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DRAFT Memorandum

To: Mr. Richard Haller, SAWPA
From: Greg Wetterau, CDM
Date: November 8, 2010
Subject: Santa Ana Regional Interceptor Phase 2 Solids Control Study Bench Testing Results

This memorandum describes bench testing conducted using water samples taken from the Santa Ana Regional Interceptor (SARI) evaluating the formation of suspended solids in blended water samples. The purpose of the bench testing was (1) to evaluate methods for monitoring organic constituents which may contribute to the formation of total suspended solids (TSS), and (2) to determine if the injection of anticoagulant or antiscalant compounds can reduce the solids formation in a controlled bench-top experiment.

1.0 Background

The Santa Ana Watershed Project Authority (SAWPA) owns and operates the SARI line within San Bernardino and Riverside Counties, accepting brine and other wastewater discharges within the Santa Ana Watershed. This interceptor was initially constructed to provide disposal of highly saline discharges from groundwater desalination facilities, power plants, and industrial users, in order to protect the inland water quality in the upper Santa Ana River Watershed. Due to the initially low flows of these higher salinity wastewaters, the SARI line has temporarily accommodated lower salinity domestic and industrial wastewaters to provide revenue and maintain system flows closer to design capacities.

The SARI pipeline conveys the wastewater to the Orange County Sanitation District (OCSD) system, where the water is treated and ultimately discharged through an ocean outfall. OCSD charges SAWPA for treatment and disposal, based on the flow, biochemical oxygen demand (BOD), and TSS of the wastewater measured at the Orange County Meter (S01). SAWPA then charges agencies discharging to the SARI line based on the same parameters, with predetermined rates established to cover the charges from OCSD, pipeline maintenance, and other related costs to SAWPA.

Large differences between measured levels of TSS entering the SARI line and those measured at the Orange County line (S01) have been observed over the last several years, with the TSS often measuring twice as high at the S01 meter, compared to the TSS entering the system. These

differences created both a problem with solids deposition in the pipeline and a revenue imbalance, where the expenses for TSS fees from OCSD could not be offset by revenue received from the SARI dischargers. SAWPA initiated the SARI Sediments and Solids Control Study to identify means of controlling organic and inorganic solids generation in the SARI line. Previous studies have determined that suspended solids are formed through the precipitation of hardness (calcium) from desalination brine and from the coagulation of dissolved organic compounds when waters with high levels of total organic carbon (TOC) are blended with high hardness desalination brine.

CDM was asked to conduct this Bench Testing Study in order to quantify the potential impacts of TOC coagulation, evaluate methods for monitoring the potential formation of TSS, and to evaluate methods for controlling this TSS formation.

2.0 Methods of Solids Formation

Previous studies have determined that suspended solids in the SARI line are formed through precipitation of sparingly soluble inorganic salts, through coagulation of dissolved organic compounds, and through biological growth in portions receiving high quantities of BOD. Each of these is described briefly below.

2.1 Inorganic Precipitation

Inorganic precipitation within the SARI line has been found to consist of primarily calcium carbonate, which enters the SARI from reverse osmosis desalination discharges, where supersaturated conditions are maintained through the use of antiscalant compounds. Upon entering the SARI line, aeration, turbulence, and blending with other discharges causes an increase in pH and the subsequent precipitation of calcium carbonate and other sparingly soluble salts (silica, magnesium hydroxide, and possibly calcium sulfate). A large quantity of these precipitated salts have been forming scale within the SARI line, accounting for the majority of the accumulated solids in many portions of the SARI line, but accounting for only 20 to 30 percent of the suspended solids continuing on to the Orange County line (S01). These inorganic solids have therefore presented a maintenance challenge, requiring costly cleaning efforts within the various reaches of the SARI line. Inorganic precipitation potential for SARI dischargers is currently monitored through the measurement of hardness and silica. An indirect fee for hardness has been incorporated into the TSS imbalance adjustment for the TSS fee.

2.2 Organic Coagulation

Organic coagulation within the SARI line appears to be caused when discharges containing high quantities of organic colloids blend with high hardness discharges from desalination brine. It is widely understood that coagulation of colloidal organic material can be induced by multiple means, including charge neutralization, interparticle bridging, and electrical double layer compression. It has been proposed in previous SARI water quality studies that double layer compression has been responsible for the formation of organic suspended solids within the SARI line.

Measurement of suspended solids is done using a glass fiber filter that retains particles greater than 1.5 micron, based on Standard Methods 2540D. A sample is filtered and the retained solids are

considered suspended (TSS), while those that pass through the filter are considered dissolved (TDS). Suspended organic colloids, formed from polysaccharides and other organic compounds, can be considerably smaller than 1.5 micron, with the smallest hydrocolloids generally identified as 0.001 to 0.005 micron in diameter (Levine, I., Physical Chemistry, 2001). Thus considerable colloidal material can exist within a measured sample that has passed through a standard 1.5 micron filter.

