ChemScan® UV-6100 Process Analyzer

PROJECT REPORT AND DATA SUMMARY
NITRATE AND PERCENT TRANSMITTANCE MONITORING
DEMONSTRATION REPORT

City of Burbank, CA
Water Reclamation Plant
Burbank, CA

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Background

The City of Burbank Water Reclamation Plant is a 9.0 MGD biological treatment facility providing treated effluent for cooling water and irrigation uses through a city owned reclaimed water distribution system.

During 1994 and early 1995 a study was conducted by Montgomery-Watson, Pasadena, CA to evaluate the feasibility of using UV disinfection to replace gaseous chlorine at this facility.

ChemScan was asked to participate in this study by furnishing an on-line process analyzer that was capable of performing an automatic analysis of percent transmittance and also of nitrate at 15 minute intervals in treated secondary effluent.

Project Summary

A method was developed to convert absorbance intensity measurements by ChemScan at 253.7 nm into a percent transmittance value. Periodic grab samples were obtained by plant personnel and analyzed by a third party certified laboratory.

Some drift was noted in the on-line percent transmittance measurements. It was concluded that the drift was directly related to the time period between zero events, with the most accurate measurements occurring after a new (manual) zero and the least accurate immediately prior to a new (manual) zero. Zeroing is the use of a non-absorbing standard (deionized water) to measure and subsequently subtract the effects of fouling on the optical surfaces of the flow cell.

A newly developed automatic zeroing and clearing mechanism was installed, which resulted in a stable, reliable output for percent transmittance.

Nitrate analysis also benefited from the use of frequent automatic zeroing and cleaning.

A draft of the Montgomery-Watson study report is attached. This information was presented by Montgomery-Watson at the WEF Specialty Conference entitled "Disinfecting Wastewater for Discharge and Reuse", March 18, 1995.

Montgomery-Watson noted that this study was "one of the first to monitor transmittance on an almost continuous basis." It was recommended that "at a minimum, every UV transmittance characterization study include continuous monitoring over some period of time in order to understand its variability."

The ChemScan system is the only known system which can simultaneously monitor transmittance, (JTU) turbidity, iron and total oxidized nitrogen which were found to be among the variable affecting UV disinfection efficiency.

OPTIMIZATION OF ULTRAVIOLET DISINFECTION DESIGN AT THE BURBANK WATER RECLAMATION PLANT

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BACKGROUND

The City of Burbank owns and operates the 9 mgd Burbank Water Reclamation Plant (BWRP) which has produced reclaimed water for local reuse since the 1960's. The treatment train consists of grinding, primary sedimentation, biological treatment through the conventional activated sludge process, sand/anthracite filtration and gaseous chlorine disinfection. Reclaimed water is used for cooling tower make-up water at the City's power plant, on-site utility water, and for green-belt and landscape irrigation. The City has also embarked on expanding its reclaimed water distribution system. Construction of the first of three phases of this program is almost complete. Unused excess reclaimed water is discharged to the Burbank Western Wash which is a tributary to the Los Angeles River. A simplified process schematic of the existing facilities is shown in Figure 1.

Chlorine gas is currently used at the plant for disinfecting the final effluent prior to reuse and/or disposal. The disinfection system consists of two chlorine contact tanks, and ton cylinder storage and feed facilities. In order to meet current codes and provide the necessary reliability, rehabilitation of the disinfection system would require replacement of the chlorine feed facilities, construction of an emergency scrubber system, rehabilitation of the disinfection building, and construction of additional contact volume.

The larger of the two existing contact tanks was damaged during the January 1994 Northridge Earthquake. In order to continue using this tank, structural repairs would be required. Recognizing that a significant portion of the plant's existing disinfection facilities is in need of rehabilitation and/or replacement, the City desires to investigate alternatives to gaseous chlorine disinfection.

A comparative evaluation of chorine gas versus sodium hypochlorite had been previously conducted and showed that chemical costs would make gaseous chlorine disinfection more cost-effective on a present worth basis. Ultraviolet (UV) light disinfection, recently approved by the California Department of Health Services (DOHS) as an alternative to chlorine disinfection in water reclamation, represents another logical option. If selected, UV disinfection would eliminate the risk of acute hazards presented by gaseous chlorine and sulfur dioxide. The UV system minimizes land requirements which is highly desirable given that land is at a premium in the plant's vicinity. Other benefits of UV disinfection include the reduction of effluent toxicity, the minimization of the potential for formation of chlorination by-products and the elimination of the need for a Risk Management and Prevention Plan.

OBJECTIVES

A comparative cost evaluation was performed for gaseous chlorine and UV disinfection. Since the design and operation of any UV disinfection system is highly dependent on the water's UV transmittance capacity, a range of values was considered. The evaluation indicated that with a transmittance value of 55 percent, consistent with the DOHS guidelines, chlorine would be more cost-effective. On the other hand, with a value of 65 percent, similar to filtered effluents from other plants in the Southern California area, UV disinfection would be more cost-effective. The two alternatives would be similar in present worth costs if UV transmittance of the effluent is 60 percent.

Initial grab samples of filtered non-chlorinated effluent from the BWRP indicated a UV transmittance of around 62 percent. While this value is higher than that recommended by DOHS, it is lower than the typical value for filtered effluent. To further evaluate the UV disinfection option, the City initiated a six month testing program. The objectives of the program were:

- to characterize the effluent's UV transmittance for the purpose of selecting a disinfection technology,
- to develop criteria for the design of the UV disinfection system should UV disinfection be selected, and
- to investigate the cause of the low transmittance values initially encountered.

METHODS

Filtered non-chlorinated samples were pumped for analysis once every 20 minutes to an on-line UV transmittance analyzer. The on-line equipment also provides analysis for NO_x using ultraviolet-visible absorption spectrometry. Equipment accuracy was evaluated by taking split samples for analysis at an independent laboratory. Other parameters also monitored included TSS, VSS, TOC and total iron. Suspended solids monitoring was soon discontinued since they were consistently low and did not show correlation with UV transmittance.

In order to maximize the use of limited funds, and in addition to sampling and analysis of the filtered non-chlorinated effluent, other parameters which are monitored as part of the normal plant operations, were also reviewed. These include influent metals (composites and grabs) and effluent turbidity (continuous). Metals are monitored at the plant influent on a weekly basis as part of the City's Industrial Pretreatment Program and include iron, cadmium, chromium, copper, silver, nickel, lead and zinc. Sampling locations are shown in Figure 2.

RESULTS

Results of the UV transmittance monitoring are presented graphically in Figure 3 for the period 10/26/94 to 12/7/94 which shows both the instantaneous values recorded, as well as the 24-hour moving average. The average transmittance for this period was 62 percent with the 90th and 10th percentile values being 67 percent and 57 percent, respectively. These results indicate both a diurnal variation as well as a longer term variation in transmittance. Instantaneous values typically varied within a 5 to 7 percent range on most days, but fluctuated as much as 10 percent on a few days. Similarly, daily average values varied within a 15 percent range (55 to 70) during that period. These are significant variations which could not have been captured by typical monitoring programs using daily or weekly grab samples. These variations may have been caused by a number of parameters. The impacts of the following parameters were investigated as part of this project:

- turbidity,
- metals,
- nitrates and nitrites, and
- organic compounds.

