

## LENOX INSTITUTE PRESS

Auburndale, Massachusetts 02466, USA

"ENVIRONMENTAL SCIENCE, TECHNOLOGY,  
ENGINEERING AND MATHEMATICS (STEM)" Series

# REDUCTION OF HIGH COLOR, HUMIC SUBSTANCES, TURBIDITY, COLIFORM BACTERIA, THMMFP, UV ABSORBANCE, CYSTS, CHLORINE DEMAND, AND METALS FROM UNPREDICTABLE WATER SOURCE BY DISSOLVED AIR FLOTATION AND FILTRATION

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**CITATION:** Wang, LK, and Wang, MHS (2023). Reduction of high color, humic substances, turbidity, coliform bacteria, THMMFP, uv absorbance, cysts, chlorine demand, and metals from unpredictable water source by dissolved air flotation and filtration. In: "*Environmental Science, Technology, Engineering, and Mathematics (STEM)*", Wang, LK, Wang, MHS, and Pankivskyi, YI (editors). Volume 2023, Number 6A, June 2023; pp.53. Lenox Institute Press, Massachusetts, USA.  
<https://hcommons.org/deposits/item/hc:55689/>

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ABSTRACT

This memoir-style publication documents: (a) the innovative dissolved air flotation and filtration (DAFF) potable water treatment systems; (b) the USEPA Drinking Water Standards and the local state drinking water quality goals; (c) promulgated standards for raw water sources of domestic water supply; (d) the procedure for determination of the trihalomethane maximum formation potential (THMMFP), (e) the alternatives of treating an unpredictable water supply source, (f) the filter backwash wastewater recycle and total chemical sludge recycle technology, (g) the glossary of drinking water quality parameters including simplified water quality standards or goals, and (h) a 4-months DAFF research conducted by the Lenox Institute of Water Technology (LIWT) and Krofta Engineering Corporation (KEC) for treatment of an unpredictable water supply source in Oneida, NY, USA. The raw water had wide ranges of color (25-90 CU; average 40 CU), humic substances (1.5-9.6 mg/l; average 5.24 mg/l), turbidity (1.08-14.2 NTU; average 1.8 NTU), coliform bacteria (1 to TNTC #/100 ml; average TNTC #/100ml), THMMFP (127 to 683 ppb; average 348 ppb), UV absorbance with 1 cm light path at 254 nm (0.13 to 0.28 UV; average 0.19 UV), cysts-size microscopic count (410 to 34623 #/ml; average 6886 #/ml), chlorine demand (2 to 2.5 mg/l; average 2.3 mg/l), lead (0.038 mg/l), and pH (6.4-7.5 units; average 7.14 units). Under the supervision of the NYS Department of Health (NYSDH), a continuous DAFF pilot plant was operated by LIWT/KEC at 100 gpm flow for treating the above Oneida raw water using alum, sodium aluminate, and polymer from November 1983 to March 1984. The DAFF effluent met the USEPA drinking water standards and NYS water quality goals, and the plant performance in terms of impurity percent removals was excellent: color (93%), humic substances (80%), turbidity (93%), coliform bacteria (99%), THMMFP (82%), UV Absorbance (86%), cyst-size microscopic count (99.6%), chlorine demand (52%), and lead (43%). The water loss of conventional water treatment plant (WTP) is about 9% due to discharges of both filter backwash wastewater and sludge flow. The chemical used for treating the lost 9% waster is also wasted. A comparable DAFF plant (including flocculation, DAF, filtration and chlorination) recycles its filter backwash wastewater and chemical flocs for reproduction of drinking water, thus its water loss is only about 0.5 % contributed by the floated sludge discharge. The chemical and water savings of the innovative DAFF WTP are very significant. Although the tested DAFF plant was KEC's

Sandfloat plant, any manufacturer's dissolved air flotation (DAF) and filtration process equipment (such as AquaDAF, Clari-DAF, etc.) may achieve similar high performance for water purification.

#### KEYWORDS:

Call for Further Research, Memoir, Dedication, Sotirios G. Grigoropoulos, Dissolved Air Flotation, Filtration, Unpredictable Water Quality, Extremely High Color, Humic Substances, Turbidity, Coliform Bacteria, Trihalomethane Maximum Formation Potential, UV Absorbance, Cyst-Size Microscopic Count, Cryptosporidium and Giardia cysts, Heavy Metals In Drinking Water, Total Chemical Sludge Recycle, Water Loss Reduction, Chemical Consumption Reduction, Chlorine Demand Reduction, Filter Backwash Wastewater Recycle, USEPA Drinking Water Standards, New York State Drinking Water Quality Goals, Krofta Sandfloat, AquaDAF, Clari-DAF.

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## DEDICATION TO THE MEMORY OF DR. SOTIRIOS G. GRIGOROPOULOS

This research report was dedicated to the memory of Dr. Sotirios G. Grigoropoulos, who was the authors' lifetime mentor and very good friend, and was the senior author's PhD academic advisor at the University of Missouri, Rolla, MO, USA. The attached photo was taken in Pireas, Greece, on May 30, 2016, when the authors had a reunion with him.

Dr. Grigoropoulos was born on March 24, 1933 in Athens, Greece. He received his Diploma in Chemical Engineering from National Technology University Athens, Greece, and both of his Master of Science and Doctor of Science from Washington University, St. Louis, USA.

His professional qualifications include: (a) Greek engineering educator, (b) License Chemical Engineer, Greece, 1955; (c) registered Professional Engineer, Missouri, USA, 1967; and (d) board certified environmental engineer, American Academy Environmental Engineers, 1979.



Dr. Grigoropoulos was an Associate Professor (1960-1963), a Professor (1963-1979) and the Director Environmental Research Center (1966-1979) at the University of Missouri, Rolla, USA. In 1979, he returned to his home country serving as the Professor and Chair of environmental engineering at the University Patras, Greece, and became a professor emeritus of civil engineering in 2001. Dr. Grigoropoulos was listed as a noteworthy engineering educator by Marquis Who's Who, and was a member of ASCE, AIChE, WEF, AWWA, and Sigma Xi.

## ACRONYM

ABS:	Alkyl benzene sulfonate
ACH:	Aluminum chlorohydrate
CU:	Color units
DAF:	Dissolved air flotation
DAFF:	Dissolved air flotation and filtration
DO:	Dissolved oxygen
KEC:	Krofta Engineering Corporation
LIWT:	Lenox Institute of Water Technology
ND:	Not detected
NYS:	New York State
NYS DH:	NYS Department of Health
NYU:	Nephelometric turbidity unit
RO:	Reverse osmosis
SCM:	Streaming current monitor
STEM:	Science, Technology, Engineering, and Mathematics
TCE:	Trichloroethane
TDS:	Total dissolved solids
THM:	Trihalomethane
THMMFP:	Trihalomethane maximum formation potential
TNTC:	Too numerous to count
USEPA:	US Environmental Protection Agency
UV:	Ultra violet
VOC:	Volatile organic compounds
WTP:	Water treatment plant

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## 1. SUMMARY

### 1.1 Coverage

This memoir-style publication documents: (a) the innovative dissolved air flotation and filtration (DAFF) potable water treatment systems; (b) the USEPA Drinking Water Standards and the local state drinking water quality goals; (c) promulgated standards for raw water sources of domestic water supply; (d) the procedure for determination of the trihalomethane maximum formation potential (THMMFP), (e) the alternatives of treating an unpredictable water supply source, (f) the filter backwash wastewater recycle and the total chemical sludge recycle technology, (g) the glossary of drinking water quality parameters including simplified water quality standards or goals, and (h) a 4-months DAFF research conducted by the Lenox Institute of Water Technology (LIWT) and Krofta Engineering Corporation (KEC) for treatment of an unpredictable water supply source in Oneida, NY, USA.

Most of the technical data reported here can be found from the US National Technical Information Service (NTIS) reports PB-86-172582 [1], [2], [3], and [4].

### 1.2. Continuous Flotation-Filtration Pilot Plant

Figure 1 shows that a complete Krofta Sandfloat DAFF water purification system was treating the unpredictable water in the field.

#### 1.2.1 Normal Water Treatment Operation

The tested dissolved air flotation (DAF) and filtration continuous pilot plant is a Krofta Sandfloat Type 8

package plant (Figure 2; Diameter = 8 ft. = 2.43 m; Flow = 100 gpm = 378.5 L/min) consisting of chemical feeding, mixing, flocculation, dissolved air flotation, filtration and chlorination. Although the tested dissolved air flotation-filtration (DAFF) pilot plant is small, the readers may visit the 37.5-MGD (142-MLD) once-largest flotation-filtration plant in the world -- Pittsfield Water Treatment Plant, Pittsfield, Massachusetts, USA. [5], [6], [7]. The Pittsfield WTP has six Krofta Sandfloat DAFF units. Each DAFF unit has a diameter of 49 ft, and each treats 6.25 MGD (23.66 MLD) . The Pittsfield WTP has been in successful operation since 1986.

The following is a short description of the continuous Sandfloat dissolved air flotation and filtration (DAFF) pilot plant. The outside tank (1) encloses an inside flocculation tank (2). A sandbed (3) is suspended with a screen over the tank bottom (4). In the upper center is located a funnel (5) for sludge collection.

A movable carriage (6) rolls and rotates on the upper rim of the tank (1). On the carriage a spiral scoop (7) is mounted for scooping off the collected floated sludge. A variable speed drive (8) drives the scoop. The electrical power enters through the electrical rotary contact (9).

A pressure pump (10) takes by flotation pre-clarified water in a spot over the sandbed and feeds it into the air dissolving tube ADT (11), with compressed air entering at (12). The pressurized water with dissolved air enters through a pipeline inside the flocculation tank (2) and discharges through the distribution pipes (13) into the upper part of the flocculated water just prior the overflowing into the main flotation tank.

The raw water enters through the inlet regulating valve (14) and through the nozzle (16) in a jet motion into the flocculating tank (2) causing an agitation to further the flocculation process. The regulating valve (14) is actuated by sensor (15) that keeps the level in the main flotation tank constant.

For improvement for the flocculation, chemicals (such as alum, sodium aluminate, etc.) are added at (17), and at (18) (polyelectrolyte). The flocculated water mixed with air bubbles from the aerated water (13) enters over the submerged overflow with a deflector ring (19) into the main flotation tank.