Organic suspended solids are often estimated as volatile suspended solids (VSS) using the same, standard 1.5 micron filter, with the VSS representing the quantity of TSS that burns off at a specified temperature (550°C). The dissolved organic solids, in contrast to VSS, are commonly identified as dissolved organic carbon (DOC), where the carbon content is measured (by combustion and carbon dioxide analysis) for any organic constituents that pass through a 0.45 micron filter. It can therefore be concluded that a significant quantity of colloidal organics may exist both in the size range between DOC and VSS (between 0.45 and 1.5 micron) and in the fraction of colloidal DOC smaller than 0.45 micron (between 0.005 and 0.45 micron).

In evaluating the formation of organic suspended solids from TDS within the SARI line, it is these colloidal organics, smaller than 1.5 micron, which may coagulate to form VSS. These solids are represented by both the colloidal fraction of DOC and the organic constituents in the size range between the DOC and VSS measurements. Formation of VSS can occur when wastewater containing colloidal organics blends with high ionic strength desalination brines, causing compression of the repulsive double-layer around the colloids and allowing the colloids to coagulate into larger particles (great than 1.5 micron). This phenomenon is similar to what can be observed in river deltas, where high DOC river flows blend with high salinity seawater. The Schulze-Hardy Rule has been used to explain the coagulation of negatively charged organic colloids in high ionic strength solutions (Hunter, R.J., Foundation of Colloid Science, 2001), stating that the concentration of divalent calcium ions needed to induce coagulation through double-layer compression is only 1 percent of the concentration of sodium required for equivalent coagulation. This rule suggests that the high hardness desalination concentrate in the SARI line is likely to be particularly susceptible to coagulation of DOC and other colloidal organics.

It is believed that coagulation of organic colloids is responsible for the majority of TSS formation carrying through to the Orange County line (S01). In order to evaluate the possible coagulation potential within the SARI line, DOC has been monitored for all discharges since February 2010. There is currently no fee for DOC or TOC, however, a portion of the TOC may be accounted for in existing BOD fees to dischargers.

2.3 Biological Growth

Biological growth has also contributed to conversion of DOC and dissolved BOD into TSS at different times and in different portions of the SARI line. Anoxic conditions have been observed in portions of the SARI receiving high domestic wastewater flows, and a loss of BOD has been correlated with an increase in VSS. The impacts of biological growth appear to be decreasing as domestic wastewater and high BOD discharges become increasingly smaller contributions to the total SARI line flow, however, significant biological growth was observed during the March 2010

water quality sampling documented in the August 9, 2010 Water Quality Sampling Memorandum. While biological growth is a concern for TSS formation, it appears to account for only a small portion of the overall TSS formation. BOD is currently monitored for all discharges and is incorporated into both a BOD fee and the TSS imbalance adjustment to the TSS fee.

3.0 Control of Solids Formation

In order to evaluate potential solids control approaches for the SARI line, four different test compounds were considered. These included two non-proprietary anticoagulant chelating agents, one proprietary anticoagulant, and one proprietary antiscalant. Each of these compounds is described briefly below:

3.1 Ethylene-Diamine-Tetraacetic Acid (EDTA)

EDTA (or $C_{10}H_{16}N_2O_8$) is a non-hazardous organic acid commonly used in manufacturing and food production as both a chelating agent and ligand. EDTA has been found to be effective at sequestering metal ions, such as calcium and iron, binding the ions into organic complexes and removing or preventing formation of scale. Calcium ions which are bound by EDTA have shown to exhibit reduced reactivity with other dissolved compounds, which may also reduce the impacts of hardness on coagulation. EDTA complexes are generally anionic, remaining highly soluble in water. EDTA is commonly purchased as a dry chemical in powder form and is relatively inexpensive compared with proprietary organic compounds.

3.2 Sodium Tri-Polyphosphate (STPP)

STPP (or $Na_5P_3O_{10}$) is an inorganic compound commonly used in manufacturing and food production, including common use in detergents. Acting as a chelating agent STPP has been found to bind divalent cations, such as calcium and magnesium, preventing their reaction with other dissolved compounds. In drinking water treatment, polyphosphate has been added to low hardness waters to prevent corrosion of iron from distribution pipes. Because polyphosphate complexes are often positively charged, they may be less effective at reducing organic coagulation than anionic EDTA complexes. It should also be noted that polyphosphates can degrade into orthophosphate, which has a relatively low solubility with calcium. STPP is commonly purchased as a dry chemical in powder form, is inexpensive compared with proprietary organic compounds, and is typically lower cost than EDTA.

3.3 Protec RO-C Anticoagulant

Protec RO-C is a proprietary organic compound manufactured by King Lee Technologies, in San Diego, CA. King Lee refers to Protec RO-C as an anticoagulant and antifoulant, recommending its use in RO pretreatment when organic foulants, such as biological colloids, polysaccharides, and humic matter are a concern. The compound is recommended for dispersing the organic foulants, preventing their accumulation on RO membranes. No information was provided on the chemical constituents used in the manufacture of this compound. Protec RO-C can be purchased in bulk, tote, or drum, and comes in liquid form at 100 percent pure concentrations.

