

Water Factory 21  
Waste Water Reclamation  
& Sea Water Barrier Facilities

February 1973  
Orange County Water District  
1629 West 17th Street  
Santa Ana, California 92706

WATER FACTORY 21  
WASTE WATER RECLAMATION  
AND SEA WATER BARRIER FACILITIES

by

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## INTRODUCTION

The Orange County Water District (OCWD) was formed in 1933 by special act of the California Legislature. Under this act, OCWD has the responsibility and authority to provide:

- 1) Management of the ground water basin;
- 2) Conservation of the ground water supplies, including both quantity and quality of the water; and
- 3) Protection of Orange County's water rights in the natural flows of the Santa Ana River.

The District covers an area of about 315 square miles, generally overlying the coastal basin of the Santa Ana River in Orange County. Water supply within the District is from the ground water basin through wells or by direct service from The Metropolitan Water District of Southern California (MWD). At the present time, the total water use within the District is about 300,000 acre feet per year; about two-thirds of this amount is supplied by the underground basin, and the remaining one-third is supplied through direct service by MWD.

The growth rate of Orange County in the transition from an agricultural to an urban economy after World War II placed large demands upon the ground water supply. The basin was overdrafted and by 1956 there was an accumulated overdraft of over 500,000 acre feet. Because of this overdraft, sea water intruded inland as much as 3-1/2 miles in the Talbert Gap (the ancient channel of the Santa Ana River). In 1949, OCWD began importing Colorado River water and percolating it into the ground water basin through surface spreading facilities in the Santa Ana River.

OCWD owns approximately 750 acres of the Santa Ana River bed, and utilizes the area for ponding imported water and natural flows of the river to replanish the underground basin. In addition, the District owns two large off-river spreading

basins of approximately 100 acres each. This ground water replenishment program by surface spreading facilities has corrected the dangerous overdraft conditions, and has provided an adequate ground water supply which has sustained the county's growing economy.

Although OCWD has managed to place enough water in the basin to keep the water table at an adequate level to prevent widespread damage from sea water intrusion, salt water has penetrated as far inland as Garfield Avenue in the Talbert Gap. To prevent further intrusion in this location, and to permit greater flexibility in the management of the ground water basin, OCWD has under construction a barrier to sea water intrusion.

The feasibility and necessity of the Orange County Coastal Barrier Project have been reviewed by several agencies, and a summary report was prepared in 1967<sup>1</sup>. This report was presented to the Board of Directors of the Orange County Water District at their meeting on January 18, 1967. At this same meeting, the Board adopted Resolution No. 67-4, which resolved that the Orange County Coastal Barrier Project is feasible and necessary.

The hydraulic barrier to sea water intrusion will be composed of a series of seven extraction wells (already constructed and in operation) about two miles inland from the coastline, and a series of 23 injection wells about four miles inland from the coastline.

OCWD reviewed the barrier project injection water requirements and concluded that about 30 mgd (million gallons per day) of injection water will be required; there are several possible sources of supply for this injection water:

1. Imported water either from the Colorado River or State Water Project;
2. Water produced from a deep aquifer not subject to sea water intrusion;

3. Reclaimed waste water;
4. Demineralized brackish ground water;
5. Desalted sea water;
6. Blend of the above waters.

A blend of reclaimed waste water and desalted sea water was selected for the injection well supply. This blend will be supplemented with deep ground water as required. A 15 mgd waste water reclamation facility is being constructed with funds provided by OCWD, the State of California Water Resources Control Board and the Federal Environmental Protection Agency. A 3 mgd sea water desalting facility is being constructed with funds from OCWD and the Federal Office of Saline Water.

#### Purpose and Scope

The purpose of this report is to summarize the District's past and present activities in waste water reclamation, and to describe the facilities required to utilize reclaimed waste water for an injection barrier supply.

The report reviews the quality of the effluent from the existing secondary treatment plant of the Orange County Sanitation District, quality requirements for injection water established by regulatory agencies, and recommended treatment processes. The report also presents the design criteria, including outline plans, construction costs and estimated operation and maintenance costs.



## EXISTING SEWERAGE SYSTEM

All but the southeasterly portion of OCWD lies within the service area of the County Sanitation Districts of Orange County. At the present time, there are seven sanitation districts which own and maintain about 400 miles of major trunk sewers with more than 20 pump stations. Jointly, the seven districts operate two treatment plants to process waste water for ocean disposal. Treatment Plant No. 1 is located about four miles from the coast adjacent to the Santa Ana River and has a capacity of 50 mgd. This plant gives primary treatment to all of the flow, and secondary treatment by trickling filters to 15 mgd. It is this secondary treated effluent which is available to OCWD for reclamation and an injection barrier supply.

Plant No. 2 is located about 1,500 feet from the ocean at the mouth of the Santa Ana River, and has a capacity of 170 mgd. The average flow rate is about 80 mgd, and the plant provides primary treatment only. The effluent from both plants is chlorinated and pumped through an outfall which extends five miles into the ocean and has a capacity of 480 mgd. In the southeasterly portion of OCWD, sewage is collected and treated by the Irvine Ranch Water District in an extended aeration activated sludge plant. The effluent from this plant is chlorinated and pumped to a storage reservoir and used for irrigation.

The quality of the trickling filter effluent from Orange County Sanitation District's Treatment Plant No. 1 is shown in Table 1. The quality of the effluent varies, and is adversely affected by the discharge of industrial wastes. The County Sanitation Districts have under construction a new headworks for Treatment Plant No. 1, and it will be possible to provide

Table 1

SECONDARY EFFLUENT QUALITY  
 ORANGE COUNTY SANITATION DISTRICTS TREATMENT PLANT NO. 1

<u>Constituent</u>	<u>Concentration, mg/l</u>
Calcium	70 - 110
Magnesium	20 - 45
Sodium	240 - 260
Potassium	20 - 35
Bicarbonate	200 - 450
Sulfate	270 - 300
Chloride	300 - 350
Phosphate	20 - 25
Nitrogen	
Organic	5 - 15
Ammonia	15 - 30
Nitrite	< 1
Nitrate	< 1
Total Dissolved Solids	1200 - 1400
Suspended Solids	30 - 80
BOD	30 - 80
COD	100 - 200
MBAS	3 - 4

the capability to segregate incoming trunk sewers. It will be possible to improve the quality of the sewage treated in the trickling filters and thus available for reclamation. Preliminary estimates indicate that by segregating trunks carrying the bulk of the industrial discharges, and treating these wastes in Plant No. 2 instead of Plant No. 1, the total dissolved solids (TDS) concentration in the secondary effluent could be lowered 10 to 15 percent.

## PROPOSED WASTE WATER RECLAMATION PLANT

### Pilot Plant Studies

OCWD has conducted pilot and laboratory tests in waste water reclamation since 1965. In July 1969, a report was completed that surveyed methods of advanced waste water treatment and recommended additional processes to be tested by OCWD<sup>2</sup>. This report set forth the guidelines for the current pilot scale work. Treatment in the pilot waste water reclamation plant included:

- 1) Clarification with lime and various coagulant aids;
- 2) Ammonia stripping;
- 3) Recarbonation;
- 4) Filtration;
- 5) Carbon adsorption;
- 6) Chlorination.

The capacity of the treatment units varied from 7,000 to 35,000 gallons per day, and the units were all constructed especially for the pilot study. Operation of the pilot clarifier began in May 1970, with the other units being put into operation several months later. Pilot plant operation continued until mid June 1971. Operation of the pilot treatment units furnished much of the data required for the design of the full scale treatment plant described below.

### Basis of Design

Water from the reclamation plant will be injected into the ground water basin and will eventually be withdrawn and reused for domestic, industrial and irrigation purposes. Therefore, at the point of withdrawal, the water must meet drinking water standards. OCWD's test program of treatment operations and injection has defined the quality parameters desirable for injection. Prior to injection, the reclaimed waste water will be blended with de-

salted sea water and, if needed, water produced from a deep aquifer not subject to sea water intrusion.

It is necessary to reduce the concentration of dissolved organic material to a low value to eliminate taste, odor and color. Ammonia nitrogen will be removed to lower the total oxygen demand and to make the water more amenable to disinfection, and phosphorous will be removed to control algal growths in the reuse system. Bacteria and virus should not be present in the injection water, and the concentration of potentially toxic elements will meet the U. S. Public Health Service drinking water standards. Suspended solids in the injection water should be as low as possible to minimize well clogging.

The California State Water Resources Control Board, Santa Ana Region, and the State Department of Public Health have established requirements for the injection water. These requirements are shown in Table 2. The State Health Department also requires monitoring for viruses.

#### Treatment Facilities

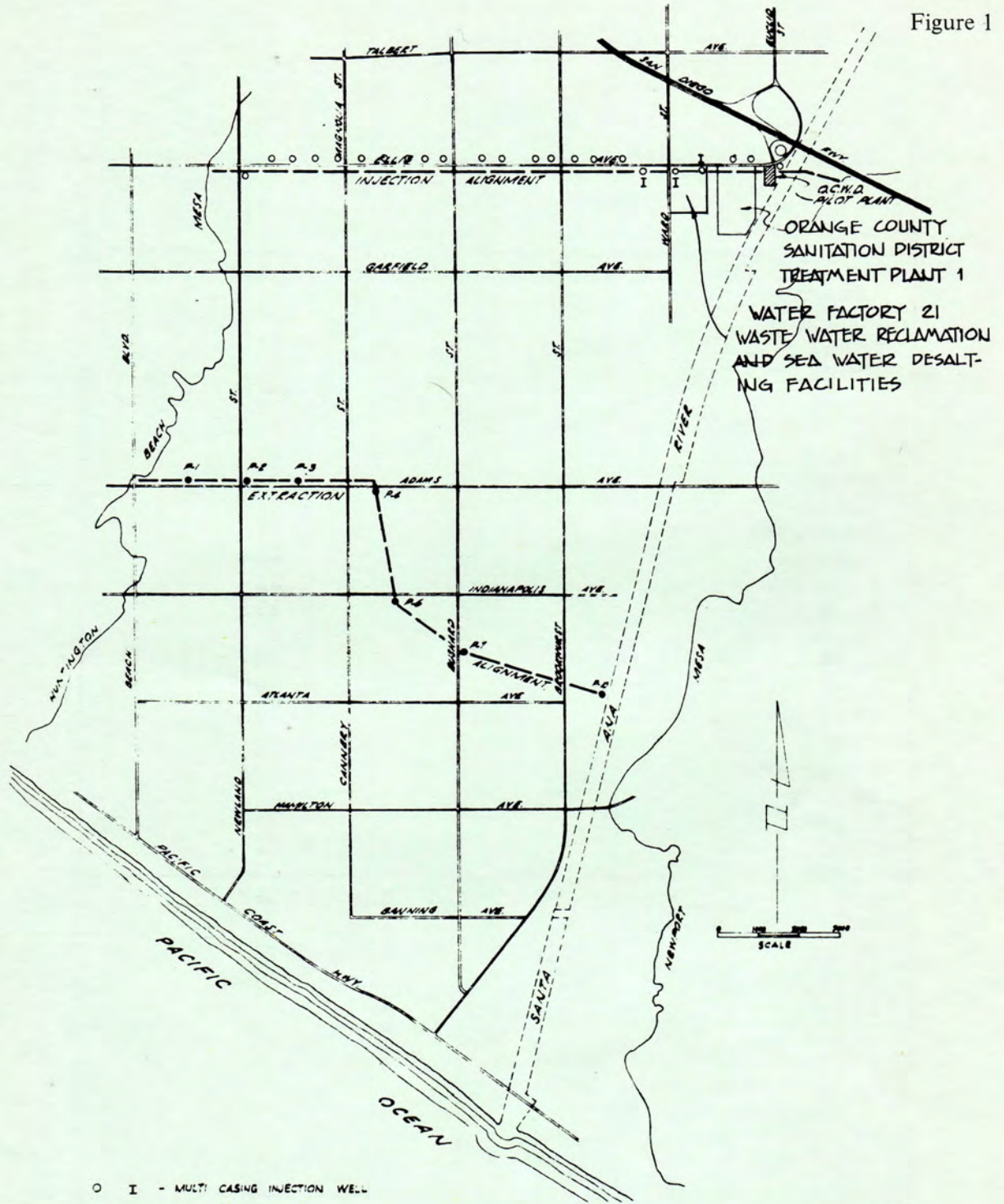
The treatment plant is under construction on a portion of a 20-acre site, owned by OCWD, at the southeast corner of Ward Street and Ellis Avenue in the City of Fountain Valley. Figure 1 shows the location of the treatment facilities and the extraction and injection well alignments. A flow diagram for the waste water treatment process is shown in Figure 2, and Figure 3 is an architect's sketch of the completed reclamation and desalting facilities. The waste water reclamation plant design criteria and unit loadings are shown in Table 3 and the units and processes are described and discussed in the following paragraphs.