Clarified water is discharged from under the sandbeds through the pipeline (21), passing the valve (22). With this valve the requested capacity and flow of the filtered water are manually preset. This valve can also be eliminated and the pipe directly connected to the user line of filtered water. In case where the raw water is not in unlimited supply, the valve (22) must be automatically operated from a separate flotation



tank level sensor that closes the outlet valve (22) when the flotation level starts to fall because of missing arrival of the raw water. This prevents the emptying of the flotation tank.

The sludge is scooped-off by the spiral scoop (7), discharged into the funnel (5) and flows out through the pipe (23). Figures 3 and 4 further describes the continuous Krofta Sandfloat Type 8 DAFF pilot plant. The diameter is the pilot plant is 8 ft. (or 2.43 m).

Figure 1. A complete Krofta Sandfloat DAFF water purification system in the field (Source: Lenox Institute of Water Technology)



Figure 2. Bird's View of Krofta Sandfloat DAFF Pilot Plant (Source: Lenox Institute of Water Technology).

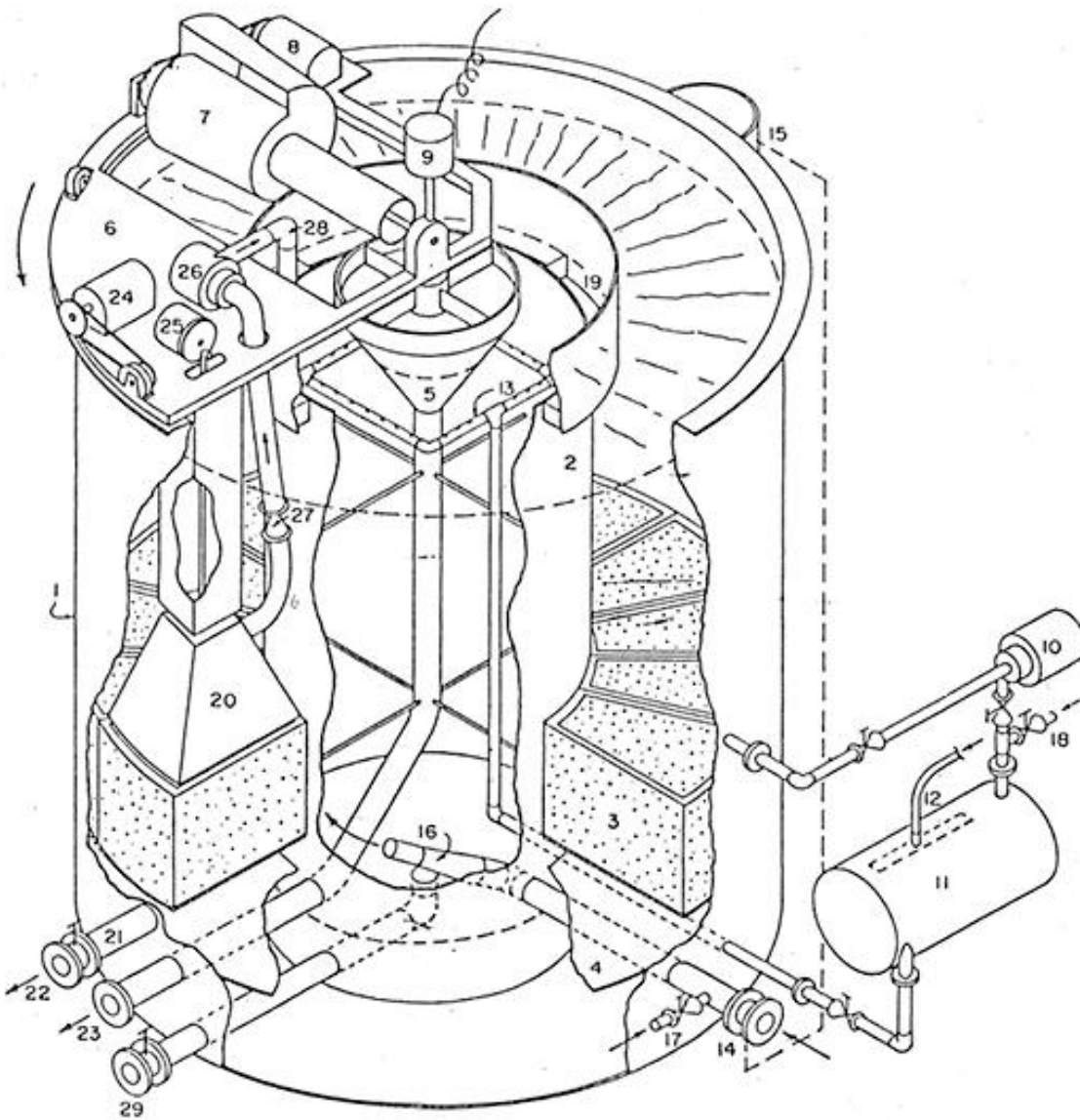
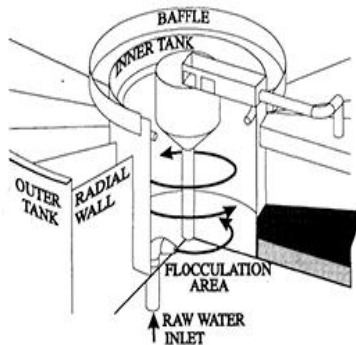


Figure 3. Flocculation, and Flotation Clarification of Continuous Krofta Sandfloat DAFF Pilot Plant  
(Source: Lenox Institute of Water Technology)

### Flocculation

Raw water mixed with flocculating agents enters through a system of nozzles into the flocculating chamber of the unit. The resulting gentle mixing velocity causes solids to aggregate together forming flocs. The extended floc tank assures proper flocculation detention time.



### Flotation/Clarification

Water with flocculated solids flows out of the flocculation tank, passing over an area where air saturated water is released. An air dissolving tube system located outside the SANDFLOAT unit generates microscopic, entrained air bubbles which attach themselves to the floc particles, causing them to float to the surface. Laminar plates located under the main flotation zone allow hydraulic loading to 4-5 GPM/SF. (1 GPM/SF = 40 LPM/M<sup>2</sup>)

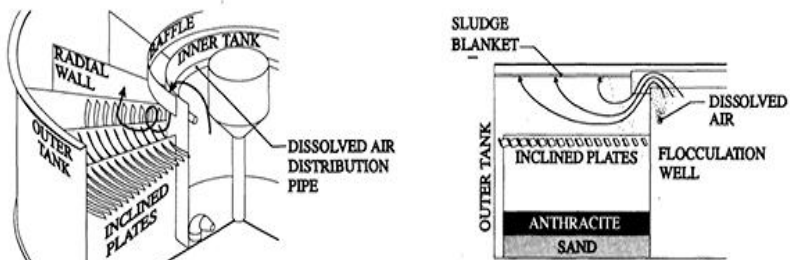
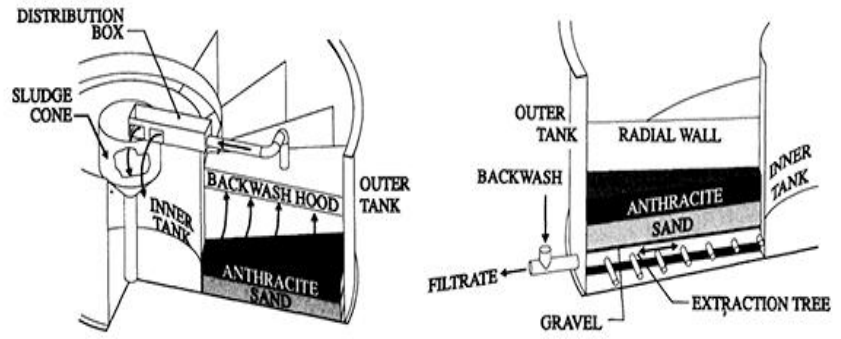


Figure 4. Filtration, On-line Backwashing and sludge Removal Operation of Continuous Krofta Sandfloat DAFF Pilot Plant (Source: Lenox Institute of Water Technology)

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### Filtration/ On-Line Backwashing

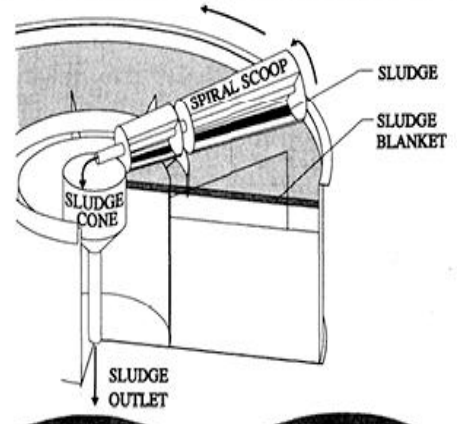
One dual media sandfilter section is individually backwashed while the other sections continue to filter water. Water from the first filtrate water reservoir is pumped from below, through the filter media, washing out impurities. Backwash water is recycled back to the flocculation chamber. The first filtrate (after backwash) isolation system allows for meeting potable water design standards.



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### Sludge Removal

The rotating KROFTA *Spiral Scoop* mounted on the carriage, circulates around the unit, gently lifting the floated impurities from the water surface. The sludge, at 1-3% consistency, is emptied into the central collector for removal from the SANDFLOAT unit.



### 1.2.2 Filter Backwash Operation

The readers are referred to Figures 2 and 4 for the filter backwash operation of the continuous Krofta Sandfloat Type 8 (diameter = 8 ft = 2.43 m) DAFF pilot plant. A suction hopper (20) with a size fitting the size of the sandbed compartments, hangs on the carriage (7). The sandbed is divided into prime number of sections (19, 23, 29, 31, 37) and the carriage stops after passing a preset number of sections. In this way the first section which is first backwashed comes ready for backwashing again after all other sections have been backwashed.

When the carriage stops, the motor (25) lowers the hopper (20) down and presses it over the sides of the backwash section. The suction pump (26) starts to pull water out of the sandbed section and lifts and fluidizes the sand. The dirty backwash water is discharged through the pipeline (28) back into the flocculation tank (2). After a preset time, in seconds the suction pump (26) stops and any return-flow is prevented by the check-valve (27). After a further preset time in seconds the sand settles under the hopper and then the motor (25) lifts the hopper again and the carriage, driven by a motor (24) moves again until it stops over the sandbed section which is in spaces further ahead.

The backwashing in this way is uniformly extended over the complete filtering time. By higher number of sections the capacity of the backwashing pump is smaller, producing a lower overload on the filter at each individual backwashing.