3.4 Pretreat Plus-2000 Antiscalant

Pretreat Plus-2000 is a proprietary organic compound also manufactured by King Lee Technologies in San Diego, CA. King Lee refers to Pretreat Plus-2000 as an antiscalant, recommending its use in RO pretreatment when calcium carbonate and sulfate scale are the primary concerns. The six municipal desalters currently discharging to the SARI line all utilize Pretreat Plus-Y2K for scale control. The Y2K product is reported to have a broader applicability for barium, iron, fluoride, and phosphate scale control in RO, however, Pretreat Plus-2000 was recommended by King Lee for control of calcium carbonate within the SARI line. No information was provided on the chemical constituents used in the manufacture of this compound. Pretreat Plus-2000 can be purchased in bulk, tote, or drum, and comes in liquid form at 100 percent pure concentrations.

4.0 Bench Testing Approach

The following section describes the procedures used in bench testing to evaluate the monitoring of solids formation potential and solids control approaches.

4.1 Test Water Selection

Test waters were taken from the Temescal desalter and the Inland Empire Utility Agency (IEUA) S-05 discharge manhole. The Temescal desalter was selected to be representative of high calcium dischargers believed to impact both the precipitation of calcium and the coagulation of TOC. Samples were collected from the concentrate sampling point of the RO skid with highest conductivity at the time of sampling (see Figure 1).

IEUA S-05 was selected to be representative of high TOC dischargers, since it represents both a high flow contribution and a high TOC/DOC discharge. S-05 samples were collected directly from the manhole using a composite sampler (see Figure 2). Samples were collected for both source waters on October 11, 2010.



Figure 1 - Temescal Desalter Sampling Location



Figure 2 - IEUA S-05 Sampling Location

4.2 Solids Control Compounds

The following solids control compounds and dosing rates were employed in the bench testing:

- EDTA - dose 10, 25, 50 mg/L
- STPP - dose 10, 25, 50 mg/L
- Pretreat Plus 2000 (Pretreat) - dose 10, 25, 50 mg/L
- Protec RO-C (Protec) - dose 10, 25, 50 mg/L

4.3 Water Quality Sampling

Organic and inorganic solids formation were evaluated based on field measurements and laboratory analyses of water quality parameters. In addition to standard measurements of TSS, VSS, TDS, TOC, DOC, and calcium, a modified procedure was developed by Babcock Laboratories for measuring TSS and VSS with a smaller pore size filter.

4.3.1 Modified TSS and VSS Testing

Babcock Laboratories developed a unique testing approach for a modified TSS and VSS measurement using a 0.45 micron filter rather than the standard 1.5 micron filter currently used for TSS and VSS monitoring. The purpose of this testing was to determine whether or not the use of a smaller pore size filter could be a better predictor of organic TSS formation than the current parameters monitored by the dischargers (TSS, VSS, DOC, and calcium). Babcock conducted experiments with numerous filters ranging from 0.1 micron to 0.7 micron pore size. They found that none of the filters tested were capable of maintaining their mass when heated to the required temperature for VSS measurement (550 °C). A modified VSS procedure was therefore developed using a 0.45 micron cellulose nitrate filter which was found by Babcock to be 100 percent combustible at the required testing temperature for VSS. The procedure used to determine TSS and VSS was:

1. Measure and record mass of unused, dry 0.45 micron filter
2. Place filter in filter apparatus, filtering required volume of test water
3. Dry used 0.45 micron filter according to requirements of Standard Methods 2540D
4. Measure mass of used filter. The difference between current mass and initial mass is recorded as modified TSS
5. Combust filter at 550 °C according to requirements of Standard Methods 2540D.
6. Measure mass of remaining solids. These represent non-volatile suspended solids. These are subtracted from the TSS measurement to obtain VSS.

Due to the nature of this testing procedure, and the imprecision involved with the combustion of the 0.45 micron filter, Babcock has reported a detection limit of 20 mg/L for the modified TSS and VSS, rather than the 5 mg/L detection limit in the standard method.

4.3.2 Testing Parameters

Field measurements included conductivity and pH. Laboratory analyses included each of the following:

- Standard TSS, VSS, TDS, calcium, TOC, and DOC
- Modified TSS, VSS using 0.45 micron filter (as described above in Section 4.3.1)
- TOC and calcium for 1.5 micron field filtered sample (samples were filtered in the field using a 1.5 micron meter glass-microfiber disc filter, then sent to Babcock Laboratories for standard TOC and calcium analysis)

4.4 Test Procedures

Conductivity and pH were measured for both test waters for initial conditions on October 11, 2010 and samples were collected for all laboratory analyses listed above. Conductivity and pH were measured at CDM's Rancho Cucamonga office, and laboratory analysis was conducted by Babcock Laboratories.

The TOC contributed by EDTA, STPP, Protec and Pretreat in the samples was determined by measuring the TOC of a 50 mg/L solution of each test compound in distilled water. The following procedures were then followed to prepare and sample the various testing solutions.

