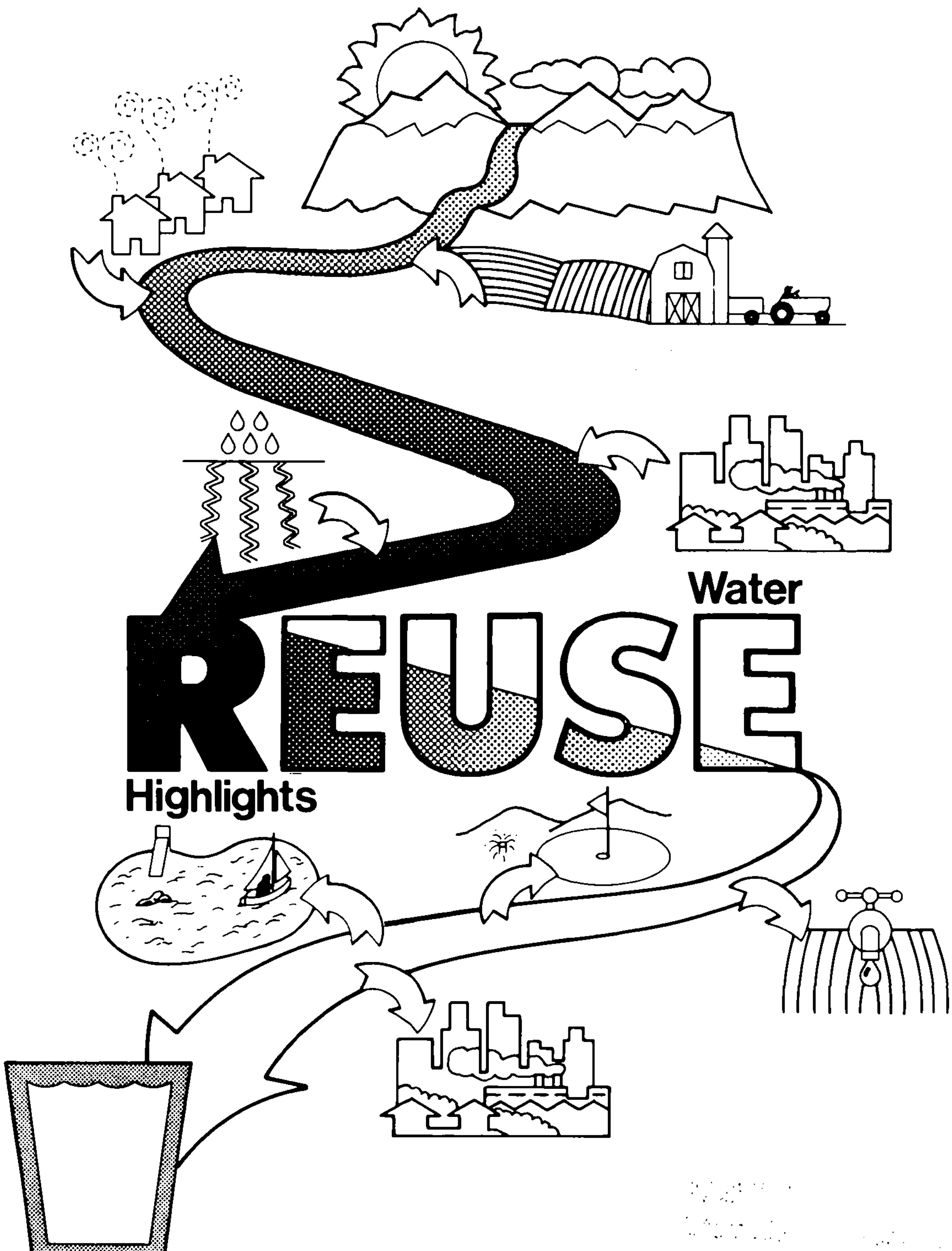
ɩearch Foundation



Water REUSE Highlights

TECHNOLOGY TRANSFER:
Office of Water Research and Technology — U.S. Department of the Interior — Washington, D.C. 20240
Environmental Research Information Center — U.S. Environmental Protection Agency — Cincinnati, Ohio 45268

WATER REUSE HIGHLIGHTS

A SUMMARY VOLUME OF
WASTEWATER RECLAMATION AND REUSE
INFORMATION

PREPARED BY:
The American Water Works Association Research Foundation

TECHNOLOGY TRANSFER FUNDING FROM:
Office of Water Research and Technology
U.S. Department of the Interior
Washington, D.C. 20240

Environmental Research Information Center
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

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INTRODUCTION

1. Since June of 1976, the AWWA Research Foundation has been involved in the gathering, preparation and distribution of technical information in the wastewater reclamation and reuse field. As a clearinghouse agent, current research data and project coordination was supplied on a contractual basis between several water utilities, federal agencies and foreign concerns interested in water reuse.

While the primary concern of the program was with potable reuse or the treating of sewage effluents to a domestic quality water, data on many water reuse alternatives was supplied.

In September of 1977, the Foundation received federal funds from the Office of Water Research and Technology and U.S. Environmental Protection Agency to publish monthly newsletters in municipal wastewater recycling. In addition to that periodical was the preparation of this summary volume of water reuse activities titled "Water Reuse Highlights". The information contained herein has been abstracted from earlier Foundation publications and attempts only to highlight a rather intensive field of endeavor. It should, however, prove to be a useful reference for those entities considering reclamation and reuse as a water supply alternative.

The material is divided into the following subheadings with a subject index on pages 118 - 119.

Advanced Wastewater Treatment (AWT) Research
Conference Calendar
Health Effects Research
Legislative and Funding Activities
Modeling for Reuse
Position Statements
Published Literature
Regulations
Water Reuse Plans and Demonstrations

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AWT RESEARCH

2. The reliability of AWT plants in reuse situations is often questioned. Using statistical analysis, Robert B. Dean, Science Advisor with the EPA, and Stanley L. Forsythe, Southwest Ohio Regional Computer Center in Cincinnati, Ohio, estimated the long-term reliability of the South Lake Tahoe, Nevada AWT plant from six years of operations data.

Sewage treatment plant performance is commonly measured in terms of average effluent quality covering different time periods. But average values give no indication of plant reliability. In water reuse circumstances, it is important to know the probability that a given process will exceed an established standard.

If an expression can be found that gives the fraction of concentration exceedance in the past, the future performance of the plant can be predicted provided it continues to operate in the same way. One can then predict how much the basic processes must be altered to meet a more stringent requirement.

Reliability of any process must be described by at least two numbers. If the distribution of the data is normal, then average and standard deviation results are adequate. But that assumption is not usually met with wastewater quality parameters where a log-normal distribution is evident. A calculated spread factor S, the antilog of the standard deviation, is a better measure of the frequency of the deviations.

The statistical methods were applied to the 7.5 mgd Tahoe AWT plant which has been operating since 1968 with the treatment sequence shown in Figure 1, and discharging a high quality effluent to Indian Creek Reservoir for recreational and agricultural reuse.