Clarification Unit Clarification and phosphate removal will be accomplished in separate rapid-mix, flocculation and settling basins. Also, many trace metals form insoluble hydroxides and

TABLE 2  
REGULATORY AGENCY REQUIREMENTS  
FOR INJECTION WATER

CONSTITUENT	MAXIMUM CONCENTRATION (mg/l)
Ammonium	1.0
Sodium	110.0
Total hardness (CaCO <sub>3</sub> )	220.0
Sulfate	125.0
Chloride	120.0
Total nitrogen (N)	10.0
Fluoride	0.8
Boron	0.5
MBAS	0.5
Hexavalent chromium	0.05
Cadmium	0.01
Selenium	0.01
Phenol	0.001
Copper	1.0
Lead	0.05
Mercury	0.005
Arsenic	0.05
Iron	0.3
Manganese	0.05
Barium	1.0
Silver	0.05
Cyanide	0.02
Electrical conductivity	900 umhos/cm
pH	6.5 - 8.0
Taste	None N
Odor	None
Foam	None
Color	None
Filter effluent turbidity	1.0 JTU
Carbon adsorption column effluent COD	30 mg/l
Chlorine contact basin effluent	Free chlorine residual

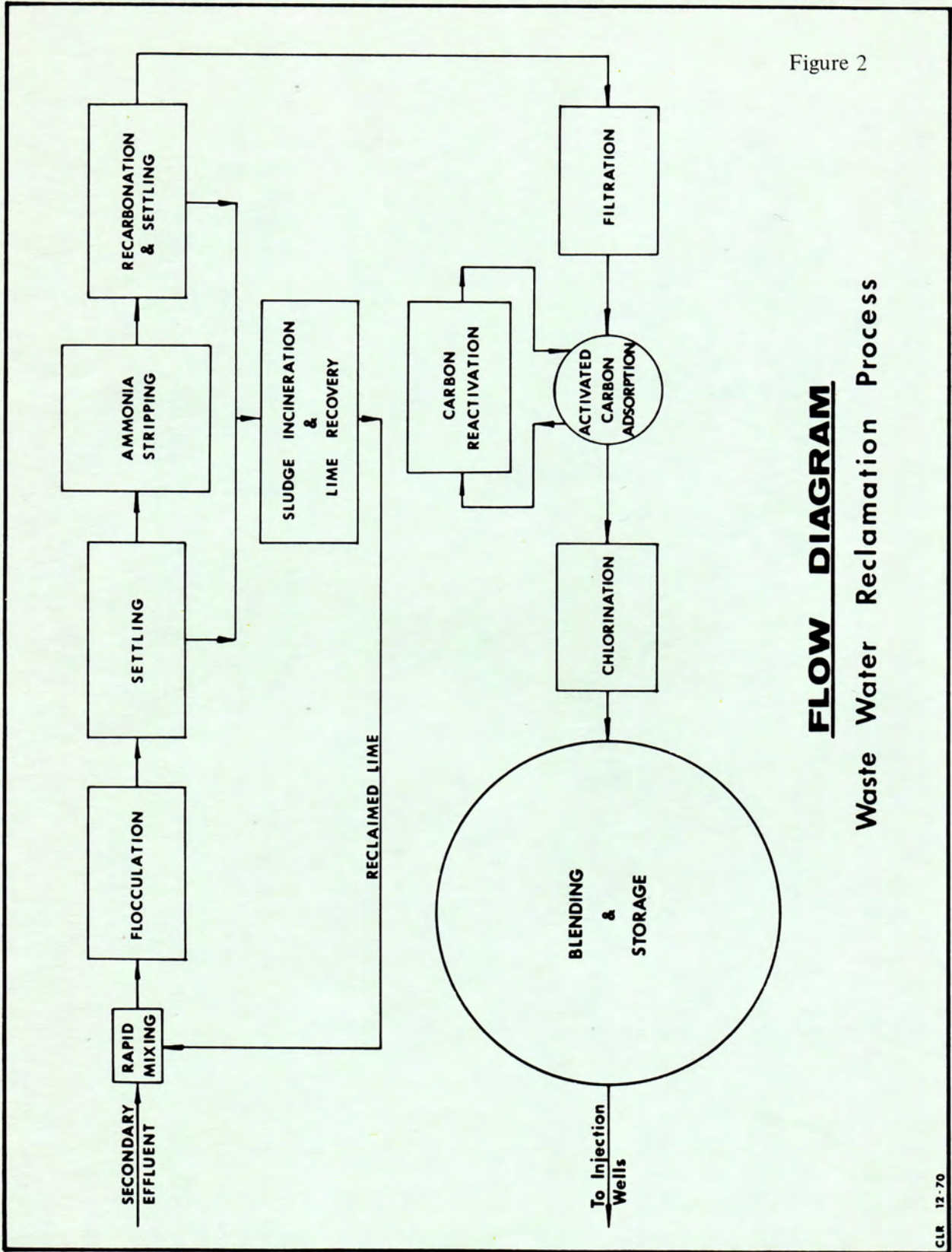
Figure 1



- I - MULTI CASING INJECTION WELL
- P-1 - PUMPING WELL

**ORANGE COUNTY WATER DISTRICT**  
**VICINITY PLAN**  
 SANTA ANA GAP  
 SEA WATER BARRIER

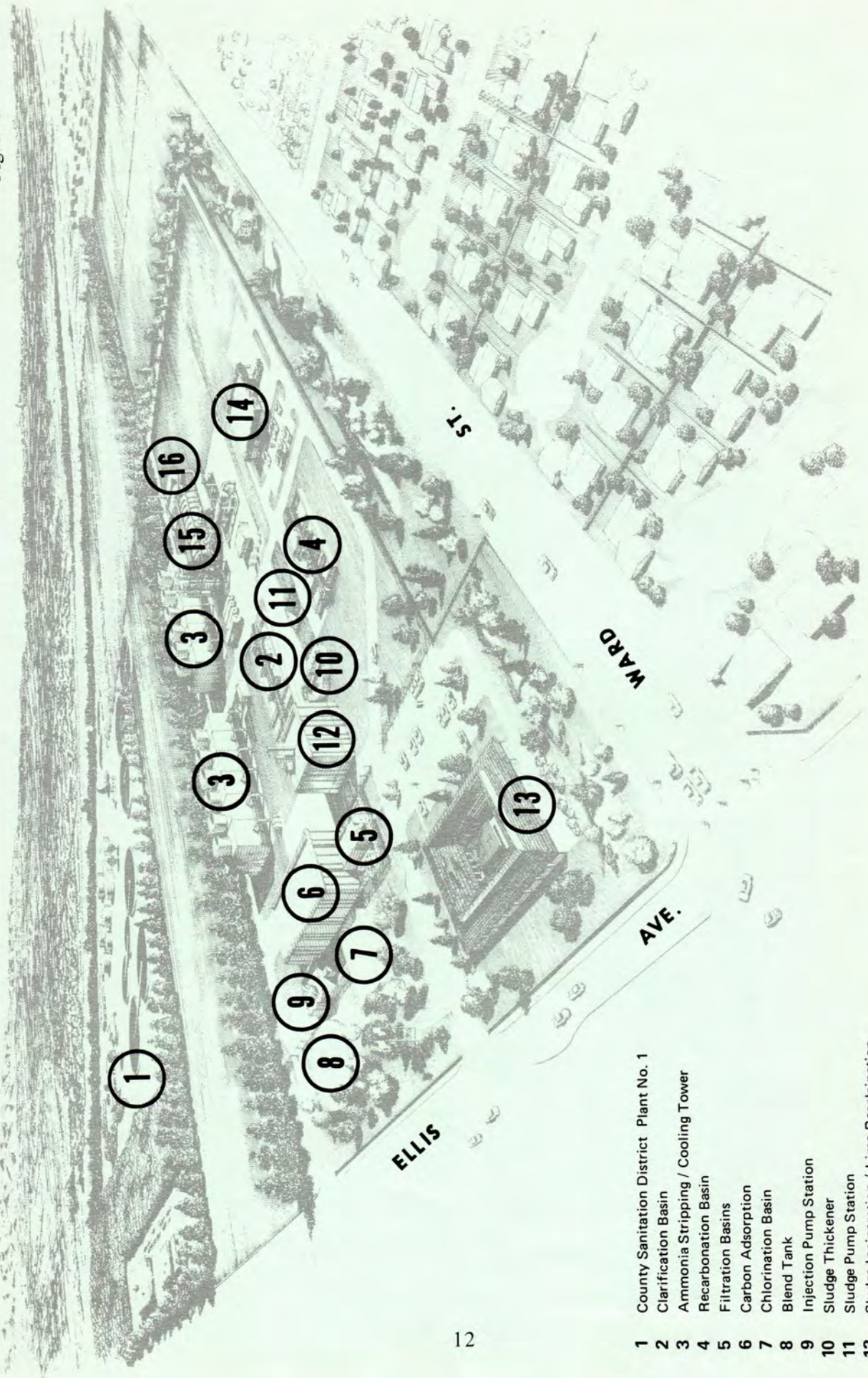
Figure 2



**FLOW DIAGRAM**  
Waste Water Reclamation Process



Figure 3



- 1 County Sanitation District Plant No. 1
- 2 Clarification Basin
- 3 Ammonia Stripping / Cooling Tower
- 4 Recarbonation Basin
- 5 Filtration Basins
- 6 Carbon Adsorption
- 7 Chlorination Basin
- 8 Blend Tank
- 9 Injection Pump Station
- 10 Sludge Thickener
- 11 Sludge Pump Station
- 12 Sludge Incineration / Lime Recalcination
- 13 Administration Building
- 14 Shop and Warehouse
- 15 VTE / MSF Sea Water Desalting Module
- 16 Natural Gas Boiler Plant