1. Filtration: After collecting all source water samples, 4 gallons of IEUA S-05 test water were filtered using a 1.5 micron glass-microfiber disc filters. Because of the high fouling potential of the water, only 500 mL could be filtered at a time before changing the 90 mm diameter filter disc. The purpose of this filtration step was to remove all suspended solids larger than 1.5 micron, creating an initial condition with no TSS or VSS in any of the blended waters. By removing the TSS and VSS in the pre-blended test waters, it was believed that the formation of suspended solids could be more accurately measured in the blended samples.
2. Control Samples: Two independent control samples were prepared by blending 3-L of Temescal Desalter brine and 1-L of filtered IEUA S-05 water. The resulting blends were thoroughly mixed and left to stand in an open, PVC container for 48 hours.
3. Test Condition 1a: 3-L of Temescal Desalter water were blended and thoroughly mixed with 1-L of filtered IEUA-S05 water. 10 mg/L of EDTA were added to the resulting mixture, which was blended and left to stand in an open, PVC container for 48 hours.
4. Test Condition 1b: Step 3 was repeated with 25 mg/L of EDTA

5. Test Condition 1c: Step 3 was repeated with 50 mg/L of EDTA
6. Test Conditions 2a-2c: Steps 3-5 were repeated with STPP
7. Test Conditions 3a-3c: Steps 3-5 were repeated with Pretreat
8. Test Conditions 4a-4c: Steps 3-5 were repeated with Protec
9. Sample Collection: After 48 hours of reaction time, samples were collected for all laboratory analyses identified in Section 4.3.2.

5.0 Bench Testing Results

The following section describes the results of the bench testing, including the effectiveness of methods for projecting TSS formation potential and the impacts of the four solids control compounds tested.

5.1 Projecting TSS Formation Potential

Results of the water quality analyses for the untreated water samples are presented in Table 1. The table includes initial water quality from unblended, unfiltered source waters, a projected time zero blended water quality (calculated as 25 percent filtered S-05 water and 75 percent Temescal brine), and the average blended water quality measured after 48 hours of reaction time when no solids control compounds were added. The change in each parameter over 48 hours is also listed.

Table 1 - Water Quality in Untreated Water Samples

Parameter	IEUA S-05	Temescal Desalter	Blend at Time Zero ¹	Blend at 48 hours ²	Change over 48 hrs
pH	8.0	8.0	8.0	8.8	+ 0.8 unit
TDS (mg/L)	9,500	6,500	7,250	7,000	- 3%
Total Calcium (mg/L)	370	910	775	755	- 3%
Dissolved Calcium ³ (mg/L)	350	930	785	790	+ 0.6%
TOC (mg/L)	330	5.5	70	27	- 61%
TSS (mg/L)	430	< 5	< 5	24	24 mg/L
0.45 Micron TSS (mg/L)	540	< 20	< 20	< 20	
VSS (mg/L)	380	< 5	< 5	19	19 mg/L
0.45 Micron VSS (mg/L)	390	< 20	< 20	< 20	

1. Blend at time zero calculated based on 75% Temescal brine and 25% filtered S-05 water
2. Blend at 48 hours was calculated as the average of two control samples. Variability in data between control samples was less than +/- 5% for all parameters listed.
3. Dissolved calcium for time zero was measured after filtering with 0.1 micron filter and for 48 hours was measured after filtering with 1.5 micron filter.

Previous studies have suggested that calcium concentrations will provide a good indication of the inorganic suspended solids formation potential in the wastewater flows, while TOC provides a measure of the organic suspended solids formation potential. In addition, it has been proposed in this study that a modified TSS and VSS measurement technique, using tighter 0.45 micron filters, could provide a projection of organic suspended solids generation potential from the wastewater flows. The validity and effectiveness of each of these three measurement approaches is discussed below.

5.1.1 Suspended Solids Measurement

TSS and VSS measurements were made using both a standard 1.5 micron filter and using a modified procedure with a tighter, 0.45 micron filter. A comparison of initial TSS readings using the two types of filters suggests that 110 mg/L of particulate solids may be present in the unfiltered S-05 sample within the size range passing through a 1.5 micron filter but retained by a 0.45 micron filter. This represents a 25 percent increase in the suspended solids reading when a tighter filter is used. No suspended solids were found in the Temescal Desalter waste flow. It has been suggested, in this and previous memoranda, that colloidal materials in this size range would be the most likely to contribute to TSS formation when coagulation is the primary driver. However, the measurements here suggest that these solids are primarily inorganic in nature, and would therefore not be expected to contribute to VSS formation.

The VSS readings for this same water, corresponding to organic suspended solids, do not show a significant difference between the readings using the two filter types. VSS readings made using a 0.45 micron filter were less than 3 percent higher than those using a standard 1.5 micron filter. This lack of disparity between VSS results from these two types of filters suggests that a 0.45 micron filter may not be a useful method for projecting organic solids formation potential in the wastewater discharges.