FIGURE 1

SOUTH LAKE TAHOE AWT PLANT FLOW PROCESS

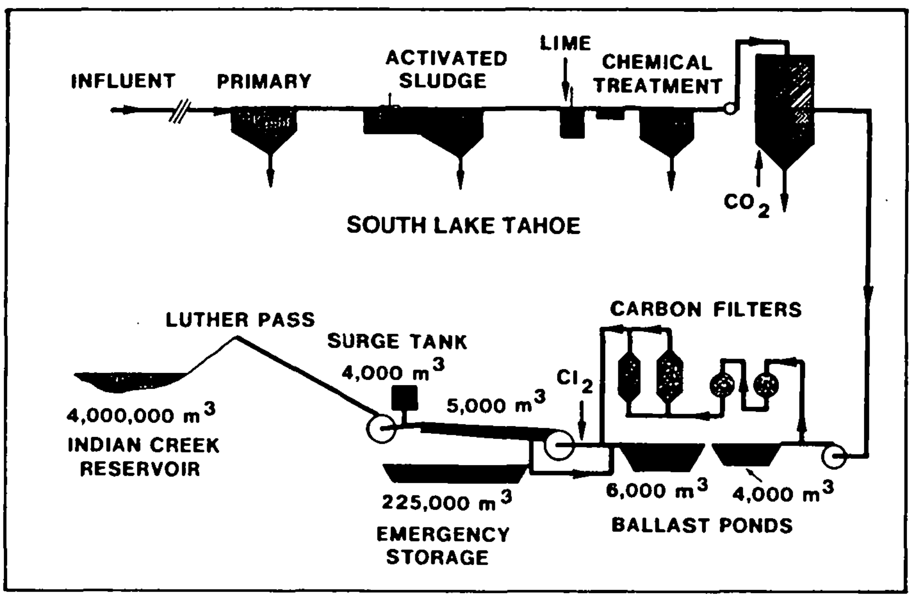

Table 1, on page 3, indicates the plant performance with median values as a good estimate of the geometric mean. Values within 98% and 99% of the median are also shown with the spread factors. The consistency of spread factors (all close to 2 except MPN) indicate good plant performance and control and suggests that any fluctuations are random and homogeneous. To improve the reliability of the plant, if warranted, would require design alterations.

What this data and tests on other AWT effluents across the U.S. is attempting to show is the need for statistical concepts in setting standards for discharges and

TABLE 1

SOUTH LAKE TAHOE EFFLUENT - 1968-1974

Parameter	Median	98%	99%	Spread Factor*
MBAS mg/l	0.18	0.54	0.64	1.72
BOD mg/l	1.3	5.36	6.36	2.05
COD mg/l	9.6	24.5	30.7	1.57
Suspended Solids	0	0	0	-
Turbidity JTU	0.30	1.20	1.50	1.94
Phosphorus mg/l	0.19	.91	1.22	2.11
Chlorine Residual mg/l	0.90	3.0	3.6	1.77
Coliform MPN/100 ml	(0.025)	5.1	13.0	13.

* *The Spread Factor, S, is the antilog of the standard deviation of the logarithms of the original data points.*

perhaps reuse situations which were previously not considered.

If the performance of a plant obeys normal or lognormal statistics, there is a real probability of exceeding any finite upper limit, although the probability may be very small. The requirement that a parameter never exceed a designated value is unrealistic from an operational point of view. If the requirement is rephrased to permit the parameter to exceed the designated value not more than one day in ten thousand, or once in about 30 years, one can at least calculate the required performance of the plant. If the Spread Factor is 2.0, the statistical tables show that the mean must be less than eight percent of the upper limit. If, instead, the designated upper limit can be exceeded one day in a thousand, the mean can be 12 percent of the upper limit and for one day in a hundred, it can be 20 percent of the limit. In any case, a plant will be designed as a compromise between the cost of meeting the regulation and the cost of not meeting it; that is, the cost of expected fines and other adverse results of exceeding the requirement.

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3. An unusual wastewater RO system using spiral wound modules was designed, built and installed for the El Dorado Irrigation District at Kirkwood Meadows in the California High Sierras. The ski resort, 30 miles from Lake Tahoe, has extremely stringent discharge requirements because of snow-melt conditions. The only alternative to demineralization was hauling the expected 50,000 gpd effluent and sludge 90 miles at tremendous expense.

RO treatment is preceded by filtration of the secondary effluent with a 90% water recovery. The quality of the final effluent, suitable for discharge to the sensitive environment and reuse is compared with the discharge limitations in Table 2.

TABLE 2

KIRKWOOD MEADOWS WATER QUALITY COMPARISON

PARAMETER	UNITS	DISCHARGE STANDARDS	R.O. PRODUCT
TDS	mg/l	20	15
BOD	mg/l	3	0
Cl_2	mg/l	0.1	0
Susp. Sol	mg/l	3	0

PARAMETER	UNITS	DISCHARGE STANDARDS	R.O. PRODUCT
Alkal.	mg/l	15	10
COD	mg/l	9	1
Calcium	mg/l	3	1
Magnesium	mg/l	1	0.3
Sodium	mg/l	3	1.8
Potassium	mg/l	1	0.9
Chlorides	mg/l	5	2
Sulfates	mg/l	0	1
Total N	mg/l	4	2
Phosphorus	mg/l	1	0
Silica	mg/l	-	0.6
Iron	mg/l	-	0
Coliform	MPN/100 ml	2.2	-
pH	units	6.5-8.5	6.5

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4. A powdered activated carbon with 2-4 times the surface area and adsorption ability of conventional products has been developed by Standard Oil Company of Indiana for use in industrial wastewater treatment. But, the new carbon will be tested at the municipal sewage treatment facility in Dyer, Indiana starting June 1, 1977. No regeneration of the carbon is expected because of high recycling and low biomass losses.

The Denver Water Department is also experimenting with the carbon in a two-stage, counter-current pilot operation to determine organic, metals, and bacterial removals for reuse research. The Amoco product has shown promising results in early tests, but heavy polymer doses were required for good settling and filtration.

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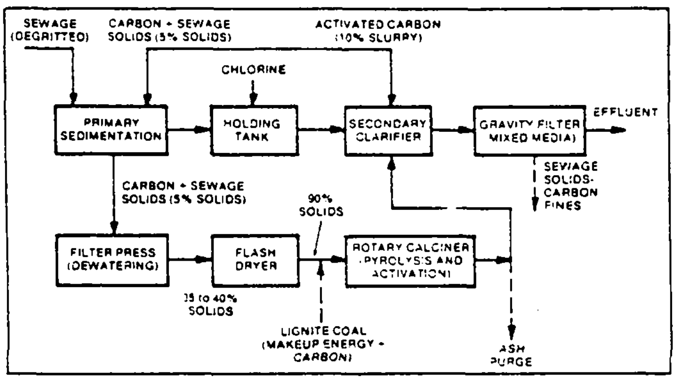
5. NASA Research at the Jet Propulsion Laboratory in Pasadena, California, in conjunction with the California Institute of Technology, has resulted in a less costly use of powdered activated carbon for physical-chemical-treatment (PCT) of sewage. Initial work in a 10,000 gpd pilot plant led to the design and construction of a 1 mgd facility in February of 1976 at the Orange County Sanitation District Plant in Fountain Valley.