Heavy settleable solids as sand etc. settle on the bottom of the flocculation tank (2). Such bottom is conical with a discharge line in the center. Accumulated heavy particles are periodically discharged through the drain line (29).

### 1.3 Unpredictable Raw Water Quality

It is very difficult to treat a raw water with unpredictable water quality. [8], [9], [10]

The raw water treated in this research had wide ranges of color (25-90 CU; average 40 CU), humic substances (1.5-9.6 mg/l; average 5.24 mg/l), turbidity (1.08-14.2 NTU; average 1.8 NTU), coliform bacteria (1 to TNTC #/100 ml; average TNTC #/100ml), THMMFP (127 to 683 ppb; average 348 ppb), UV absorbance with 1 cm light path at 254 nm (0.13 to 0.28 UV; average 0.19 UV), cysts-size

microscopic count (410 to 34623 #/ml; average 6886 #/ml), chlorine demand (2 to 2.5 mg/l; average 2.3 mg/l), lead (0.038 mg/l), and pH (6.4-7.5 units; average 7.14 units).

A comparison between the above raw water quality and the promulgated standards for raw water sources of domestic water supply (Section 9), it can be seen that the unpredictable raw water source is between the "good source of water supply" and the "poor source of water supply", requiring special or auxiliary treatment (such as chemical coagulation, dissolved air flotation, filtration and disinfection)

#### 1.4 100-gpm Pilot-Scale Treatment and Performance Results

Under the supervision of the NYS Department of Health (NYSDH), a continuous DAFF pilot plant (Figures 1 and 2) was operated by LIWT/KEC at 100 gpm flow for treating the above Oneida raw water using alum, sodium aluminate, and polymer from November 1983 to March 1984. The following sections introduce the more detailed data of the 4-month research:

Section 2. INTRODUCTION AND WATER QUALITY

Section 3. CHLORINE DEMAND REDUCTION

Section 4. CORROSION CONTROL AND DOWN-TIME RECORD

Section 5. CHEMICAL CONSUMPTION

Section 6. EFFECT OF WATER LOSS ON CHEMICAL CONSUMPTION

Section 7. SLUDGE GENERATION

Section 8. TOTAL SLUDGE RECYCLE SYSTEM

Complete research data, however, are only available from the US National Technical Information Service (NTIS), No. PB-86-172582 [1], [2], [3], and [4].

The DAFF effluent met the USEPA drinking water standards and NYS water quality goals (Sections 10 and 12), and the plant performance in terms of impurity percent removals was excellent: color (93%), humic substances (80%), turbidity (93%), coliform bacteria (99%), THMMFP (82%), UV Absorbance (86%), cyst-size microscopic count (99.6%), chlorine demand (52%), and lead (43%).

In addition to the "Standard Methods for the Examination of Water and Wastewater" (AWWA/APHA/WEF), special analytical methods were used for determinations of humic substances [11], cysts-size particles [12] and trihalomethane maximum formation potential (THMMFP) (Section 11).

### 1.5 Filter Backwash Wastewater Recycle for Water Loss Reduction and Chemical Consumption Reduction

The water loss of conventional water treatment plant (WTP) is about 9% due to discharges of both filter backwash wastewater and sludge flow. The chemical used for treating the lost 9% waster is also wasted.

A comparable DAFF plant (including flocculation, DAF, filtration and chlorination) recycles its filter backwash wastewater and chemical flocs for reproduction of drinking water, thus its water loss is only about 0.5 % contributed by the floated sludge discharge. Therefore,

$$\text{Conventional WTP water production rate} = \text{Plant flow} \times 0.91 \quad (\text{Equation 1})$$

$$\text{Innovative DAFF WTP water production rate} = \text{Plant flow} \times 0.995 \quad (\text{Equation 2})$$

Accordingly the chemical and water savings of the innovative DAFF WTP are very significant, and can not be ignored.

### 1.6 Total Chemical Sludge Recycle Technology

The total alum sludge recycle technology has been proven to be technically feasible. [13]. However, the concerned water treatment plant prefers to reuse the recovered alum and/or sodium aluminate for wastewater treatment elsewhere instead of reusing the recovered chemicals within the water treatment plant. Marketing the recovered chemicals will remain to be a business research topic for a long time.

### 1.7. Alternatives of Treating an Unpredictable Poor Source of Raw Water Supply

It has been proven that the dissolved air flotation and filtration (DAFF) will be an excellent process system for reduction of high color, humic substances, turbidity, coliform bacteria, trihalomethane (THM) precursors, cysts, THM formation potential, lead, chlorine demand, water loss, and chemical consumption.

Although the tested DAFF water treatment plant (WTP) was KEC's Sandfloat DAFF plant, any manufacturer's dissolved air flotation (DAF) and filtration process equipment (such as AquaDAF, Clari-DAF, etc.) may achieve similar high technical performance for water purification. [14], [15].



## 2. INTRODUCTION AND WATER QUALITY

### INTRODUCTION

In September 1983, Krofta Engineering Corporation was retained by the City of Rome to conduct a pilot plant study for determination of the feasibility of treating the City's raw reservoir water by Krofta Sandfloat process system, which consists of chemical mixing/flocculation, dissolved air flotation, and sand filtration. Post-chlorination was provided in the effluent pipe of the Sandfloat clarifier when necessary. The purpose of this study was to test Krofta Sandfloat Type 8 at a location adjacent to the Rome pre-chlorination station in Annsville. Data on water purification by the pilot plant were collected from November 17, 1983 to March 5, 1984.

This report briefly summarizes the data of water quality, chemical consumption and sludge generation of our Sandfloat Pilot Plant Study which was conducted in Rome, NY, in the 4-month testing period. All technical data and important correspondence are properly documented in the following four reports:

- a. "Treatment of Rome Raw Water by Krofta Sandfloat Process System--Project Summary", Report No. KEC/12-83/4A, Dec. 20, 1983.
- b. "Treatment of Rome Raw Water by Krofta Sandfloat Process System--Project Documentation, Part A", Report No. KEC/01-84/4B1, Feb. 29, 1984.
- c. "Treatment of Rome Raw Water by Krofta Sandfloat Process System--Project Documentation, Part B", Report No. KEC/01-84/4B2, Feb. 29, 1984.
- d. "Treatment of Rome Raw Water by Krofta Sandfloat Process System--Project Documentation, Part C", Report No. KEC/03-84/1, March 16, 1984.

### WATER QUALITY

Based on the findings of our pilot plant investigations, we conclude that Krofta Sandfloat is feasible for significant removal of turbidity, color, UV absorbance (Tables A1, A2) trihalomethane formation potential (Table B) coliform bacteria

(Table C), microscopic particulates (Table D), iron, manganese and lead (Table E) from the City of Rome's raw water.

The effluent of the Sandfloat pilot plant met the New York State Water Quality Goals (Tables F1, F2, F3) for color, turbidity, residual aluminum and removal of Giardia cyst-sized particles (in terms of microscopic particle count). The chlorinated water had no coliform bacteria and was non-corrosive after a corrosion control chemical was added. The water quality range and average values of a few selected important parameters are further summarized below:

**Turbidity** (135 analyses each for raw water and Sandfloat effluent)

Raw Water Turbidity, NTU	1.08 - 14.2 (1.8 ave.)
Effluent Turbidity, NTU	0.05 - 0.39 (0.13 ave.)
Percent Removal	93% (ave.)
US Drinking Water Standard	1 NTU or less
NY Water Quality Goal	over 95% time $\leq$ 0.5 NTU

**Color** (135 analyses each for raw water and Sandfloat effluent)

Raw Water Color, CU	25 - 90 (40 ave.)
Effluent Color, CU	2 - 3 (2.1 ave.)
Percent Removal	95% (ave.)
US Drinking Water Standard	15 CU or less
NY Water Quality Goal	over 95% time $\leq$ 5.0 CU

**pH** (135 analyses each for raw water and Sandfloat effluent)

Raw Water pH, units	6.4 - 7.5 (ave. 7.14)
Effluent pH, units	6.7 - 7.5 (ave. 7.05)
US Drinking Water Standard	6.5 - 8.5 units

The efficiency of Krofta Sandfloat Process for removal of trihalomethane precursors (in terms of trihalomethane formation potential, UV absorbance and humic substances) and coliform bacteria can be demonstrated by the following removal data:

**Trihalomethane Formation Potential (THMFP)** (80 analyses for raw water and 78 analyses for Sandfloat effluent)

Raw Water THMFP, ppb	127 - 683	(347.5 ave.)
Effluent THMFP, ppb	2 - 97	(61.9 ave.)
Percent Removal	82%	(ave.)
US Drinking Water Standard	100 ppb	

**UV Absorbance** (1 cm light path at 254 nm) (51 analyses for raw water and 33 analyses for effluent)

Raw Water UV	.13 - .28	(.19 ave.)
Effluent UV	.002 - .09	(.026 ave.)
Percent Removal	86%	(ave.)

**Humic Substances** (49 analyses for raw water and 44 analyses for Sandfloat effluent)

Raw Water, ppm	1.5 - 9.6	(5.24 ave.)
Effluent, ppm	0 - 3.4	(1.06 ave.)
Percent Removal	80%	(ave.)

**Coliform Bacteria** (8 analyses for raw water and 8 analyses for Sandfloat effluent)

Raw Water Coliform, #/100 ml	<1 - TNTC	(TNTC ave.)
Effluent Coliform, #/100 ml	<1	(<1 ave.)
Percent Removal	99%	(ave.)
US Drinking Water Standards	<1	#/100 ml

TNTC stands for "too numerous to count". The total coliform counts were determined by the Rome Laboratory of Murphy Memorial Hospital, a NYSDH certified laboratory in Rome, NY.

It can be seen that the trihalomethane formation potential (THMFP), humic acid, UV absorbance and total coliform bacteria were all significantly removed. Partial data on the THMFP removal in the period January-March 1984 and the coliform bacteria removal in the period November-December 1983, are presented in Tables B and C, respectively, for the proposed illustration.

It is important to note that there was a close correlation among trihalomethane formation potential (THMFP), UV absorbance, and humic substances concentration. The removals for THMFP, UV absorbance and humic substances were 82%, 86% and 80%, respectively. The color and turbidity removals, however, were 95% and 93%, respectively. It is tentatively concluded that the trihalomethane precursor's removal is directly proportional to the removal of THMFP, UV absorbance and humic substances (but not color and turbidity).