This conclusion is supported by the TSS and VSS readings after the 48 hour reaction time. Blended water samples for testing were prepared using IEUA S-05 water that had been filtered using a standard 1.5 micron filter, which removed all suspended solids (both TSS and VSS) prior to blending. After 48 hours of reaction time, 24 mg/L of standard TSS was measured in the blended water, with 80 percent of these suspended solids found to be organic VSS. In contrast to the standard measurements, TSS and VSS measurements using the tighter 0.45 micron filter were both below the detection limit of 20 mg/L. Because suspended solids measured with a tighter filter read lower than those measured with a standard filter, it does not appear that the proposed testing procedure provides an accurate measure of solids in the size range between the two filters. This may be due to the difference in materials between these filters, as solids may be removed through processes other than simple size exclusion. The chemistry of the looser filter (glass fiber filament) may allow it to remove solids not removed by the tighter filter made from a different material (cellulose nitrate). Previous testing with alternate filter materials was also found to be unreliable as a measure of smaller diameter suspended solids. It is therefore not recommended that this modified TSS and VSS measurement procedure be utilized for future characterization of SARI discharge flows.

5.1.2 Inorganic Scaling Potential

The chemistry dictating calcium precipitation is complex, and is influenced by multiple factors, including alkalinity, pH, temperature, and the nature and concentration of complexing constituents. A simplified estimate can be made of the calcium carbonate precipitation potential (CCPP) using the RTW mathematical model, if the alkalinity, calcium, and pH are known. For the blended water at time zero, an initial alkalinity of 1200 mg/L can be assumed based on historic data. Using this alkalinity, the initial pH of 8.0, and the initial calcium of 755 mg/L, the initial CCPP for blended water is calculated as 739 mg/L, suggesting a high potential for calcium scale even before the 48 hour reaction time. In reality, however, the scaling potential is significantly lower, due to the impacts of antiscalant compounds used in the RO facility. The CCCP value should only be considered an upper limit of scale potential if all constituents capable of forming soluble complexes with calcium are removed or rendered ineffective.

Calcium in the blended water was introduced predominantly from the Temescal Desalter, which had measured calcium concentrations 2.5 to 3 times higher than the IEUA S-05 water. To determine the extent of calcium directly contributing to TSS, both filtered (dissolved) and non-filtered (total) calcium measurements were taken. Results for both the time zero and 48 hour samples suggest that the precision of the calcium measurements was less than the difference in calcium between filtered and unfiltered samples. Filtered calcium levels were measured higher than unfiltered levels for the Temescal Desalter and the 48 hour blended sample. Filtered and unfiltered measurements were within 5 percent of each other for all measurements taken.

The change in calcium concentrations from time zero to 48 hours was less than 3 percent and is in line with the variability in TDS measurements, which was also 3 percent. This suggests that no calcium precipitation was observed in the untreated blended waters during the bench testing. It is not clear why precipitation did not occur, even after a significant increase in pH over 48 hours, however, it will be seen later in this memorandum that calcium precipitation was observed for many of the samples receiving various solids control compounds.

5.1.3 Total Organic Carbon (TOC)

TOC was measured in the source waters and the blended water using three different methods. TOC measurements made without any filtration give a characterization of the total organic content, both dissolved and suspended, in the water. A second measurement of TOC after filtration with a 1.5 micron filter was done to give a characterization of all TOC not contributing directly to TSS and VSS. Finally, the dissolved organic carbon (DOC) was measured by Babcock Laboratories using a standard 0.45 micron filter. By subtracting the DOC value from the 1.5 micron filtered TOC, an estimate of the mid-range TOC, sized between 0.45 micron and 1.5 micron, can be made. As discussed previously in Section 5.1.1, it is this size organic material that was expected to contribute most to the formation of VSS and TSS when coagulation is the primary driver. Table 2 presents the measured and calculated values for DOC, mid-range TOC, and large TOC (greater than 1.5 micron) for the two source waters and blended samples.

Table 2 – Organic Carbon Characterization in Untreated Water Samples

	IEUA S-05	Temescal Desalter	Blend at Time Zero ²	Blend at 48 hours ³	Percent Change
DOC (<0.45 micron)	210	5.8	57	21	63%
Mid-Range TOC	50	ND ¹	13	ND	>73%
Large TOC (> 1.5 micron)	70	ND	ND	4	

1. Detection limit for TOC was 3.5 mg/L
2. Blend at time zero calculated based on 75% Temescal brine and 25% filtered S-05 water
3. Blend at 48 hours was calculated as the average of two control samples. Variability in data was +/- 2 mg/L for DOC and +/- 1 mg/L for TOC

These results suggest that 64 percent of the organic content in the unfiltered S-05 water was small diameter, passing through a 0.45 micron filter. An additional 15 percent of the organic content was in the intermediate size range below the 1.5 micron cut-off for suspended solids measurements. The remaining 21 percent was larger than 1.5 micron and is expected to have been removed through filtration prior to blending the S-05 water with Temescal concentration. TOC characterization for the Temescal concentrate demonstrates that the low organic content in this water was all small diameter, capable of passing through a 0.45 micron filter.

Initial characterization for the blended water at time zero was calculated to be 81 percent small diameter organics (DOC) and 19 percent mid-range TOC. After 48 hours of reaction time, no mid-range TOC could be measured, while 4 mg/L of large TOC (>1.5 micron) had been formed. In addition, the concentration of small diameter DOC had decreased by 63 percent. The sizable decrease in small diameter DOC suggests that although mid-range TOC may be coagulating to form TSS, small diameter DOC is also being lost and therefore may contribute to TSS formation as well. It is therefore recommended that TOC and DOC continue to be monitored for dischargers to continue characterizing changes in organic content within the SARI line.