As diagrammed in Figure 2, the process uses activated carbon to provide secondary treatment. The settled carbon-sludge mixture from the secondary clarifier is added to degritted raw sewage to improve primary clarification. This primary underflow is then dewatered through a filter press to 35-40% solids before entering a rotary calciner for pyrolysis and regeneration of the mixture to activated carbon and ash. The carbon is then fed back to the secondary clarifier to complete the cycle. A portion of the carbon ash is purged from the recycle to accommodate removal of sand, clay, metals and other inorganics. The P-C-T sludge could be converted to carbon itself,but the reaction is not self-sustaining. In

FIGURE 2

CAL TECH/JPL SYSTEM



the NASA research the supplemental carbon is delivered from cheap lignite coal which acts as a catalyst in the activation process. In addition, by-product gases can provide an energy source.

Laboratory-scale studies have indicated the feasibility of the method. Coal was pulverized to -40 mesh and mixed with an equal amount of primary sludge; the pyrolysis and activation conditions were 850^{o} C with steam applied for 20 minutes. The resulting carbon was 61.7% ash with an iodine adsorption of 684 mg/l of carbon. A raw sewage sludge COD of 421 was reduced to 59. Commercial activated carbon resulted in a COD of 60.

Secondary effluent goes to a gravity, mixed-media filter before ocean discharge. The main sewage plant itself is the feed source to Water Factory 21 with recharge facilities.

Capital costs were projected for installation of a 175 mgd plant based on the "JPL-Acts" process exclusive of land. The total ranged from $150-200 million which would provide up to 25% capital cost savings over conventional methods to meet the same ocean discharge standards.

Amortizing capital and O & M costs also reflected a 20-25% savings in total annual charges.

In an effort to find alternatives to wastewater disinfection with chlorine and the resultant chemical complexes, yet remove pathogens, additional research at the 1 mgd pilot plant has been conducted on carbon-chlorine systems.

Laboratory tests were conducted on the ability of chlorination between a 2-stage adsorption process to remove phenols, aliphatic amines, aromatic amines and PCB's. Satisfactory disinfection was accomplished with a product water low in chlorine and derivatives.

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6. As reported in the April, 1976 and March, 1977 issue of Desalination from the Elsevier Scientific Publishing Company in Amsterdam, research is being conducted in Israel on wastewater desalting for reuse purposes. Israel Desalination Engineering, Ltd., reported the development of new asymmetric, non-cellulosic membranes having a performance between that of a conventional RO and ultrafilter membrane.

Its main characteristics are high fluxes (4-10 m^3/m^2day) at low pressures (6-10 atm.) and moderate rejections for various salts. The new membranes can withstand large variations in pH (1-13), temperature (70°-120°C), and have excellent chemical and biological stability.

Both RO and ultrafiltration were deemed inadequate for the special conditions in treating sewage effluents such as the high particulate matter problem. In the new process, sewage ultrafiltration (SUF), clogging was prevented by tubular configurations, relatively high axial feed velocities and large flow channels.

Field tests were performed at the Dan Region Wastewater Treatment and Reclamation Plant which employs a series of three oxidation ponds. Typical effluent and the feed to the mobile membrane pilot plant is shown in Table 3.

TABLE 3

Effluent Composition mg/l	Oxidation Pond Effluent	HUF Membrane Effluent
BOD	72	5
Dissolved COD	100	20
Total COD	370	20
N_{Kj}	42	22
Suspended Solids	160	0
TDS	975	790
Turbidity JTU	70	0.3
Orthophosphate	13	1.6

Fluxes increased with increasing velocity reaching 37.2 gsfd at 10 ft./sc., and 8 atm. Periodical mechanical cleanings, performed by the passage of an oversized sponge ball through the membranes, combined with occasional acid and tap water cleaning were found to be effective in flux restoration.

It is the author's conclusion that the one step SUF process can produce without restriction suitable water for agriculture, groundwater recharge and industry, and with minor additional treatment, even for complete municipal recycle.

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7. Recent experiments at the Applied Physics Laboratory of the Johns Hopkins University in Maryland indicate the potential for wastewater disinfection with laser radiation. Bacterial destruction was due primarily to molecular oxygen which has been laser excited. Substantial coliform reduction was noted by oxygen pressurization (increased DO) alone but was increased when simultaneously irradiated. No thermal kills were evident as the samples tested rose in water temperature only 1°C. Theoretical interpretation of the data indicated that 10^5 collisions of O_2 molecules with a pathogenic microorganism are required for inactivation. An area for future research is the ability of lasers and O_2 to inactivate virus, plus determine the economics and safety.

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8. Westgate Research Corporation of Marina del Ray, California has for the past two years been investigating the ultraviolet-light catalyzed ozonation process for the U.S. Army Medical BioEngineering R & D Command and NASA.

The first year effort in 1974 determined the feasibility of water purification and disinfection with UV-ozone. The combination was much more effective in destroying E.coli, streptococcus faecalis, klebsiella pneumonia and acanthamoeba castellanii than either of the unit processes alone.

In the second year development of the oxidation process, effort was directed toward specific organic compounds. Those tested included hydroquinone, pyrogallol, xylenol, urea, sodium acetate, ethanol, glycerol, glycine and acetic acid. Process variables such as UV intensity, ozone concentrations and mass flow, agitation, residence time, temperature and pH were examined on a batch and continuous basis to determine their effect on oxidation efficiency. Preliminary design data based upon experimental results were then formulated for the Army MUST-reuse system and NASA long-term, manned space flight application.

Specific results as indicated in the NTIS Report, "UV-Ozone Water Oxidation/ Sterilization Process" - December 1975, AD-A026 571, $5.50 are as follows:

a. Higher concentrations of ozone in oxygen reduces the amount of UV energy required but the efficient utilization of O_3 suffers. With UV radiation, there is an increase in the utilization of ozone.

b. Composition of the solute in the wastewater appeared to have an influence on process efficiencies. It has been observed in limited experimentation that higher efficiencies are obtained if benzene derivatives, ring compounds, and compounds with unsaturated bonds are predominant in the solute; alcohols and urea appear to be more resistant to UV-ozonation.

c. A UV light path of 3 inches appeared to be more effective than 1½ inches.

