CASE STUDY: POLLUTION PREVENTION INITIATIVES AT AN INDUSTRIAL WASTEWATER TREATMENT PLANT

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ABSTRACT

During production and maintenance operations at the Oklahoma City Air Logistics Center [OC-ALC], industrial wastewater streams are generated which contain organic and heavy metal compounds. These waste streams result from chemical depainting operations, chemical cleaning processes, and electroplating operations. Processes discharging wastewater are treated at the on-site industrial wastewater treatment facility [IWTF]. The objective of this paper is to highlight some of the experiences that OC-ALC engineers have had over the last years with everything from odor mitigation efforts to evaluating the performance of zeolite media pressure filters. The presentation shall include the following topics:

1. POTW NESHAP: Determine if the OC-ALC IWTF was considered to be a major or minor source as defined by the National Emission Standards for Hazardous Air Pollutants [NESHAP] for Publicly Owned Treatment Works [POTW].

2. INVESTIGATION OF IWTF ODORS: OC-ALC has made numerous process changes to minimize the odors and improve operations [*i.e.*, installing process unit covers, shutting down redundant process units, lowering sludge levels, lowering wastewater tank levels, minimizing sludge levels, adding chemicals, use of odor mitigation chemicals, etc.].

3. AIR-SPARGED HYDROCYCLONE TECHNOLOGY: Collaboration with Air Force Research Laboratory to investigate, evaluate, field-test, and design an air-sparged hydrocyclone [ASH] system for application at OC-ALC. The technology has been tested to determine performance at three sites around the installation.

4. IWTF EMISSION FACTORS: Collaboration with the Oklahoma State University Department of Civil Engineering to develop emission factors for individual process units [*i.e*., oil-water separators, equalization basins, solid contact clarifiers, lift stations, etc.] at the industrial waste treatment plant. This will be accomplished through application of commercially available computer models [General Fate Models, *i.e*., WATER9 and TOXCHEM3].

5. IWTF LIFECYCLE COSTS: Collaboration with the US Air Force Academy Student Research Program to quantify the lifecycle costs associated with operating the industrial wastewater treatment plant processes. This effort quantified IWTF operating costs, *i.e.*, sludge disposal, utility, process unit maintenance, equipment, chemical treatment, labor, etc.

6. IWTF HYDRAULIC LOADING: Collaboration with the Oklahoma State University Department of Civil Engineering to investigate the impact of increased hydraulic, solids, and constituent loading on industrial wastewater treatment plant.

7. METALS TREATMENT OPERATION: Collaboration with the Oklahoma State University Department of Civil Engineering to improve the current metals treatment operation at the IWTF by quantifying the temperature impact on the chemical feed rates and develop a mathematical expression / correlation that will incorporate a temperature correction factor.

8. IWTF FINAL FILTER PERFORMANCE: OC-ALC engineers have been tracking the performance of the IWTF final pressure filters since the addition of a new zeolite media.

DISCUSSION

1. POTW NESHAP: In production and maintenance operations at the Oklahoma City Air Logistics Center [OC-ALC], industrial wastewater streams are generated which contain organic compounds and heavy metals from chemical depainting operations, chemical cleaning processes, and electroplating operations. The wastewater is treated at an on-site industrial wastewater treatment facility in open surface impoundments and collection systems. The objective of this effort was to determine if the OC-ALC IWTF is considered to be a major or minor source as defined by the National Emission Standards for Hazardous Air Pollutants [NESHAP] for Publicly Owned Treatment Works [POTW]. Section 112 of the NESHAP—POTW Act addresses stationary sources of hazardous air pollutants [HAP]. Section 112(b) of the Act, as amended, lists 188 chemicals, compounds, or groups of chemicals as HAPs. The EPA is directed by section 112 to regulate the emissions of HAP from stationary sources by establishing national emission standards. The statute requires the EPA to establish standards to reflect the maximum degree of reduction in HAP emissions. Section 112(a)(1) of the Act defines a major source as any stationary source or group of stationary sources located within a contiguous area and under common control that emits or has the potential-to-emit considering controls, in the aggregate 10 tons per year [TPY] or more of any HAP or 25 TPY or more of any combination of HAPs. This paper presents estimates of hazardous air pollutant emissions for the OC-ALC industrial wastewater treatment facility. As regulatory reporting requirements become increasingly more stringent [40 CFR Part 63, National Emission Standards for Hazardous Air Pollutants: Publicly Owned Treatment Works, effective date: 26 October 1999], Air Force installations are being required to quantify and report chemical releases to the environment. Computer software designed by the EPA was used to identify and quantify HAP discharges from the IWTF process units to the ambient environment.

There are a number of computer-based fate and transport models including BASTE, WATER8, CINCI, CORAL, EPA FATE, NOCEPM, PAVE, SIMS, TORONTO, and TOXCHEM. BASTE [Bay Area Sewage Toxics Emissions] is a proprietary model developed for a consortium of POTWs [Bay Area Air Toxics BAAT group] in California by R.L. Corsi of the University of Texas at Austin [1]. BASTE is a general fate model that includes split flows, quiescent surfaces, drops, weirs, aerated processes, biological processes, and covered processes, organized in a flexible building block approach. WATER8 is a fate and transport model for aerated and non-aerated wastewater treatment processes and impoundments [3,4]. WATER8 works in conjunction with CHEM8, which is a computer program used to estimate compound properties. WATER8 was developed by the Research Triangle Institute for the U.S. EPA Office of Air Quality Planning and Standards. WATER8 utilizes the building block approach and does adjust the Henrys Law constant with wastewater temperature. Richard Dobbs developed CINCI [U.S. EPA Cincinnati model] at the University of Cincinnati for the U.S. EPA Risk Reduction Engineering Laboratory [1] and incorporates some conceptual model components selected from the literature. CORAL [Collection System Organic Release Algorithm] is a fate model that simulates two-phase, transient VOC transport and gas-liquid partitioning in enclosed wastewater treatment systems including collection reaches [1] and is the only computer-based simulation designed to model VOC stripping in enclosed sewer networks. The EPA FATE [Fate and Treatability Estimator] model was developed by ABB Environmental and is a computerized-model designed for municipal wastewater treatment systems. NOCEPM [NCASI Organic Compound Elimination Pathway Model] is limited to modeling only activated sludge and aerated lagoon systems in paper and pulp wastewater treatment systems. PAVE [Programs to Assess Volatile Emissions] is a set of computer models for determining volatile emissions from wastewater treatment units and from spills of liquid solutions. SIMS [Surface Impoundment Modeling System—1990] was developed by RADIAN for the U.S. EPA Office of Air Quality Planning and Standards [2,3,4] to determine the expected air emissions for IWTFs to produce rule-making support data and later replaced with the WATER8 model. The TORONTO model is designed for evaluating the fate of organic chemicals in a biological wastewater treatment facility [1]. TOXCHEM consists of various conceptual model components selected from the literature to address the fate of contaminants through all stages of municipal wastewater treatment [3,4] and is the only proprietary model with unsteady state capability that allows prediction of an industrial facilities response to a spill condition.