Coliform bacteria are also classified as one type of trihalomethane precursors. It has been demonstrated by the data in Table B that the newly developed Sandfloat process can remove over 99 percent of coliform bacteria even without the use of any disinfectant (i.e. chlorine).

The post-chlorination process is still recommended for a final safeguard in the water distribution system. The chlorine dosage, however, shall be reduced by about 50 percent if Sandfloat process instead of conventional flocculation/sedimentation/filtration process is used for water purification.

Additional data on removal of metals and anions by the Sandfloat pilot plant are presented in Table E. It is seen that lead was also removed by the Sandfloat process. All metal concentrations (chromium, lead, sodium, iron, manganese, silver, barium, cadmium, copper, selenium, zinc, and aluminum) and non-metal inorganics (arsenic, nitrate, fluoride, sulfate and chloride) in the Sandfloat effluent met the New York State Drinking Water Standards.

Both the New York State Department of Health (NYS DH) Water Quality Goals and the Sandfloat pilot plant performance are summarized in Tables F1-F3 for the entire period November 7, 1983 to March 5, 1984. It can be seen that the pilot plant filter effluent in the testing period met the four water quality goals on effluent turbidity, color, residual aluminum and microscopic count.

The microscopic counts were determined in accordance with the APHA/AWWA/WPCF ~~Standard Methods for the Examination of Water~~

### 3. CHLORINE DEMAND REDUCTION

and Wastewater, (15th Edition, 1980). The objective of this measurement was for monitoring the consistent efficiency for Giardia cysts removal by the Sandfloat plant. Since no practical means of rapid detection for Giardia cysts could be employed, KEC and LIR utilized the electronic microscope to verify removal of cyst-size ( $\geq 8$  microns) contaminants by dissolved air flotation and filtration. The following summarized data show that over 99.6 percent of microscopic particles (with a size range of 8 microns or larger) can be efficiently removed.

**Microscopic Count** (82 analyses for raw water and  
24 analyses for Sandfloat effluent)

Raw Water Microscopic Count, #/ml	410 - 34623 (6886 ave.)
Effluent Microscopic Count, #/ml	0 - 267 (29 ave.)
Percent Removal	99.6% (ave.)
NY Water Quality Goal	over 95% of time $\leq 1000$ #/ml

Partial data on the removal of microscopic particulates by Sandfloat process in the period January-March 1984 are presented in Table D for illustration.

#### CHLORINE DEMAND REDUCTION

The Sandfloat pilot plant removed the chlorine demand of raw reservoir water by about 52 percent. The treatment results in the testing period November 7-December 9, 1983 are summarized below:

**Chlorine Demand:** (3 analyses for raw water and  
13 analyses for Sandfloat effluent)

Raw Water Chlorine Demand, mg/l	2.0 - 2.5 (2.3 ave.)
Effluent Chlorine Demand, mg/l	0.65 - 1.5 (1.2 ave.)
Percent Reduction	52% (ave.)

It is expected that when the proposed new Rome Water Treatment Plant (using four Sandfloats Type 49 or three Sandfloats Type 55) is constructed and operational, the chlorine requirement for disinfection will be reduced by about 50 percent.

#### 4. CORROSION CONTROL AND DOWN-TIME RECORD

#### CORROSION CONTROL

In addition to the pH values of both influent and effluent presented earlier in this report, the following are the total alkalinity data generated from Sandfloat pilot plant study in the entire testing period:

**Alkalinity** (65 analyses for raw water and  
63 analyses for Sandfloat effluent)

Raw Water Alkalinity, mg/l as CaCO<sub>3</sub>  
4-40 (15.5 ave.)  
Effluent Alkalinity, mg/l as CaCO<sub>3</sub>  
4-20 (8.2 ave.)

The pH Sandfloat effluent was near neutral, and its total alkalinity was positive in value after sodium aluminate was dosed for increasing pH and alkalinity.

In addition, sodium meta-phosphate was added to the Sandfloat effluent for further corrosion control. It is concluded that the treated water was non-corrosive

#### DOWN-TIME RECORD

In the entire Sandfloat pilot plant testing period (November 7, 1983 to March 5, 1984), the pilot plant performed properly and had no major mechanical breakdowns. There was no down time for the pilot plant operation in Rome, NY due to the use of a flexible work schedule at a minimum of 7 hours per day operation.

We are very pleased that our Krofta Sandfloat process has been officially approved by the New York State Department of Health for potable water treatment (Appendix A) because of the Sandfloat's extremely and consistently higher removals of impurities, lower costs for construction, lower costs for chemicals, and more superior reliability, in comparison with conventional water purification technologies.

## 5. CHEMICAL CONSUMPTION

#### CHEMICAL CONSUMPTION

The chemical consumption data were calculated based on our pilot plant studies in the period January 11 - March 5, 1984, when both Krofta pilot plant and Neptune were treating the same Rome raw water. Our raw chemical dosages used in the said period are properly documented in the Krofta Engineering Corporation Technical Report No. KEC/03-84/1, March 16, 1984. Our average chemical dosages are calculated and summarized here:

a. Chemicals required for basic water purifications:

Magnifloc 1849A	0.956 ppm
Alum (as Al <sub>2</sub> O <sub>3</sub> )	4.662 ppm

b. Chemical required for alkalinity supplement & corrosion control:

Sodium Aluminate (as Al <sub>2</sub> O <sub>3</sub> )	4.222 ppm (pH >7)
	2.111 ppm (pH 6.5)

Our estimated annual chemical requirements (assuming 15 MDG) shall also be divided into two parts:

a. Chemicals required for basic water purification:

Mgnifloc 1849A	43661.3 llb/yr
Alum (8.3% Al <sub>2</sub> O <sub>3</sub> )	2533812 llb/yr

b. Chemical required for alkalinity supplement & corrosion control at pH >7

Sodium Aluminate (ASA 38)	951874.4 llb/yr
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or Sodium Aluminate (ASA 45) 742835.3 llb/yr

Please note that ASA 45 instead of ASA 38 is recommended.

#### 6. EFFECT OF WATER LOSS ON CHEMICAL CONSUMPTION

c. Chemical required for alkalinity supplement & corrosion control at pH 6.5

Sodium Aluminate (ASA 38) 475937.2 lb/yr

or Sodium Aluminate (ASA 45) 371417.65 lb/yr

The latest chemical cost data for Magnifloc 1849A, alum, and sodium aluminate are attached in the Appendixes for more detailed cost estimate below:

a. Chemicals required for basic water purification

Magnifloc 1849A \$ 36,893.8/yr

Alum (8.3% Al<sub>2</sub>O<sub>3</sub>) \$121,622.9/yr

b. Chemical required for alkalinity supplement & corrosion control

ASA 45 \$118,853.7/yr at pH ≥7

or ASA 45 \$ 59,426.9/yr at pH 6.5

EFFECT OF WATER LOSS ON CHEMICAL CONSUMPTION

The water loss of a conventional flocculation-sedimentation-filtration plant is about 9 percent due to the fact that its filter backwash wastewater is totally wasted. A comparable innovative Krofta Sandfloat plant (including flocculation, flotation and filtration) recycles its filter backwash wastewater and chemical flocs for reproduction of drinking water, thus its water loss is only about 0.5 percent contributed by floated sludge. The rates of water treatment by the two plants can be estimated as follows:

Conventional Plant

Water Consumption Rate = Plant Flow x 0.91

Plant Flow = 1.0989 Water Consumption Rate

7. SLUDGE GENERATION



**Innovative Plant**

Water Consumption Rate = Plant Flow x 0.995

Plant Flow = 1.005 Water Consumption Rate

Assuming the coagulant dosages (mg/l) for both conventional and innovative plants are identical, the conventional plant requires much more coagulants by weight (ton/day) because the conventional plant must treat about 9% more water (i.e. factor 1.0989 vs. factor 1.005) in order to supply the same water consumption rate to the City of Rome, NY.

**SLUDGE GENERATION**

Extensive study on sludge generation from our Rome pilot plant (Sandfloat Type 8) was conducted in the period November 16, 1983 to January 10, 1984. The raw data are properly documented in the Technical Report No. KEC/01-84/4B1, February 29, 1984.

The sludge flow generated from the Sandfloat's dissolved air flotation clarifier and the sludge's total suspended solid (TSS) concentrations content were measured and summarized below based on 33 data points listed in Table G:

Influent Flow Range, gpm	70 - 100	(Ave. 96.36)
Sludge Flow Range, gpm	0.3 - 2.1	(Ave. 0.855)
Sludge TSS, mg/l	394 - 10086	(Ave. 2057)

In accordance with a design flow of 15.0 MGD, and the average TSS concentration of 2057 mg/l, the sludge production rate is estimated to be 2281.66 dry pounds per day. The average sludge flow for the future Rome Water Treatment Plant is estimated to be 0.133 MGD, or 92.426 gpm.

The amount of waste sludge to be generated for a one-year period (at 15 MGD plant flow) is estimated to be:

Volume as Wasted Sludge (Gallons)	Total Suspended Solids (Pounds)
48,545,000	832,808

**8. TOTAL SLUDGE RECYCLE SYSTEM**

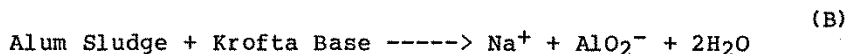
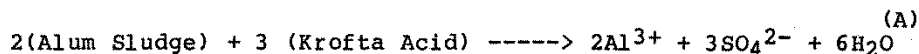
#### TOTAL SLUDGE RECYCLE SYSTEM

The general public as well as the responsible officials of governmental and industrial sectors are becoming increasingly conscious of the need to safeguard our environment. The development and implementation of pollution control techniques to minimize industrial waste discharges have made significant gains during recent years. Further efforts for environmental quality improvements by achieving "zero" waste discharges are being suggested. It is recognized that a major difficulty in achieving a "zero" discharge objectives lies in the lack of satisfactory technologies for ultimate disposal of liquid and solid waste residuals accumulated from pollution abatement controls. Inasmuch as any further treatment of such residuals will introduce an endless cycle of air, water or land contaminants, recovery and recycle of waste treatment reagents would have to be implemented if "zero" waste discharge is to be achieved.