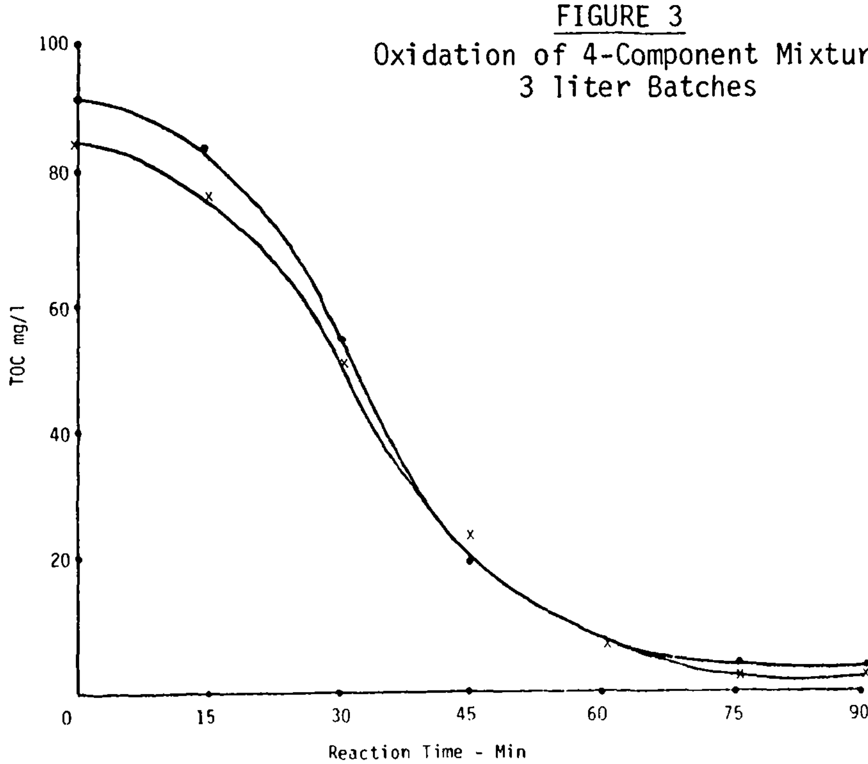
d. Increasing the temperature from 28°C to 48°C has little effect on efficiencies.

e. Agitation did not improve efficiencies.

f. Input power to the UV lamps can be decreased after 50% of the TOC is removed without affecting the rate of oxidation for a 60-minute detention time.

g. Figure 3 is a typical TOC reduction curve for a 4 component waste over a 90-minute exposure period.

FIGURE 3
Oxidation of 4-Component Mixture
3 liter Batches



Westgate will begin marketing UV-O_3 modules capable of treating 20,000 gpd with multiple combinations to handle 10 mgd. According to the manufacturer, the system exposes ozone enriched secondary effluent to a series of UV lamps which converts practically all dissolved organics into CO_2, water and oxidation products. Viruses and other organisms are also destroyed with heavy metal complexes precipitating.

Chlorinated organics are said to be attached faster than others so the system can be used selectively and reduce organics to lower levels than carbon adsorption with a slight increase in energy costs.

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9. Engineers and scientists from the FMC Santa Clara, California Laboratory and Baylor College of Medicine in Houston, Texas presented a paper on the "Photodynamic Inactivation of Infectious Agents in Water" at the ASCE National Water Resources and Ocean Engineering Convention in San Diego in April of 1976.

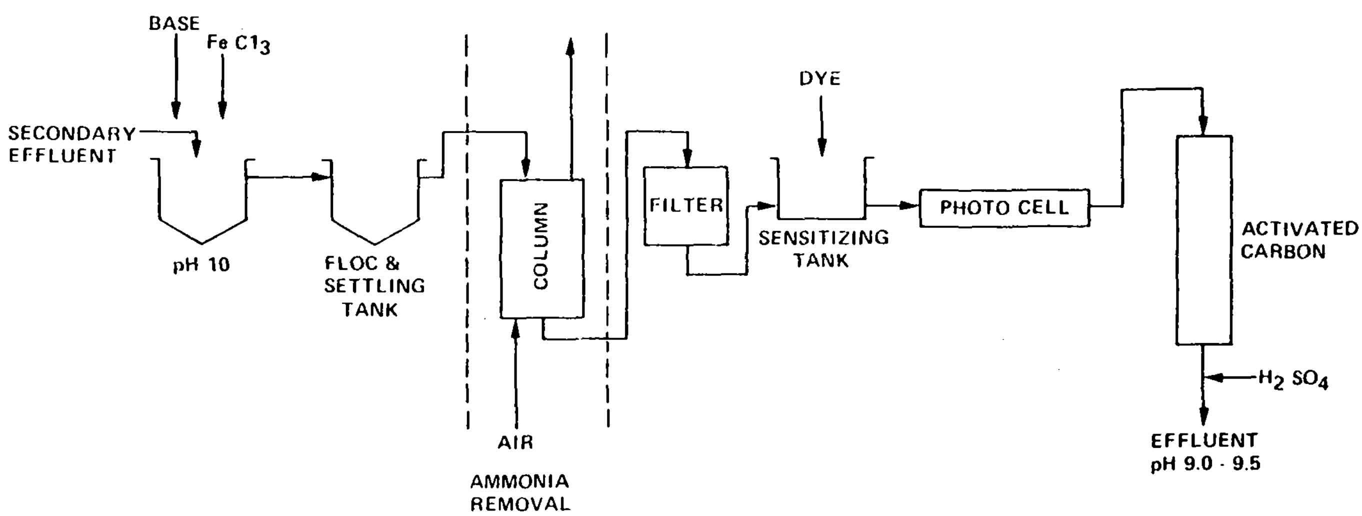
The process involves adding a photoreactive dye, methylene blue, to the wastewater at pH 10 and then irradiating the water with white light at the specific dye absorption wavelength. This results in complete inactivation of virus and bacteria. It is believed that the mode of inactivation is an attack on the nucleic acid chain which does not allow for subsequent cell division of bacteria or replication of viral nucleic acid in host cells. Consequently, the photodynamic inactivation process may allow for a more positive control of infectious agents in wastewater than either halogens or ozone.

The process appears to be readily adaptable to physical-chemical treatment (PCT) plants of either the smaller package variety or to the larger municipal facilities. Photodynamic inactivation requires various unit operations that are inherent to tertiary processes for phosphorus, ammonia and organics removal.

A proposed treatment sequence is shown in Figure 4 which involves chemical clarification, air stripping, recarbonation, filtration and carbon adsorption. The plant is expected to produce an effluent with a consistent coliform count of less

FIGURE 4

PROPOSED PROCESS FOR PHOTODYNAMIC INACTIVATION



than 2.2/100 ml and a turbidity of less than 2 JTU's. The added dye is to be removed with the carbon columns. Virus concentrations will be reduced from 1000 PFU's/gallon to 1 PFU/gallon or a 4 log reduction.

The process is more costly as compared to chlorination, breakpoint chlorination and ozonation with the major factors being pH control and power costs. Solar energy has been shown to be a possible alternative to the use of high intensity monochromatic lamps for photo oxidation and may well reduce costs in the future.