The results of these investigations are discussed below.

Turbidity

Effluent turbidity offers perhaps the most obvious correlation with UV transmittance. Turbidity of the final effluent is monitored on a continuous basis as part of normal plant operations. The two parameters are plotted in Figure 4 for the period 11/23/94 to 11/27/94 which represents typical plant performance and effluent quality. This figure shows that every time effluent turbidity improved, so did transmittance, and vice versa.

It should be noted that the existing filters are old and are not in accordance with current industry standards. With one unit out of service, the peak hydraulic loading rate is 6 gpm/sq.ft. Furthermore, the media bed is only 2 feet deep. Based on the diurnal fluctuations observed in effluent turbidity, it appears that the higher turbidities observed occurred during peak flows when the filters were overloaded. It is expected that filtered effluent turbidity will exhibit less variation once the new filters, designed using current industry standard criteria and to be installed under the upcoming plant upgrade project, are operational. Other improvements planned under the plant upgrades project such as modifications to the aeration system should enhance plant reliability and further improve effluent quality.

Metals

A significant area served by the BWRP consists of light industries including metal plating, metal finishing and anodizing, electrical component manufacturing, film processing/media support, metal forging, chemical manufacturing, cosmetics and plastics. Although the City's Industrial Pretreatment Program has successfully increased compliance with federal categorical standards from 62% to over 95%, the industrial component continues to represent a significant portion of the plant influent flow. It is known that some metals typical of those present in industrial discharges such as iron, chromium, copper and nickel are identified to be absorbers of UV radiation in solution. Further, based on historical operation of the BWRP, illegal discharges into the collection system reportedly containing high concentrations of some of these metals have resulted in process upsets and reduction in treatment efficiency. Hence, it was important to evaluate the potential impacts of metals on UV transmittance.

In order to examine the impact of iron on UV transmittance, a sample of distilled water was spiked with ferric chloride ($FeCl_3.6H_2O$) and UV-254 transmittance was measured at various concentrations of iron up to 3.5 mg/l. As shown in Figure 5, this confirmed the UV radiation absorbing properties of iron. It also indicated that, within the range of iron concentrations encountered in the BWRP filtered effluent (0.1 to 0.28 mg/l), dissolved iron has a detectable but not major impact on UV transmittance (2 to 3 percent), especially when considering the impacts of other constituents and variables in the water and the accuracy of experimental procedures. In order to verify this conclusion for the BWRP, samples of filtered non-chlorinated effluent were monitored for iron. Total iron concentrations encountered ranged between 0.1 and 0.28 mg/l. At these concentrations, no correlation could be made between iron and UV transmittance, as shown in Figure 6.

Even though iron, and perhaps other metals, may not have a direct significant impact on UV transmittance, as demonstrated above, these metals may still potentially impact performance of a UV disinfection system in a water reclamation plant. At high concentrations, some of these metals can be toxic to the biological treatment process, and hence can reduce treatment performance of the plant. This may result in poorer effluent quality (e.g., higher turbidity) which may, in turn, reduce transmittance.

In order to investigate if this is occurring, available data on influent metals were reviewed. A comparison of these influent metals data and the filtered effluent UV transmittance data suggests that, although some high metal events can be responsible for low transmittance values, there is no definitive correlation between the two parameters. An example of this comparison is shown in Figure 7 which shows concentrations of chromium in 24-hour composite samples and presents the average, maximum and minimum UV transmittance values for the respective 24-hour period. Based on the data collected, this comparison cannot suggest a relationship between influent metals and effluent transmittance.

While not directly related to this study, it is of interest to note that the influent iron concentrations to the BWRP are typically around 1 mg/l but have been as high as 2.3 mg/l within the duration of this project. Effluent concentrations of iron, on the other hand, were observed to be in the 0.1 to 0.28 mg/l range. Hence, there appears to be an order-of-magnitude reduction in iron concentrations between the raw influent and final effluent. The significance of this observation is that iron is commonly dosed at various locations within a collection system or a treatment train for enhancing precipitation and/or control of hydrogen sulfide production. This finding indicates that the use of iron in the treatment train may not necessarily have a significant adverse impact on effluent UV transmittance, assuming that most of the iron dosed will precipitate out with the sludge upstream of the disinfection process. Of course, this finding should be verified with site-specific conditions by characterizing the influent and performing demonstration-scale testing prior to proceeding with actual design of a UV disinfection system. This finding is consistent with the findings of Noesen et al (1995) which indicated that the addition of ferric chloride in the collection system did not appear to have an impact on the inactivation of total coliform when UV disinfection is used.

Nitrates and Nitrites

As with most reclamation plants in the Southern California area, the BWRP has a NO_x-N (NO_3-N + NO_2-N) effluent limitation. For the BWRP, the limit is 8 mg/l. Other reclamation plants, which do not discharge to a surface body of water, may not be regulated for nitrates and, hence, may have higher nitrate values in the effluent depending on the type of treatment process. Since nitrates and nitrites are known to absorb UV radiation in solution, it is important to evaluate the impact of NO_x on UV disinfection performance.

The UV absorption spectrum for nitrates is presented in Figure 8 and shows that the maximum absorption occurs around a wavelength of 212 nm. It also shows that UV absorption becomes negligible at a wavelength of 254 nm, indicating that the impact of nitrates on UV disinfection performance should be minimal. To further investigate the impact of nitrates on UV-254 transmittance, five samples of filtered non-chlorinated water from the BWRP were spiked with up to 10 mg/l of nitrates (as N). The results of this experiment are summarized graphically in Figure 9 which clearly shows a reduction in transmittance with increased nitrate concentrations. The results indicate that with an increase of 10 mg/l in NO_3-N, UV transmittance drops by approximately 2 to 3 percent. Since any reduction in transmittance will increase operating costs of a UV disinfection system, there may be some merit to controlling effluent NO_x concentrations.

Organic Compounds

Some organic compounds normally found in wastewater, such as lignin, tannin, humic substances and aromatic compounds are known to absorb UV radiation (Eaton, 1995). UV absorption may be a useful surrogate measure of selected organic constituents in wastewater (Bunch et al, 1961, and Mrkva, 1971). UV absorption has also been used to monitor industrial wastewater effluent (Bramer et al, 1966). Specific absorption, the ratio of UV absorption to organic carbon concentration, has been used to characterize natural organic matter (Edzwald et al, 1985, Thurman 1985, and Owen et al, 1993).