One of the most important water treatment processes in which relatively large quantities of chemical reagents are expended is coagulation-clarification (by sedimentation or flotation). Conventional water treatment plants use sedimentation for clarification; while Krofta Sandfloat plants use flotation for clarification. The coagulations containing aluminum are generally accepted as the primary coagulants in a series of physical-chemical treatment practices. Effective coagulant recycle would represent a major step in achieving "zero" waste discharge objectives. This study is therefore directed toward evaluating potential coagulant recovery and reuse techniques. Waste sludges from a Krofta Sandfloat treatment plant have been selected as study materials to provide a study addressing to realistic waste management applications.

In a Krofta Sandfloat treatment plant, major waste components consist of sludges collected from flocculation-clarification and filter backwash water. When alum and/or sodium aluminate is employed as the primary coagulant, the sludge may be characterized chemically as a combination of inert silt and alum floc. Aluminum floc can be recovered from the sludge mixture by solubilization with either acid or alkaline reagents. The relevant chemical reactions are illustrated as

equations (A) and (B):

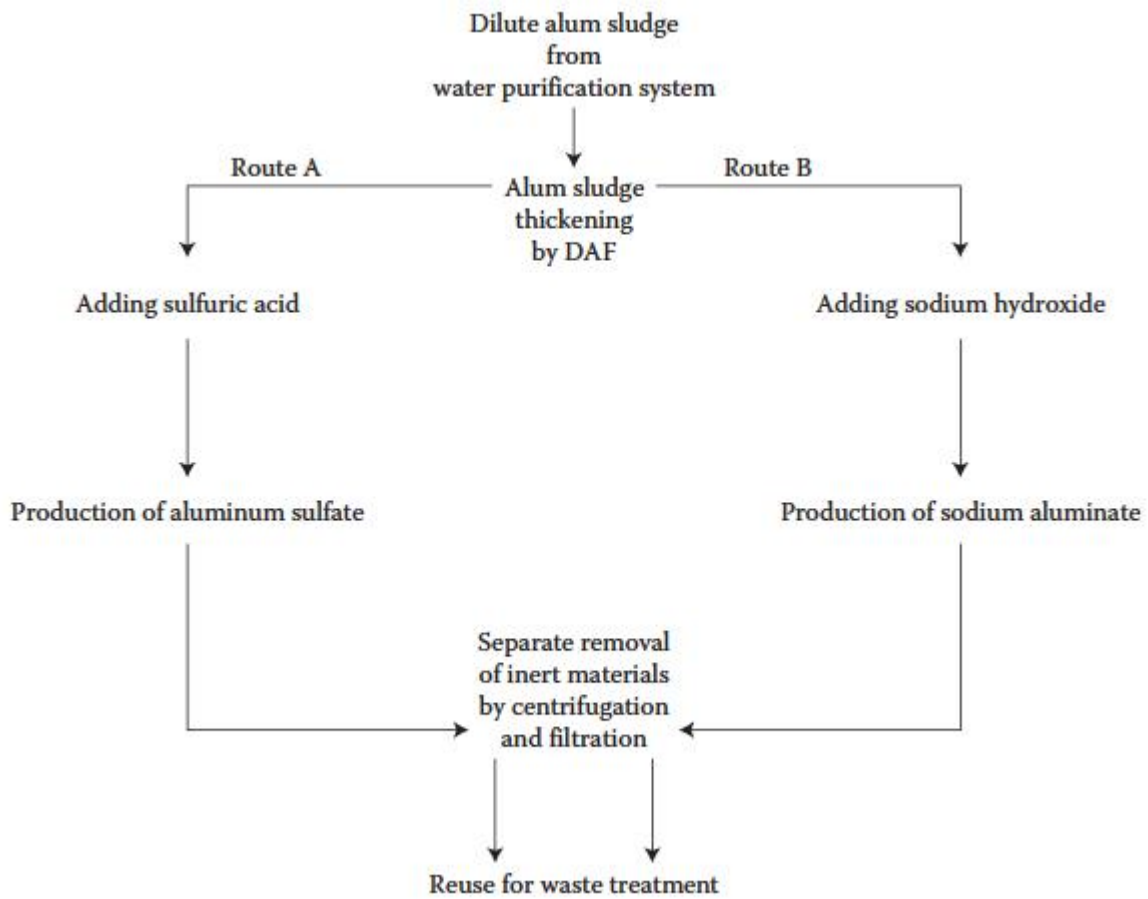


The solubilized reagent must be subjected to pH adjustments to regenerate aluminum floc for effective reuse as a coagulant. The systems approach employed in this study is based on optimum design applications of adequate acid and alkaline reagents so that the requirement for added pH adjustment reagents would be minimized. Waste characterization and aluminum recovery experimental data are presented elsewhere. The significance of our findings is then applied in evaluation of the process feasibility for alum sludge recovery and reuse in Sandfloat treatment plants.

A plausible alum sludge recovery scheme is presented as shown in Figure 1. The major source of alum sludge comes from the clarification units (i.e. flotation or sedimentation). A small portion of alum sludge could be contributed by backwashing the sand filters. Route A in Figure 1 shows the alum can be recovered as aluminum sulfate (i.e., filter alum) by adding Krofta acid. Route B shows the alum can be recovered as sodium aluminate (i.e. soda alum) by adding Krofta base. Route A and Route B have been demonstrated to be feasible, but a pH adjustment procedure is generally needed when either recovered alum is being recycled for reuse. This is due to the fact that the pH of the acid reactor effluent must be extremely low, and the pH of the alkaline reactor effluent must be extremely high. The optimum pH for alum coagulation, however, is about 6.3.

A suggested alum recycle alternative is that part of alum sludge can be regenerated by adding a strong Krofta acid (route A in Figure 1) in an acid reactor and the remaining portion of alum sludge can be regenerated by adding a strong Krofta base (route B in Figure 1) in an alkaline reactor. Recycling both aluminum sulfate and sodium aluminate (or the like), at appropriate ratios, to the intake system for reuse would eliminate the additional pH adjustment requirement. Each reactor consists of a

Figure 5. Recovery and reuse of chemical sludge containing aluminum hydroxide. Chemical sludge recycling system can be route A, route B, or combination of routes A and B (Source: Lenox Institute of Water Technology)



mixing chamber and a solids separation chamber. The chemical reactions taking place in the acid reactor and the alkaline reactor are represented by equations (A) and (B), respectively. The residual sludges are mainly inert materials which can be separated in the solids separation chambers. The two supernatants containing high concentrations of recovered alums can then be withdrawn for reuse either separately or combinely at any desired ratio.

The daily chemical treatment costs can be significantly reduced if the newly developed Complete Sludge Recycle System can be adopted.

The purpose of sludge recovery is to solve a sludge problem. Coagulant recovery offers added economic benefits.

These benefits include less coagulation chemical cost, and smaller amounts of a more easily handleable solid carried to disposal. Most of the chemical cost saving involves the acid and base treatment. The design engineer can be assured that there will always be a cost difference between Krofta acid and alum as it requires acid to manufacture the sulfate. There will be a big cost difference between Krofta base and sodium aluminate, because the former is the raw chemical and the latter is the product.

Table H is an abstract of annual operating costs from Study of Raw Water No. 3. Raw Water No. 3 might be considered the typical raw water source with no unusual problems, so the economics are typical of what is to be expected. Annual costs include: coagulation and stabilization chemicals, dewatering costs on a stationary horizontal vacuum bed, and hauling and disposal of the residue. These annual costs show a saving in favor of coagulant recovery of \$48,350.00/yr; some 20% more than the cost of commercial alum itself if recovery is not practiced.

Table I is an excerpt of a bonded bid to design, construct, and operate a plant treating Water No. 4. A coagulant recovery system was bid against contract hauling and disposal of several years' sludge accumulated in a large lagoon. The final column, calculated at a conservative annual inflation of 4% shows a cumulative saving of \$20,079,000 in 20 years in favor of coagulant recovery. The annual saving the 20th year is

\$1,928,000.

In another study in Germany ("Methods and Feasibilities of Aluminum Recovery from Precipitation Sludge", Recycling Institute. Recovery. Energy. Matter. Residues. Waste, p. 792-799, 1982; by Juslyna Kempa), a computer program has been developed which compares the capital and operational costs for water treatment plants with and without aluminum recovery from precipitation sludges. Annual costs of chemical consumption in a water treatment plant with aluminum recovery is at least 25 percent lower than those with no coagulant recovery.

Coagulant recovery systems are economically worthy of the design engineer's consideration. Such systems can be properly designed and safely operated. With the extreme variability from one raw water or wastewater to another, it is highly recommended that pilot testing be undertaken before such a design is attempted.

TABLE A1. WATER QUALITY DATA SUMMARY OF ROME WATER TREATMENT PILOT PLANT  
 OPERATED AT 70-100 GPM RANGE 11/07/83-12/09/83  
 PARAMETERS RANGE AVERAGE U.S. DRINKING WATER STANDARDS

PARAMETERS	RANGE	AVERAGE	U.S. DRINKING WATER STANDARDS
<b>INFLUENT</b>			
Flow, gpm	70-100	82.2	
Temperature, °F	34-48	41.2	
pH, unit	6.9-7.5	7.1	
Turbidity, NTU	0.4-12.0	1.3	
Color, unit	35-90	45	
Microscopic Count, #/ml	410-14382	6669	
Aluminum, ppm	0-0.074	.009	
Alkalinity, ppm CaCO <sub>3</sub>	4-40	15.5	
THMFP, ppb	127-683	392	
UV (254 nm)	.13-.28	.222	
Total Coliform, #/100 ml	<1-TNTC		
Total Plate Count #/1 ml	4-6	5.0	
Humic Substances, ppm	4.2-8.8	5.9	
Polymer, Type	1849A	1849A	
Polymer Dosage, ppm	1.0-3.0	2.1	
Sodium Aluminate, ppm Al <sub>2</sub> O <sub>3</sub>	3.0-4.0	3.9	
Alum, ppm Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	10.0-33.0	14.5	
Other Chemical, Type	NONE	NONE	
Other Chemical, ppm	0	0	
<b>SANDFLOAT EFFLUENT</b>			
Flow, gpm	67-99.4	80.8	
pH, unit	6.8-7.3	7.0	
Turbidity, NTU	0.1-0.39	.14	
Color, Unit	2-3	2.0	
Microscopic Count, #/ml	<1.0-67	29	
Aluminum, ppm	0-.08	.024	
Alkalinity, ppm CaCO <sub>3</sub>	4-20	8.6	
THMFP, ppb	19-97	66	<100
Chlorine Demand, ppm	.65-1.5	1.2	
UV (254 nm)	.02-.089	.037	
Total Coliform, #/100 ml	<1	<1	
Total Plate Count #/1 ml	0	0	
Humic Substances, ppm	0.3-3.1	1.26	
<b>CHLORINATED EFFLUENT</b>			
Flow, gpm	3.0-3.5	3.4	
pH, unit	6.8-7.2	7.2	6.5-8.5
Turbidity, NTU	0.17-0.35	.2	< 1
Color, unit	2-3	2.0	<15
Microscopic Count, #/ml	22-85	37	
Aluminum Residue, ppm Al	0-.04	.03	
Chlorine Residue, ppm	.2-.5	.3	
Temperature, °F	39-48	44	
Calcium Hardness, ppm CaCO <sub>3</sub>	20-30	23	
Corrosion Control	OK	OK	non corrosive
THMFP, ppb	34-65	40	<100
UV (254 nm)	0-.05	.09	
Total Coliform, #/100 ml	<1	<1	0
Total Plate Count	NA	NA	
Humic Substances	0.4-2.0	1.4	
<b>SLUDGE FROM SANDFLOAT</b>			
Flow, gpm	.4-3.0	1.4	
Total Suspended Solids, ppm	549-4931 (B)	2645 (B)	
	394-1341 (D)	1003 (D)	

