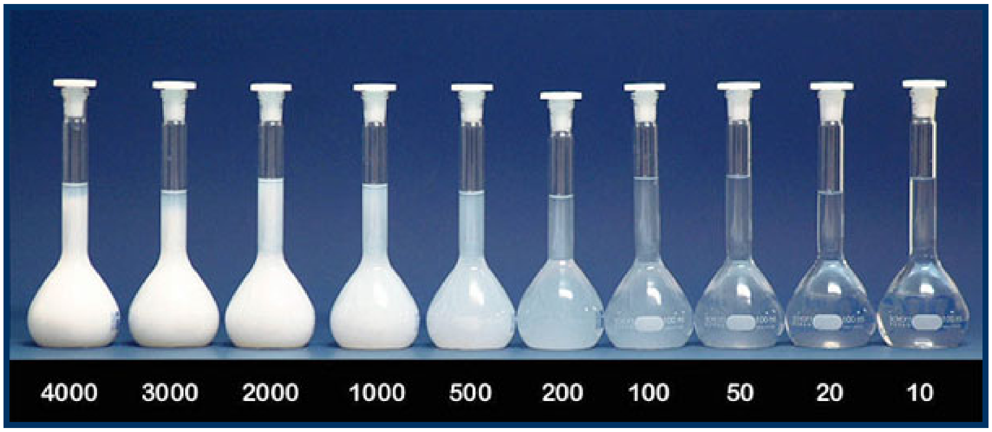
TURBIDITY METRICS



Regenerative Media Filters vs. High Rate Sand Filters
Turbidity Performance Comparison

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White Paper Index

Introduction

The focal point of this paper is the clarity of water. Water has many uses, all of which come with corresponding specifications specific to chemistry, processing and other criteria. This white paper centers on filtered recreational water treated by Regenerative Media Filters (RMF) and High-Rate Sand Filters (HRSF)

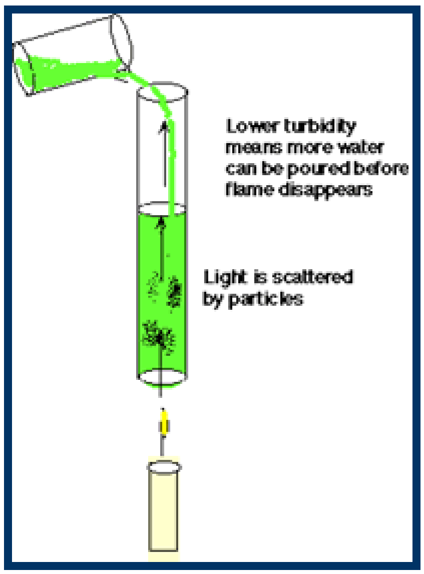
Simply stated, turbidity is the measurement of the relative clarity of a liquid. The only function the filter has in water purification is to remove particulate matter which effectively lowers turbidity. Outside of the filter itself other systems are present and responsible for additional aspects of pool water processing.

The following pages will define and analyze turbidity and the different filter technologies employed to reduce turbidity levels in pool water.

Turbidity History and Measurement

Quantifying turbidity dates back to the early 20th century. A standard suspension fluid was developed using 1,000 parts per million (PPM) of Diatomaceous Earth (DE) in distilled water (Sadar, 1996). Dilution of this reference suspension resulted in a series of standard suspensions which were then used to derive a ppm-silica scale for calibrating turbidimeters.

The resulting application is known as the "Jackson Candle Turbidimeter." (See Figure 1) It consists of a special candle and a flat-bottomed glass tube that's calibrated in graduations equivalent to ppm of suspended silica turbidity. (EPA 1999) A water sample is poured into the tube until the visual image of the candle flame, as viewed from the top of the tube, is diffused to a uniform glow. When the intensity of the scattered light equals that of the transmitted light, the image disappears; the depth of the sample in the tube is read against the ppm-silica scale and turbidity is denoted in Jackson Turbidity Units (JTU).