Dr. Joseph L. Melnich, co-developer of the system, believes the treatment could replace chlorine as the standard water purifier. He also feels "the new disinfection method will speed the day when water-short communities can recycle sewage effluents into drinking water instead of discharging it as waste."

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10. A test facility for wastewater recycle devices and water conservation systems was established in the National Sanitation Foundation Building in Ann Arbor, Michigan. The activity looks forward to a new standard that will cover various types of self-contained onsite wastewater disposal and reuse systems. Several home wastewater renovation and recycling systems are expected to be evaluated.

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11. Aqueonics, Inc., in California has developed community water recycling systems for reuse of generated effluents. In a proprietary treatment sequence, sewage can enter a primary and secondary bioreactor but, depending on the reuse alternatives, several optional add-on processes are available. The names, if not the unit processes, are impressive to a community seeking additional water resources and include: synergistic irradiation, diatomaceous earth filtration, low pressure reverse osmosis, acid and caustic recharge ion exchangers and ozonated dechlorination.

Several demonstration projects are being completed using the company's Re-Serv system with projected municipal usage of the effluents for landscape irrigation, ponds, golf courses and toilet flushing.

Typical effluent qualities are as follows:

BOD	< 5 mg/l
NH_3	< .1 mg/l
S.S.	< 3.7 mg/l
TOC	< 5 mg/l
COD	<16 mg/l
Total N	1.17 mg/l

The system is said to cost about $5.00 per gallon per day capital and 2¢ per 1,000 gallons O & M. Further information is available from: Aqueonics, Inc., 2115 De La Cruz Boulevard, Santa Clara, California 95050 (408) 985-1765

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12. Pure Cycle Corporation in Boulder, Colorado has developed a totally closed-loop home recycling system. The proprietary 500 gpd unit incorporates a biological reactor using rotating contactors, upflow clarification, tube ultrafiltration, adsorption with carbon and resins, ion exchange with a blend of four resins and UV sterilization to produce a water said fit for human consumption.

Effluent qualities are typically TOC -<1 mg/l, TDS - 1.5 mg/l, turbidity <0.1, and NO_3 - 10 mg/l.

The key to success in demonstration models has been the development of a digital control unit to monitor quality, trigger alarms and eventually initiate correction procedures.

The firm, before marketing begins, is involved in predictive mode analysis, improved monitoring capabilities, fail-safe operation, home-owner education, health effects research, gcms analysis and the development of reuse quality standards.

While some units are being used in homes in the Boulder area, permission is being sought from EPA and State and County Health Departments to market the units in 1978 with mountain communities and isolated homes as the key targets.

Further information is available from: Pure Cycle Corporation, 2855 Walnut Street, Boulder, Colorado 80301, (303) 449-6530.

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13. Modular Conceptual Systems, Inc., of Ivyland, Pennsylvania, U.S.A. has developed a compact AWT plant for water reuse. A schematic of the system is shown in Figure 5 on the following page. Biological treatment is followed by filtration, carbon adsorption and disinfection to prepare the effluent for use in toilet flushing or irrigation. The on-site treatment units have a capacity of 1000 - 200,000 gpd.

OPERATION

Wastewater flows by gravity or by pump to a raw waste holding tank. The raw waste holding tank is equipped with an overflow to the sludge holding tank. From the raw waste holding tank the combined wastewater is pumped via a grinder pump to a vibrating primary solids separator. Primary solids separated from the liquid wastewater are deposited in a sludge holding tank and the liquid wastewater flows by gravity to a trickling filter. The trickling filter, packed with plastic filter media biologically removes the organic constituents of the wastewater.

Following biological treatment, the wastewater flows into a sump and is pumped to a vibrating secondary solids separator. The primary and secondary solids separators are integral units with one common drive motor. Secondary solids flow to the sludge holding tank and the clear effluent flows by gravity to a sump. A portion of the effluent is recycled to the primary separator while the remainder is pumped to a dual media filter.

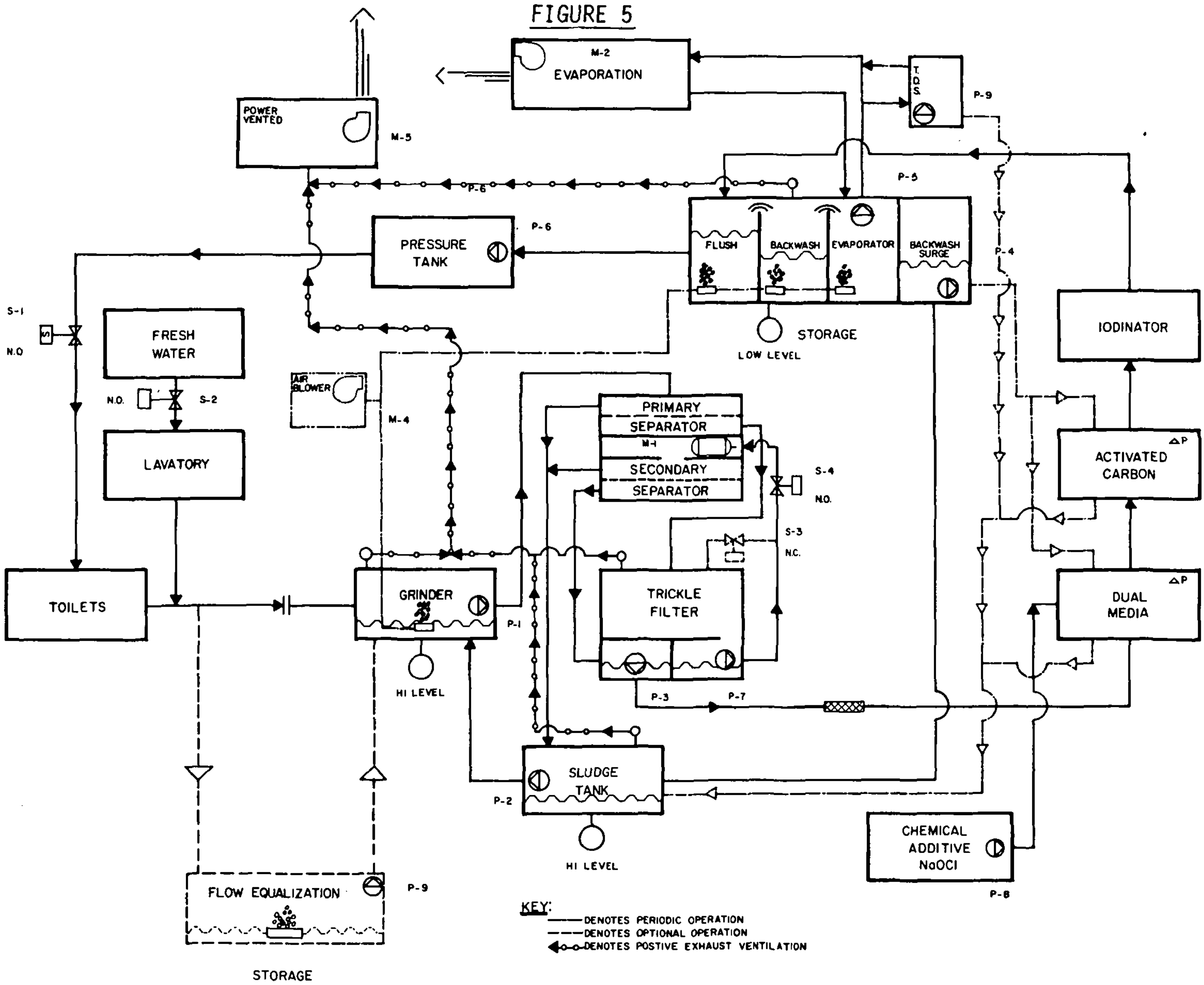
Prior to the dual media filter, sodium hypochlorite is injected on a periodic basis in order to reduce the ammonia nitrogen concentration via break point chlorination. Proper mixing of sodium hypochlorite and wastewater is assured by the use of an in-line static mixer.