Through the City's Industrial Pretreatment Program, it is known that some surfactants are periodically discharged to the City's collection system by the industries. In order to test for the presence of organics in the plant effluent, and to investigate whether they have an impact on transmittance, filtered non-chlorinated samples were also monitored for TOCs. The data are summarized graphically in Figure 10 which appears to verify the correlation between the two parameters. The correlation seems to be confirmed throughout a wide range of TOC values ranging between 9 and 21 mg/l, with a correspondingly wide variation in UV transmittance which ranged between 68 and 54 percent, respectively.

This correlation between TOC and UV transmittance may suggest that the organics in the effluent represent a significant element impacting transmittance. This, however, may be the result of organics bound up in effluent volatile suspended solids, and consequently may be linked to effluent turbidity and treatment efficiency. If that is the case, then this finding is a consequence, or extension, of the correlation between effluent quality and transmittance discussed earlier. However, review of limited solids (TSS and VSS) data collected (4 data points) for the samples plotted in Figure 10 shows no correlation between VSS and TOC. Therefore, the high TOC values reported are not necessarily related to high turbidity or compromised plant performance, but appear to be mostly in the dissolved form.

CONCLUSIONS

1. This UV transmittance characterization study is perhaps one of the first to monitor transmittance on an almost continuous basis. It has shown that variations normally overlooked by the typical daily or weekly monitoring programs may have serious impacts on system design and/or operation. It is recommended that, at a minimum, every UV transmittance characterization study include continuous monitoring over some period of time in order to develop an understanding of its variability.

2. The data collected suggest a correlation between turbidity and UV transmittance. As expected, the relationship is one of an inverse dependence. This relationship was observed within the range of effluent quality typically observed in tertiary treatment plants, with turbidity less than 2 NTU.

3. Although iron in solution is known to be a strong absorber of UV radiation, the concentrations at which it was observed in the final effluent were sufficiently low (less than 0.3 mg/l) that no correlation could be made with UV transmittance. The relationship was verified in distilled water at these concentrations, but was most likely masked by other interferences found in the final effluent.

4. While the local industries are known to contribute metals to the BWRP, there was no conclusive evidence that the metals were a direct cause of low transmittance values encountered. In fact, based on the data collected it appears that organics, measured by TOC, had a more significant impact on effluent transmittance. It appears that these organic compounds were mostly dissolved.

5. In order to meet effluent NO_x-N limitations of 8 mg/l and to minimize operating costs, the plant is operated in a non-nitrifying mode. Hence, effluent NO_x-N concentrations were typically less than 4 mg/l. At these concentrations, nitrates and nitrites had no detectable impact on UV transmittance of the effluent. Based on some spiking experiments that were performed, however, higher NO_x-N concentrations may have an impact on UV-254 transmittance. Therefore, facilities that have nitrogen control capabilities and use UV disinfection may benefit from minimizing effluent NO_x-N even if not required to do so by regulatory limitations.