(Figure 1)

Jackson Candle Turbidimeter

The JCT was calibrated using suspensions of Kaolin (fine clay), Fuller's Earth, or Bed Sediment. The use of multiple calibration materials meant obtaining consistency in formulation was difficult. *Limitation; the lowest turbidity value possible with this instrument was 25 JTU.*

During the 1920's a new unit of turbidity measurement was introduced called "Formazin Turbidity Units" (FTU). Formazin is an easily measured polymer which is suspended in test liquid by weighing and dissolving 5.00 grams of hydrazine sulfate and 50.0 grams of hexamethylenetetramine in one liter of distilled water. The solution develops a white hue after standing at 25 degrees C for 48 hours. *Limitation; FTU is unable to measure extremely high or low turbidity.* Today's turbidity measurement standard, as adopted by the water industry brain-trust "Standard Methods" http://www.standardmethods.org is Nephelometric Turbidity Units (NTU). Nephele is Greek for cloud.

A Nephelometer (see figure 2) determines turbidity by the light (focused through a stream or sample of water) scattered at an angle of 90 degrees from an incident beam. Formazin has been historically used to calibrate Nephelometers by suspending the polymer such that a value of 40 Nephelometric units (NTU) is approximately equal to 40 JTU.

(Figure 2)

<u>Nephelometer</u>

At other levels the two units are not equivalent due to different instruments and different calibration materials. A specified concentration of Formazin suspension is defined as 4000 NTU and is used to calibrate most Nephelometers today. *<u>Note; the European Union equivalent to NTU is Formazin Nephelometric Unit (FNU)</u>*

How do Nephelometers work? A good turbidity description is "an expression of the optical property that causes light to be scattered or absorbed." Suspended solids in the water are what scatters and absorbs the light. It's less about how many suspended particles there are, or the total mass of the particles, but has more to do with their size, shape and reflective index. The light source is a tungsten filament light operating at a color temperature of 2200-3000°k that impinges on a water sample held in a clear glass cell.
A spectral peak response detector, tuned between 300-400nm, is located at a 90° angle to the incident light beam to measure the amount of light reflected towards the detector (Allhands, 2007).

The USEPA states that effluent Turbidity level for drinking water must not exceed 1.0 NTU, but also must not exceed 0.3 NTU in 95% of samples in any given month. Department of health requirements for NTU levels in pools vary. For instance Florida limits the effluent NTU value to 0.5 while Edmonton, Canada calls for a maximum effluent value of 0.2 NTU.

Filter Science

Regenerative Media and High Rate Sand (see figure 3) are the two most commonly used filter types in the aquatics industry. The names are descriptive of the media elements contained within a pressure vessel. Media is the active component charged with the removal of suspended solids. The primary purpose of both filter technologies is to lower turbidity levels by reducing the level of "Total Suspended Solids" (TSS) contained within the water.

(Figure 3)

High-Rate Sand Filters

Besides suspended-solids there are a few other categorizations; total solids, settleable solids, and dissolved solids. Total solids are the sum of suspended, settleable and dissolved solids. Settleable solids are materials that settle out of a suspension within a specified period of time. Dissolved solids, aka filterable solids, are solids small enough to pass through a 2.0 micron filter pore. Suspended solids are those particles large enough to be retained by the filter element. Historically, science points to the 2.0 micron size when differentiating suspended solids from dissolved solids. *Note; today's Regenerative Media Filter technology is rewriting the rule by capturing particulate matter down to 1.0 micron, thus improving turbidity levels and filtration performance.*

In High Rate Sand Filter technology water is supplied to the top of a bed of sand which is supported on a bed of graded gravel that encapsulates a system of underdrains. The filtration process takes place in a pressure vessel typically made of fiberglass or steel.