The dual media pressure filter, containing anthracite and sand, will remove residual suspended solids and turbidity. Filter effluent will flow to two parallel activated carbon columns to provide dechlorination, color and trace organic removal. Two standby columns are provided.

Following the activated carbon columns, the treated water flows through an iodinator which imparts a 0.5 mg/l iodine residual to the treated water. A multi-compartment storage tank then provides storage capacity for the flush water supply, backwash supply, evaporator supply and backwash surge. Water in excess of that required for flushing and backwash is pumped from the evaporator storage tank to an evaporator which will remain in use until all excess water is evaporated. The flush storage tank is equipped with a pH meter and sodium bicarbonate will be manually added as needed. A flush pump recycles all water required for flushing with a hydro-pneumatic tank retaining the pressure.

The sludge holding tank receives solids from the primary and secondary separators and from backwashing. The excess liquid in the sludge holding tank will be pumped to the raw waste holding tank based on a level sensor. Excess solids will be pumped from the sludge holding tank on a periodic basis.

FIGURE 5



14. In a report entitled "Feasibility Study of a Nuclear Power-Sewage Treatment System for the Conservation and Reclamation of Water Resources" produced for the OWRT by the University of Arizona, the authors reported a significant increase in pollutant removal by applying waste heat.

Seventy percent of the energy produced in a nuclear power reactor is rejected to the environment as low quality heat. One possible use of the available heat was examined in a ferric-chloride, powdered activated carbon (PAC) and an aluminum sulfate, PAC, physical-chemical wastewater treatment pilot plant. The one-step process was evaluated as a function of temperature (20-80°C) with COD, SS, turbidity and phosphorus removal as monitors. Optimum removals of all four parameters occurred between 50-60°C.

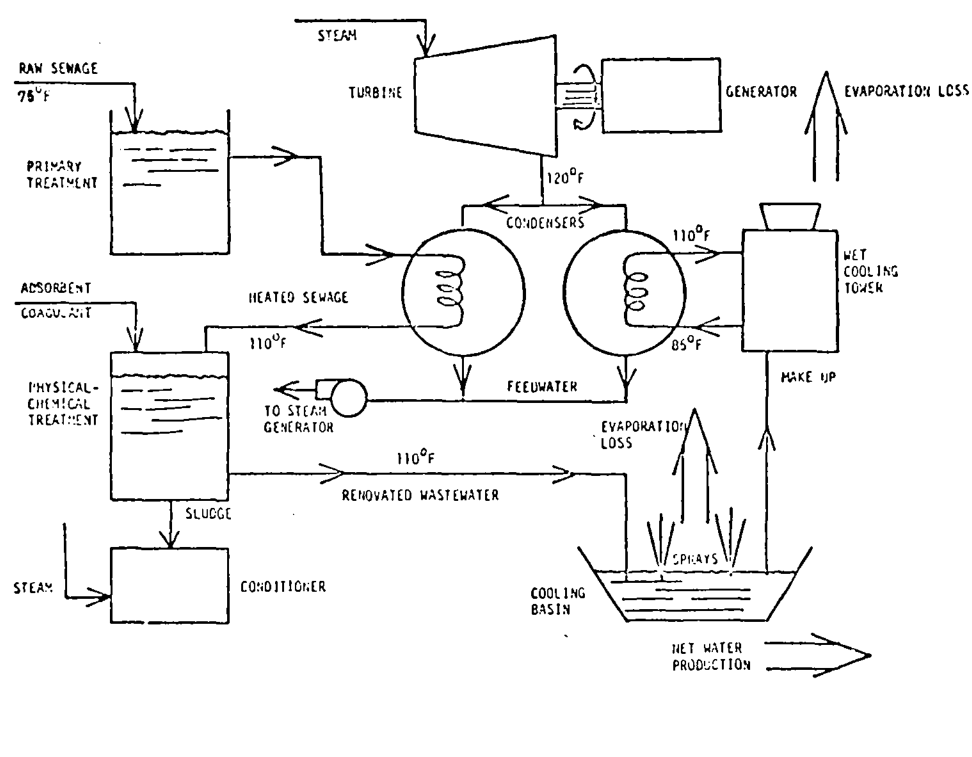
It is the author's contention that a combined plant, which is population dependent, would generate recycleable wastes. The most significant effect of heat was on the floc characteristics and settling rates.

Figure 6 indicates the proposed commercial system. Raw sewage is passed through primary clarification to remove large particulates that hinder heat transfer. Passing through a condenser, the flow is heated to 43°C which is optimum for turbine back pressures. The metal coagulant and carbon are added, settling occurs and improves the quality by aeration. Makeup water for cooling towers is withdrawn from the basins.

Biofouling, scaling, foaming, etc. has not been a problem, but the number of cycles will determine additional treatment needs.

FIGURE 6

POWER PLANT - WASTEWATER TREATMENT - COOLING LAKE COMPLEX



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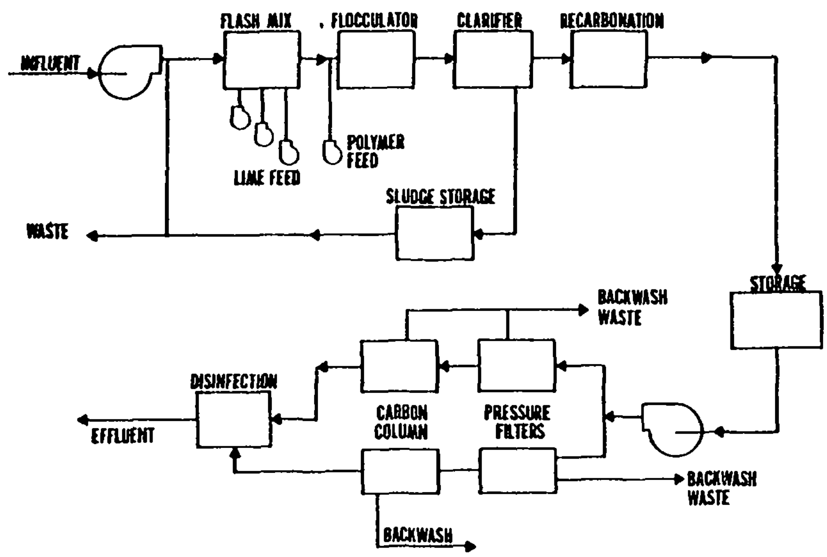
15. Engineers at the Cleveland, Ohio Westerly Wastewater Treatment Plant have been experimenting with a 30 gpm pilot plant to optimize ozone and carbon treatment for possible effluent reuse. The results as reported at the Minneapolis 1976 WPCF Convention are as follows:

a. With a PCT flow scheme of raw sewage of lime, solids separation, carbon adsorption and disinfection, inconsistent and unacceptable effluent quality was evident.