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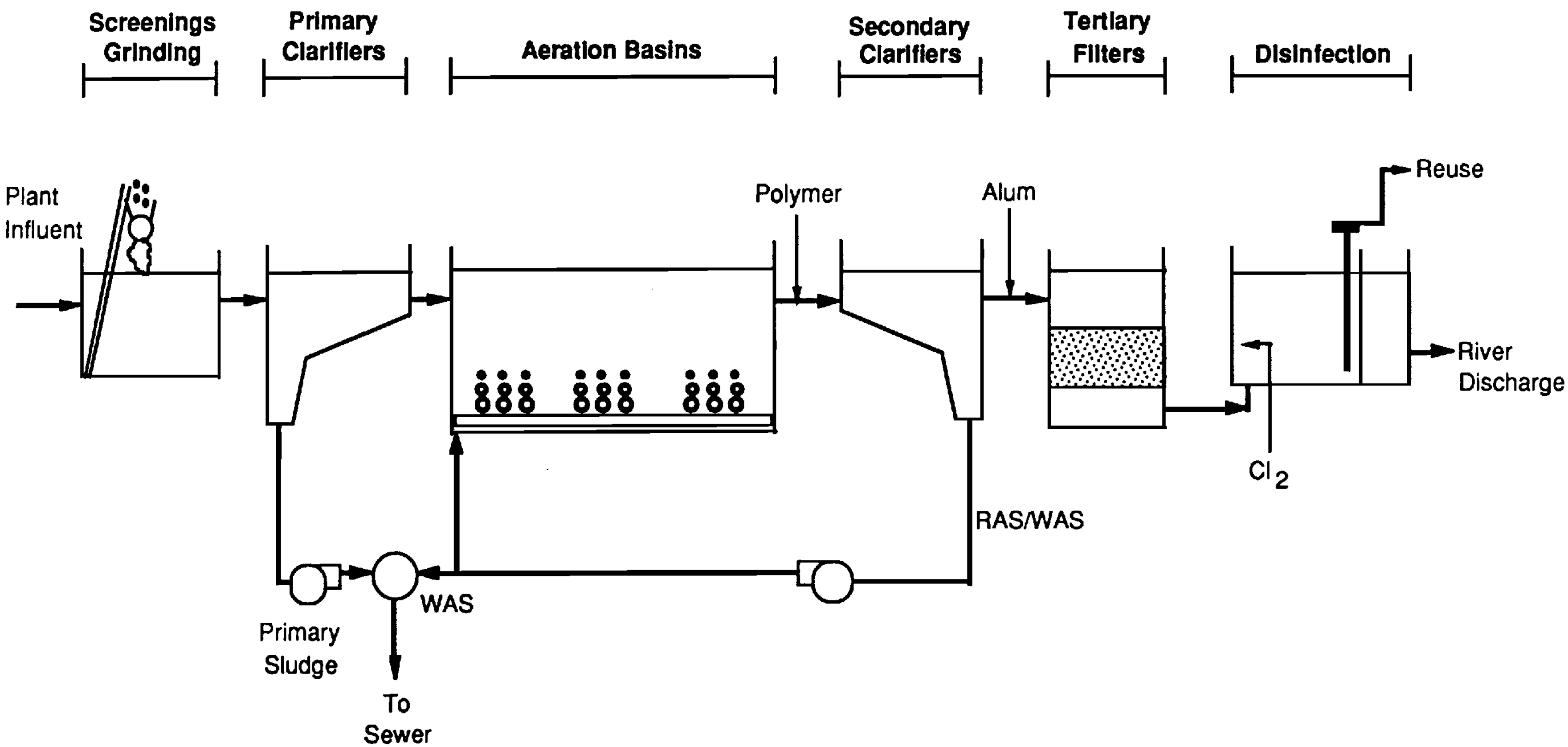
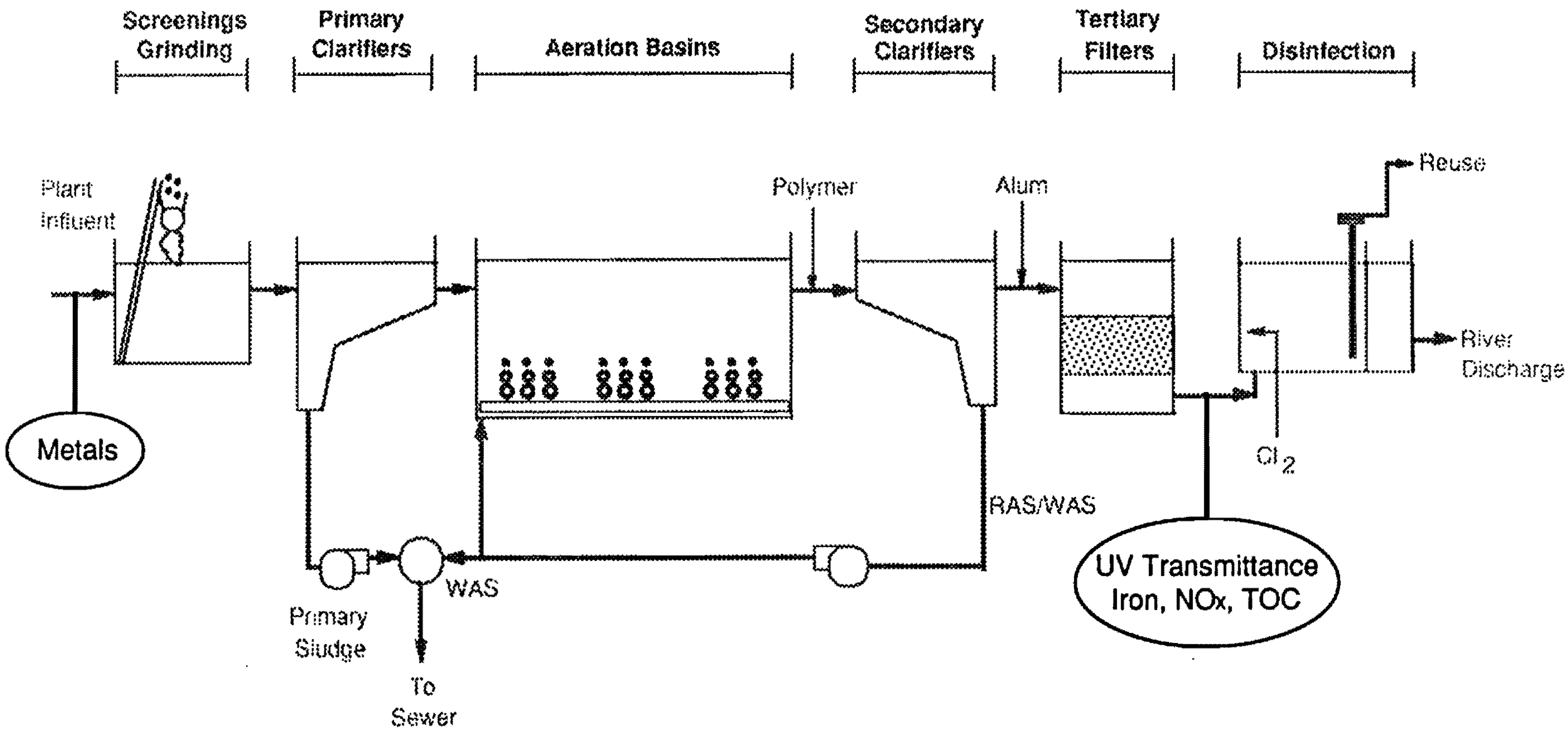
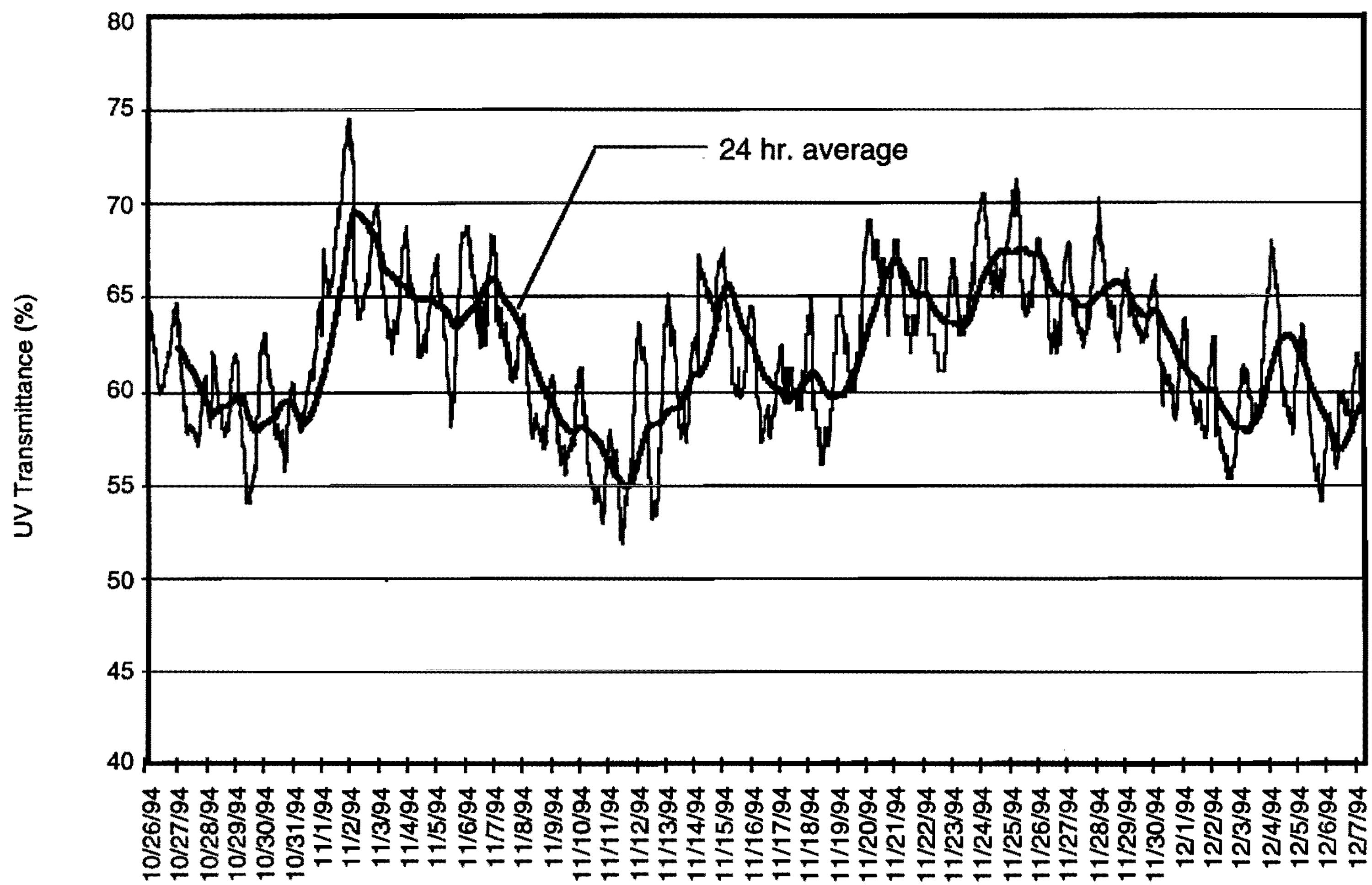