WATER FACTORY 21  
 WASTE WATER RECLAMATION PLANT – SEA WATER DESALTING PLANT  
 FOUNTAIN VALLEY, CALIFORNIA

TABLE 3  
PLANT DESIGN CRITERIA

<u>PLANT CAPACITY</u>	
15 mgd	
16,800 ac. ft/year.	
10,400 gpm	
23 cfs	
<u>RAPID MIXING</u>	
No. of basins: 2	
Mechanical mixers	
Detention time: 1 min. (each)	
<u>FLOCCULATION</u>	
No. of 3-compartment basins: 2	
Mechanical mixers in each compartment	
Detention time: 30 min.	
<u>SETTLING</u>	
No. of basins: 2	
Overflow rate: 1560 gpd/ft <sup>2</sup>	
Detention time: 85 min.	
Equip with settling tubes	
<u>AMMONIA STRIPPING</u>	
No. of towers: 2	
Hydraulic loading: 1.0 gpm/ft <sup>2</sup>	
Air flow: 400 ft <sup>3</sup> /gallon	
Depth of packing: 25 ft.	
Packing: accessible for cleaning and removable	
<u>RECARBONATION</u>	
Three-compartment basins: two-stage recarbonation with intermediate settling	
No. of basins: 2	
Compartment 1 and 3: detention time = 15 min. (each)	
Compartment 2 (settling basin): Detention time = 40 min.	
<u>FILTRATION</u>	
No. of units: 4	
Hydraulic loading: 5 gpm/ft <sup>2</sup>	
Backwash rate: 15 gpm/ft <sup>2</sup>	
Surface wash flow: 0.6 gpm/ft <sup>2</sup>	
Backwash water receiving tank capacity: 160,000 gallons	
<u>CARBON ADSORPTION</u>	
No. of upflow pressure units: 16	
Contact time: 30 minutes	
Carbon volume, each unit: 2,700 ft <sup>3</sup>	
Tank diameter: 12 ft.	
Carbon depth: 24 ft.	
Hydraulic loading: 5.8 gpm/ft <sup>2</sup>	
<u>CHLORINATION</u>	
No. of basins: 1	
In-line feeding and mixing	
Contact time: 30 minutes	
Chlorine feeders: 3	
Feeder capacity: 2,000 lbs/day (each)	
On site manufacture of chlorine: 2,000 lbs/day	
<u>CARBON REGENERATION FURNACE</u>	
Capacity, dry carbon: 12,000 lbs/day	
Equip to feed 1 lb. steam per lb. carbon	
<u>SLUDGE THICKENER</u>	
Flow: 1,000 gpm	
Surface overflow rate: 1,000 gpd/ft <sup>2</sup>	
Surface dry solids loading: 200 lbs/day/ft <sup>2</sup>	
Thickened sludge solids: 8 - 20%	
<u>SLUDGE DEWATERING</u>	
No. of centrifuges: 2	
Capacity: 2,000 lbs/hr. (each)	
<u>LIME RECALCINING FURNACE</u>	
Capacity, dry Cao: 30 tons/day	
<u>CHEMICAL FEED EQUIPMENT</u>	
Gravimetric lime feeders and paste-type lime slakers:	
No. of feeders and slakers: 2	
Capacity: 4,000 lbs/hr.	
Polymer solution feed pumps:	
No. of pumps: 4	
Capacity: 5 - 50 gpm	
Alum solution feed pumps:	
No. of pumps: 3	
Capacity: 1 - 10 gpm (one pump); 9 - 90 gpm (two pumps)	

can be removed in this unit operation. A detailed discussion of the removal of heavy metals and results of OCWD's pilot study are included in Appendix A. Lime is the primary coagulant with anionic coagulant aids used as required to improve settling. The flocculation basins are rectangular and divided into three chambers so that mixing energy can be varied and a large floc developed. The settling basins are also rectangular, with provision for sludge recirculation to the rapid-mix basins.

Rapid-mixing, flocculation, and settling will be accomplished in separate basins because the secondary effluent was difficult to flocculate and settle during pilot studies, and the separate basins enable the operation to be more closely controlled. A single-tank solids-contact type clarifier is not as satisfactory a unit for this water.

Nitrogen Removal Nitrogen in the trickling filter effluent is almost all in the form of either organic nitrogen or ammonia, with very little nitrate or nitrite. Nitrogen in the ammonia form will be removed in two combined ammonia stripping/water cooling towers. There are two streams from the sea water desalting process which require cooling: One is concentrated brine which will be cooled and then disposed of in the ocean; and the other is water from the barometric condensers which will be cooled and returned to the desalting plant. The ammonia removal sections of the combined towers are counter-flow units while the cooling sections are cross-flow type units.

The two ammonia stripping/cooling towers are each equipped with six 18-foot diameter fans. The stripping sections are designed for a hydraulic loading of 1.0 gpm(gallons/minute)per cu.ft. & an air flow of 400 cubic feet per gallon. The cooling sections are designed to cool the desalting process water to 80°F (26.6°C) and as a result will raise the exit air temperature to the stripping section to about 87°F (30.5°C). The desalting plant brine will

be cooled to 85°F (29.4°C), raising the exit air temperature to about 91°F (32.7°C). Splash-bar packing will be used for ammonia stripping and a film packing will be used for cooling. A prime design criterion was that the ammonia stripping packing be accessible and removable for cleaning because scaling of the packing might reduce ammonia removal efficiency. The warm saturated air exhausted from the cooling sections would theoretically permit the tower packing to be less than the design height of 25 feet. However, because during the first few years of operations the desalting plant will operate on an intermittent basis, it was not considered advisable to reduce the packing depth. There should be no visible plume from the tower, and the ammonia concentration in the exhaust air will be well below the odor threshold.

The early pilot treatment work and injection by OCWD did not include ammonia removal in the treatment process. The ammonia concentration of 15 to 30 mg/l (milligrams/liter) in the injection water caused odors and made water difficult to disinfect. Also, the aquifer material has some capacity to adsorb ammonia, but injecting water containing relatively large concentrations of ammonia creates a large oxygen demand and would eventually appear in water withdrawn from the basin. Other methods of removing ammonia were considered and it was concluded that ammonia stripping is the most economical and reliable method for this water and this location.

Recarbonation Effluent from the ammonia stripping tower will be recarbonated in two stages with intermediate settling. In the first stage, which has a detention time of 15 minutes, carbon dioxide gas from the recalcining furnace will be added to lower the pH to about 10. The intermediate settling basin provides for a detention time of 40 minutes followed by another 15 minutes for pH adjustment in the second recarbonation basin. Two-stage recarbonation will produce a water lower in hardness and total dissolved solids, and the sludge produced will be almost pure calcium carbon-

ate which can be reused. The sludge can also be recirculated to the clarifier rapid mix basins.

Filtration Effluent from the recarbonation basins will be filtered in four mixed-media, coarse-to-fine, gravity filters. The filter beds will be composed of 30-inches of anthracite and sand as shown below (gravel support is not shown):

<u>Media</u>	<u>Depth (in.)</u>	<u>Specific Gravity</u>	<u>Grain Size Range (mm.)</u>
Anthracite Coal	18	1.5	0.84-2.00
Graphite or Silica Sand	9	2.4	0.42-0.84
Garnet Sand	3	4.2	0.18-0.42

The design hydraulic loading is 5 gpm per square foot.

Mechanical straining is a relatively unimportant factor in a mixed media filter since efficient filtration is a physical-chemical process involving particle destabilization and particle transport similar to the mechanism of coagulation. Filter aids such as alum and/or polymers will be added to the filter influent to adjust the water to optimum filtrability. When filter aids are used, the filtration process is so effective that conventional sand and other surface filters clog very rapidly; therefore, effective filtration without excessive head loss can be accomplished only by use of a coarse-to-fine, in-depth filter. Multimedia filters are considered the key to the proven successful performance of the reclamation plant at Lake Tahoe.

The role of coarse-to-fine filters in the treatment process includes:

1. Coarse-to-fine filtration adds greatly to overall plant reliability in terms of continuous operation and consistent effluent quality. Solids carryover from secondary or chemical clarifiers or settling basins is stopped without harm to subsequent treatment units or processes or interruption of normal operation.

Even major surges of suspended solids can be handled by mixed-media filters without plant shutdown or sacrifice in effluent quality. Filtration is an excellent backup to overcome irregularities common to biological and chemical treatment.

2. Coarse-to-fine filtration produces a water of exceptionally high clarity which can be accomplished in no other practical way. With use of a filter aid, any desired turbidity down to 0.05 Jackson Units (JU) can be maintained, although 0.2 to 0.3 JU are more realistic values for normal operation.
3. Filtration prior to granular carbon adsorption protects the carbon against fouling by suspended solids and colloidal matter and prevents loss of carbon efficiency upon regeneration due to the residual ash from incinerated solids. Prior filtration reduces the load of organics applied to the carbon and thus will permit either greater overall removals of organics with equal carbon contact time or shorter carbon contact time for the same removals.
4. The complete removal of suspended matter by filtration permits more effective disinfection of the water.

Activated Carbon Adsorption Effluent from the filters will be pumped to the activated carbon adsorption units. The purpose of these units is to remove odor and color-causing dissolved organic material. There is also some evidence that activated carbon will remove certain heavy metals (see Appendix A).

There will be 17 carbon adsorption columns, 16 of which operate in parallel, with the remaining unit used for carbon storage and stand-by service. The columns are upflow pressure units and are designed similarly to the units that have been operating successfully at the South Lake Tahoe plant. The design

contact time is 30 minutes (empty bed basis), and the hydraulic loading is 5.8 gpm per square foot. Carbon will be thermally regenerated on the site in a multiple-hearth furnace with a rated capacity of 12,000 pounds of dry carbon per day. Also, the system is designed so that one pound of steam per pound of carbon can be supplied to the furnace.

Chlorination Effluent from the carbon columns will flow to the chlorine contact basin for break-point chlorination to destroy any remaining bacteria and virus, and to oxidize any residual ammonia. Chlorine will be added, through a diffuser in the pipeline, just upstream of the entrance to the contact basin which is designed for 30 minutes contact time.

Chlorine gas will be supplied from purchased one ton cylinders and by an on-site electrolytic generator rated at 2,000 pounds per day. The chlorine generation system will utilize an electrochemical cell to electrolyze sodium chloride brine to chlorine gas and sodium hydroxide solution. The sodium hydroxide solution will be used in the sea water desalting process.

Sludge Handling Sludge from the clarifier settling basin and from the recarbonation basin will be thickened, dewatered by centrifuging, and incinerated in a multiple hearth furnace rated at 30 tons per day of dry calcium oxide. The sludge pump station is designed so that sludge from either the clarifier or recarbonation settling basins can be recycled to the clarifier rapid-mix basin.

The estimated composition of the sludge feed to the centrifuges is shown below:

Solids feed rate	4160 lbs. per hour
Solids concentration	8 to 13%
Feed rate	64 to 105 gpm
Solids Composition:	
Calcium carbonate	70%
Magnesium hydroxide	8%
Phosphate compounds	10%
Organics	8%
Other	4%

In the incineration process, calcium oxide is derived from the calcium carbonate and carbon dioxide is produced. The carbon dioxide will be used in the recarbonation process and calcium oxide reused in the clarification process. Remaining ash will be disposed of by contract for a soil conditioner, or hauled to a landfill disposal site.

#### Method of Operation

The operation of the proposed treatment facilities will require a highly qualified operation and maintenance staff of about 14 persons, including one superintendent, eight operators, one chemist, and four maintenance people.

Water from the waste water reclamation plant, desalted sea water and ground water from the deep aquifer (if required) will be blended and stored prior to injection. Interruptions in the water supply to injection wells, which cause stopping and restarting of injection, results in reduced efficiency and increased well operation costs. Therefore, deep ground water will be used for blending, as required, in order to prevent stoppages in injection operations.