5.2 Solids Control Approaches

Varying concentrations of four solids control compounds were added to prepared blends of IEUA S-05 water and Temescal Desalter concentrate. TSS, VSS, and other related water quality parameters were measured to determine whether the compounds could effectively reduce the formation of TSS in the test waters. Results for each test compound are described below.

5.2.1 EDTA Results

The impact of EDTA addition on TSS and VSS formation is shown in Figure 3. These results indicate that EDTA was effective at reducing both TSS and VSS formation in the blended water during the 48 hour test. VSS formation in the sample water containing 50 mg/L of EDTA was 7 mg/L, compared with 19 mg/L when no EDTA was added, representing a 63 percent decrease in VSS formation. Similarly, total TSS formation decreased by 63 percent with the highest dose of EDTA.

While these results suggest that EDTA addition may be effective at controlling TSS formation within the SARI line, a dose of 50 mg/L could cost \$10,000 to \$15,000 per month for each 1 mgd of flow in

the SARI line. In contrast, the cost of 24 mg/L of TSS formation is less than \$2,000 per month for each 1 mgd of flow, based on the current OCSD rate structure. It is therefore unclear whether the use of EDTA offers an economical approach to TSS control. It was also not shown whether or not the use of EDTA will be effective at reducing calcium scale in the pipelines. While there was a clear reduction in non-volatile (inorganic) TSS formation with the use of EDTA, calcium monitoring results did not suggest that scaling occurred in the baseline samples receiving no EDTA.

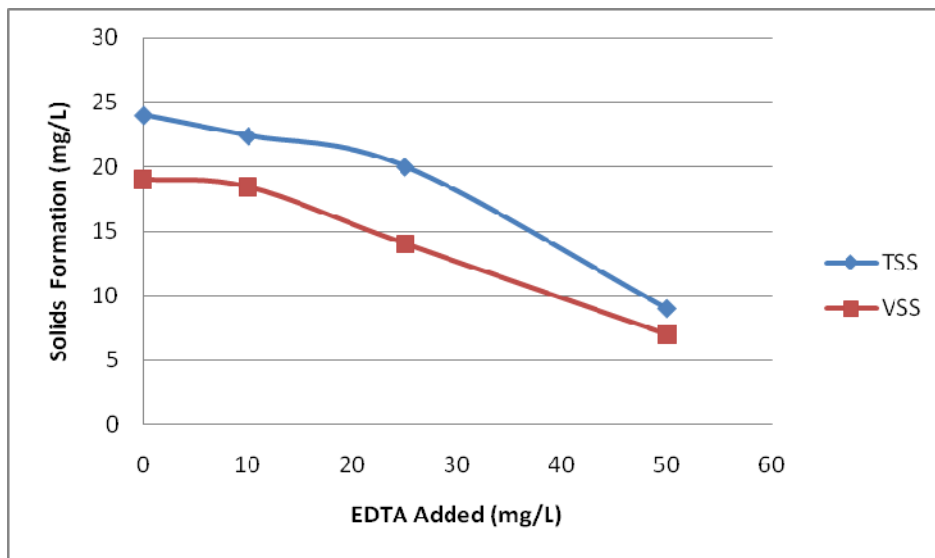


Figure 3 - Suspended Solids Formation in Samples Receiving EDTA

5.2.2 STPP Results

The impact of STPP addition on TSS and VSS formation is shown in Figure 4. These results indicate that STPP was ineffective at controlling TSS formation, but rather had a negative impact, drastically increasing the formation of both VSS and non-volatile (inorganic) TSS. Total TSS formation increased from 24 mg/L, when no STPP was used, to 90 mg/L at a dose of 50 mg/L STPP.

The majority of this TSS formation appears to be non-volatile, or inorganic in nature. Figure 5 presents the calculated non-volatile suspended solids (shown as nVSS) in the samples, along with the change in dissolved calcium between initial conditions and 48 hours. This comparison suggests that the formation of inorganic suspended solids correlates relatively well with a reduction in dissolved calcium. It can be inferred from these results that the primary driver for TSS formation in the STPP samples was precipitation of calcium, through either calcium carbonate or calcium phosphate. It is therefore not recommended that STPP be considered for use in the SARI line.