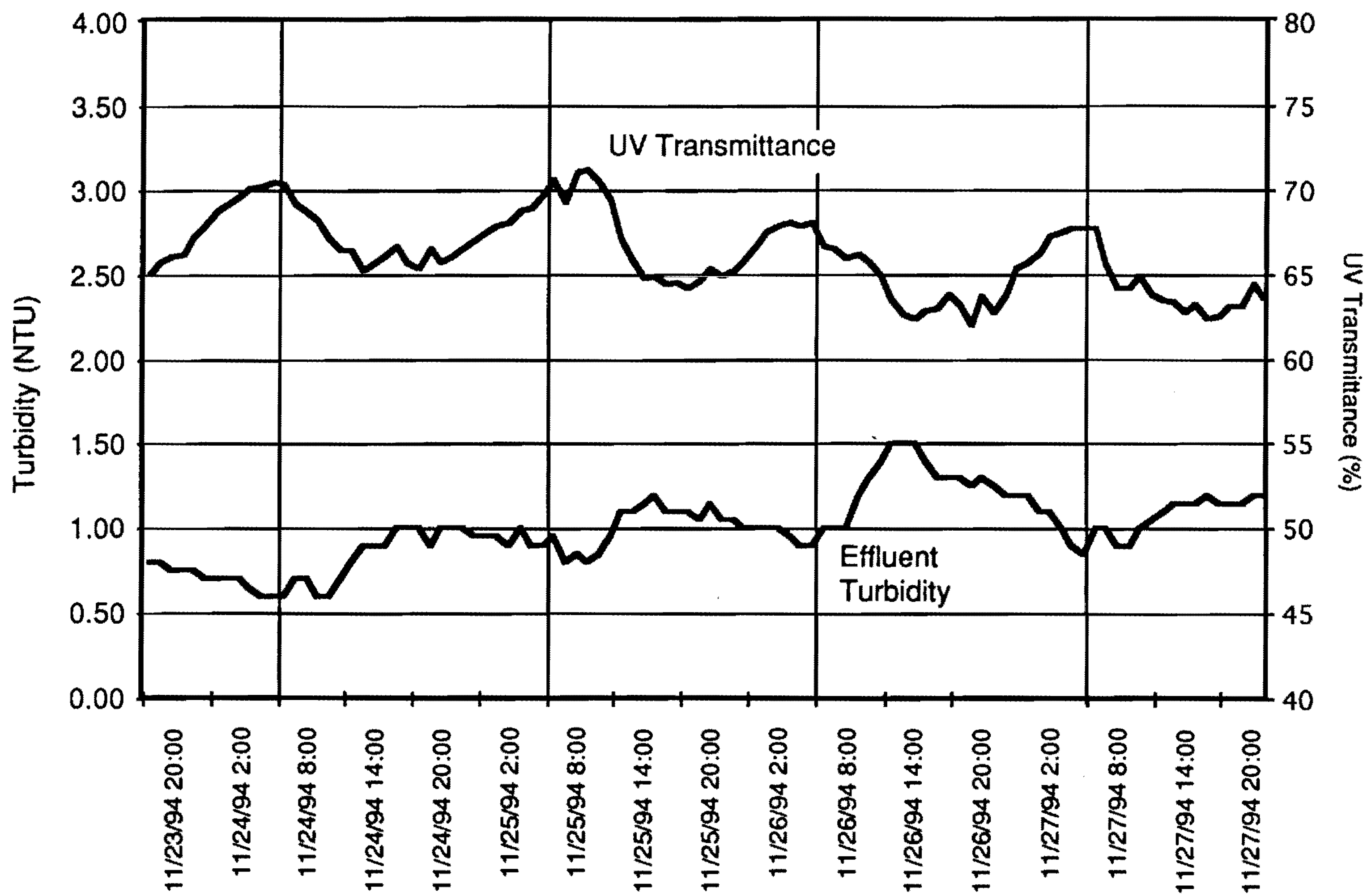
Burbank Water Reclamation Plant Simplified Process Schematic
Figure 1