## ALTERNATE TREATMENT METHODS STUDIED

During the first phase of the pilot treatment and injection study, treatment consisted of clarification with alum as the primary coagulant in a solids contact-type unit, followed by rapid sand filtration in dual media filters and chlorination. This treatment sequence did an adequate job of removing suspended material, but did not remove dissolved organics, which caused odor and color in the injection water. The alum treatment increased the TDS and sulfate concentrations in the product water. Also, ammonia was not removed, and the water was difficult to disinfect. A complete report on this first phase of the pilot work, which included the results of injection in one well, was prepared and is available from OCWD.<sup>3</sup>

For ten months during 1969, the alum clarification and filtration treatment sequence was used to produce water for a demonstration injection program. The final report on this project is also available from OCWD.<sup>4</sup>

It was the general conclusion of the demonstration injection program that more treatment was required prior to injection, and that the incoming raw sewage should be segregated to provide a better quality secondary effluent for reclamation.

Throughout the five years of the pilot treatment investigation by OCWD, a wide range of treatment operations, in addition to those already mentioned, have been tested including: foam fractionation; diatomaceous earth filtration; intermittent sand filtration; demineralization by electro-dialysis, reverse osmosis and ion exchange; and disinfection by ultraviolet irradiation. Also, various coagulants and coagulant aids were tested with bench-scale equipment.

During these studies, OCWD retained the services of consultants and experts in various fields.

It is believed that the sequence of treatment processes under construction includes the most reliable processes currently available which would produce the required water quality. Results from the pilot plant operation indicate that the recommended treatment plant will produce water: (a) which is odorless and colorless; (b) free of bacteria and virus; (c) which will meet the regulatory agencies requirements; and (d) with very low concentrations of suspended material, nitrogen and phosphorous.

## ENVIRONMENTAL IMPACT

The proposed plant location is in the City of Fountain Valley; representatives of the District have discussed the proposed facilities with the Planning Department and the City Council. The National Environmental Policy Act and the California Environmental Quality Act require public agencies to consider the environmental impact of any proposed project. The firm of Jones and Stokes Associates, Inc. was retained by OCWD to prepare an environmental impact report. The results of this study are contained in a separate report<sup>5</sup>, and the conclusions and recommendations are summarized below.

Both beneficial and adverse impacts were identified. Major beneficial impacts include:

1. Protection of ground water quality by the maintenance of a barrier to sea water intrusion;
2. Recycling of waste water, one of the keys to long-range maintenance of the environment;
3. Reduction of the biostimulants and other undesirable substances now being released in the ocean.

Potential adverse impacts exist in the form of noise, air pollutants and artificial light. The sources of these potential problems were identified and the possible cumulative effect along with similar threats from the desalting plant was considered. All the problems were found responsive to treatment.

1. Noise The noise produced by equipment at the reclamation plant was predicted from measurements of similar equipment at the South Lake Tahoe reclamation plant. Special consideration will be given to noise in the design of all equipment and buildings in order to maximize the insulating ability of the buildings and minimize the noise levels.

All buildings and equipment will be designed so that the resulting cumulative noise levels will comply with criteria developed for the area. A special section in the specifications is devoted to noise and the requirement that the facilities must meet the noise objectives.

2. Air Pollution The sludge incineration furnace, the carbon regeneration furnace and the ammonia stripping towers all produce emissions to the atmosphere. None appears to present any serious pollution problems however, and emissions will be minimized by the installation of control equipment. The Orange County Air Pollution Control District has issued permits authorizing the construction of these features. Ammonia stripping will not create an air quality problem. The ammonia discharge to the atmosphere is a stable material which is not oxidized to nitrogen oxides in the atmosphere. There will be no oxides of carbon in the stripping tower air discharge. Odor will not be a problem since the ammonia concentration in the air discharge will be a maximum of about  $10 \text{ mg/m}^3$ , well below the odor threshold of  $35 \text{ mg/m}^3$ .

The possible effects of ammonia which would be added to the atmosphere have been investigated and no adverse effects on the adjacent property and landscape are foreseen. There is the potential for reduction in atmospheric visibility due to ammonium sulfate formation from the interaction of ammonia and sulfur dioxide; however, there are no major sources of sulfur dioxide in the vicinity of the proposed plant.

Sludge incineration consists of heating lime sludge to temperatures of about  $1850^\circ\text{F}$ . At this temperature,

combustion of any organics contained within the sludge is complete. The major portion of all exhaust gases produced by incineration will be water vapor and carbon dioxide, and this exhaust gas will be utilized as a source of carbon dioxide.

Instead of releasing the exhaust gases to the atmosphere, they will be diverted and compressed by water sealed compressors, and the compressed gas will be used to recarbonate the effluent from the ammonia stripping towers. Under actual plant operations very little of the exhaust gas from the lime furnace will be vented to the atmosphere. In any event, the organic content of the lime sludge will be much lower than the content associated with ordinary sewage sludge incineration and there should be no odor in the exhaust gases.

The reason an afterburner is necessary on the carbon furnace and not the lime furnace is because carbon regeneration is a completely different process from lime sludge incineration. Temperatures measured in the carbon furnace are air temperatures only, while the temperatures in the lime furnace are a measurement of the furnace brick temperatures. Inside the carbon furnace no actual burning takes place; the adsorbed organics are volatilized and the process is simply one of distillation. The actual burning and consumption of the volatile gases takes place in the afterburner. However, in the lime furnace, temperatures are much higher and complete combustion occurs within the furnace and the use of an afterburner would be superfluous.

The lime recalcining and carbon regeneration furnaces will be equipped with 3-stage impingement scrubbers which will control the emissions of particulate

matter within 0.03 grains/standard cubic foot, which is in contrast to the 0.3 grains required by the Orange County APCD. In addition, a standard has been set in the design of this equipment which endeavors to eliminate completely the steam plume normally associated with scrubber exhaust. To achieve this, the scrubber exhaust temperature will be held to approximately 110°F. Test data for a similar furnace at the advanced waste treatment plant at South Lake Tahoe shows that the emissions are far below the APCD standards for particulate matter and oxides of sulfur.

The open basins in the reclamation plant are: (1) chemical clarifier; (2) recarbonation basin; (3) filters; and (4) sludge thickener. There should be no odors from any of these basins. The water in the recarbonation basin and the filters has been through the clarification and ammonia stripping operations and will have a high degree of clarity with a turbidity of about five units. Water in the chemical clarifier and the sludge thickener is treated with lime and will have a pH value of over 11. There is no bacterial activity in these units and odors were not experienced in the pilot plant operation in Orange County. Odors have not been experienced in similar units at the treatment plant at South Lake Tahoe.

3. Lights The outdoor lights will be directional and restricted to the areas of need. Shades and screens attached directly to the lighting device, coupled with the undulating ridge and landscaping, will prevent light from impinging on residential areas. These lighting requirements are shown on the engineering plans, and the requirements are described in detail in the specifications.

## REGIONAL PLANNING

A regional planning agency, the Santa Ana Watershed Planning Agency (SAWPA), was organized under a joint powers agreement in 1969 by the four principal water districts in the Santa Ana Watershed: Orange County Water District, Western Municipal Water District of Riverside County, Chino Basin Municipal Water District, and the San Bernardino Valley Municipal Water District. SAWPA's primary responsibility is to analyze alternative methods of controlling water quality in the Santa Ana River Watershed, and to develop a comprehensive basinwide water quality management plan. Also, SAWPA has been designated by the Governor of California as the agency responsible for the administration and coordination of development of a comprehensive water pollution control plan for the Santa Ana River Watershed. The proposed waste water reclamation and injection facilities are in accord with the plans of SAWPA, and are a necessary part of the regional water quality management program.

## COSTS

There were six bids for the construction of the reclamation facilities. The bids were opened on March 14, 1972 and the total bid prices are shown below:

<u>Contractor</u>	<u>Reclamation Plant and Distribution Facilities</u>
A	\$ 11,705,900
B	12,655,160
C	13,181,000
D	13,805,000
E	13,988,600
F	14,357,000

The above bids include the distribution pipeline to the injection wells, and the well vaults and piping and other injection well appurtenances. The maintenance building and laboratory for the plant are not included in the above bids; also not included is the chlorine generation system or the fine filter media. Adding and deducting the cost of these items makes the total cost, including engineering design and inspection, for the 15 mgd waste water reclamation facilities \$11,624,000. A breakdown of these capital costs by treatment operation is shown in Table 4. The estimated operation and maintenance costs are shown in Table 5 and the total costs are shown in Table 6.

The estimated costs of water produced in the reclamation facilities are summarized below:

	WATER COST	
	<u>\$/acre foot</u>	<u>\$/million gallons</u>
Capital	55	170
Operation & Maint.	45	140
TOTAL	100	310

These costs are based on the following assumptions:



1. Service life of facilities = 30 years;
2. Interest rate = 6%;
3. Facilities operate 330 days/year and produce 15 mgd.

There were three bids for the construction of 20 multi-casing injection wells. The bids were opened on March 13, 1972 and the total bid prices are shown below:

<u>Contractor</u>	<u>Injection Wells</u>
A	\$ 613,000
B	747,236
C	1,378,847

Adding the cost of three previously constructed wells to the above low bid, plus the cost of the distribution pump station and pipeline, well vaults, instrumentation, piping and other appurtenances, makes the total cost of the injection system \$1,820,000. This cost also includes engineering design and inspection. The estimated annual cost of operation and maintenance of the injection facilities is \$100,000.

TABLE 4  
 CAPITAL AND ENGINEERING COSTS  
 15 mgd Waste Water Reclamation Facilities  
 Orange County Water District

Land. . . . .		\$ 200,000
Influent Pipeline & Pump Station. . . . .		341,000
Clarification . . . . .		756,000
Ammonia Stripping . . . . .		2,834,000
Recarbonation . . . . .		381,000
Filtration. . . . .		861,000
Granular Carbon Treatment . . . . .		3,027,000
Adsorption	\$1,310,000	
Regeneration	452,000	
Building, controls & other equipment	1,265,000	
Chlorination. . . . .		361,000
Building & equipment	\$ 79,000	
Contact basin	153,000	
Generator	129,000	
Sludge Treatment. . . . .		1,688,000
Pump station	\$ 94,000	
Thickener	47,000	
Centrifuges	115,000	
Furnace	565,000	
Building, controls, piping, electrical, & other equip.	867,000	
Blending and Storage Reservoir. . . . .		235,000
Maintenance Building and Lab. . . . .		<u>240,000</u>
	TOTAL CAPITAL COST:	\$10,924,000
Engineering . . . . .		700,000
Design	\$ 530,000	
Construction	170,000	
	TOTAL COST:	<u><u>\$11,624,000</u></u>

Note: Sitework, landscaping, electrical work and yard piping are charged to the individual treatment operations according to their percentage of total capital cost.