(Figure 4)

Defender™ Filter

(Figure 5)

Perlite Media

The filtering action of the sand is entirely mechanical as suspended matter is accumulated in the interstices between the grains until the output flow drops too low. The output is monitored by tracking pressure differentials. When the pressure differential rises above 10 psi (10 psi more-than the psi value of the filter operating in a clean state) the filter is cleaned by backwashing. *Backwashing sends large amounts of contaminated (dirty) water to waste.*

High Rate Sand Filters capture particulates down to 20 microns. These filters work at very high flow rates, up-to 50 m3/m2 per hour (approx. 20 gallons/sq. ft).

Regenerative Media Filters (See figure 4) were originally popularized by using Diatomaceous Earth (D.E.) which consists of the fossilized remains of certain unicellular sea plants and can be obtained in various grades. DE was used as the active media element in many of the earlier RMF versions. Alternatively, a specially treated volcanic ore called "Perlite" is now the popular media choice (see figure 5). Sometimes called pre-coat filters these systems yield water of very high quality because they remove large amounts of turbidity.

The principle of precoat filtration begins with a layer of media attaching to tubes or candles. Functionally it carries out filtration on the surface of the attached media which is commonly called the "cake". The filter area created, i.e. the surface area of the cake, is dependent on the size and quantity of the components provided for media attachment and the thickness of the media coating itself. *Inherently 10 times more filtration surface area is incorporated in a Regenerative Media Filter compared to a similarly sized High Rate Sand Filter.*

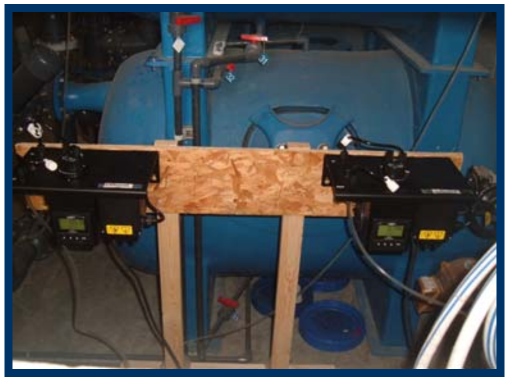
Regenerative Media Filters (sometimes called Pre-coat filters) can provide large reductions in water usage due to filtration design and operational parameters, rather than five minute backwash cycles conducted once or twice a week (more on waterpark attractions) which send thousands of gallons to waste. Regenerative Media Filters empty their filter tanks containing only hundreds of gallons once a month. Also, the increased filter area provided by RMF generates a much lower filter rate which greatly enhances turbidity removal.

Data Collection and Analysis

Two separate turbidity case-studies were undertaken where data was collected and charted over the course of eight days. Municipal recreation centers were the chosen sites to study turbidity levels associated with Regenerative Media Filter and High Rate Sand Filter technology. *Each facility averaged over (300) bathers per day during the test periods.*

(Figure 6)

Nephelometer Monitoring Defender™ RMF Filter System



(Figure 7)

Nephelometers Monitoring High Rate Sand Filter System

A George Fisher Signet model WL-0-1000 NTU was used to collect turbidity data from a Regenerative Media Filter (see figure 6), and from a High Rate Sand Filter system (See figure 7). Both systems were commissioned in 2010.

Defender™ Regenerative Media Filter: Data Sheet

Backwash and Turbidity Tracking
Main Recreation Pool, Defender Filter Model SP-48-38-1452

Pool Volume: 107,013 gallons — **Flow Rate:** 1076 gpm (244.4 m3/hr)

Filter Area: 935 ft2 (86.9 m2)

Turnover Rate: 1.65 hours — **Filter Rate:** 1.15 gpm/sf (2.81 m3/h/m2)

	AM			PM		
	Influent		Effluent	Influent		Effluent
Date	Time	Turbidity	Turbidity	Time	Turbidity	Turbidity
8/11/10	9:41	0.102	0.094	5:15	0.172	0.069
8/12/10	7:14	0.060	0.050	4:45	0.181	0.074
8/13/10	8:00	0.054	0.051	8:00	0.146	0.061
8/14/10	11:00	0.084	0.076	5:00	0.134	0.062
8/15/10	10:10	0.072	0.070	7:00	0.100	0.059
8/16/10	7:00	0.055	0.053	1:00	0.108	0.051
8/17/10	8:00	0.114	0.092	6:00	0.179	0.059
8/18/10	7:00	0.101	0.047	8:00	0.118	0.043