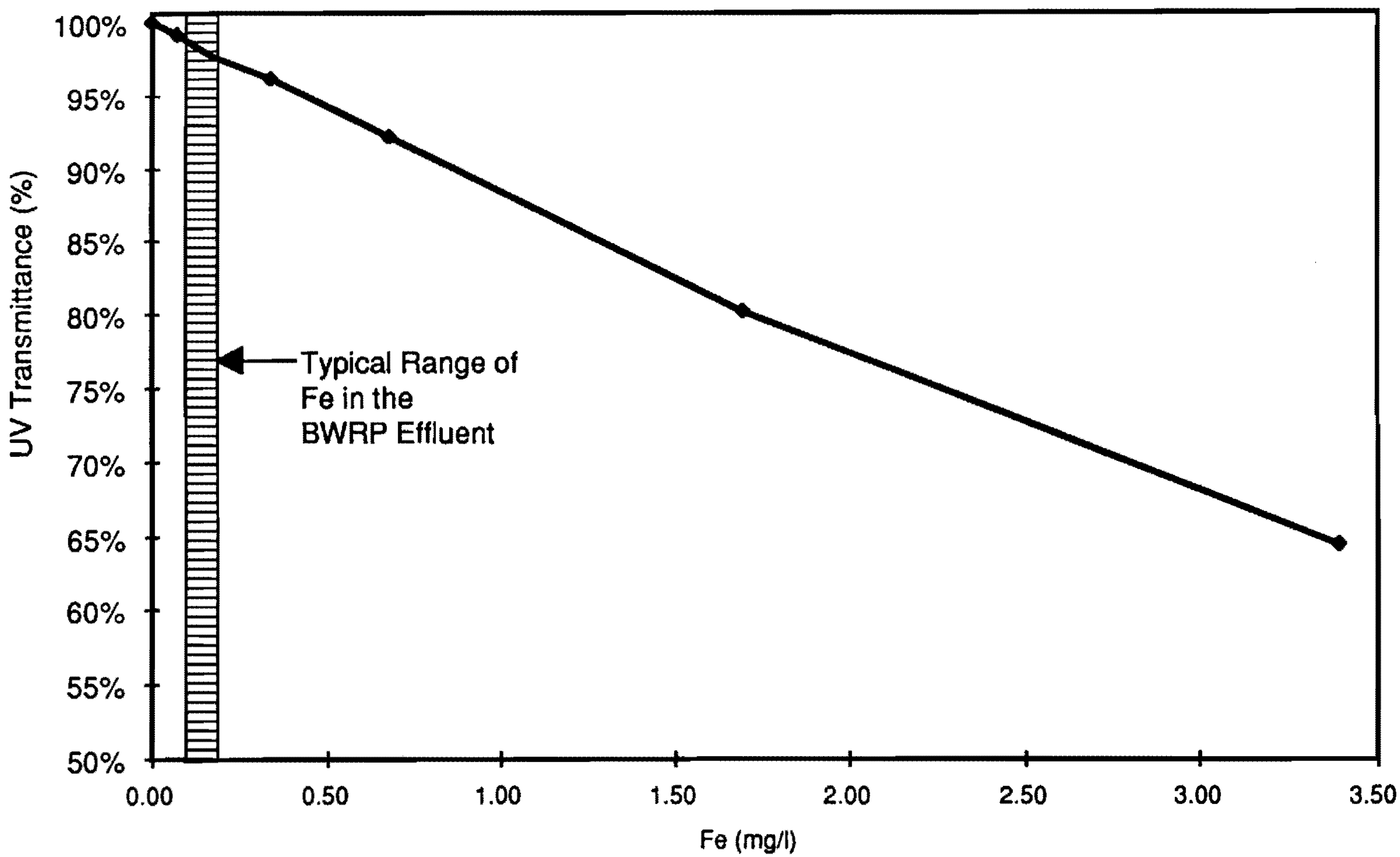
Sampling Locations
Figure 2



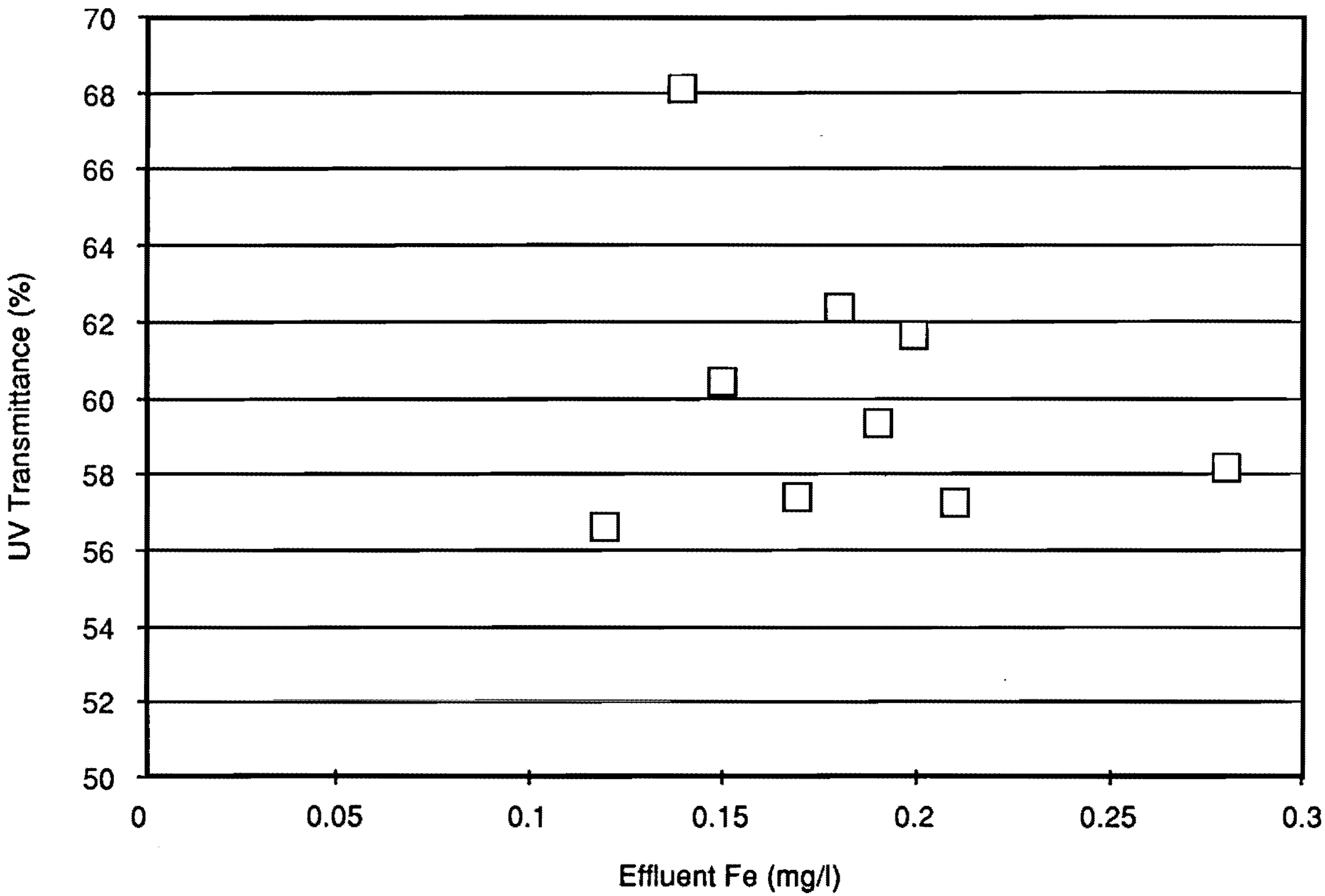
UV-254 Transmittance Data (10/26 - 12/7)
Figure 3



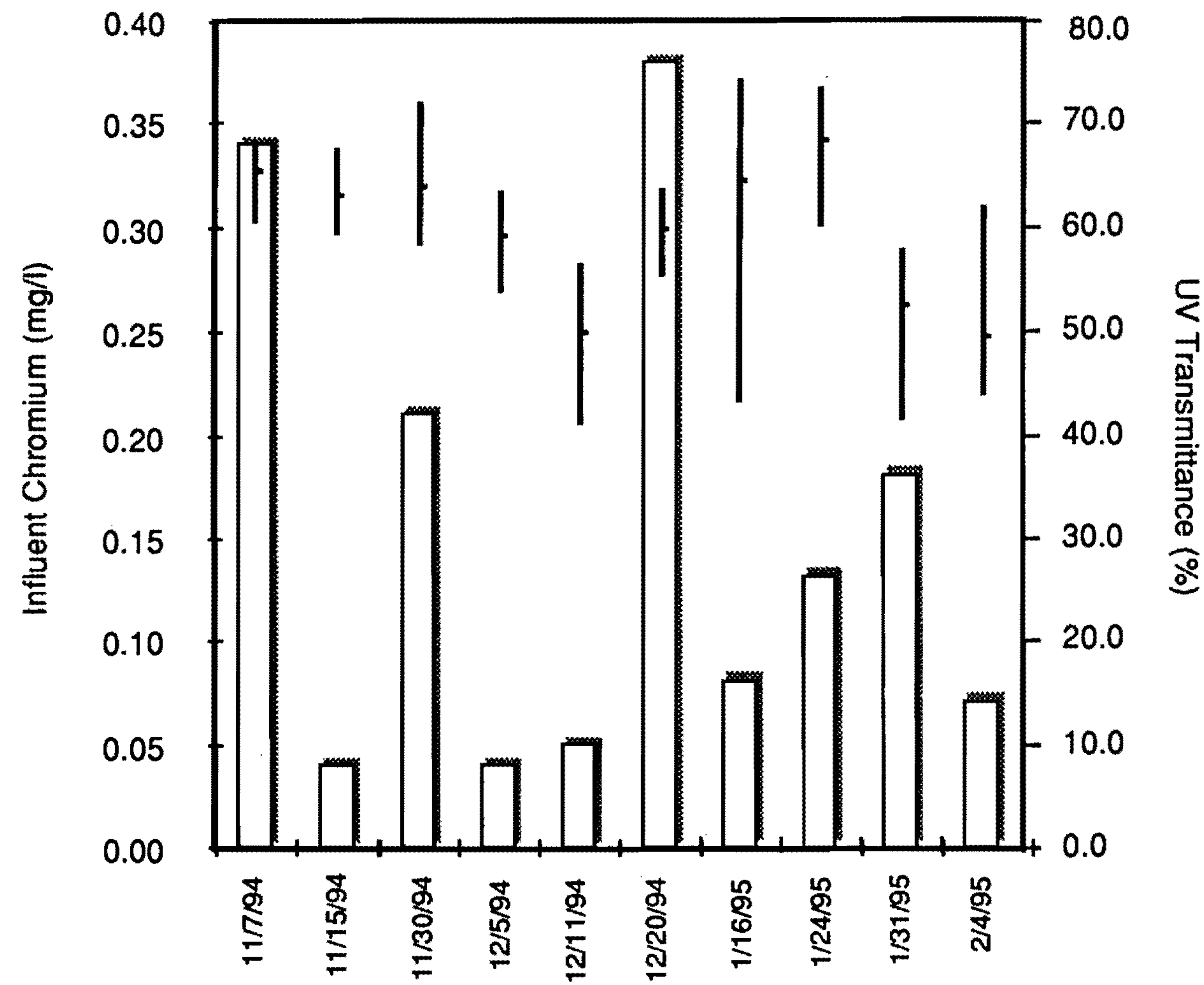
Impact of Turbidity on Transmittance
Figure 4