TABLE 5  
 ESTIMATED ANNUAL COST OF OPERATION AND MAINTENANCE  
 15 mgd Waste Water Reclamation Facilities  
 Orange County Water District

<u>Salary Cost</u>			
1 Superintendent	\$ 15,000		
1 Chemist	12,000		
4 Maintenance	36,000		
8 Operators	90,000		
1 Custodian	7,000		
Sub-total	<u>\$ 160,000</u>	x 1.25	\$ 200,000
<u>Maintenance Materials</u>			40,000
<u>Utilities</u>			
Electricity	\$ 205,000		
Natural gas	40,000		
Other	5,000		
Sub-total	<u>          </u>		250,000
<u>Chemicals and Carbon</u>			
Lime	\$ 70,000		
Chlorine	10,000		
Activated carbon	45,000		
Alum and Polymers	55,000		
Sodium chloride	10,000		
Sub-total	<u>          </u>		<u>190,000</u>
Total Operation & Maintenance			<u>\$ 680,000</u>

TABLE 6  
TOTAL COSTS  
15 mgd Waste Water Reclamation Facilities  
Orange County Water District

	COSTS (¢/thou. gal.)		
	<u>Capital</u>	<u>Oper. &amp; Maint.</u>	<u>Total</u>
Influent pipeline & pump station	0.5	0.3	0.8
Clarification	1.1	2.4	3.5
Ammonia stripping	4.2	2.9	7.1
Recarbonation	0.6	0.6	1.2
Filtration	1.3	1.4	2.7
Carbon adsorption	4.5	2.9	7.4
Chlorination	0.5	0.7	1.2
Sludge treatment	2.5	2.5	5.0
Other	1.8	0.3	2.1
TOTAL	17.0	14.0	31.0

Note: Costs are based on the following assumptions

1. Service life of facilities = 30 years;
2. Interest rate = 6%;
3. Facilities operate 330 days per year & produce 15 mgd.

## MAJOR CONTRIBUTORS

### Pilot Studies, Conceptual Design and Project Report

The bench scale treatment studies, and the pilot treatment work was conducted by the staff of the Orange County Water District under the general direction of George M. Wesner. Henry Milosz performed most of the laboratory analyses; Gary Johnson and George Hansford constructed and operated the pilot treatment facilities.

The conceptual design and project report were prepared by the staff of the District.

Russell L. Culp and Gordon L. Culp were special consultants to the District during this phase of the project.

### Detail Design, Plans and Specifications

The construction plans and specifications were prepared by Toups Engineering, Inc. under the direction of Lewis J. Ewing, Junior. Russell L. Culp, William F. Ettlich and Peter Phelps were special consultants to the District during the design of the facilities.

### General Contractor

A. G. Tutor Co. and N. M. Saliba, Joint Venture, North Hollywood, California.

### Major Sub-Contractors

Mechanical: Bovee and Crail  
Electrical: Lord Electric  
Structural Steel: Allied  
Reinforcing: Judson Steel

## Equipment Suppliers

<u>Equipment Item</u>	<u>Supplier</u>
Flocculation, clarification and thickening mechanisms	Linc Belt
Tube Settlers	Neptune MicroFLOC
Lime Feeders and Slakers	Wallace and Tiernan
Centrifuges	Sharples
CO <sub>2</sub> compressors	Nash
Filter bottoms	Leopold
Filter media	Neptune MicroFLOC
Activated carbon	Calgon
Chlorinators	Wallace and Tiernan
Lime furnace and accessories	Nichols
Carbon furnace and accessories	Nichols
Control systems	Taylor
Gas Engines	Cummins
Vertical process pumps	Johnston
Air compressor and dryer	Ingersol Rand
Ammonia Stripping/Cooling Equipment	Lilie-Hoffmann

#### REFERENCES

1. "Summary Report on the Feasibility and Necessity of the Orange County Coastal Barrier Project," by L. W. Owen, H. O. Banks and J. M. Toups, Jan. 1967.
2. "Recommended Advanced Waste Water Treatment Investigation for Fiscal Year 1969-70," by Toups Engineering, Inc., July 1969.
3. "Pilot Waste Water Reclamation and Injection Study, Orange County Water District," by Montgomery-Toups, Joint Venture, December 1967.
4. "Final Report on Injection Demonstration Program, 1969," by Orange County Water District, October 1970.
5. "Environmental Impact Study for the Orange County Coastal Project," by Jones and Stokes Associates, Inc., Oct. 1971.

APPENDIX A  
HEAVY METALS REMOVAL IN  
WASTE WATER TREATMENT PROCESSES

This report was published in the August and September, 1972 issue of Water and Sewage Works and is reprinted here with the permission of Water and Sewage Works.



Interest in wastewater reuse has uncovered the need for critical evaluation of the performance of various advanced water and wastewater treatment processes used in reclamation plants.

# Heavy metals removal in wastewater treatment processes: Part 1

By David G. Argo and Gordon L. Culp\*

**Because of increasing water demand and rising costs of imported water delivered to the Southern California area the Orange County Water District is investigating the feasibility of wastewater reclamation. The Orange County Water District (OCWD) has conducted studies in wastewater reclamation and ground water recharge through injection wells since 1965.**

The total water use within the OCWD is presently about 300,000 acre-ft/yr. Approximately two-thirds of this amount is supplied by the underground basin. The ground water basin was overdrafted in the mid-1950's and because of this overdraft, sea water intruded inland as much as 3.5 mi. This overdraft was corrected by percolation of imported Colorado River water through surface spreading facilities in the Santa Ana River. Although the overdraft has been corrected by surface spreading and the water table is maintained at an adequate level to prevent widespread sea water intrusion, a sea water barrier is under construction to prevent further intrusion and to permit greater flexibility in management of the ground water basin.

The Coastal Barrier will consist of a line of extraction wells, already completed and in operation, located about 2 mi inland from the coastline, and a line of injection wells about 4 mi inland from the coastline.

The OCWD staff reviewed the Barrier Project injection water requirements and found that about 30,000 acre-ft/yr of injection water will be required. The several possible sources of water supply for the injection barrier included:

1. Imported water, either from the Colorado River or the State Water Project;
2. Water produced from a deep aquifer not subject to sea water intrusion;
3. Reclaimed wastewater;
4. Demineralized brackish ground water; or
5. Desalted sea water.

It was decided to use a blend of reclaimed wastewater and desalted sea water supplemented with deep ground water as needed.

All but the southeasterly portion of the OCWD lies within the service area of the County Sanitation Districts of Orange County. At the present time, there are seven sanitation districts which own and maintain about 400 miles of major trunk sewers. Jointly, the seven districts operate two treatment plants to process wastewater for ocean disposal. Treatment Plant No. 1 is located about four miles from the coast adjacent to OCWD's proposed plant site and has a

\*Orange County Water District and vice president, CH2M/Hill Consulting Engineers, Reston, Va., respectively.

capacity of 50 mgd. Treatment Plant No. 1 provides primary treatment to the total plant flow and secondary treatment by trickling filters to 15 mgd. It is this secondary treated effluent which has been made available to the OCWD as a source of supply for the reclamation plant and subsequent injection barrier supply.

### Evaluation Necessary

Interest in wastewater reuse has uncovered the need for critical evaluation of the performance of various advanced water and wastewater treatment processes used in reclamation plants. The recent publicity on mercury contamination of fish has focused attention on one particular area of concern, which is the removal of heavy metals by advanced wastewater treatment processes.

The following list of heavy metals has been classified as having very high or high pollution potential.<sup>1</sup>

1. Very high pollution potential:
 

silver
gold
cadmium
chromium
copper
mercury

lead
antimony
tin
selenium
zinc.
2. High pollution potential:
 

barium
bismuth
iron
manganese

molybdenum
titanium
uranium.

Public health considerations are the ultimate concern in reuse of wastewater. It has been estimated that one municipal usage of water increases the total dissolved solids concentration by 300 mg/l.<sup>2</sup> Included in this increase in dissolved solids is some increase in heavy metals. If recycling wastewaters is to be successful, this increase due to the "use increment" must be effectively controlled by advanced waste treatment removal processes. In regard to the public health implications, some of these heavy metals are particularly troublesome because of their toxic effects at extremely low concentrations. Accumulation of these heavy metals due to "use increment" could not be tolerated.

The pollution potential of these metals is based on their toxicity to individual species covering a broad spectrum of living things. The level of toxicity to human beings is not clearly defined in many cases, although heavy metals toxicity to human beings is reflected in drinking water standards published by the U. S. Public Health Service.<sup>3</sup> Since the level of toxicity is not clearly defined, it is extremely difficult to know what standards should apply to an effluent to ensure no deleterious effects on the population at large. Due to this uncertainty, stringent standards have been set on the injection water by both the California Department of Public Health and the California Regional Water Quality Control Board (summarized in Table 1). It should be noted that the criteria for heavy metals is the same as the U.S. Public Health Service Drinking Water Standards.

This report will review the literature to determine what is known about the reduction in concentration of heavy metals by wastewater treatment. Also, it will evaluate the efficiency of OCWD's pilot-scale

**Table 1: Regulatory Agency Requirements**

Constituents in the injection water not to exceed the following concentrations:

Constituent	Concentration (mg/l except electrical conductivity and pH)
Electrical Conductivity	900 $\mu$ mhos/cm
pH	6.5 to 8.0
Ammonium	1.0
Sodium	110
Total Hardness (as CaCO <sub>3</sub> )	220
Sulfate	125
Chloride	120
Total Nitrogen (as N)	10
Fluoride	0.8
Boron	0.5
MBAS	0.5
Hexavalent Chromium	0.05
Cadmium	0.01
Selenium	0.01
Phenol	0.001
Copper	1.0
Lead	0.05
Mercury	0.005
Arsenic	0.05
Iron	0.3
Manganese	0.05
Barium	1.0
Silver	0.05
Cyanide	0.2

The injection water shall not cause taste, odors, foam or color in ground water.

The filter effluent turbidity shall not exceed 1.0 unit.

The carbon adsorption column effluent shall not exceed a chemical oxygen demand concentration of 30 mg/l.

The chlorine contact basin effluent shall always contain a free chlorine residual.

wastewater treatment plant for removing heavy metals from trickling filter effluent.

### Removal — Biological Treatment

The removal of heavy metals during primary and secondary treatment can proceed by two mechanisms:

1. Precipitation of metal hydroxides, which are removed with the sludges;
2. Sorption of soluble trace metals by the sludges.

The precipitation of metal hydroxides is governed by the concentration of the metal ion in solution and the pH. Generally, as the pH increases, the solubility of the metal hydroxides decreases. This relationship is expressed by the equation for the solubility product of a compound:

$$\frac{[M_x^{++}] [(OH^-)^2]}{[M_x(OH)_2]} = K_{sp} = \text{solubility product.}$$

As the concentration of the hydroxyl ion increases with increasing pH, the concentration of  $M_x(OH)_2$  (metal hydroxide), must increase for the solubility product to remain constant. The solubility products of several cationic heavy metals oxides and hydroxides are listed in Table 2.

The precipitation of copper, chromium, nickel and zinc by sewage has been reported by Jenkins, et al.<sup>7</sup> They found that within the range of concentrations of copper used, 0.5 — 100 ppm Cu, the percentage precipitated increased with the concentration of copper and decreased with decreasing pH. At pH 3.0, the maximum precipitated was only 20 percent compared to 85 percent precipitated at pH 7-8. Soluble nickel salts were also precipitated by

**Table 2: Solubility products of cationic heavy metal oxides or hydroxides<sup>4,5,6</sup>**

Compound	K <sub>sp</sub>
Ag <sub>2</sub> O	2 x 10 <sup>-8</sup>
Au(OH) <sub>3</sub>	8.5 x 10 <sup>-45</sup>
BaCO <sub>3</sub> *	1.6 x 10 <sup>-9</sup>
BaSO <sub>4</sub> *	1 x 10 <sup>-10</sup>
BiOOH	3 x 10 <sup>-11</sup> **
Cd(OH) <sub>2</sub>	2 x 10 <sup>-14</sup>
Cr(OH) <sub>3</sub>	1 x 10 <sup>-30</sup>
Cu(OH) <sub>2</sub>	3 x 10 <sup>-19</sup>
Fe(OH) <sub>2</sub>	1.8 x 10 <sup>-15</sup>
Fe(OH) <sub>3</sub>	6 x 10 <sup>-38</sup>
HgO	3 x 10 <sup>-26</sup>
Mn(OH) <sub>2</sub>	2 x 10 <sup>-13</sup>
Pb <sub>2</sub> O(OH) <sub>2</sub>	1.6 x 10 <sup>-15</sup>
SnO	1 x 10 <sup>-61</sup>
Ti(OH) <sub>3</sub>	1 x 10 <sup>-40</sup> **
Zn	4.5 x 10 <sup>-17</sup>

\*Barium compounds that will form preferentially to the hydroxide in most waters.