The weakness of most General Fate Models, except WATER8 and TOXCHEM, is the lack of a temperature correction for the Henrys Law coefficient. For VOCs in industrial wastewater treatment systems, volatilization is the dominant removal mechanism, which could translate to significant errors. Also, all the models neglect the interaction between target VOCs except PAVEs treatment of binary mixtures. NOCEPM, PAVE, SIMS, and WATER8 are based on industrial wastewater systems, unlike the others, which are focused on municipal wastewater applications where the dominant mechanism is biological digestion.

The WATER8 software program was written in response to the federal, state, and local need for a methodology to estimate emissions from surface impoundments and collection system components located in treatment, storage, and disposal facilities, publicly owned treatment works, and other similar processes [3]. The WATER8 model utilizes equipment information to predict air emission discharges from each individual process unit utilizing mass transfer expressions, process unit information, in addition to chemical and physical property data for the interested chemicals. By inputting influent concentrations, WATER8 determines the wastewater effluent concentrations, the air emission releases, and the amount of organic constituent biologically digested from each individual process unit. The individual discharge amounts are totaled to obtain the total air emissions for the modeled system [3]. By using a General Fate Model [WATER8], the OC-ALC IWTF is considered a minor source because the industrial wastewater treatment facility released approximately 8,600 pounds in 1999 [under maximum operating conditions], which is below the amount defined by the POTW NESHAP.

2. INVESTIGATION OF IWTF ODORS: OC-ALC has made numerous process changes to

minimize the odors and improve operations [*i.e.*, installing process unit covers, shutting down redundant process units, lowering sludge levels, lowering wastewater tank levels, minimizing sludge levels, eliminating biological degradation process, adding chemicals, use of odor mitigation chemicals, etc.]. In late 1998, Tinker AFB officials began receiving complaints from surrounding communities concerning offensive nuisance odors emanating from the industrial wastewater treatment plant. Since the installation of the IWTF, nuisance odors and offensive smells have been an intermittent problem at the IWTF. Historically, the odor events were of short duration and mild intensity, and were associated with the metals treatment process, downstream secondary clarification [solid contact clarifiers, final clarifiers, and gravity thickener], and mechanical sludge dewatering operations. While the odors were a nuisance, they were never a danger to the health of the surrounding community or IWTF workforce [9]. The severity of the odor complaints to Tinker AFB and the Oklahoma Department of Environmental Quality [ODEQ] increased from late-1998 through early-1999. The odor complaints described numerous odors including cat-box urine, hair salon odor, sour sulfur, chemical odor, amine / ammonia, and refined petroleum. Odor complaints were being reported to the ODEQ, Civil Engineering Group, Environmental Management, Public Affairs, and Midwest City Chamber of Commerce. The number of complaints reached a maximum of over 40 during the more odorous months. By late 1998, the odor events were becoming a persistent, daily occurrence with a noticeable increase in odor intensity that emanated from every IWTF process unit.

After a detailed investigation, an organic terpene [*d*-limonene] component in a citrus-based degreaser was responsible for cat-box urine and hair salon odors. On-site laboratory jar tests were performed where varying concentrations of the citrus-based degreaser was added to different sludges in the IWTF recreating the identical odors. Formal laboratory tests were conducted by a local university bioenvironmental laboratory recreating the cat-box urine odor by inoculating biological and thickener sludges with the citrus-based product. From laboratory tests, the odor was found to be inversely related to the dissolved oxygen of the wastewater--as the DO increased, the odor decreased, and visa versa. The Environmental Management Information System [EMIS] was used to investigate purchase and usage records for the citrus-based degreasers and cleaners. EMIS was able to determine the major purchasing organization and demonstrate that the purchase and use of the product had increased 100-fold over the last year and mirrored the odor complaints [initial use began in the last quarter of 1998 and peaked in the first quarter of 1999, which paralleled the odor complaints].

To minimize additional odors, process unit redundancy was eliminated by reducing the number of process units from 28 to 14. In addition, permanent covers were placed on seven of the remaining 14 process units reducing the exposed surface area by 75 percent. To eliminate the reduced hydrogen sulfide odors, the metals treatment process [ferrous sulfate / sulfide system] was replaced with polyelectrolytic polymers [aluminum chlorohydrate, blend of cationic polymers, followed with an anionic polymer]. One of the biggest changes involved eliminating the sludge blanket in the solid contact clarifier, thereby eliminating the organic decomposition odors associated with the septic sludge blanket. Much of the cat-box urine odor was attributed to the activated sludge process. The biological decomposition odor was eliminated by removing the activated sludge process, which included two aeration basins and two secondary clarifiers. Since shutting down the activated sludge process, the installation has been operating well below [ten percent] of the present Total Toxic Organic discharge permit limit. By shutting down the biotreatment process, the IWTF was able to save $250-350K annually in disposal, operating, maintenance, and utility costs. Additional process changes include improving the sludge management practices [minimizing sludge levels] in all process units, *i.e*., gravity thickener, solid contact clarifier, etc.