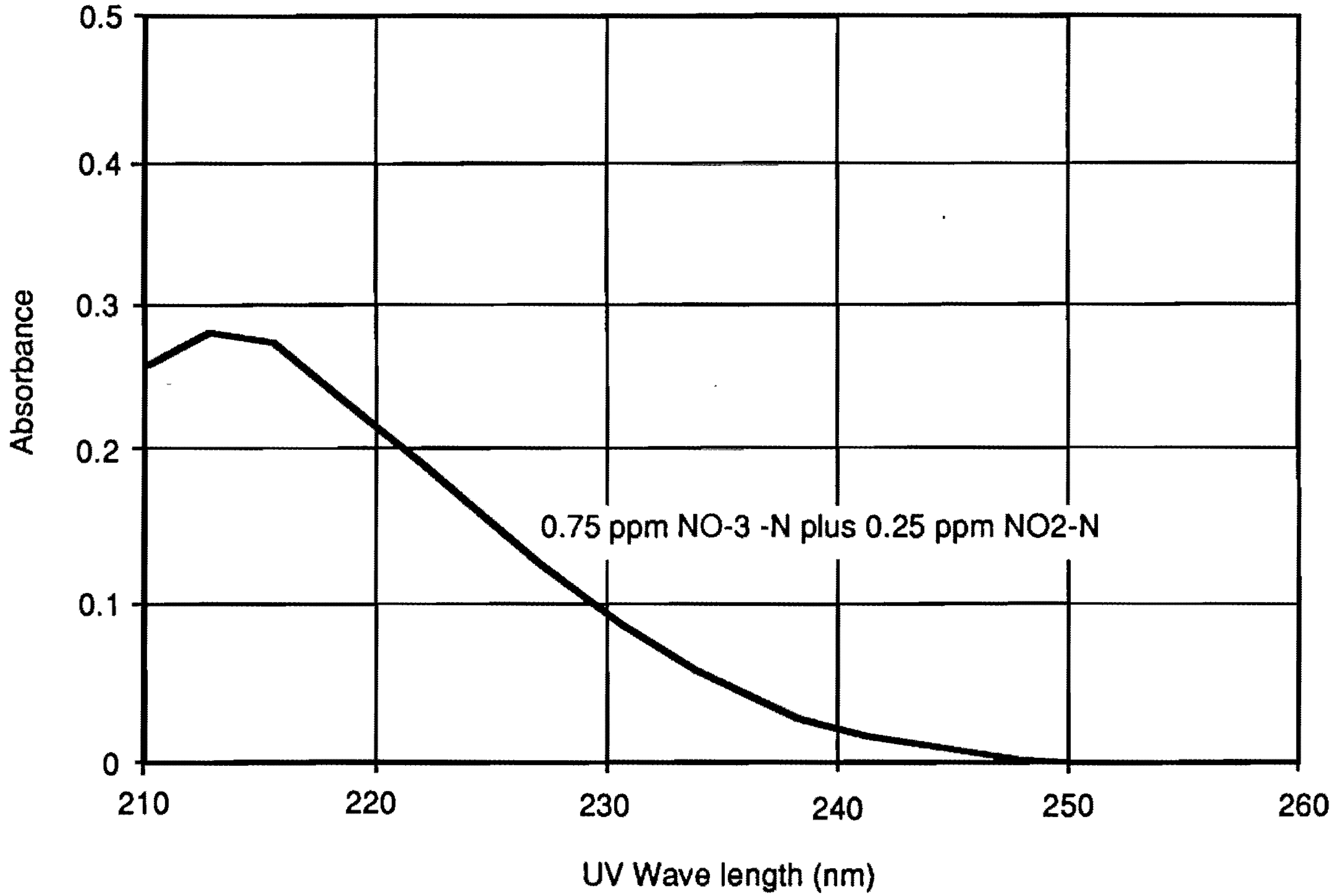
Impact of Iron on UV Transmittance in Distilled Water
Figure 5