The treatment sequence including post ozonation as the disinfection step is shown in Figure 7. Organic removals across the carbon indicated no relationship to cumulative surface loading rates.

FIGURE 7

PILOT PLANT FLOW SCHEME



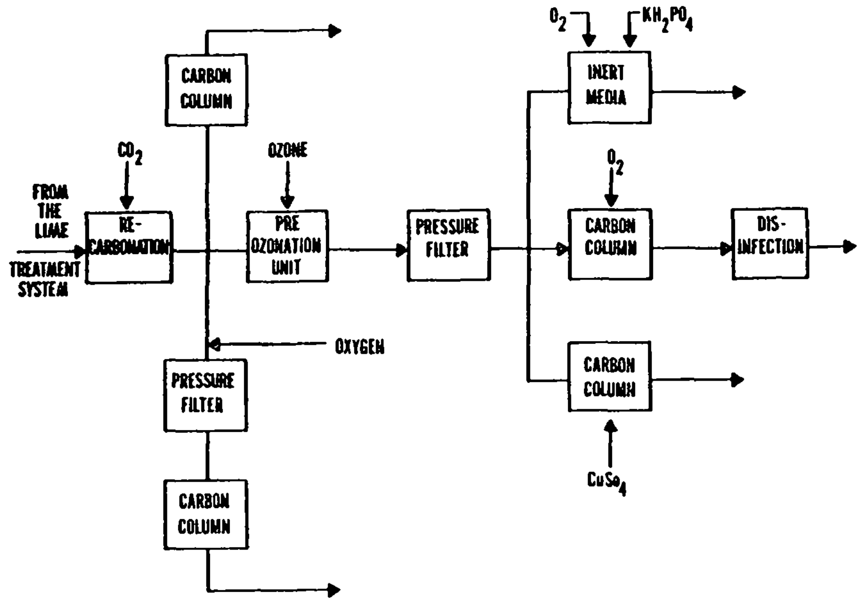
b. Monitoring the distribution of relative molecular weights before and after carbon confirmed a hypothesis of selective adsorption. Larger molecular weight groups were simply not adsorbed with the resultant effluent quality difficult to maintain. The inconsistent performance of carbon in turn hindered ozone effectiveness as a disinfectant. Noticeable COD reductions across the ozone step were noted but unreliable disinfection occurred.

c. Ozone after carbon was forming intermediate organic products with different molecular weights which exhibited better adsorption characteristics. This led to the use of ozone prior to carbon.

d. The treatment scheme was modified, Figure 8, to include preozonation and filtration. Consistent effluent values were 20 mg/l BOD, 15 mg/l SS and 1 mg/l P. A steady state condition was achieved indicating no sign of carbon media exhaustion or breakthrough.

e. Ozone pretreatment rendered certain organic species more soluble and biodegradable. The ozonated effluent contained dissolved oxygen in sufficient concentrations to promote the growth of active micro-organisms in the filter unit and on the carbon media surfaces. The biological action in the macropores of the activated carbon restored adsorption capacity and extended useful life. Sulfide formation was eliminated.

FIGURE 8



Pilot Plant Modified Flow Scheme

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16. NASA's scientists at the National Space Technology Laboratory in Mississippi have spent the last two years experimenting with water hyacinths as a tertiary wastewater treatment system. Results from the Vascular Aquatic Plant Project indicate the successful preparation of an effluent for agricultural reuse and the use of the hyacinths for bio-gas production, a protein and mineral additive to cattle feed and as a soil fertilizer and conditioner.

The plants can grow in water with a TDS of 1000-1500 ppm reducing that value by 25%. High removals of cadmium, mercury, nickel, lead, silver, and toxic organics have been noted in pilot studies. Seven-tenths of an acre of lagoons can be used to treat 0.5 mgd of wastewater at very low cost.

Drying and grinding the plants after they have concentrated the pollutants into cattle feed will be demonstrated using solar methods. Each acre of hyacinths is capable of producing 2 million cubic feet of methane through anaerobic fermentation.

Additional spinoffs include using the bio-system for detecting heavy metals in water because of the concentrating ability and recovering gold from tailings piles near Colorado streams and worked out gold mines.

A 1 mgd system is envisioned for Disney World in Florida.

Previously considered to be nuisance growths, the plants have desirable characteristics and have proven to be of value as shown in Table 4.

The vascular aquatic plant (VAP) program is being conducted at several research sites in the U.S. The results will indicate design, cost and operating values, winter production, plant harvesting into useful products, carcinogenic removals and valuable metal recovery.

The treatment sequence, in most cases, resembles that shown in Figure 9.

Additional information can be obtained from:

Technology Applications Office
Nat'l Space Technology Laboratories
Bay St. Louis, MS. 39520 U.S.A.

(601) 688-3155

Program Manager
Office of Application, Code ET
NASA
Washington, D.C. 20546 U.S.A.
(202) 755-8573

TABLE 4

WASTE TREATMENT WITH WATER HYACINTHS

Value of Water Hyacinths

- As a natural biological filtration system for industrial and sewage waste treatment.
- As a dried plant material grown in nutrient-rich waters (free of toxic metals), the plants manufacture (or synthesize) crude protein (which contains essential food value for human and animal consumption) from nutrients absorbed by the plant.
- As a source of methane gas attained through anaerobic fermentation.
- As a fertilizer obtained from residual sludge which contains nitrogen, phosphorus and potassium, essential for plant growth.
- As a means for metal recovery in wastewaters, the hyacinth can absorb metals (such as silver, lead, mercury, cadmium) which can be recovered from the harvested plants.