TABLE A2. WATER QUALITY DATA SUMMARY OF ROME WATER TREATMENT PILOT PLANT			
OPERATED AT 100 GPM (12/10/83 - 03/05/84)			
PARAMETERS	RANGE	AVERAGE	U.S. DRINKING WATER STANDARDS
<b>INFLUENT</b>			
Flow, gpm	100	100	
Temperature, °F	33-37.4	34.4	
pH, unit	6.4-7.5	7.2	
Turbidity, NTU	0.08-14.2	1.16	
Color, unit	25-73	34.36	
Microscopic Count, #/ml	2430-34623	6980.4	
Aluminum, ppm	0-0.05	0.025	
Alkalinity, ppm CaCO <sub>3</sub>	5-20	15.5	
THMFP, ppb	176-560	328.4	
UV (254 nm)	0.110-0.202	0.157	
Total Coliform, #/100 ml	NA	NA	
Total Plate Count #/1 ml	NA	NA	
Humic Substances, ppm	1.5-9.6	4.56	
Polymer, Type	1849A	1849A	
Polymer Dosage, ppm	0.40-1.9	1.16	
Sodium Aluminate, ppm Al <sub>2</sub> O <sub>3</sub>	3.0-5.2	4.58	
Alum, ppm Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	4.0-7.0	4.94	
Other Chemical, Type	NONE	NONE	
Other Chemical, ppm	0	0	
<b>SANDFLOAT EFFLUENT</b>			
Flow, gpm	97.9-99.7	99.16	
pH, unit	6.7-7.5	7.11	
Turbidity, NTU	0.05-0.20	0.12	
Color, Unit	2	2.0	
Microscopic Count, #/ml	0-267	134.6	
Aluminum, ppm	0.01-0.11	0.047	
Alkalinity, ppm CaCO <sub>3</sub>	5-14	7.98	
THMFP, ppb	2-96	59.9	<100
Chlorine Demand, ppm	0.3-0.5	0.386	
UV (254 nm)	0.002-0.063	0.022	
Total Coliform, #/100 ml	NA	NA	
Total Plate Count #/1 ml	NA	NA	
Humic Substances, ppm	0-3.4	0.88	
<b>CHLORINATED EFFLUENT</b>			
Flow, gpm	Batch	Batch	
pH, unit	5.6-7.4	7.0	6.5-8.5
Turbidity, NTU	0.2-0.5	0.245	< 1
Color, unit	0-5	1.0	<15
Microscopic Count, #/ml	NA	NA	
Aluminum Residue, ppm Al	0.01-0.11	0.0495	
Chlorine Residue, ppm	0.2-0.4		
Temperature, °F	NA	NA	
Calcium Hardness, ppm CaCO <sub>3</sub>	NA	NA	
Corrosion Control	OK	OK	non corrosive
THMFP, ppb	NA	NA	<100
UV (254 nm)	NA	NA	
Total Coliform, #/100 ml	NA	NA	0
Total Plate Count	NA	NA	
Humic Substances	NA	NA	
<b>SLUDGE FROM SANDFLOAT</b>			
Flow, gpm	0.3-2.1	.822	
Total Suspended Solids, ppm	811-10086	2075	



TABLE B  
 REDUCTION OF  
 TRIHALOMETHANE FORMATION POTENTIAL (THMFP)  
 BY SANDFLOAT WATER TREATMENT PLANT IN ROME, NY  
 (1/11/84 - 3/05/84)

DATE	RAW WATER THMFP ppb	SANDFLOAT EFFLUENT THMFP ppb	THMFP REMOVAL %
1/11/84	425	68	84
1/12/84	338	66	81
1/13/84	285	70	75
1/16/84	300	63	79
1/17/84	380	75	80
1/18/84	261	35	87
1/19/84	350	59	83
1/20/84	270	69	74
1/23/84	310	45	85
1/24/84	450	73	84
1/25/84	330	68	79
1/26/84	490	89	82
1/27/84	263	70	73
1/30/84	259	68	74
1/31/84	335	82	76
2/01/84	410	87	79
2/02/84	346	64	82
2/03/84	295	61	79
2/06/84	286	30	90
2/07/84	257	81	68
2/08/84	260	73	72
2/09/84	246	75	70
2/10/84	265	65	75
2/13/84	280	73	74
2/14/84	278	69	75
2/15/84	275	66	76
2/16/84	269	70	74
2/17/84	271	68	75
2/22/84	256	59	77
2/23/84	283	71	75
2/24/84	290	70	76
2/29/84	266	72	73
3/01/84	300	80	73
3/02/84	256	67	74
3/05/84	273	63	77

\* NOTES:

Samples were spiked with calcium hypochlorite.  
 Average raw water THMFP = 305 ppb  
 Average Sandfloat effluent THMFP = 68 ppb  
 Average percent THMFP removal = 77.7%

TABLE C  
CITY OF ROME  
SANDFLOAT WATER TREATMENT PILOT PLANT  
SAMPLING<sup>a</sup> AND ANALYSES<sup>b</sup>

Site <sup>c</sup>	Date	Sample	Total Coliforms <sup>d</sup> #/100 ml	Total Plate Count
1	11/14/83	1127	<1	NA
2	11/14/83	1129	<1	NA
3	11/14/83	1128	<1	NA
1	11/15/83	1130	<1	NA
2	11/15/83	1132	<1	NA
3	11/15/83	1131	<1	NA
1	11/16/83	1153	<1	NA
2	11/16/83	1155	<1	NA
3	11/16/83	1154	<1	NA
1	11/17/83	1156	<1	NA
2	11/17/83	1158	<1	NA
3	11/17/83	1157	<1	NA
1	11/21/83	1174	TNTC	NA
2	11/21/83	1176	<1	NA
3	11/21/83	1175	<1	NA
1	11/22/83	1177	TNTC	NA
2	11/22/83	1179	<1	NA
3	11/22/83	1178	<1	NA
1	12/05/83	1232	<1	6
2	12/05/83	1233	<1	0
1	12/06/83	1234	<1	4
2	12/06/83	1235	<1	0

## NOTES:

- a. Sampling was done by Krofta Engineering Corporation and Lenox Institute for Research Inc., Lenox, MA 01240
- b. Samples were analyzed by Rome Hospital & Murphy Memorial Hospital.
- c. Site 1 = raw water influent; Site 2 = Sandfloat effluent; Site 3 = chlorinated effluent
- d. TNTC = too numerous to count; NA = not available.

TABLE D  
 REMOVAL OF MICROSCOPIC PARTICULATES  
 BY SANDFLOAT WATER TREATMENT PLANT IN ROME, NY  
 (1/11/84 - 3/05/84)

Date	Sandfloat Influent Microscopic Count, #/ml	Sandfloat Effluent Microscopic Count, #/ml	Micro. Count Percent Removal, %
1/11/84	9306	254	97.3
1/12/84	6341	120	98.1
1/13/84	7383	214	97.1
1/16/84	5006	227	95.5
1/17/84	6313	147	97.7
1/18/84	5260	187	96.4
1/19/84	4531	147	96.8
1/20/84	5660	160	97.2
1/23/84	4872	147	97.0
1/24/84	3884	107	97.2
1/25/84	4245	67	98.4
1/26/84	4245	93	97.8
1/27/84	4325	93	97.8
1/30/84	4138	107	97.4
1/31/84	4365	120	97.3
2/01/84	3484	107	96.9
2/02/84	3417	134	96.0
2/03/84	3404	147	96.0
2/06/84	4512	234	95.0
2/07/84	3497	227	94.0
2/08/84	2669	107	96.0
2/09/84	4672	214	95.0
2/10/84	3831	220	94.3
2/13/84	3777	200	95.0
2/14/84	4178	174	95.8
2/15/84	3777	254	93.3
2/16/84	3644	187	95.0
2/17/84	3323	154	95.3
2/22/84	3364	187	94.4
2/23/84	3604	174	95.0
2/24/84	3257	240	93.0
2/29/84	3430	174	95.0
3/01/84	4243	254	94.0
3/02/84	4018	214	95.0
3/05/84	4245	240	94.0

\* NOTES:

- All microscopic particulates with sizes greater than or equal to 8 microns were counted.
- Sandfloat Type 8 was used for treatment of raw reservoir water in Rome, NY.
- Average Sandfloat influent microscopic count = 4406 #/ml.
- Average Sandfloat effluent microscopic count = 172 #/ml.
- Average microscopic count removal = 96.1%.

TABLE E  
REMOVAL OF METALS AND ANIONS BY ROME PILOT PLANT

PARAMETERS	WATER QUALITY DATA	
	RAW (11/17/83)	EFF (11/17/83)*
Manganese	0.005	.004
Chromium	0	0
Iron	0.114	0
Lead	0.038	0.020
Sodium	0	3.28
Silver	0.002	0.001
Arsenic	0.000	0.000
Cadmium	0.001	0.001
Copper	0.007	0.007
Selenium	0.007	0.007
Zinc	0	0
Aluminum	NA	0.04
Nitrate	0	0
Fluoride	0	0
Sulfate	20	18
Chloride	2.5	1.5

\*NOTE:

Both raw reservoir water and Sandfloat effluent were collected on November 17, 1983 for analyses.