\*\*Estimated value, not verified.

**Table 4: Sand filtration**

Metal	Ref.	Concentra. Before Treatment mg/l	Concentra. After Treatment mg/l	pH	Percent Removal
Cd	14	Trace		8.1	95
	15	0.00075	0.00070	7.6	6.6
Cr <sup>+6</sup>	15	0.0503	0.049	7.6	2.6
Cr <sup>+3</sup>	16	2.7	0.63	8.7	77
Cu	16	0.79	0.32		59.5
	17	—	0.5	9.5	
Fe	19		0.1	10.8	
	19		1.2 Organic	10.5	
Mn	19		<0.1	10.8	
	19		1.1 Organic	10.5	
Ni	16	0.08	0.1	8.7	
	17		0.5	9.5	
Se	15	.0103	0.00932	>11	9.5
Ag	15	0.00164	0.00145	>11	11.6
Zn	16	0.97	0.23	8.7	76.3
	17		2.5	9.5	

Note: Temperature: Ambient 20-25 °C.

**Table 5: Carbon Adsorption**

Metal	Ref.	pH before Carbon	Concentration before Carbon mg/l	Concentration after Carbon mg/l	Percent Removal
Cd	15	7.6	0.00070	9 x 10 <sup>-6</sup>	98.7
Cr <sup>+6</sup>	15	7.6	0.049	0.00171	96.5
Se	15	7.6	0.00932	0.00585	37.2
Ag	15	7.6	0.00145	0.000048	96.7

Note: Temperature: Ambient 20-25 °C.

sewage. Average removals ranged between 50 and 60 percent and a reduction in pH produced little effect upon the precipitation of nickel.

Soluble salts of zinc were precipitated by sewage to the extent of 60 percent at 100 ppm Zn, but increased to 80 percent at 10 ppm Zn. The efficiency of precipitation was reduced to 50 – 60 percent at pH 5 and less than 20 percent at pH 3. The precipitation of chromium (Cr<sup>+6</sup>) was dependent on the period of contact to a much greater extent than the other metals. At low concentration, 50 – 70 percent was precipitated at the 0.5 ppm Cr level in sewage for periods up to 24 hours, but instantaneous precipitation was less than 20 percent. It appears that the removal of chromate in sewage depends upon the reduction of hexavalent chromium to one trivalent form and subsequent precipitation of trivalent chromium.

Moore, et al.<sup>8</sup> conducted pilot plant studies to determine the effects of chromium on the activated sludge process and to determine the extent of its removal. Their results indicated that concentrations of hexavalent chromium up to 0.5 ppm were usually completely removed. For higher chromate feed concentrations, an increasing-but-variable amount of the chromium passed through the system.

McDermott, et al.<sup>9</sup> studied the effects of copper on three activated sludge pilot plants. Copper was added to two of the three plants, while the third served as a control. The effects of the copper were measured by differences in effluent quality. The activated sludge process averaged from 50 to 79 percent efficiency in removing copper over a range of feed concentrations from 0.4 to 25 ppm.

McDermott, et al.<sup>10,11</sup> also studied the removal of zinc and nickel in pilot-scale activated sludge plants. Their results show that 95 to 74 percent of the zinc was removed at feed concentrations of 2.5 and 20 ppm respectively. Their results show the process was only about 30 percent efficient in removing nickel from wastewaters.

Barth, et al.<sup>12</sup> conducted pilot-scale studies on the effect of heavy metals on biological treatment processes and reported a material balance of the metals through an activated sludge process. They found the average efficiencies of the process for removing the metals were 44, 75, 28 and 89 percent for hexavalent chromium, copper, nickel and zinc, respectively. A survey of four municipal wastewater treatment plants was conducted by Barth, et al.<sup>13</sup> and the distribution of Cr<sup>+6</sup>, copper, nickel and zinc through these plants indicated a satisfactory correlation with the pilot plant results.

### Removal – Chemical Treatment

Chemical treatment with lime results in a reduction of heavy metal concentrations, since many of the metals form insoluble hydroxides at high pH. It appears that it is possible to reduce some of the metal concentrations below that predicted by the solubility products. This may be due to adsorption of the metal ions by the chemical floc.

Table 3 gives the results of lime coagulation treatment of a number of different types of municipal and industrial wastes. Some of the industrial metal wastes have pretreatment metal ion concentrations a great deal higher than would probably appear in any municipal treatment plant. These data were included due to the scarcity of metal reduction results from actual chemical coagulation of secondary sewage. In any case, the treatment was similar. For those metals where actual plant or good laboratory data were not found, the concentration reduction was estimated from solubility data of the hydroxides or, in the case of barium and lead, the carbonate.

### Removal – Mixed Media

After chemical treatment of a wastewater, it can be filtered to remove residual particulate matter. Filtration may be performed before or after recarbonation. It appears that a higher metal reduction occurs if filtration is performed before recarbonation because a part of the metal hydroxides that remain in unsettled particulate form are removed. Table 4 gives the results of sand filtration of the same wastes considered in lime coagulation.

**Table 3: Lime coagulation and recarbonation**

Metal	Ref.	Concentration Before Treatment mg/l	Concentration After Treatment mg/l	Final pH	Percent Removal
Antimony <sup>1</sup>	5			11	~90
Arsenic <sup>1</sup>	5			11	<10
Barium <sup>1</sup>	5		~1.3 (sol) <sup>2</sup>	11	
Bismuth <sup>1</sup>	5		0.0002 (sol)	11	
Cadmium	14	Trace		11	~50
	15	0.0137	0.00075	>11	94.5
Chromium (+6)	15	0.056	0.050	>11	11
Chromium (+3)	16	7,400	2.7	8.7	99.9+
Copper	16	15,700	0.79	8.7	99.9+
	17	7	1	8	86
	17	7	0.05	9.5	93
	18	302	Trace	9.1	99+
Gold <sup>1</sup>	5		< .001 (sol)	11	90+
Iron	18	13	2.4	9.1	82
	19	17	0.1	10.8	99+
	19	2.0	1.2 <sup>3</sup>	10.5	40
Lead <sup>1</sup>	5		< .0001 (sol) <sup>2</sup>	11	90+
Manganese	19	2.3	< 0.1	10.8	96
	19	2.0	1.1 <sup>3</sup>	10.5	45
	20	21.0	0.05	9.5	95
Mercury <sup>1</sup>	5		Oxide soluble		<10
Molybdenum	14	Trace		8.2	~10
Nickel	16	160	0.08	8.7	99.9+
	17	5	0.5	8	90
	17	5	0.5	9.5	90
	21	100	1.5	10.0	99
Selenium	15	0.0123	0.0103	>11	16.2
Silver	15	0.0546	0.0164	>11	97
Telurium <sup>1 4</sup>	5		(< 0.001?)	11	(?90+)
Titanium <sup>1 4</sup>	5		(< 0.001?)	11	(?90+)
Uranium <sup>5</sup>	5		?		?
Zinc	5		.007 (sol)	11	90+

**Notes:**

1. The potential removal of these metals was estimated from solubility data.
2. Barium and lead reductions and solubilities are based upon the carbonate.
3. These data were from experiments using iron and manganese in the organic form.
4. Titanium and Telurium solubility and stability data made the potential reduction estimates unsure.
5. Uranium forms complexes with carbonate ion. Quantitative data were unavailable to allow determination of this effect.
6. Temperature: Ambient 20-25 °C.

**Removal – Carbon Adsorption**

Activated carbon may be contacted with the wastewater following lime coagulation, filtration or directly after secondary treatment. With water containing no organics, carbon contacting usually has little effect on metal ions. Lindstedt and O'Connor<sup>15</sup> have found, however, for several metal ions, that activated carbon treatment results in a surprising reduction (over 96 percent for 3 of the 4 metal ions studied.) Table 5 summarizes their results. The cause of this is not well known, but it appears possible that some of the organics in the wastewater stream serve as coadsorbates linking the metal ions and the carbon. More research is needed before the capacity of activated carbon to adsorb metal ions from a municipal waste stream is fully explained. ■

Part II, Pilot plant operation, will appear next month. — Ed.

**References**

1. Pringle, B. H., Hissange, D. E., Katz E. L. & Mulawka, S. T. Trace Metal Accumulation by Estuarine Mollusks. *Jour. San. Eng. Div.* 94:455-473 (1968).
2. Bunch, R. L. & Ettinger, M. B. Water Quality Depreciation by One Cycle of Municipal Use. *Jour. WPCF.*, 36:1411 (1964).
3. Drinking Water Standards. USPHS Publ. No. 959 (1962).
4. Homer, Jackson & Thurston. *Industrial Waste Treatment Practice*. Butterworths Associated with Imp. Chem. Ind. Ltd. (1961).
5. Latimer, W. M. *The Oxidation States of the Elements and Their Potentials in Aqueous Solutions*. 2nd Ed. Prentice-Hall,

- Inc., Englewood Cliffs, N. J. (1952).
6. Feitknecht, W. & Schindler, P. Solubility Constants of Metal Hydroxide Salt in Aqueous Solution. *IUPAC Pure and Applied Chemistry*, 6:180 (1963).
7. Jenkins, S. H., Keight, D. G. and Ewins, A. The Solubility of Heavy Metal Hydroxides in Water, Sewage and Sewage Sludge — II, The Precipitation of Metals by Sewage. *Int. Jour. Air Water Poll.*, 8:679-693 (1964).
8. Moore, W. A., McDermott, G. N., Post, M. A. et al, Effects of Chromium on the Activated-Sludge Process. *Jour. WPCF*, 33:54 (Jan. 1961).
9. McDermott, G. N. Moore, W. A., Post, M. A. & Ettinger, M. B. Effects of Copper on Aerobic Biological Sewage Treatment. *Jour. WPCF*, 35:227 (Feb. 1963).
10. McDermott, G. N., Barth, E. F., Salotto, B. V. & Ettinger, M. B. Zinc in Relation to Activated-Sludge and Anaerobic Digestion Processes. *Proc. 17th Ind. Waste Conf., Lafayette, Ind. May 1-3, 1962*. Eng. Ext. Ser. 112. Eng. Bull., Purdue Univ. 47 (2), 461 (Mar. 1963).
11. McDermott, G. N., Post, M. A., Jackson, B. N. & Ettinger, M. B. Nickel in Relation to Activated-Sludge and Anaerobic Digestion Processes. *Jour. WPCF*, 37:163 (Feb. 1965).
12. Barth, E. F. Ettinger, M. B., Salotto, B. V. & McDermott, J. N. Summary Report on the Effects of Heavy Metals on Biological Treatment Processes. *Jour. WPCF*, 37: 1:86 (Jan. 1965).
13. Barth, E. F., English, J. N., Salotto, B. V., Jackson, B. N. & Ettinger, M. B. Field Survey of Four Municipal Wastewater Treatment Plants Receiving Metallic Wastes. *Jour. WPCF*, 37:1101, 1121 (Aug. 1965).
14. Robert A. Taft Sanitary Engineering Center. Report of the Joint Program of Studies on the Decontamination of Radioactive Waters. ORNL-2557, TID-4500 (14th ed) Oak Ridge National Laboratory (Feb. 1959).
15. Lindstedt, K. D., Houck, C. P. & O'Connor, J.T. Trace Element Removals In Advanced Wastewater Treatment Processes. *Jour. WPCF*, 43:1507 (July 1971).