After some formal laboratory jar tests, engineers began chemically treating the thickener supernatant with potassium permanganate [$KMnO_4$]. The potassium permanganate treatment demonstrated a 70 to 80 percent reduction in the offensive sour sulfide odors from the thickener supernatant return and indirectly reduced odors from the mechanical sludge dewatering operations [*i.e*., plate and frame filter press]. Approximately 30 gallons per day of a three-percent solution of potassium permanganate was added to the thickener, minimizing the sour sulfide odor at the thickener and headworks [from supernatant return]. It is important to note that prior to treating with potassium permanganate, an odor-neutralizing deodorant was used to minimize the thickener odors. The product was costly and did not minimize the odors. The potassium permanganate chemical treatment successfully minimized the odors at a chemical cost of about $11 per day as compared to $167 per day with the odor neutralizer / maskant, translating to a savings of $50K annually.

Another odor source was associated with the gravity thickener sludge dewatering activities. There are odors released as the sludges are mixed and prepared for dewatering and during the dewatering operation. The solution was to chemically treat the mixed sludges with potassium permanganate and lime to reduce the sour sulfide odors and maintain an alkaline pH to reduce the generation of offensive hydrogen sulfide. Engineers implemented a chemical treatment routine where roughly four gallons of a three-percent potassium permanganate solution was added for every 1000 gallons of thickener sludge dewatered. The chemical treatment not only reduced the sour sulfide odors, but improved the filterability of the sludges [*i.e*., shorter process times, produced more dense filter cakes, and required less diatomaceous earth body feed].

The facility was able to save another $130,000 annually by eliminating the use of an odor maskant. In the initial stages of the odor investigation, an expensive odor maskant was added to the major process units in an attempt to suppress / mask the offensive odors. The maskant was determined to contain another odor-causing terpene similar to the *d*-limonene component, which further exaggerated the existing odors. Once the maskant was determined to be contributing to the odor, the use was stopped, savings roughly $130,000 annually.

3. AIR-SPARGED HYDROCYCLONE TECHNOLOGY: Collaboration with the Air Force Research Laboratory to investigate, evaluate, field-test, and design an air-sparged hydrocyclone [ASH] system for application at OC-ALC. The technology has been tested to determine performance at three sites around the installation. The overall effectiveness was quantitatively measured by reviewing analytical results of influent and effluent samples with respect to the removal of aqueous film forming foam [AFFF], oils and grease, total petroleum hydrocarbons, biological / chemical oxygen demand, volatile organic chemicals [VOC], and others. This technology developed by the U.S Air Force, in partnership with the U.S. Navy and Kemco Systems. The ASH system combines froth flotation principles with the flow characteristics of a hydrocylone. This configuration has proven to provide an excellent means for oil and grease

separation as well as AFFF removal. In ASH technology, the O&G / AFFF-containing wastewater is pumped from the waste stream source into the first wastewater tank. The water is then carried in series through a total of three tanks, with each tank providing mixing and hydraulic retention time required for adequate chemical treatment of the waste stream. Polymer and metal coagulant may be added into the first two wastewater tanks by use of chemical pumps. The wastewater chemical mixture is vigorously mixed in the two tanks by means of a paddle mixer. Any additional chemical [pH adjuster, second polymer, etc.] required may be injected into tank three via an additional chemical pump, where it is also mixed using a paddle mixer. The chemically pretreated waste stream [slurry] is then pumped from the third wastewater tank through ASH pump to the first ASH unit. The slurry is introduced tangentially into the ASH chamber to develop a tangential swirl flow of water inside a porous tube. A jacketing tube contains the porous tube. Pressurized air is forced into the jacketing chamber and passes through the porous tube entering the inner surface area of the porous tube. As the air enters the inner surface area of the porous tube, it is sheared by a tangential swirl of water and forms numerous fine bubbles or foam. The bubbles attach to fine particles and or oil droplets in the water and via production of foam, AFFF is stripped from the water and concentrates at the air / water interface of these fine bubbles. Laboratory results are highlighted in TABLE I and compared to nine other DOD sites where the ASH system was tested. From TABLE I, the ASH technology did very well on the heavy metals and AFFF, but struggled with the oil and grease, TSS, and COD reductions. The poor performance on removing organics was attributed to the use highly soluble, alcohol-based chemical-depainting agents that are specific to OC-ALC operations.

TABLE I. Air sparged hydrocyclone test results for OC-ALC sites

PARAMETER	**OC-ALC**, *percent removal*	**OTHER DOD SITES**, *percent removal*
Oil & grease	21%	84 – 99%
TSS	57%	60 – 99%
AFFF	90%	90 – 98%
COD	31%	38 – 97%
Metals	87 – 96%	85 – 97%

4. IWTF EMISSION FACTORS: Collaboration with the Oklahoma State University Department of Civil Engineering to develop emission factors for individual process units [*i.e.*, oil-water separators, equalization basins, solid contact clarifiers, lift stations, etc.] at the industrial waste treatment plant. This will be accomplished through application of commercially available computer models [General Fate Models, *i.e.*, WATER9 and TOXCHEM3]. Current methods for quantifying IWTF air emissions are accomplished through the use of US EPA published emission factors, engineering estimates, chemical purchase data, general fate computer models, and/or periodic emission sampling. General fate modeling [GFM] methods employ process unit and waste stream information [chemical constituent concentrations, physical and chemical properties, plant process configurations, meteorological impacts, etc.]. Among the models identified are models such as WATER9, BASTE [Bay Area Sewage Toxics Emissions], and TOXCHEM3 [1,3]. Each of these models has been used to predict air emissions of volatile organics from

various treatment facilities.

The objective of this effort was to improve / validate the accuracy, reliability, and repeatability of target pollutant emissions [toxic release inventory or other targeted chemicals, etc.] through monitoring, process unit sampling, and computer modeling of OC-ALC / IWTF air emission sources [primary paint chip clarifier, oil-water separators, equalization basins, storage / stabilization tanks, metals treatment basins, solid contact clarifiers, lift stations, and gravity thickeners]. Current methods need to be improved to satisfy current and future regulatory tracking and reporting requirements and improve compliance with maximum ambient air concentration [MAAC] standards. The intent of this project is to quantify target chemical emissions from the major IWTF emission sources and develop an air emission sampling strategy to improve the accuracy of the air emissions reporting data.