TABLE F1

STATISTICAL DATA OF SANDFLOAT EFFLUENT TURBIDITY,  
 COLOR, ALUMINUM AND MICROSCOPIC COUNT IN  
 COMPARISON WITH NEW YORK STATE WATER QUALITY GOALS  
 (NOVEMBER 7 - DECEMBER 9, 1983)

Water Quality Parameters	NYSDH Water Quality Goals	KEC Effluent
<b>Turbidity</b>		
≤ 0.5 TU	Over 95% time	100% time
≤ 0.3 TU	Over 75% time	Over 92% time
≤ 0.2 TU	Over 50% time	Over 94% time
<b>Color</b>		
≤ 5 CU	Over 95% time	100% time
<b>Aluminum</b>		
≤ 0.15 mg/l	Over 95% time	100% time
≤ 0.09 mg/l	Over 75% time	100% time
≤ 0.05 mg/l	Over 50% time	Over 83% time
<b>Microscopic Count</b>		
≤ 1000 #/ml	Over 95% time	100% time
≤ 400 #/ml	Over 75% time	100% time
≤ 300 #/ml	Over 50% time	100% time

TABLE F2  
 STATISTICAL DATA OF SANDFLOAT EFFLUENT TURBIDITY,  
 COLOR, ALUMINUM AND MICROSCOPIC COUNT IN  
 COMPARISON WITH NEW YORK STATE WATER QUALITY GOALS  
 (DECEMBER 10, 1983 - JANUARY 10, 1984)

Water Quality Parameters	NYS DH Water Quality Goals	KEC Effluent
Turbidity		
≤ 0.5 TU	Over 95% time	100% time
≤ 0.3 TU	Over 75% time	Over 100% time
≤ 0.2 TU	Over 50% time	Over 100% time
Color		
≤ 5 CU	Over 95% time	100% time
Aluminum		
≤ 0.15 mg/l	Over 95% time	100% time
≤ 0.09 mg/l	Over 75% time	21% time
≤ 0.05 mg/l	Over 50% time	Over 68% time
Microscopic Count		
≤ 1000 #/ml	Over 95% time	100% time
≤ 400 #/ml	Over 75% time	100% time
≤ 300 #/ml	Over 50% time	100% time

TABLE F3

STATISTICAL DATA OF SANDFLOAT EFFLUENT TURBIDITY,  
 COLOR, ALUMINUM AND MICROSCOPIC COUNT IN  
 COMPARISON WITH NEW YORK STATE WATER QUALITY GOALS  
 (JANUARY 11 - MARCH 5, 1984)

Water Quality Parameters	NYSDH Water Quality Goals	KEC Effluent
Turbidity		
≤ 0.5 TU	Over 95% time	100% time
≤ 0.3 TU	Over 75% time	100% time
≤ 0.2 TU	Over 50% time	100% time
Color		
≤ 5 CU	Over 95% time	100% time
Aluminum		
≤ 0.15 mg/l	Over 95% time	100% time
≤ 0.09 mg/l	Over 75% time	Over 93% time
≤ 0.05 mg/l	Over 50% time	Over 70% time
Microscopic Count		
≤ 1000 #/ml	Over 95% time	100% time
≤ 400 #/ml	Over 75% time	Over 97% time
≤ 300 #/ml	Over 50% time	Over 94% time

TABLE G.  
SLUDGE GENERATION DATA IN ROME

Date	Sludge Flow gpm	Sludge TSS mg/l	Plant Flow gpm
11/16/83	0.6	2542	70
11/17/83	0.4	4931	70
11/28/83	0.8	567	70
11/29/83	0.5	955	70
11/30/83	0.6	549	100
12/01/83	1.5	1341	100
12/02/83	1.5	1282	100
12/03/83	1.5	616	100
12/04/83	1.0	394	100
12/05/83	1.0	4213	100
12/06/83	1.0	2682	100
12/07/83	1.0	639	100
12/08/83	0.7	1180	100
12/13/83	0.6	1675	100
12/14/83	1.0	2556	100
12/15/83	1.3	1028	100
12/16/83	1.0	1042	100
12/17/83	1.0	3557	100
12/19/83	0.6	1665	100
12/20/83	1.0	1052	100
12/21/83	0.5	3901	100
12/22/83	0.8	1885	100
12/23/83	0.8	1826	100
12/27/83	2.1	3396	100
12/28/83	0.6	1477	100
12/29/83	1.0	997	100
12/30/83	0.4	2007	100
01/03/84	0.3	10086	100
01/04/84	0.66	1111	100
01/05/84	0.4	3023	100
01/06/84	0.53	811	100
01/09/84	0.53	939	100
01/10/84	1.0	1970	100
Total	28.22	67895	3180
Average	0.855	2057	96.36



## 9. PROMULGATED STANDARDS FOR RAW WATER SOURCES OF DOMESTIC WATER SUPPLY

PROMULGATED STANDARDS FOR RAW WATER  
SOURCES OF DOMESTIC WATER SUPPLY

Constituent	Excellent Source of Water Supply, Requiring Dis- infection only, as Treatment	Good Source of Water Supply, Requiring Usual Treat- ment Such as Filtration and Disinfection	Poor Source of Water Supply Requiring Spe- cial or Auxili- ary Treatment & Disinfection
<b>BOD (5 day)-mg/l</b>			
monthly average	0.75-1.5	1.5-2.5	>2.5
maximum day of sample	1.0-3.0	3.0-4.0	>4.0
<b>Coliform MPN per 100 ml</b>			
monthly average	50-100	50-5,000	>5,000
maximum day of sample	less than 5 per cent over 100	less than 20 per cent over 5,000	less than 5 per cent over 20,000
<b>Dissolved oxygen</b>			
average-mg/l	4.0-7.6	4.0-6.5	4.0
saturation-%	75 or better	60 or better	
<b>pH average</b>	6.0-8.5	5.0-9.0	3.8-10.5
<b>Chlorides (max) mg/l</b>	50 or less	50-250	>250
<b>Fluorides-mg/l</b>	<1.5	1.5-3.0	>3.0
<b>Phenolic compounds (max)-mg/l</b>	none	.005	>.005
<b>Color-units</b>	0-20	20-150	>150
<b>Turbidity-units</b>	0-10	10-250	>250

10. US ENVIRONMENTAL PROTECTION AGENCY AND LOCAL STATE DRINKING WATER STANDARDS

Parameters (1)	US EPA Primary MCL	US EPA Secondary MCL	Safe Drinking Water Regula- tions, MCL
<b>Physical factors</b>			
Color, platinum standard	-	15	-
Odor, threshold number	-	3	-
Turbidity, JTU	1	-	1
pH, unit	-	6.5 - 8.5	-
<b>Chemical factors</b>			
Arsenic	0.1	-	-
Barium	1	-	1
Cadmium	0.01	-	0.01
Chloride	-	250	-
Chromium	0.05	-	0.05
Copper	-	1.0	-
Fluoride	1.4 - 2.4	-	1.4 - 2.4
Iron	-	0.3	-
Lead	0.05	-	0.05
Manganese	-	0.05	-
MBAS	-	0.5	-
Mercury	0.002	-	0.002
Nitrate (as N)	10	-	10
Selenium	0.01	-	0.01
Silver	0.05	-	0.05
Sulfate	-	250	-
Total dissolved solids	-	500	-
Zinc	-	5	-
<b>Corrosion and scaling factors</b>			
Hardness	-	noncorrosive	-(2)
Sodium	-	noncorrosive	15
<b>Bacteriological factors</b>			
Coliform (membrane filter)	1/100 ml	-	-
<b>Radiologic factors</b>			
Gross alpha activity	15 pCi/l	-	15 pCi/l
Gross beta activity	-	-	50 pCi/l(3)
Radium 226 and 228	5 pCi/l	-	5 pCi/l
Strontium 90	-	-	8 pCi/l(3)

Parameters (1)	US EPA Primary MCL	US EPA Secondary MCL	Safe Drinking Water Regula- tions, MCL
<b>Pesticides-Herbicides</b>			
Chlorinated hydrocarbons			
Endrin	0.0005	-	0.0002
Lindane	0.005	-	0.004
Methoxychlor	1.0	-	0.1
Toxaphene	0.005	-	0.005
Chlorophenoxy herbicides			
2, 4-D	0.02	-	0.1
2, 4, 5-TP (Silvex)	0.03	-	0.01
Total trihalomethane	0.1	-	0.01

**Notes:**

1. Units are in mg/l unless noted otherwise.  
MCL = Maximum Contaminant Level.
2. A quality monitoring program must be installed. Supplier must give annual notification if sodium level reaches 20 mg/l.
3. Annual average concentration.

11. METHOD FOR DETERMINATION OF TRIHALOMETHANE MAXIMUM FORMATION POTENTIAL

METHOD FOR DETERMINATION OF  
TRIHALOMETHANE MAXIMUM FORMATION POTENTIAL

The Trihalomethane Maximum Formation Potential (THMMFP) is defined as the maximum THMMFP as the concentration of trihalomethane produced in a given water, containing excess free chlorine after seven days at 25°C. Therefore, in order for the tests to be valid, the water samples must be chlorinated and have an applied chlorine dose that will result in a free chlorine residual after the seven day holding period. The chlorine dosages employed for the THMMFP test should be proportional to the organic content (such as TOC) of the test sample.

## 12. GLOSSARY OF DRINKING WATER QUALITY AND SIMPLIFIED DRINKING WATER STANDARDS

**Alkalinity (No Limit) Additional:** Alkalinity is a measurement of the capacity of water to neutralize acids. It is also called the buffering capacity of water. The greater the alkalinity, the less effect environmental problems such as acid rain have on water.

**Alkyl benzene sulfonate (ABS) (0-2.0 mg/l):** ABS indicates detergent contamination (check leach field). Common household products contain ABS (non-biodegradable alkyl benzene sulfonate).

**Ammonia (No Limit):** Ammonia ( $\text{NH}_3$ ) is a gas produced by the breakdown of organic waste materials. It is a part of nitrogen cycle, and an indication of organic waste contamination.

**Arsenic (0-0.05 mg/l) Primary:** Arsenic (As) is a naturally occurring heavy metal that can contaminate well waters. Arsenic is very toxic at high levels. It has been used as an insecticide in the past. Arsenic can be removed by filtration, flotation and adsorption

**Calcium (No Limit) Additional:** Calcium (Ca) is a component of the water's hardness. Calcium is found in soil and can leach into water supplies affecting hardness, alkalinity, and pH.