# Heavy metals removal in wastewater treatment processes:

## Part 2 — pilot plant operation

By David G. Argo and Gordon L. Culp\*

**Part I, which appeared last month, reviewed the literature to determine what is known about the reduction in concentration of heavy metals in wastewater treatment. Part II evaluates the efficiency of Orange County Water District's pilot-scale treatment plant for removing heavy metals from trickling filter effluent.**

The Orange County Water District's wastewater reclamation pilot plant consisted of units for chemical treatment, sedimentation, ammonia stripping, recarbonation, mixed media filtration, activated carbon adsorption and chlorination. The capacity of the treatment units varied from 7,000 to 35,000 gpd and most of the units were constructed especially for the pilot study. The process flow diagram is shown in Figure 1.

Secondary effluent pumped from the Orange County Sanitation District's Treatment Plant No. 1 provided the influent for OCWD's pilot plant. Plant No. 1 provides conventional secondary treatment employing trickling filters to 15 mgd of the total plant flow of about 50 mgd. The remaining 35 mgd receives primary treatment only.

Lime was the only primary coagulant used in the chemical treatment process. Lime as calcium hydroxide was pumped with a metering pump to a rapid-mix basin in a 10 percent slurry. An average lime dose of 500 mg/l as calcium hydroxide was required to achieve a pH greater than 11.0. The high pH and subsequent high lime dose was needed not only to achieve good coagulation but is also a necessary step for satisfactory operation of the ammonia

stripping unit. The detention time in the rapid-mix basin was about 1 minute.

Following the rapid-mix basin was a flocculation basin divided into three bays and baffled in an attempt to provide plug flow. The total detention time in the flocculation basin was about 30 minutes. Each bay was equipped with a variable-speed paddle mixer. This enabled variation of the mixing energy. Generally, the units were operated with a G value ( $\text{sec}^{-1}$ ) of 100, 40 and 10 in the first, second and third bays, respectively.

Sedimentation was accomplished in a basin that was 8.5 ft long, 2.5 ft wide and 9 ft deep. The chemical clarifier was operated with or without settling tubes.\*\* The detention time in the clarifier was approximately 45 minutes and the overflow rate about 1,440 gpd/sq ft.

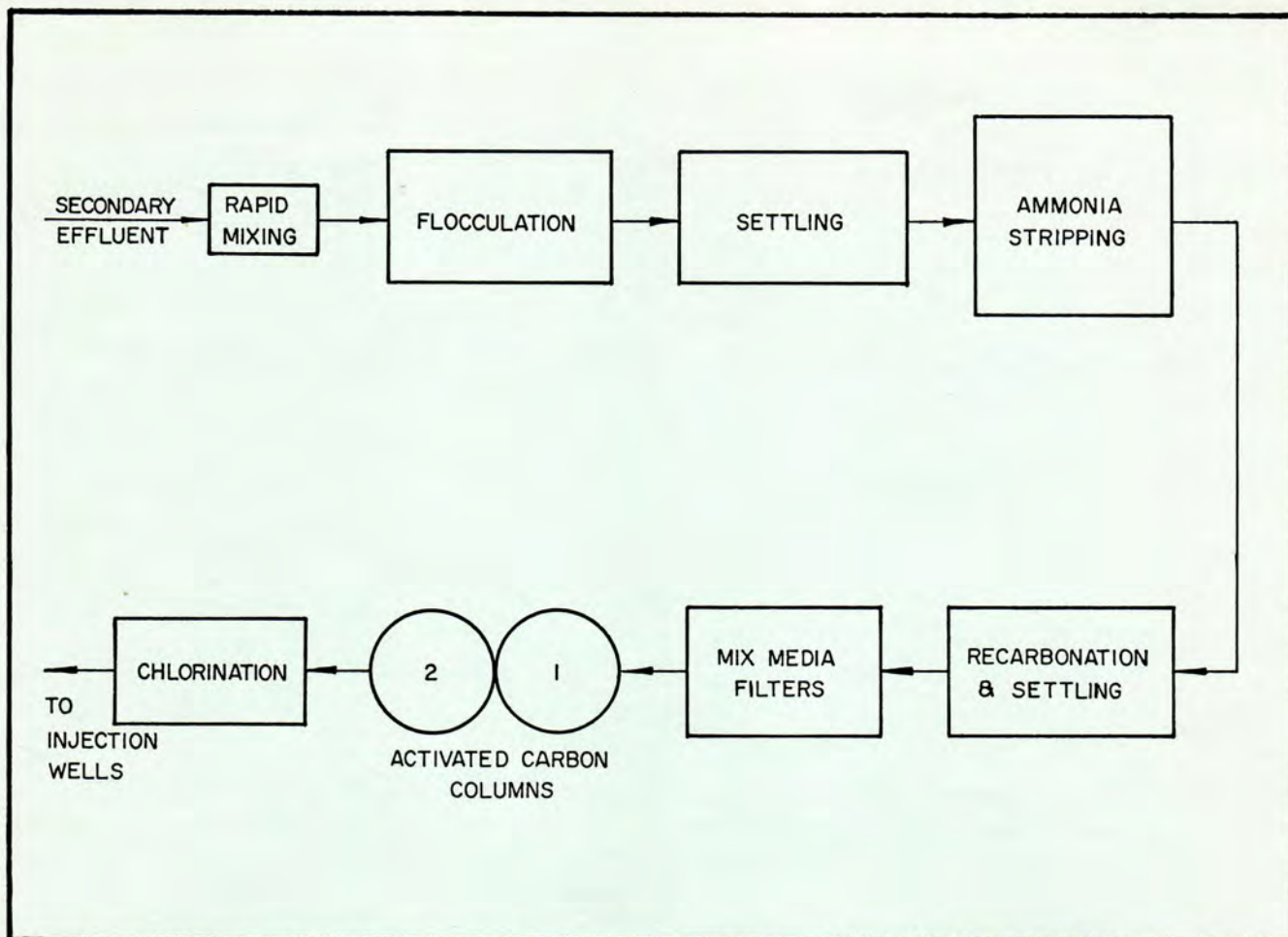
An ammonia stripping tower followed the chemical clarifier. This unit was included in the pilot plant study for nitrogen removal but its presence is of little concern with regard to this report.

After the stripping tower recarbonation was achieved by bubbling compressed  $\text{CO}_2$  gas into the effluent to adjust the pH to about 7.5.

The mixed-media filter used was a pressure unit, and effluent from the recarbonation basin was pumped downflow through the filter prior to entering the activated carbon units. This filter was used to reduce the suspended solids loading of the carbon columns. The test filter was constructed from a 14-in. diameter pipe, complete with viewing windows at specific locations. The filter media was supplied

\*Orange County Water District and vice president, CH2M/Hill, consulting engineers, Reston, Va., respectively.

\*\* Settling tubes, manufactured by Neptune MicroFloc, Inc., Corvallis, Oregon.



Process flow diagram for the Orange County Water District's wastewater reclamation pilot plant.

by Neptune MicroFloc. The filter was operated at a hydraulic loading of 5 gpm/sq ft.

The two activated carbon units used were packed bed, downflow columns which were operated in series. Each column was 20 in. in diameter and approximately 10 ft high. The columns were filled to a depth of 6 ft with 360 lb of activated carbon.\* The carbon columns were operated to provide a minimum 35-minute contact time.

Effluent from the carbon columns flowed into a chlorine contact tank 8 ft long, 2 ft wide and 3 ft deep. Five baffle plates were placed in the tank in an effort to provide plug flow. The detention time in the basin was about 30 minutes and an average chlorine dose of 25 ppm was required to maintain a free chlorine residual.

During the operation of the pilot plant, monthly composite samples of the plant's influent and effluent were collected. Each month these samples were sent to the California State Health Department where the analyses for several heavy metals were performed. Unfortunately, due to the limitations of time and budget, composite samples of the effluent from the various unit operations were not analyzed for heavy metals.

However, from the public health standpoint, overall plant performance is the primary criterion when evaluating the removal of heavy metals from wastewater. Therefore, the authors feel that, although the data do not permit evaluation of the effective-

\*Filtrisorb 300, manufactured by Calgon Corp., Pittsburgh, Pa.

ness of the individual unit processes, a starting point is provided for some much-needed information on the overall performance of advanced wastewater and water treatment processes in removing heavy metals from secondary sewage effluent.

### Results and Discussion

The Orange County Water District pilot wastewater reclamation plant study was performed for the express purpose of obtaining design data for a full-scale 15 mgd reclamation plant. Table 6 contains typical water quality data indicating the per-

Table 6: Typical water quality pilot wastewater reclamation plant influent and effluent

Constituent	Concentration, mg/l	
	Influent	Effluent
Calcium	70 - 110	80
Magnesium	20 - 45	2
Sodium	240 - 260	240 - 260
Potassium	20 - 35	20 - 35
Bicarbonate	200 - 450	250
Sulfate	270 - 350	270 - 350
Chloride	300 - 350	300 - 350
Phosphate	20 - 25	< 1
Nitrogen		
Organic	5 - 15	< 1
Ammonia	15 - 30	< 2
Nitrite	< 1	< 1
Nitrate	< 1	< 1
Total Dissolved Solids	1200 - 1400	1000 - 1100
Suspended Solids	30 - 80	< 1
BOD	30 - 80	< 2
COD	100 - 200	10 - 30
MBAS	3 - 4	0.1

**Table 7: Heavy metals removed by the Orange County Water District Pilot Plant**

Constituent — Arsenic  
Regulatory Agency Requirement — 0.05 mg/l

Month	Influent Concentration mg/l	Effluent Concentration mg/l	Percent Removed
June 1971	0.00	0.00	--
May	0.01	0.00	100
April	0.00	0.00	--
March	0.01	0.00	100
February	0.01	0.03	+ 300
January		0.02	
Dec. 1970		0.00	
November		0.01	
October		0.00	

**Table 8: Heavy metals removed by the Orange County Water District Pilot Plant**

Constituent — Barium  
Regulatory Agency Requirement — 1.0 mg/l

Month	Influent Concentration mg/l	Effluent Concentration mg/l	Percent Removed
June 1971	0.0	0.0	—
May	0.0	0.0	—
April	0.0	0.0	—
March	0.0	0.0	—
February	<0.02	<0.02	—
January	—	0	—
Dec. 1970	—	0	—
November	—	0	—
October	—	<1	—

**Table 9: Heavy metals removed by the Orange County Water District Pilot Plant**

Constituent — Cadmium  
Regulatory Agency Requirement — 0.01 mg/l

Month	Influent Concentration mg/l	Effluent Concentration mg/l	Percent Removed
June 1971	0.011	0.004	74
May	0.015	0.003	80
April	0.130	0.002	98
March	0.022	0.002	91
February	0.020	0.000	100
January		0.005	
Dec. 1970		0.003	
November		0.000	
October		0.000	

**Table 10: Heavy metals removed by the Orange County Water District Pilot Plant**

Constituent — Hexavalent Chromium  
Regulatory Agency Requirement — 0.05 mg/l

Month	Influent Concentration mg/l	Effluent Concentration mg/l	Percent Removed
June 1971	0.11	0.01	91
May	0.09	0.00	100
April	0.09	0.01	89
March	0.12	0.01	92
February	0.19	0.02	89
January		0.02	
Dec. 1970		0.03	
November		0.01	
October		0.04	

formance and efficiency of the pilot wastewater reclamation plant. Several heavy metals were also analyzed to determine the treatment system effectiveness for their removal and any possible public health implications.