(Figure 8)

High-Rate Sand Filter: Data Sheet

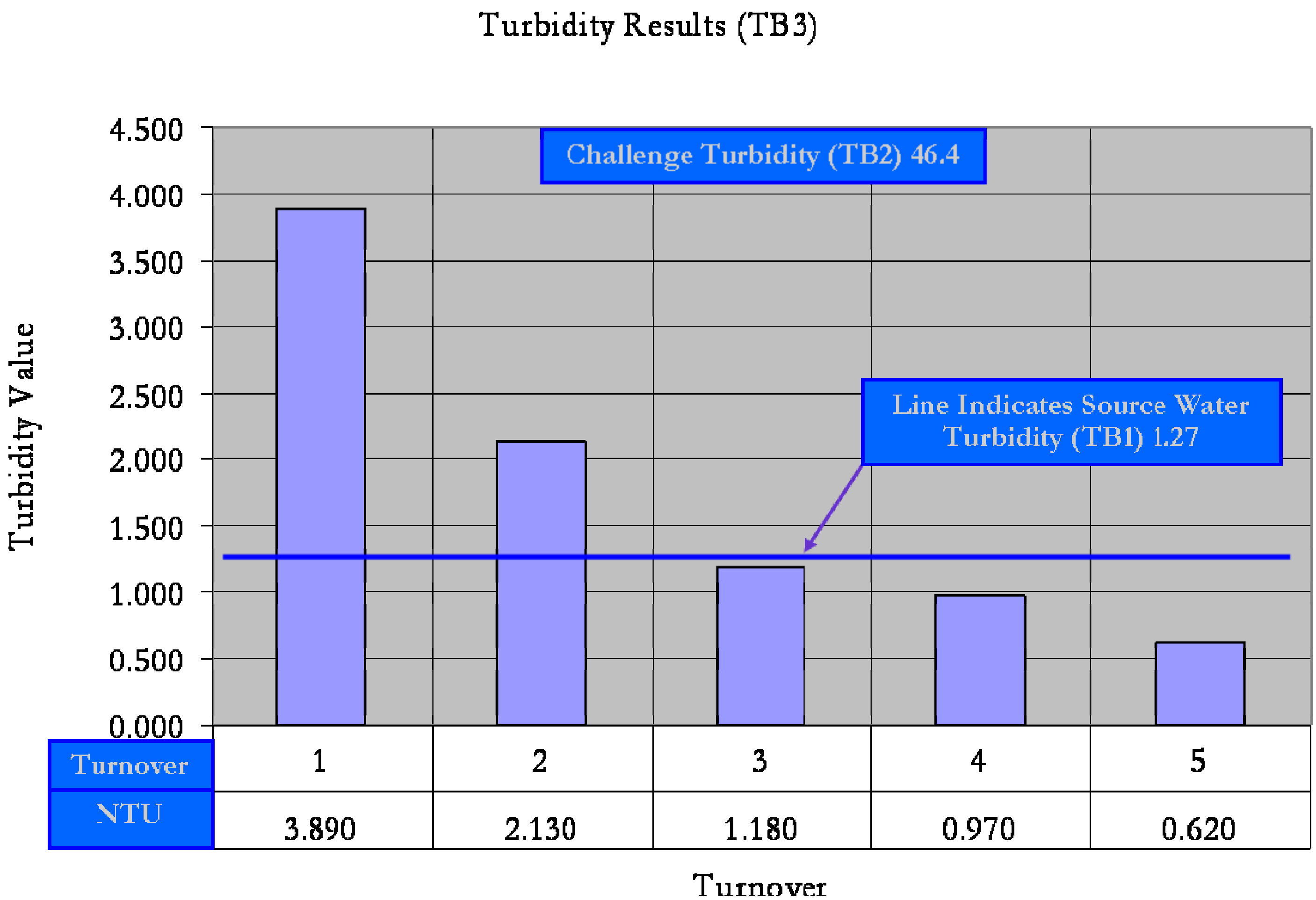
Backwash and Turbidity Tracking Main Recreation Pool, (2) High-Rate Horizontal Sand Filters						
Pool Volume: 100,000 gals			**Flow Rate:** 833 gpm		(189 m3/hr)	
Filter Area: 79.4 ft2	(7.4 m2)		*** Indicates Reading After backwash**			
Turnover Rate: 1.65 hours			**Filter Rate:** 10.5 gpm/sf		(26 m3/h/m2)	
	AM			PM		
	Influent		Effluent	Influent		Effluent
Date	Time	Turbidity	Turbidity	Time	Turbidity	Turbidity
7/23/11	8:15	0.550	0.443	7:00	0.595	0.397
7/24/11	8:00	0.460	0.352	8:00	0.602	0.390
7/25/11	7:00	0.510	0.255	8:00	0.580	0.315
7/26/11	7:30	0.503	0.244	8:15	0.554	0.280
7/27/11	8:00 *	0.551	0.445	8:00	0.632	0.485
7/28/11	8:00	0.511	0.319	8:00	0.565	0.319
7/29/11	7:30	0.501	0.281	8:30	0.550	0.235
7/30/11	8:00	0.410	0.255	8:00	0.500	0.225