The project involved two tasks: (1) involves the acquisition of facility data and application to the various air emission models and (2) establish emission factors from each of the individual industrial wastewater treatment plant process units [primary paint chip clarifier, oil-water separators, equalization basins, storage / stabilization tanks, metals treatment basins, solid contact clarifiers, lift stations, and gravity thickeners]. Field-sampling phase of the project required acquisition of both air and process water samples to be input into the models, and their predicted outputs accumulated. Simultaneous with this effort, a gas chromatograph [GC] and/or Fourier Transform InfraRed [FTIR] spectrometer will be used to assay liquid and gas phase samples from across the plant for a selection of the most critical pollutants. The study will allow sampling events during various seasons [at least summer and winter] to help confirm predicted model output under different scenarios, which should help reducing uncertainties in annual emission estimates [and ultimately environmental compliance reports]. After all the sampling, analyses and model manipulations have been accomplished, recommendations will be made to Tinker AFB regarding emission factors for the IWTF. Recommendations for routine use of the general fate models will also be made. Once reliable air emissions data and computer model simulations for the emission of organic and inorganic air emissions have been developed for each of the major units of the IWTF, these chemical concentration profiles shall be used to perform a health risk assessment for both plant personnel and the general populations in the surrounding community. By incorporating prevailing meteorological data, current populations demographics, and standard chemical exposure parameters, relative health risks for living and working surrounding the IWTF can be calculated. This activity is a necessary step, as previous risk assessments are out-dated and based upon plant parameters [*i.e.*, chemical concentrations, process unit configurations, etc.] that have changed significantly. This effort should be completed in the fall 2003.

5. IWTF LIFECYCLE COSTS: Collaboration with the US Air Force Academy Student Research Program to quantify the lifecycle costs associated with operating the industrial wastewater treatment plant processes. This effort quantified IWTF operating costs, *i.e.*, sludge disposal, utility, process unit maintenance, equipment, chemical treatment, labor, etc. This report presents the results from a qualitative and quantitative investigation of lifecycle costs for the operation of the OC-ALC IWTF. By analyzing the hazards created by the various chemicals treated in the wastewater and identifying their upstream source, this study provides a more accurate cost analysis for treating the industrial wastewater and gives an opportunity for a cost

determination based on hydraulic and pollutant mass loadings. After incorporating all the costs associated with facility operations, those product directorates providing the majority of the chemicals support the majority of the cost of the plant operations, as they actually contaminate other, relatively dilute, waste streams. The mathematical expression created to solve this problem can be applied to other organic and inorganic compounds as well as other flow streams, requiring only a concentration in milligrams per liter and a flow rate in gallons per day, resulting in a cost in dollars per year and dollars per 1000 gallons of wastewater treated.

This initiative was developed from a need to better quantify environmental savings in order to validate pollution prevention opportunities in the product directorates. Currently, the product directorates pay a portion of the industrial wastewater treatment charges according to the volume of wastewater generated in their specific operations, *i.e.*, hydraulic loading. These charges are limited to one variable and neglects the hazardous targeted pollutant, toxicity, chemical constituent concentrations, and the level of difficulty of treatment. For example, the Aircraft Product Directorate makes up approximately ten percent of the total volume of wastewater treated at the IWTF and are charged accordingly. This methodology neglects the chemical concentrations, chemical toxicity, and level of treatment for the wastewater constituents. The Aircraft Product Directorate wastewater discharge contains high levels of organic and metal constituents and requires additional treatment when compared to the other IWTF wastewater components. The methodology would require that the Aircraft Product Directorate pay more for treatment because of the high chemical concentrations, degree of toxicity, and the level of difficulty in removing the hazardous chemicals. This methodology is a more realistic and fair representation of how the product directorates should be charged based on hydraulic loading, mass loading, and constituent toxicity.

The OC-ALC provided depot level maintenance of large frame aircraft that use hazardous chemicals in their processes. For example, all aircraft undergo a chemical depainting process, which allows for cleaning of the aircraft, repair, and a new coat of paint. The depainting process, however, uses many harsh chemicals, such as phenols, methylene chloride, and chromates, which fall under use and disposal restrictions from the US EPA and other government agencies. Before these harmful compounds reach the Oklahoma City Publicly Owned Treatment Works [POTW] facilities, they must be treated and the wastewater effluent must meet the environmental compliance requirements set by the US EPA. Depending on the concentration of the chemicals found in the water, the cost of treating the wastewater increases as it is much more difficult on the processes. As the influent waste stream enters the IWTF, all the hazardous chemicals flow throughout the entire plant with the wastewater. In order to associate a treatment cost to a specific operation, a weighting factor must be assigned to each chemical species. Many different options exist regarding the determination for a chemical species weighting factor. The literature recommends using physical-chemical properties, such as Henry's law constant, vapor pressure, octanol-water coefficient, surface tension, material hardness, solubility, cancer potency index, molecular weight, reference dose values, hydrogen ion or acid equivalents, carbon equivalents, oxygen equivalents, halogen ion equivalents, acute toxicity values, sensory irritation index, chemical "potentials", environmental or ecotoxity data, partition coefficients, and quantitative risk assessments [5]. This effort used physical-chemical properties, *i.e.*, Henry's law constant, vapor pressure, octanol-water coefficient, surface tension, material hardness, solubility, surface tension, molecular weight, and reference dose values to determine the costs associated with treating industrial wastewater. Many of these weighting factors have different values, units, and orders of magnitude. The normalization of these factors for use required an additional step. Using the normal use of the octanol-water coefficient as an example, this study uses the logarithms of every category, except for the Henry's law constants. This achieves two goals. First, it normalizes all the values to a scale of approximately zero to ten. Second, all of the factors enter the equation dimensionless. This includes the Henry's law constant, which has been converted to the dimensionless value. These values, however, do provide equivalence for each of the compounds based on their properties, determining their treatability and toxicity.