### Arsenic Removal

Table 7 gives the results of the treatment processes for removing arsenic. During the nine-month test period, the arsenic concentration in the plant's influent varied between 0.00-0.01 mg/l. The plant's effluent concentration varied from 0.00-0.03 mg/l. The pilot plant treatment system was not particularly consistent in removing arsenic; however, this is probably a result of the extremely low concentration found in the plant's influent. During two months the plant removed 100 percent of the arsenic. Then, during the month of February, there was an increase in arsenic concentration through the plant of 0.02 mg/l. This increase is not fully understood. Possibly a shock load or operational upset stripped previously adsorbed arsenic from the carbon columns. Also, there is always a possibility there was an error in the lab analysis.

The results indicate that there is little danger of a public health hazard from arsenic in the wastewater reclamation plant's effluent. Concentrations of arsenic found in the plant's influent and effluent were always below the regulatory agencies' requirements of 0.05 mg/l.

### Barium Removal

Table 8 gives the results of the treatment processes for removing barium. The results indicate that the secondary effluent used as the pilot plant's influent usually contained no barium. Only once during the test period was any barium detected, and then its concentration was less than 0.02 mg/l.

### Cadmium Removal

Table 9 shows the pilot plant efficiency for removing cadmium. Cadmium concentrations found in the plant's influent ranged from a low of 0.011 mg/l to a high of 0.022 mg/l. Following treatment, effluent concentrations were reduced to a range of 0.00 mg/l to 0.005 mg/l. The operating efficiency of the plant for removing cadmium varied between 74 and 100 percent. The average removal was 89 percent. Higher efficiency appears to be a function of influent concentration. As influent concentration increases, so does removal.

During the test period, the cadmium concentration in the pilot plant's influent was never below the 0.01 mg/l limit set by the regulatory agencies. But after treatment, the pilot plant's effluent was always well below the 0.01 mg/l limit.

### Hexavalent Chromium Removal

Table 10 gives the results of the pilot treatment processes for removing hexavalent chromium. The concentration of chromium in the plant influent ranged from 0.09 to 0.19 mg/l. After treatment, the pilot plant effluent contained only 0.01 to 0.04 mg/l of chromium. The pilot treatment processes were very effective in removing chromium. Removal efficiencies varied from 89 to 100 percent.

During the test period, the pilot plant influent always contained concentrations of hexavalent chromium that exceeded the 0.05 mg/l limit. After

treatment, however, the concentration was always reduced below the permissible limit.

### Lead Removal

Table 11 shows the efficiency of the pilot plant's treatment processes for removing lead from wastewater. The concentration of lead in the plant's influent varied from 0.00 to 0.05 mg/l. Following treatment, these concentrations were reduced to a range of 0.00 to 0.04 mg/l. The removal efficiency varied from 0 to 50 percent. The average removal was 30 percent.

While the treatment processes were not particularly effective or consistent in removing lead from the wastewater, there is no need for immediate concern. Possibly, the poor removals may have been a result of the very low concentrations of lead in the influent. During the test period, both the pilot plant influent and effluent always contained concentrations of lead within the imposed limit of 0.05 mg/l.

### Selenium Removal

Table 12 gives the efficiency of the pilot plant's treatment processes for removing selenium. The concentration of selenium in the plant's influent varied from 0.00 to 0.003 mg/l. The concentration of selenium in the plant's effluent was 0.000 to 0.003 mg/l. A large variation in removal efficiency was observed. Removals ranged from 0 to 89 percent. The highest efficiency was observed when the influent concentration of selenium was a maximum. It appears that higher efficiencies are increasingly difficult to achieve at lower concentrations. During the test period, neither the plant's influent nor effluent contained concentrations of selenium that exceeded the imposed limit of 0.01 mg/l.

### Silver Removal

Table 13 shows the results of the pilot plant's treatment processes for removing silver. The influent concentration of silver was 0.00 to 0.01 mg/l. The effluent concentration also varied between 0.00-0.01 mg/l. The pilot treatment processes were not very consistent in removing silver, though during one month 100 percent of the silver was removed. This inconsistency was probably a result of the extremely low influent concentrations. During the test period, silver was found in the plant influent only three times. Neither the plant's influent nor effluent ever exceeded 0.01 mg/l in silver concentration, an amount below the maximum allowable silver concentration of 0.05 mg/l imposed by the regulatory agencies.

### Mercury Removal

Table 14 shows the results of the pilot plant's treatment processes for removing mercury. The mercury concentration in the plant's influent was between <0.001 to 0.003 mg/l. The plant's effluent concentration varied from 0.000 to 0.006 mg/l. Again, the pilot plant was inconsistent in further reducing the extremely low influent mercury concentration. Also during the month of February, there was a 0.003 mg/l increase in mercury concentration through the pilot plant. The cause of this increase was not understood. Possibly a change in plant operation or a shock load resulted in stripping previously adsorbed mercury from the carbon columns, or

Table 11: Heavy metals removed by the Orange County Water District Pilot Plant

Constituent — Lead

Regulatory Agency Requirement — 0.05 mg/l

Month	Influent Concentration mg/l	Effluent Concentration mg/l	Percent Removed
June 1971	0.00	0.00	—
May	0.02	0.01	50
April	0.02	0.02	—
March	0.04	0.02	50
February	0.05	0.04	20
January		0.01	
Dec. 1970		0.03	
November		0.01	
October		0.01	

Table 12: Heavy metals removed by the Orange County Water District Pilot Plant

Constituent — Selenium

Regulatory Agency Requirement — 0.01 mg/l

Month	Influent Concentration mg/l	Effluent Concentration mg/l	Percent Removed
June 1971	0.00	0.00	—
May	0.009	0.001	89
April	0.003	0.002	33
March	0.002	0.002	0
February	0.002	0.002	0
January		0.003	
Dec. 1970		0.003	
November		0.000	
October		0.001	

Table 13: Heavy metals removed by the Orange County Water District Pilot Plant

Constituent — Silver

Regulatory Agency Requirement — 0.05 mg/l

Month	Influent Concentration mg/l	Effluent Concentration mg/l	Percent Removed
June 1971	0.01	0.01	0
May	0.00	0.00	—
April	0.00	0.00	—
March	0.01	0.00	100
February	0.01	0.01	0
January		0.00	
Dec. 1970		0.00	
November		0.00	
October		0.00	

Table 14: Heavy metals removed by the Orange County Water District Pilot Plant

Constituent — Mercury

Regulatory Agency Requirement — 0.005 mg/l

Month	Influent Concentration mg/l	Effluent Concentration mg/l	Percent Removed
June 1971	< 0.001	< 0.001	—
May	0.001	0.001	0
April	< 0.001	< 0.001	—
March	0.003	0.002	33
February	0.003	0.006	+100
January		0.000	
December 1970		< 0.001	
November		< 0.001	
October		< 0.001	



**Table 15: Heavy metals removed by the Orange County Water District Pilot Plant**

Constituent — Copper			
Regulatory Agency Requirement — 1.0 mg/l			
Month	Influent Concentration mg/l	Effluent Concentration mg/l	Percent Removed
June 1971	0.12	0.05	58
May	0.12	0.03	75
April	0.39	0.02	95
March	0.12	0.04	67
February	0.09	0.04	56
January		0.30	
Dec. 1970		0.13	
November		0.05	
October		<0.2	

**Table 16: Heavy metals removed by the Orange County Water District Pilot Plant**

Constituent — Zinc			
Regulatory Agency Requirement — None			
U. S. Public Health Service			
Drinking Water Standards — 5.0 mg/l			
Month	Influent Concentration mg/l	Effluent Concentration mg/l	Percent Removed
June 1971	0.09	0.02	78
May	0.07	0.02	71
April	2.08	0.02	99
March	0.12	0.03	75
February	0.16	0.07	56
January		0.07	
Dec. 1970		0.03	
November		0.07	
October		<0.05	

an error in sampling or in lab analysis may have occurred.

The maximum concentration of mercury permitted by the discharge requirements was 0.005 mg/l. During the test period, the pilot plant influent was always below this allowable concentration. The pilot plant's effluent mercury concentration was also below the imposed limit every month except February, when the unexplained increase took place.

#### Copper Removal

Table 15 gives the efficiency of the pilot treatment processes for removing copper. The copper concentration in the plant's influent varied from 0.09 to 0.39 mg/l; the concentration of copper in the plant's effluent varied from 0.02 to 0.30 mg/l. The removal efficiency ranged from 56 to 95 percent, with average removal 70 percent. Again, the highest removal occurred when influent copper concentration was maximum. During the test period, neither the influent nor effluent copper concentration exceeded the limit of 1.0 mg/l.

#### Zinc Removal

Table 16 gives the efficiency of the pilot treatment processes for removing zinc. The zinc concentration in the plant's influent varied between 0.07-2.08 mg/l and the zinc concentration in the effluent was between 0.02-0.07 mg/l. The removal efficiency varied from 56 to 99 percent. The highest removal occurred when influent concentration was maximum. During the test period, neither the influent nor effluent zinc concentration exceeded the imposed limit of 5.0 mg/l.

#### Summary and Conclusions

The Orange County Water District's pilot plant treatment system of lime coagulation and settling, mixed media filtration and activated carbon adsorption was very effective in reducing the concentrations of cadmium, hexavalent chromium, zinc and copper. This advanced wastewater treatment scheme also reduced the concentrations of the remaining heavy metals studied with varying degrees of success. It was observed that removal efficiency appeared to be dependent on influent concentration. The lower removals always occurred when influent concentrations were very low.

The results of this investigation indicate that certain heavy metals can be removed along with organics, suspended solids and other inorganics by lime coagulation, mixed media filtration and activated carbon adsorption. Further research is needed to more fully define the mechanism of these removals. The advanced wastewater treatment processes selected for the Orange County Water District's wastewater reclamation plant could effectively reduce potentially hazardous concentrations of heavy metals and produce an effluent compatible with water quality discharge standards imposed by the regulatory agencies. ■

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#### References

- Stone, E. H. F. Treatment of Non-Ferrous Metal Process Wastes of Kynoch Works, Birmingham, England. *Proceedings, 22 Annual Ind. Waste Conf.*, Purdue University, Part 2, 848 (1967).
- Walker, C. A., et al. Treatment of Lagoon Waters. *Sewage and Ind. Wastes*, 26:8:1008 (1954).
- McElhoney, H. W. Metal — Finishing Wastes Treatment at the Meadville, Pa. Plant of Talon, Inc. *Sewage and Ind. Wastes*, 25:4:475 (1953).
- Nordell, Eskel. *Water Treatment for Industrial and Other Uses*. 2nd Ed. Reinhold Pub. Corp., New York (1961).
- Robinson, L. R., Jr., and Dixon, R. I. Iron Manganese Precipitation in Low Alkalinity Ground Waters. *Water and Sewage Works* (Nov., 1968).
- Kantawala, D. and Tomlinson, H. D. Comparative Study of Recovery of Zn and Ni by Ion Exchange Media and Chemical Precipitation. *WATER AND SEWAGE WORKS*, R280 (1964).