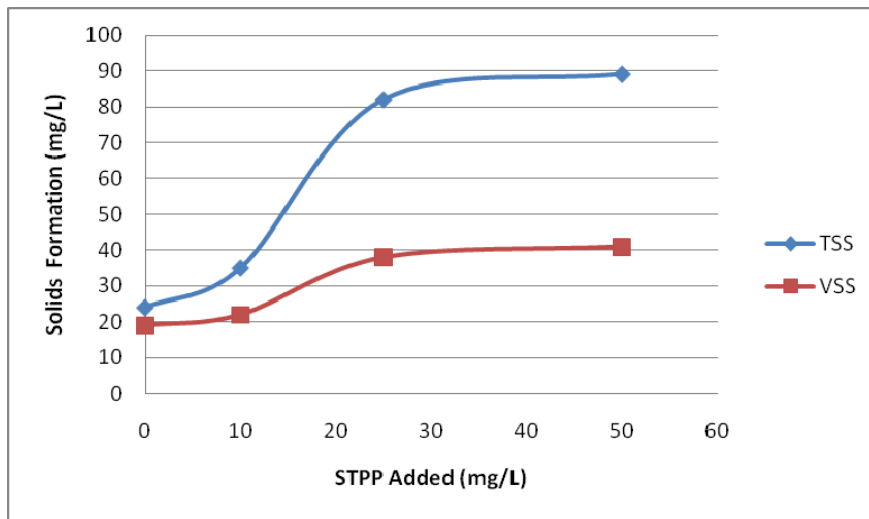


Figure 4 - Suspended Solids Formation in Samples Receiving STPP

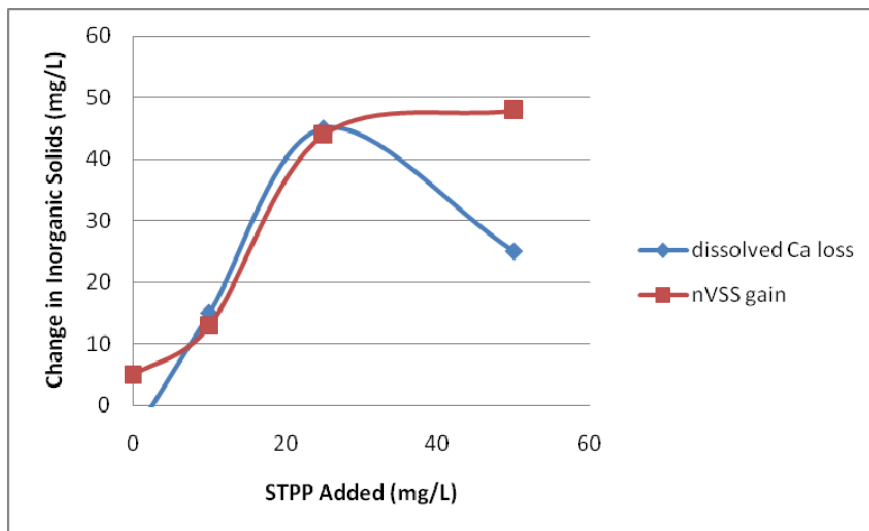


Figure 5 - Change in Inorganic Solids for Samples Receiving STPP

5.2.3 Protec Results

The impact of Protec RO-C addition on TSS and VSS formation is shown in Figure 6. These results indicate that this compound was ineffective at controlling TSS formation, but rather had a negative impact at the 10 mg/L and 25 mg/L doses, with no apparent net impact at the 50 mg/L dose. Total TSS formation increased to 38 mg/L (a 58 percent increase) when 25 mg/L of Protec was added. The majority of this TSS formation appears to be VSS or organic in nature, however, the formation of non-volatile suspended solids was also observed for all doses less than 50 mg/L. Based on the results of this bench testing, it is not recommended that this compound be utilized for TSS formation control within the SARI line.

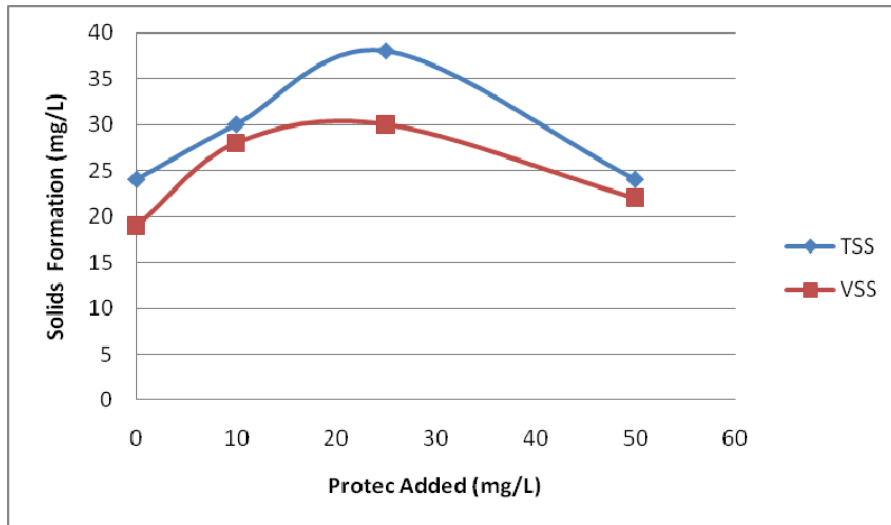


Figure 6 - Suspended Solids Formation in Samples Receiving Protec RO-C

5.2.4 Pretreat Results

The impact of Pretreat Plus-2000 addition on TSS and VSS formation is shown in Figure 7. These results indicate that this compound was ineffective at controlling TSS formation. The compound does not appear to have had any impact on TSS or VSS formation at the 10 mg/L dose, however, an increase in both TSS and VSS was seen for the 25 mg/L and 50 mg/L doses. While this compound was recommended primarily for control of inorganic scale, the bench testing results suggest that its use did not cause a reduction in either organic or inorganic solids generation. It is therefore not recommended that this compound be utilized for TSS formation control within the SARI line.