Table II tabulates the estimated cost for treating different chemicals based on both hydraulic and chemical loading. This methodology weighs both determinants equally, weighs the different chemicals depending on their treatability and harmfulness to the environment, and determines a cost that relates to the current cost of treating wastewater through the plant. Note that aircraft depainting operations [LS #6 and B2280] accounts for less than 10 percent of the total flow, but would pay for more than 40 percent of the treatment costs because of the toxicity of the chemical depaint agents and associated heavy metals. This would make pollution prevention projects more cost effective and ultimately reduce the environmental compliance burden costs associated with chemically depainting activities. From this, the average cost to treat industrial wastewater is roughly $7.50 per 1000 gallons.

TABLE II. Estimated IWTF treatment costs by Product Directorate

WASTEWATER SOURCE	**FLOW** [GPD]	**$ / gal**	**$ / year**	**% of flow**	**% of cost**
LA [LS #6]	20,720	0.05881	$444,735	2.8%	20.8%
LA [B2280]	49,392	0.02429	$437,947	6.8%	20.5%
LP [B3221]	233,343	0.00869	$739,763	31.9%	34.6%
LP [M34]	31,002	0.00733	$82,932	4.2%	3.9%
LP [Chemical Cleaning]	198,094	0.00388	$280,351	27.1%	13.1%
LI [B2210 / B2211]	690	0.00337	$848	0.09%	0.04%
LP [LS #10]	28,160	0.00240	$24,670	3.9%	1.15%
LP [Plating]	50,112	0.00245	$44,817	6.9%	2.10%

6. IWTF HYDRAULIC LOADING: Collaboration with the Oklahoma State University Department of Civil Engineering to investigate the impact of increased hydraulic, solids, and constituent loading on the industrial wastewater treatment plant. The objective was to develop a hydraulic profile throughout the IWTF to assess hydraulic bottlenecks and worst-case scenarios, and to identify possible pollution prevention projects.

The classic method of determining reactor hydraulic performance is to conduct stimulus-response experiments [tracer study] on the units under study [9]. Due to the variable flow inside the IWTF, and therefore variable hydraulic residence time, it was decided a step-input tracer study would be easier to conduct, where the tracer component is continuously injected into the influent stream over the duration of the test while the effluent is sampled. In conducting the step dose procedure, it is desirable to continue to dose for a period of two or three basin residence times in order that equilibrium conditions may be approached [9]. The response data from a step-input can be used to create an *F*-curve, which shows the tracer output signal. The *F*-Value normally dimensionless [C / C_o], represents the fraction of tracer molecules having an exit age younger than some time, *t*. This type of curve can be used to evaluate the extent of short circuiting being experienced by the unit process. The *F* curve can be transformed into an *I* curve [$I = 1 - F$], which is a measure of the distribution of ages of fluid in the unit. This *I* curve can be utilized to assess the extent of deadwater or stagnant regions in the unit process [9].

The intent of the tracer study was to raise the lithium concentration in each tank to approximately 0.25 mg/L using a step influent feed and track the lithium concentrations ascent to this level. For each tank, lithium chloride in solution was pumped into the influent flow into the tank or at an upstream lift station. Influent samples were taken downstream of tracer feed and effluent samples were taken at or near the effluent from each tank. Tracer was injected at approximately 20 milliliters per minute. A lithium chloride concentration of 139 g/L was required for the main part of the IWTF based on an average flow of 729,000 GPD.

The objective is to determine the stagnant areas [dead spaces] of slow moving fluids. Fluids that stay in a unit reactor for more than twice the theoretical hydraulic retention time are considered stagnant [9]. TABLE III tabulates some of the average dead volumes in the process treatment train. From the tracer study, each of the units had a significant amount of short-circuiting and dead space, which will negatively impact unit performance. The worst short-circuiting was found in the oil-water separators, which may be partially attributed to the oil layer on the surface of the unit and uptake of lithium chloride in the oil layer, thereby extending the residence time.

TABLE III. Percent dead volume in each IWTF process unit

TREATMENT UNIT	**DEAD VOLUME**, *percent*
Paint chip clarifier	36%
Oil-water separator [south]	69%
Oil-water separator [north]	53%
Equalization basin	53%
Mixing Basins #1 & #2	43%
Mixing Basin #3	71%
Solid contact clarifier	27%

From this information, pollution prevention projects can be developed to improve the operation. For example, there appears to be a significant amount of dead space in Mixing Basin #1 that can be attributed to incorrectly sized mixing / flocculation paddles, undersized paddles for the specific volume and configuration of the mixing basin, incorrect number of paddles, orientation and angulation of the mixing shafts, baffles in the mixing tanks, and incorrect mixer speeds. The dead space negatively impacts the efficiency of the treatment process [coagulation / flocculation / precipitation] by requiring more chemicals [polymers, caustic, etc.], increases the amount of hazardous industrial metal hydroxide sludge generated, increases the sludge disposal costs, and increases operating costs. It is estimated that an improvement in this process may reduce operating costs by as much as $100K annually.

7. METALS TREATMENT OPERATION: Collaboration with the Oklahoma State University Department of Civil Engineering to improve the current metals treatment operation at the IWTF. [9] This effort was completed in three tasks: (1) determine the appropriate pH range for TAFB-specific chemicals of interest, (2) quantify the temperature impact on the chemical feed rates and develop a mathematical expression / correlation that will incorporate a temperature correction factor, and (3) determine the optimum feed rate for the electrolytic polymers [ACH, A50, and B1120]. A chemical speciation equilibrium model [MINEQL+] was used to compare applicability to TAFB wastewater conditions [9]. Figure 1 illustrates the IWTF metals treatment process. Aluminum chlorohydrate [ACH] and a blend of cationic polymers [A50] are added to Mixing Basin #1 based on hydraulic loading. Caustic is added to Mixing Basin #2 to maintain a constant pH. An anionic polymer is added to the solid contact clarifier based on influent flow rate.