**Chloride (0-250 mg/l) Secondary:** Chloride ( $\text{Cl}^-$ ) is a component of salt. The concentration of chloride in water tends to relate to the concentration of sodium. Salt run-off from roads will contribute to high sodium and chloride levels.

**Chlorine (0-0.05 mg/l) Additional:** Chlorine ( $\text{Cl}_2$ ) is used to disinfect waters which contain bacteria or other pathogens. Residual chlorine present can cause taste and odor problems along with forming chlorinated by-products (CBP). Carbon filtration can remove residual chlorine.

**Coliform Bacteria (1 or less in 100 ml) Primary:** Coliform bacteria are widely distributed in nature. Contamination from surface waters, septic systems and direct contamination from animal feces can contribute to the growth of coliform bacteria in wells. Chlorine is used to disinfect well water that contains more than 1 coliform bacteria per 100 ml of water. If one has a problem with coliform bacteria in his/her

well it is a good idea to check for coliform bacteria content every month.

**Color (0-15 CU) Secondary:** A measurement of clarity or discoloration. Color is considered for aesthetic reasons, and can also be used to confirm problems with various minerals and metals such as iron.

**Copper (0-1.0 mg/l) Secondary:** Copper (Cu) is not naturally found in well waters. It is commonly the result of corrosive water or a low pH. A blue/green stain or bitter taste may indicate higher than normal levels of copper ions in water.

**Conductivity (No Limit) Additional:** Water will conduct electricity when ions such as soluble sodium, iron and manganese are present. This conductivity test confirms high levels of ions (minerals).

**Corrosiveness (Non-Corrosion) Secondary:** It is a calculation of the Langelier index, which is related to pH, alkalinity, dissolved oxygen (DO) and hardness.

**Dissolved Oxygen (No Limit) Additional:** Stagnant waters do not contain dissolved oxygen (DO). DO indicates a non-polluted water.

**Fecal Coliform Bacteria: (1/100 ml):** Fecal bacteria are normally a good indication of septic contamination, or bacterial growth caused by the feces of any warm blooded animal.

**Hardness (No Limit) Additional:** The term “hard water” has been traditionally used to describe conditions that limit soap foaming ability in water. On your water test, results of 0-75 as calcium carbonate are considered soft water, 76-150 as calcium carbonate are considered normal hardness and above 150 as calcium carbonate is hard. High hardness may be objectionable due to scaling and poor lathering. A water softener can be used to eliminate or reduce hardness.

**Iron (0-0.3 mg/l) Secondary:** Iron (Fe) is a naturally occurring element in soils. From soil it can leach into well waters. Iron causes problems because it can affect the water’s color and taste, and because it causes brown stains on laundry and plumbing fixtures. Iron can easily be removed from water with chemical coagulation-precipitation and filtration systems.

**Lead (0.05 mg/l) Primary:** Lead (Pb) contamination normally caused by the corrosion of lead pipe. High levels can be toxic if accumulated in the blood stream and affect the growth of children.

**Magnesium (No Limit) Additional:** Magnesium (Mg) is a component of the water's hardness. Magnesium is found in soil and can leach into water supplies affecting hardness.

**Manganese (0-0.05 mg/l) Secondary:** Manganese (Mn) is another naturally occurring element commonly found in well waters in the United States. As with iron, manganese levels over the US Environmental Protection Agency (USEPA) contaminant levels do not necessarily cause health problems, but do cause taste and staining problems. Manganese can cause laundry to turn gray. Oxidation and filtration systems are used to remove manganese from water.

**Nitrate (0-10 mg/l) Primary:** Nitrate ( $\text{NO}_3^-$ ) contamination from septic systems, fertilizers, and decayed plant material can add nitrate to well waters. At high levels, nitrates can be poisonous to infants. Nitrates can be removed by reverse osmosis (RO). However, if high levels are present, it is better to eliminate or correct the source of well contamination.

**Nitrite (No Limit):** Nitrite ( $\text{NO}_2^-$ ) is a part of the nitrogen cycle. It can be correlated or converted to high levels of nitrate.

**Odor (0-3 Units) Secondary:** Odor is measured in threshold number units. Its presence indicates possible contaminants.

**pH (6.5-8.5 Units) Secondary:** The pH measurement indicates how acidic (e.g. acid rain, vinegar) or alkaline (e.g. baking soda) your water is. A scale from 0-14 is recognized, with 7.0 being neutral, below 7 being acidic, and above 7 being basic or alkaline. Water in the northeastern U.S. tends to be acidic, which can create corrosion problems with plumbing. A pH conditioner or neutralization process can correct problems.

**Potassium (No Limit) Additional:** Potassium (K) is a soft metal often linked up with chloride to form a salt. Normally it is not considered a toxic metal.

**Sediment (No Limit):** A visual identification made for the presence or absence of sediment after a period of standing.

**Sodium (0-20 mg/l) (0-250):** Sodium (Na) is commonly found in table salt, rock salt and in soils. High levels of sodium are found in wells that are near roads that are salted during the winter months. People on low sodium diets need to be aware of the sodium content of the water they drink. Reverse osmosis (RO) systems are available for removal of sodium.

**Sulfate (No Limit) Secondary:** When high levels of sulfate ( $\text{SO}_4^{2-}$ ) and calcium (Ca) are present, scaling can occur in boilers and heat exchangers. High levels may affect taste, odor and be a laxative.

**Total Dissolved Solids (TDS) (0-500 mg/l) Secondary:** The total amount of dissolved materials present. High levels of TDS may affect the corrosiveness of the water. Remove by filtration.

**Turbidity (1-5 NTU) Primary:** A suspension of fine particles in water. Usually turbidity is caused by bacterial contamination, organic matter, iron, manganese or silt. Obviously it is very important to have drinking water free of foreign matter. Turbidity may cause sediment.

**Volatile organic compounds (VOC) (Variable):** VOCs are chemicals from the chlorination of water, local industry, or waste leaking from landfills. Both chlorinated and aromatic compounds are detected with USEPA methods 601 and 602. Chlorinated chemicals such as trichloroethane (TCE) are found in drain cleaners, industrial degreasers and commercial cleaners. Aromatic chemicals such as benzene and toluene are found in gasoline and oils. Granular activated carbon filtration systems are generally used to eliminate VOCs from water.



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**APPENDIX:****INTRODUCTION OF THE EDITORS OF ENVIRONMENTAL SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS (STEM) SERIES****1. Editor Lawrence K. Wang**

Editor Lawrence K. Wang has served the society as a professor, inventor, chief engineer, chief editor and public servant (UN, USEPA, New York State) for 50+ years, with experience in entire field of environmental science, technology, engineering and mathematics (STEM). He is a licensed NY-MA-NJ-PA-OH Professional Engineer, a certified NY-MA-RI Laboratory Director, a licensed MA-NY Water Operator, and an OSHA Instructor. He has special passion, and expertise in developing various innovative technologies, educational programs, licensing courses, international projects, academic publications, and humanitarian organizations, all for his dream goal of promoting world peace. He is a retired Acting President/Professor of the Lenox Institute of Water Technology, USA, a Senior Advisor of the United Nations Industrial Development Organization (UNIDO), Vienna, Austria, and a former professor/visiting professor of Rensselaer Polytechnic Institute, Stevens Institute of Technology, University of Illinois, National Cheng-Kung University, Zhejiang University, and Tongji University. Dr. Wang is the author of 750+ papers and 50+ books, and is credited with 29 invention patents. He holds a BSCE degree from National Cheng- Kung University, Taiwan, ROC, a MSCE degree from the University of Missouri, a MS degree from the University of Rhode Island and a PhD degree from Rutgers University, USA. Currently he is the book series editor of CRC Press, Springer Nature Switzerland, Lenox Institute Press, World Scientific Singapore, and John Wiley. Dr. Wang has been a Delegate of the People to People International Foundation, a Diplomat of the American Academy of Environmental Engineers, a member of ASCE, AIChE, ASPE, WEF, AWWA, CIE and OCEESA, and a recipient of many US and international engineering and science awards.

**2. Editor Mu-Hao Sung Wang**

Editor Mu-Hao Sung Wang has been an engineer of the New York State Department of Environmental Conservation, an editor of CRC Press, Springer Nature Switzerland, and Lenox Institute Press, and a university professor of the Stevens Institute of Technology, National Cheng-Kung University, and the Lenox Institute of Water Technology. Totally she has been a government official, and an educator in the

USA and Taiwan for over 50 years. Dr. Wang is a licensed Professional Engineer, and a Diplomate of the American Academy of Environmental Engineers (AAEE). Her publications have been in the areas of water quality, modeling, environmental sustainability, solid and hazardous waste management, NPDES, flotation technology, industrial waste treatment, and analytical methods. Dr. Wang is the author of over 50 publications and an inventor of 14 US and foreign patents. She holds a BSCE degree from National Cheng-Kung University, Taiwan, ROC, a MS degree from the University of Rhode Island, RI, USA, and a PhD degree from Rutgers University, NJ, USA. She is the Co-Series Editor of the Handbook of Environmental Engineering series (Springer Nature Switzerland), Coeditor of the Advances in Industrial and Hazardous Wastes Treatment series (CRC Press of Taylor & Francis Group) and the Coeditor of the Environmental Science, Technology, Engineering and Mathematics series (Lenox Institute Press). She is a member of AWWA, NYWWA, NEWWA, WEF, NEWEA, CIE and OCEESA.

### **3. Editor Yuriy I. Pankivskyi**

Editor Yuriy I. Pankivskyi has 25 years of professional experience of scientific research and environmental education. He has expertise in strategic environmental assessment, environmental impact assessment, drinking water treatment, waste waters treatment, water and air pollution control, solid waste management. He works as environmental consulting engineer for industrial enterprises, state administrations of cities and towns of Western Ukraine, communities, private firms and institutions and as researcher, educator for state universities. He is the Associate Professor and Deputy Head of Department of Ecology of Ukrainian National University of Forestry. His research and publications have been in areas of water and air quality control, waste water treatment, environmental sustainability and education, analytical methods, investigations of multifunctional material for optoelectronics and environment testing. Dr. Pankivskyi is author of over 70 scientific publications. He earned his Specialist degree from Lviv State Ivan Franko University (Ukraine), ME degree from Lenox Institute of Water Technology (MA, USA), and his PhD degree from Lviv National Ivan Franko University (Ukraine). He is a member of National Ecological Center of Ukraine (Lviv Department).