(Figure 9)

Besides the analysis represented in (figures 8 & 9) a third party certification group conducted additional turbidity testing on Regenerative Media Filters which we will refer to as "Turbidity Reduction Test."

The Turbidity Reduction Test was conducted on a line of Regenerative Media Filters manufactured by Neptune-Benson called Defender™ Filters.

The source water provided for filtration testing had an initial turbidity level of 1.27 NTU. A measured amount of #140 silica sand was then added to the water increasing the turbidity level to 46.4. The testing criteria dictated five filtration turnovers with turbidity measurements to be taken between each turnover. TB1 = 1.27 NTU (Source Water) TB2 = 46.4 (Challenge Water)



(Figure 10)

Test results shown in figure 10 indicate that after the third turnover the Defender™ filter began improving the turbidity value of the source water.

Performance Comparison

In reference to the comparative case study defined earlier in the Data Collection and Analysis section; the turbidity data for Regenerative Media Filters shown in figure 8 found an average AM influent value of 0.080 and an average effluent value of 0.059. A breakdown of the PM readings reveals a turbidity value of 0.142 on the influent and 0.066 on the effluent. These readings are consistent with bather-loading influences and the hours of operation. The water logically reveals lower turbidity levels in the AM as the pool had not seen any bathers for a number of turnovers.

The breakdown of turbidity data for High Rate Sand Filters as shown in figure 9 reveals an average AM influent value of 0.499 and an average effluent value of 0.324. A breakdown of the PM readings reveals a turbidity value of 0.572 on the influent and 0.330 on the effluent.

There are a few constants discovered by analyzing the numbers; the influent readings are higher than the effluent, the PM readings are higher than the AM, and the High Rate Sand Filter turbidity levels are MUCH higher than the Regenerative Media Filter turbidity readings.

Regenerative Media Filter technology consistently produced lowers turbidity levels than High Rate Sand Filter technology. These findings have been corroborated by our research and by independent third-party testing.

In conclusion both technologies remove particulate matter and improve turbidity levels. The data indicates they do so at different rates and at varying degrees of success dependent on the specific technology employed.

Research References

1. M. N. Allhands; November 21, 2007 "A treatise on Turbidity and TSS"
2. EPA; April 1, 1999 "EPA guidance manual, Turbidity provisions"
3. M.J. Sadar; 1996 "Understanding Turbidity Science"
4. P. Steinback; 2008 "Aquatics – Regeneration next"