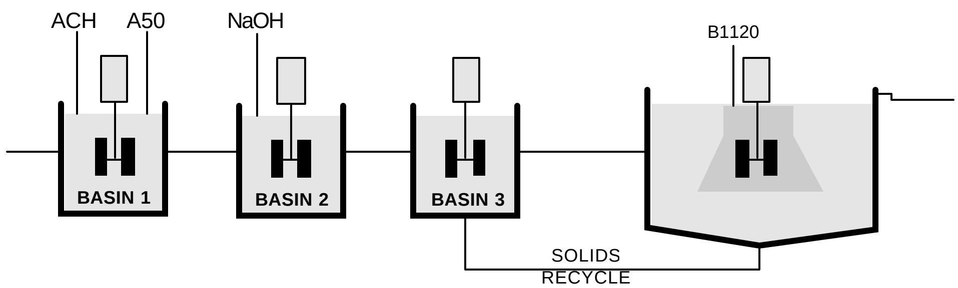

Figure 1. IWTF metals treatment process

For Task 1, jar tests were used to evaluate the effectiveness of the current coagulant / flocculant usage under a variety of operating conditions, particularly at various pH values [14]. Jar test procedures can be used to provide information on the most effective flocculants, optimum dosage, optimum feed concentration, effects of dosage on removal efficiencies, effects of concentration on influent suspension on removal efficiencies, effects of mixing conditions, and effects of settling time. The initial focus was on the potential for different pH values in the mixing basins to improve the metals precipitation. As part of this task, MINEQL+ 4.0, a chemical speciation model, was used to determine the chemical distribution of all species in solution at equilibrium. The model was used to predict the complete equilibrium state [final concentration and bindings] as a function of initial state of pH titration in the simultaneous presence of metal ions. MINEQL+ output was compared to laboratory jar tests and determined the applicability for TAFB applications. From jar tests, a pH range of 8.3 to 8.5 as determined to be the optimum operating range for metals removal. The MINEQL+ does not appear to be practical as a process control and was not recommended for further development [9].

For Task 2, the objective was to examine the effect of seasonal temperature fluctuations on the process and determine if the dosage and timing of the coagulant scheme currently in use should be adjusted as a function of the wastewater temperature. Once coagulant dosages have been optimized for varying temperature, potential savings from any decreased chemical usage will be examined. At least three temperature conditions [average winter, average spring / fall, and average summer] were tested, focusing on the effect of these temperatures on the effectiveness of the current coagulation and metals precipitation process. Standard jar test techniques, run with samples of IWTF influent and varying concentrations of the various chemical amendments currently in use, will be performed at each of the temperature ranges of interest. It is known that water temperature affects fluid and particle motion and the rate of adsorption and precipitation reactions. Temperature changes from 20°C to near freezing produced significant problems in the flocculation process. To determine the effects of temperature on process effectiveness, the various jar tests were carried out at 5°C, 15°C, 23°C, and 35°C, respectively [9]. A systematic approach, varying one amendment at a time, was used to determine which coagulants, if any, were particularly sensitive to temperature change. The goal was to determine an optimum dose for each amendment at any operating temperature. All involved altering the reaction time available for the primary coagulants currently used.

Based on the preceding discussion of the experimental results, the following conclusions are proposed: (1) at all but the lowest temperatures [5°C], the dosage of A50 can be lowered without negatively affecting the plant's performance; (2) when the wastewater temperature is above 23°C, the A50 polymer dosage can be lowered by 50 to 75 percent without impacting the effluent turbidity; (3) decrease in the ACH dosage has a negative impact on process performance, irrespective of temperature; (4) there is no benefit to changing the dosage of the B1120 polymer; (5) variations in the timing or location of coagulant additions did not appear to have any positive effect on process performance; and (6) minor changes to the coagulant dosage did not negatively impact the efficiency of the metals precipitation process.

For Task 3, the following recommended polymer dosages are made for optimum IWTF operation [coagulation / flocculation / metals precipitation reactions]: (1) the ACH and B1120 doses remain unchanged at all wastewater temperatures; (2) below 5°C [which is never expected, based on available temperature data], the A50 dose can be lowered from its current levels. Taking a conservative approach, it is recommended that when wastewater temperatures are below 15°C [59°F] current A50 dosages remain in place. When wastewater temperatures are 15°C and above, the A50 dose can be lowered to 50% of its current value; (3) a less conservative approach would recommend that when wastewater temperatures exceed 27°C [80°F], the A50 dose can be lowered further, to 75% of its current dose. Caution should be exercised with this approach, and additional monitoring is recommended to allow quick reaction should process upsets occur; and (4) it is recommended that the current location and timing of coagulant doses remain unchanged.

Benefits include a reduction in polymer purchase costs, reduction in the amount of hazardous waste discharged off-site, reduction in the hazardous waste disposal costs, reduction in the environmental compliance burden, and improvement in the quality of the plant wastewater effluent. The most tangible cost reduction is associated with purchasing less chemical [ACH, A50, and B1120]. An additional cost benefit will be reducing the costs from disposing of the hazardous waste. Intangible benefits are the reduction in the amount of hazardous waste disposed off base, reducing the environmental compliance burden, and improving the IWTP effluent quality. While the last three have cost savings, they will be difficult to quantify. By contrast, the first two tangible benefits will be easy to quantify because of historical polymer purchase data and hazardous waste disposal data. Note that there will be labor and maintenance savings, but neither will be determined because of their difficulty and insignificance. The total projected annual savings is roughly $110,000 [9].

8. IWTF FINAL FILTER PERFORMANCE: OC-ALC engineers have been tracking the

performance of the IWTF final pressure filters since the addition of a new zeolite media. From the initial data, it appears that there is very little to no improvement with the zeolite media. According to the literature, we should be seeing 75 percent or better reduction in turbidity, but are seeing little to no reductions [1]. One method of tracking filter performance is to monitor the effluent turbidity over time. Figure 2 tracks the range of final filter effluent turbidity over the last two years [CY2001 and CY2002]. The final filtration process was brought back in service in late MAY02 [520 on the *x*-axis of Figure 2]. Graphically, the operating range for the effluent turbidity has increased. Comparing the average and standard deviation before and after the new filters were on-line, indicates that the average turbidity has increased 48 percent from 31 to 46 NTUs. The standard deviation has increased from 23 to 29, indicating an increased in the instability of the new final filters and zeolite media.