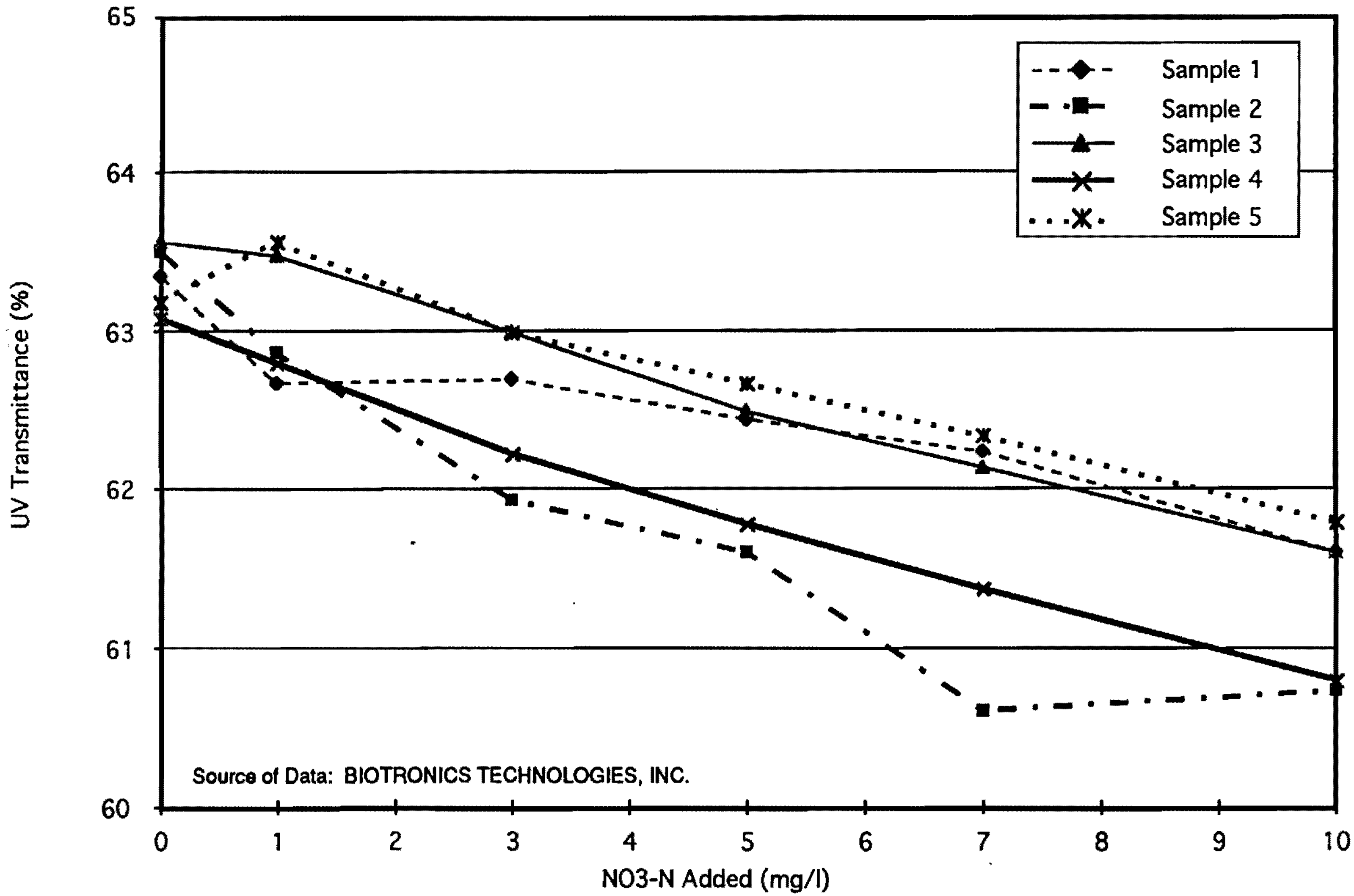
Transmittance vs. Iron in Filtered Effluent
Figure 6



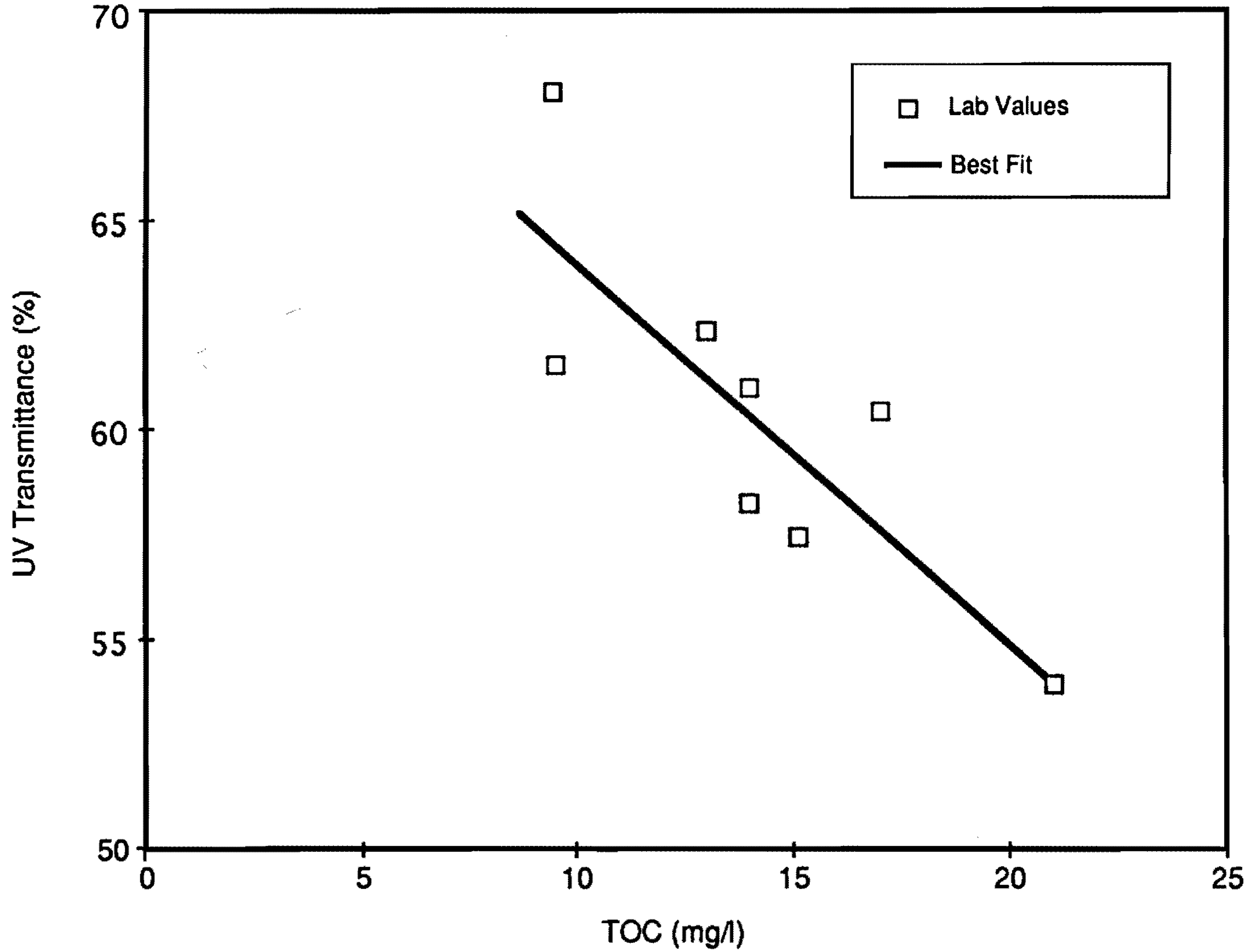
Impact of Influent Chromium on Effluent Transmittance
Figure 7



UV Absorption Spectrum for Nitrates
Figure 8



Impact of Nitrates on UV Transmittance in Final Effluent
Figure 9



Impact of Total Organic Carbon on Transmittance in Final Effluent
Figure 10