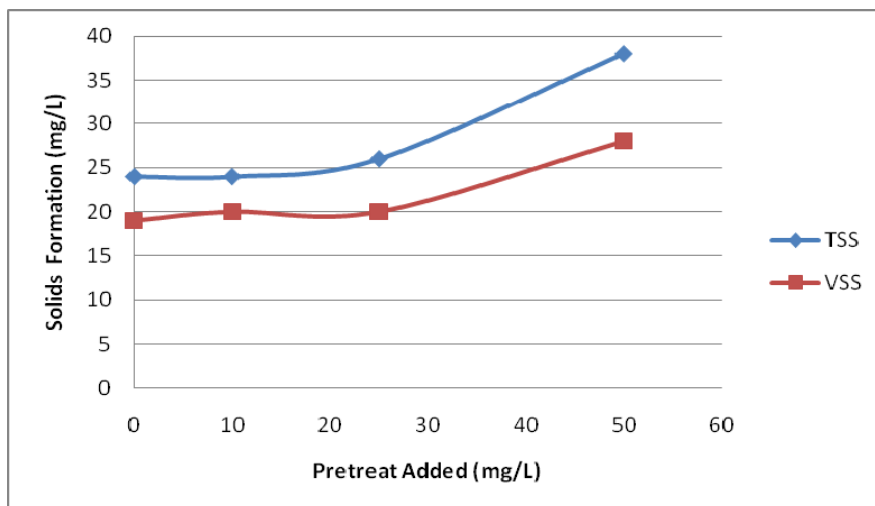


Figure 7 - Suspended Solids Formation in Samples Receiving Pretreat Plus-2000

6.0 Conclusions and Recommendations

Babcock laboratories developed a modified TSS and VSS measurement approach using a 0.45 micron cellulose nitrate filter as a means of measuring solids in the size range smaller than the standard 1.5 micron glass fiber filament filter. It had been suggested in previous memoranda that organic material in this size range would be the most likely to contribute to VSS formation through coagulation. Testing results suggest that this method was not effective at characterizing the solids in this size range. In many cases TSS and VSS measurements made with 0.45 micron filters were smaller than those made with looser 1.5 micron filters. It was concluded that the chemistry of the looser filter may allow it to remove solids not removed by the tighter filter made from a different material. It is not recommended that this modified TSS and VSS measurement procedure be utilized for future characterization of SARI discharge flows.

Monitoring of both dissolved (filtered) and total calcium at time zero and after 48 hours suggests that significant calcium precipitation did not occur in the blended water that did not receive solids control compounds. While projected calcium carbonate concentrations were well above calculated saturation limits, the antiscalant residual remaining from the desalination facility was apparently sufficient to prevent calcium precipitation during the 48 hour bench testing. Calcium precipitation was observed in samples receiving STPP, Protec RO-C, and Pretreat Plus-2000.

Blended water which did not receive any solids control compounds formed an average 24 mg/L of TSS and 19 mg/L of VSS after 48 hours of undisturbed reaction time. While the source waters had been filtered to remove all initial levels of TSS, this TSS formation represents levels that are approximately 22 percent of the calculated TSS in the water had filtration not been carried out before blending. This 22 percent TSS formation is lower than the historic 50 to 100 percent increase often seen in the SARI line.

Initial TOC characterization for the blended water at time zero was calculated to be 81 percent small diameter organics (DOC) and 19 percent mid-range TOC (between 0.45 micron and 1.5 micron in size). After 48 hours of reaction time, no mid-range TOC could be measured, while 4 mg/L of large TOC (>1.5 micron) had been formed. In addition, the concentration of small diameter DOC had decreased by 63 percent. The sizable decrease in small diameter DOC suggests that although mid-range TOC may be coagulating to form TSS, small diameter DOC is also being lost and therefore may contribute to TSS formation as well. It is therefore recommended that TOC and DOC continue to be monitored for dischargers to continue characterizing changes in organic content within the SARI line.

Results of testing with EDTA found that the addition of 50 mg/L was effective at reducing the formation of TSS by 63 percent. While the use of this compound could present an alternative for reducing both inorganic scale and organic coagulation in the SARI line, a dose of 50 mg/L could cost \$10,000 to \$15,000 per month for each 1 mgd of flow treated. In contrast, the charge for 24 mg/L of TSS is less than \$2,000 per month for each 1 mgd of flow, based on the current OCSD rate

structure. It is therefore unclear whether the use of EDTA offers an economical approach to TSS control.

Other solids control compounds, include STPP, Protec RO-C anticoagulant, and Pretreat Plus-2000 antiscalant, were ineffective at controlling TSS formation, significantly increasing both TSS and VSS formation in the majority of the samples. It is not recommended that these compounds be utilized for control of solids formation within the SARI line.

References

Levine, I.N. (2001), *Physical Chemistry* (5th ed.). McGraw-Hill.

Hunter, R.J. (2001), *Foundations of Colloid Science* (2nd ed.). Oxford University Press.