Another method of graphically representing the performance of process units is to plot the influent parameter as a function of the effluent parameter. For example, to track the performance of the final filtration process, Figure 3 plots the influent turbidity as a function of the effluent turbidity. At the least, there should be a linear relationship, whereby the effluent turbidity should be equal to the influent turbidity. In reality, the effluent turbidity should be 50 to 75 percent lower than the influent turbidity [1]. For all of CY2001 and the first five months of CY2002, the wastewater polishing was accomplished with the chemical treatment filters [CTFs], which needed work. As you can see from Figure 3, the performance of the CTFs was not much better if not worse. In late MAY02, the final filters were brought back into service. From Figure 3, the performance did not improve significantly. After one month of service, the final filters were beginning to have trouble removing the turbidity. As illustrated, the performance of the final filters with the zeolite media did not improve the effluent quality. Over the last months, the zeolite media has actually lowered the effluent quality as indicated by an increase in the effluent turbidity.

9. IWTF HAZARDOUS WASTE MINIMIZATION: OC-ALC engineers have reduced the amount of hazardous waste sludge disposal by 3,745,600 pounds annually [80.2 percent], translating to a savings of $750,000 in hazardous waste disposal costs [82 percent]. From Figure 4, in CY1995, the IWTF disposed of 4.66 million pounds of wet industrial hazardous waste at a cost of $916,000. In CY2002, the IWTF had reduced the amount of hazardous waste disposed off-site by 3.75 million pounds [80 percent reduction]. Hazardous waste disposal costs for CY2002 totaled $165,000, saving over $750,000, annually. This significant reduction was primarily accomplished by the use of a plate-and-frame mechanical filter press to dewater the industrial sludges prior to disposal.

REFERENCES

1. Metcalf & Eddy, *Wastewater Engineering: Treatment-Disposal-Reuse*, McGraw-Hill Book Company, New York, 1979.

2. U.S. EPA, *Background Document for the Surface Impoundment Modeling System [SIMS]—Version 2.0*, EPA-450/4-90-019b, National Technical Information Services, 1990.

3. U.S. EPA, *Air Emissions Models for Waste and Wastewater*, EPA-453/R-94-080A, National Technical Information Services, 1990.

4. Metcalf & Eddy, *Wastewater Engineering: Collection-Treatment-Disposal*, McGraw-Hill Book Company, New York, 1979.

5. Vigon, B.W., D.A. Toole, B.W. Cornaby, and H.C. Latham, *Lifecycle Assessment—Inventory Guidelines and Principles*, Lewis Publishers, Boca Raton, FL, 1992.

6. Adams, C.A., & Eckenfelder, W.W., *Process Design Techniques for Industrial Waste Treatment*, Envir Press, Nashville, 1974.

7. Hudson, Herbert E., *Water Clarification Processes Practical Design and Evaluation*, Van Nostrand Reinhold Company, New York, 1981.

8. Levenspiel, Octave, *Mixed Models to Represent Flow of Fluids through Vessels*, Canadian Journal of Chemical Engineering, pp 135-138, August 1962.

9. Wilber, G.G., *Industrial Wastewater Treatment Plant Hydraulic Loading: Part 2-Temperature Effects on the Coagulation Process*, OC-ALC/TIET Technology and Engineering Projects, Summer 2002.

