BDOC. In contrast, total dissolved carbohydrates (TDCH), which contributed from 3.4 to 6.8% of the river DOC, showed a consistent decline through treatment and a selective removal in the bioreactors, representing between 3.4 and 6.8% of the river DOC but 15.3 to 23% of the river BDOC (Table 4). Carbohydrate analyses were performed on single samples, but this method is precise, with a cv of 5% (22). TDCH contributions to the DOC in the White River were typical of those reported for other surface waters (range 5–10%) (38). Carbohydrates (as well as amino acids) generally fluctuate seasonally and have been reported to increase in spring and summer samples because of increased algal production (37). For the White River, the dominant sugars within the carbohydrate pool were fructose, xylose, galactose, rhamnose, and arabinose, which represented individually between 14 and 20% of the total carbohydrates, while glucose and mannose were less abundant (8.4 and 6.7%, respectively). This distribution of monomers suggests a lower contribution of allochthonous C, as the glucose moiety is representative of cellulose contributions from higher plants, while arabinose has been found to correlate with alanine and aminobutyric acid and is an indicator of NOM of bacterial origin (39), as well as representing 15% of the carbohydrate in hydrolyzed fulvic acid (40). In this way, the carbohydrate data support

the humic substances and SUVA data for White River. Carbohydrates exist as free saccharides and in forms bound to humic substances and have been used as indicators of diagenesis (41). The association between carbohydrates and humic material could lead to carbohydrate removal after coagulation, while free carbohydrates could be targeted during biological filtration. Others have reported that carbohydrates are partially removed during treatment involving settling, adsorption, and biological filtration (37).

NOM characterization remains a priority for the water utilities to understand, predict, and control the behavior of the various organic fractions during treatment and distribution. Overall, the fraction of organic matter most affected by treatment was the total dissolved saccharides (71% removal), followed by BDOC (62% removal), humic substances (44% removal), and refractory DOC (33% removal). When considering the settling and filtration steps separately, these fractions were affected in the same order during settling (TDCH, BDOC, HS, and RDOC removals of 62, 51, 37, and 27%, respectively). During filtration, the BDOC and carbohydrate removals were 23% and 21%, respectively, compared to removals of only 7% and 6% for the RDOC and HS, respectively. These data provide some insights on the organic fraction targeted during water treatment, and our models illustrate how water utilities using conventional treatment can predict the quality of treatment plant effluent from a set of relatively easily determined parameters. This information can be used to guide decisions on modifications to treatment in a short amount of time.

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