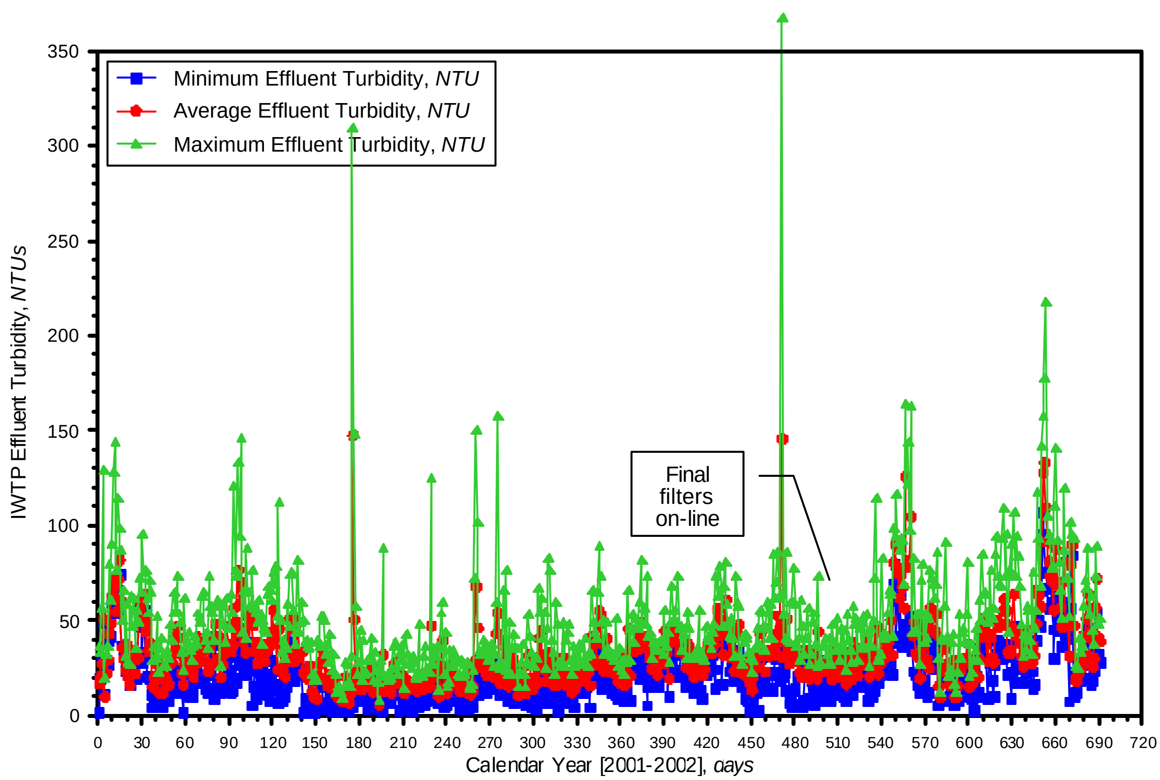

Figure 2. Effluent turbidity as a function of CY2001 and CY2002

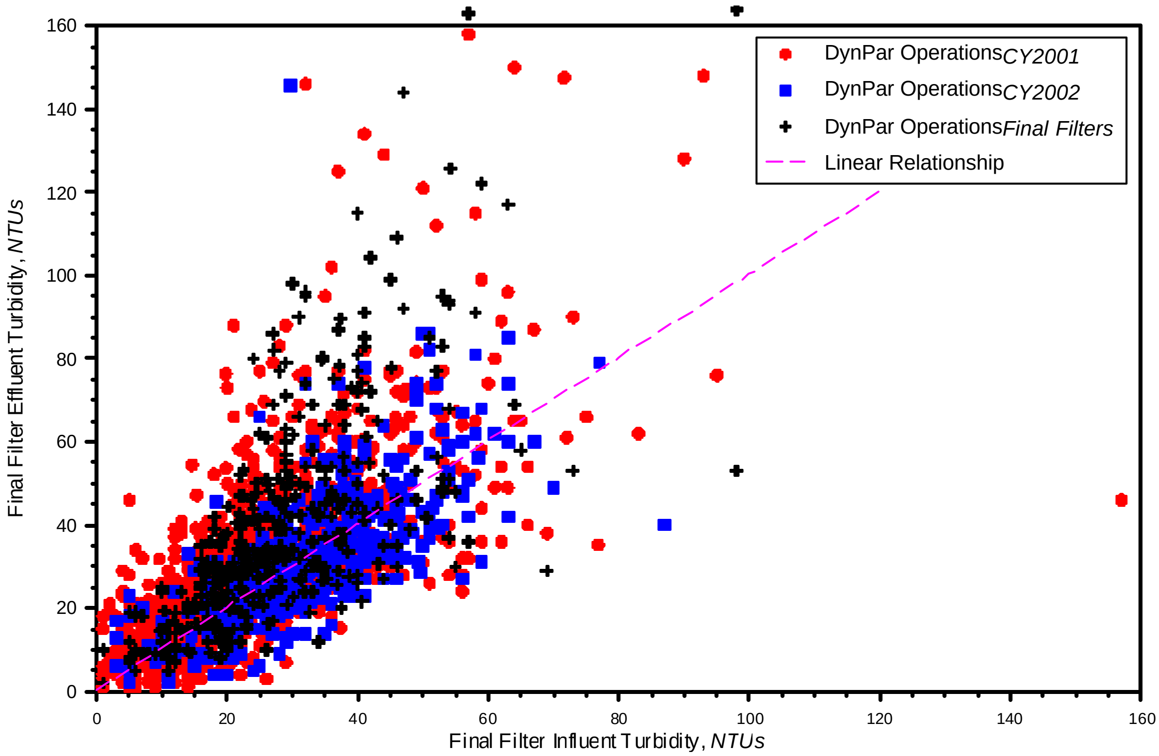

Figure 3. Correlation between final filter influent and effluent turbidity

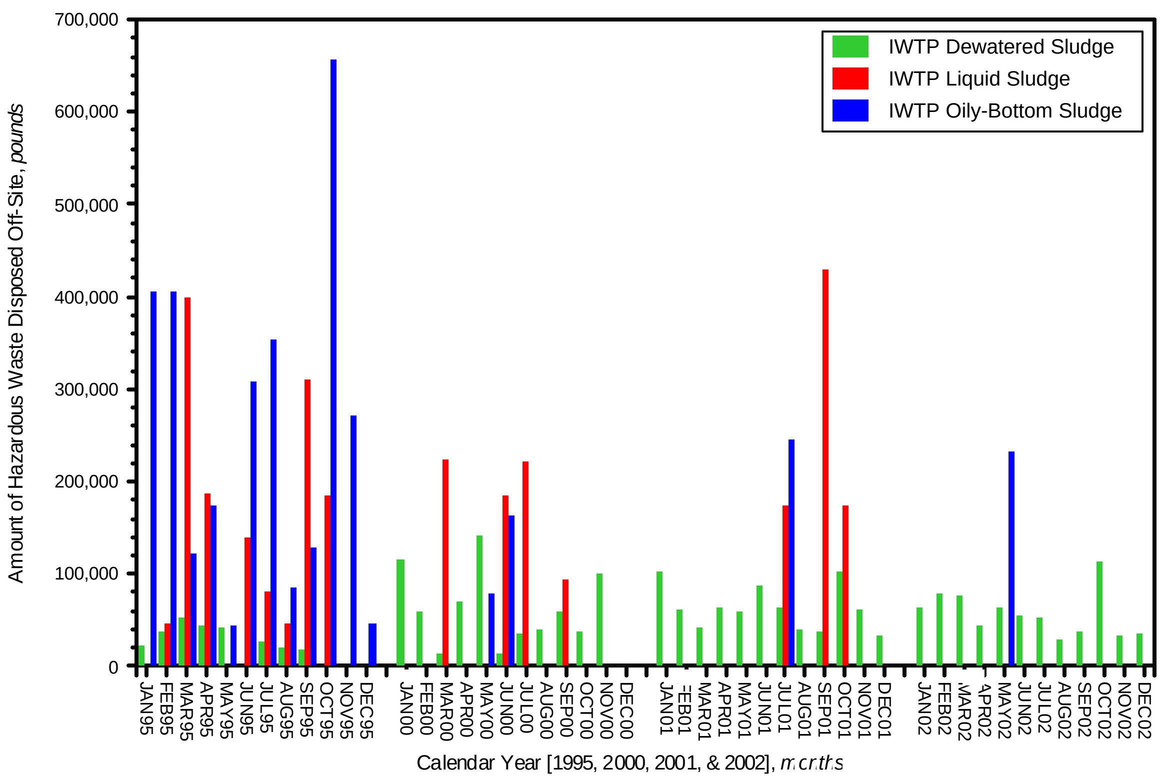

Figure 4. IWTF hazardous waste disposal [dewatered, liquid, and oily-bottom], *pounds*