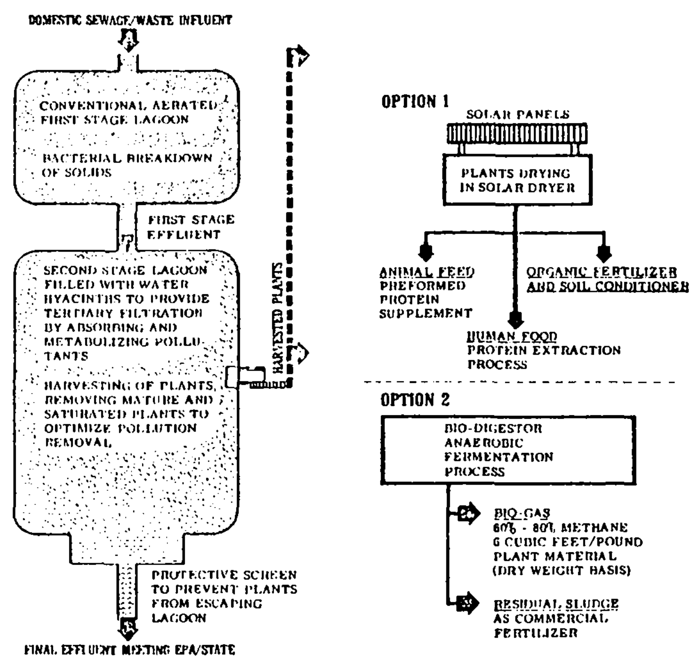
Desirable Characteristics

The characteristics of this vascular aquatic plant, which make it ideally suitable for these applications, are:

- It floats - the root system feeds on nutrients in the water and the leaves are exposed to the air.
- Its harvesting accessibility - its floating nature facilitates harvesting.
- Its growth rate - under ideal temperature and nutrient conditions, it will produce over 500 pounds of dry plant material per acre per day.
- It grows freely in warm climates - from Missouri to Virginia, Texas, Louisiana, Florida and California.
- Its absorbant qualities - of metals, organics and nutrients.

FIGURE 9

TREATMENT PROCESS AND RECOVERY



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17. Additional hyacinth research is taking place in Austin, Texas where year-round plant growth and treatment is possible with protective covers.

Research on polishing stabilization pond effluent indicated the plants are capable of removing algae, suspended particles and dissolved impurities. The clear effluent was low in nitrogen and fecal coliforms with the following reductions noted:

BOD	97%
SS	95%
COD	90%

Accumulations in plant tissue of chloride, magnesium, potassium and phosphorus were evident. It was estimated that a one-acre standing crop of mature plants would have contained 2500 pounds of minerals. The experimental facility treated 28,800 gpd in 0.14 acres with little attention or maintenance and energy furnished by sunlight.

****

18. Drs. Juh Chen and Gerard Smith of the Thermal and Environmental Engineering Department at Southern Illinois University reported at an American Chemical Society Symposium in the Fall of 1976 on the use of sonocatalytic oxidation in wastewater treatment.

The authors oxidized secondary effluent with ozone in combination with several catalysts to increase reaction rates and efficiency. The catalysts in varying dosages included the following:

air	Silica Gel	MoO_2
activated Raney-Nickel (R-N)	FeO_3	Pt. Black
ultra high frequency sound	Al_2O_3	ZnO
MnO_2	V_2O_5	

The most effective combination for almost total COD, TOC removal was with ozone, air, ultrasound and R-N. Coliforms, phosphate and ammonia compounds were also reduced. The R-N catalyst proved to be the most effective from the standpoint of stability under intensive sound bombardment. Typical COD, TOC removals are shown in Figures 10 and 11 respectively.

FIGURE 10

COD REDUCTION BY OZONATION, CATALYTIC OZONATION AND SONOCATALYTIC OZONATION

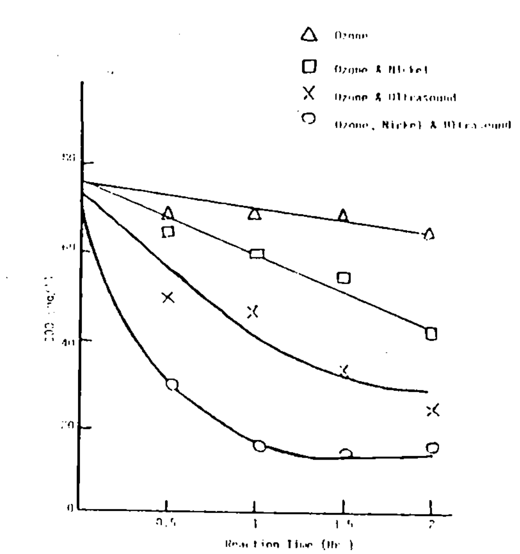
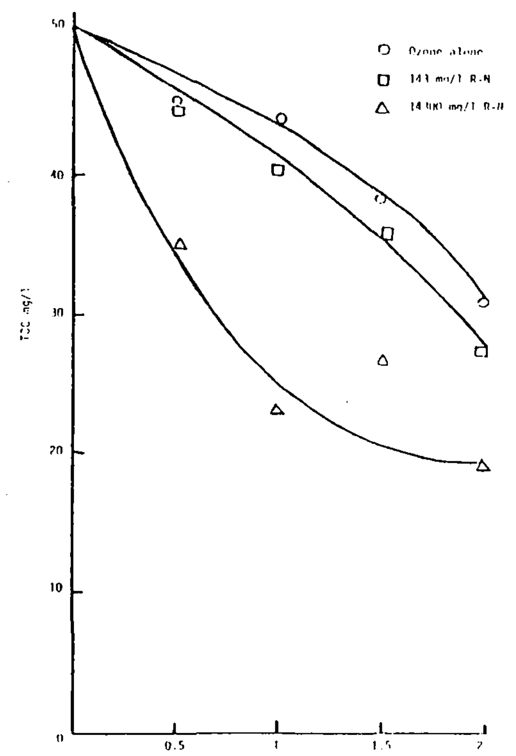


FIGURE 11

TOC REMOVAL BY CATALYTIC OZONATION



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19. At the ASCE National Conference on Environmental Engineering, July 13-15, 1977, at Vanderbilt University in Nashville, Tennessee, Los Angeles County Sanitation District personnel described the addition of gravity carbon filters to their Pomona Plant to meet reuse requirements.

Although the secondary effluent has been reused by industry and irrigation for a number of years, public contact was increasing with the resultant more stringent discharge requirements. Regulations proposed by the Regional Water Quality Control Board included coagulation, sedimentation, filtration and disinfection to achieve a coliform MPN of less than 2.2/100 ml. In addition, a maximum chlorine residual limit of 0.1 mg/l at a designated point in the receiving stream was specified for the protection of aquatic life. The City of Pomona included removal of virus to the maximum practicable extent, maximum chlorine residual of 1.5 mg/l and reduction of color to 10 units or less. If the requirements were met, it was hoped the reuse market could expand 10-fold as shown in Table 5.

Rather than build the necessary treatment units, the County began researching less expensive alternatives as shown in Figure 12.

Results indicated that each of the methods complied with the discharge limitations.

Annual cost analysis favored alternative No. 3 as shown in Table 6. The treatment facility ultimately approved for construction in 1976 provided flexibility in operation with either a single or two-stage system indicated in Figure 13.

The plant has been operational since early 1977 with an effluent quality shown in Table 7.

FIGURE 12

TREATMENT ALTERNATIVES

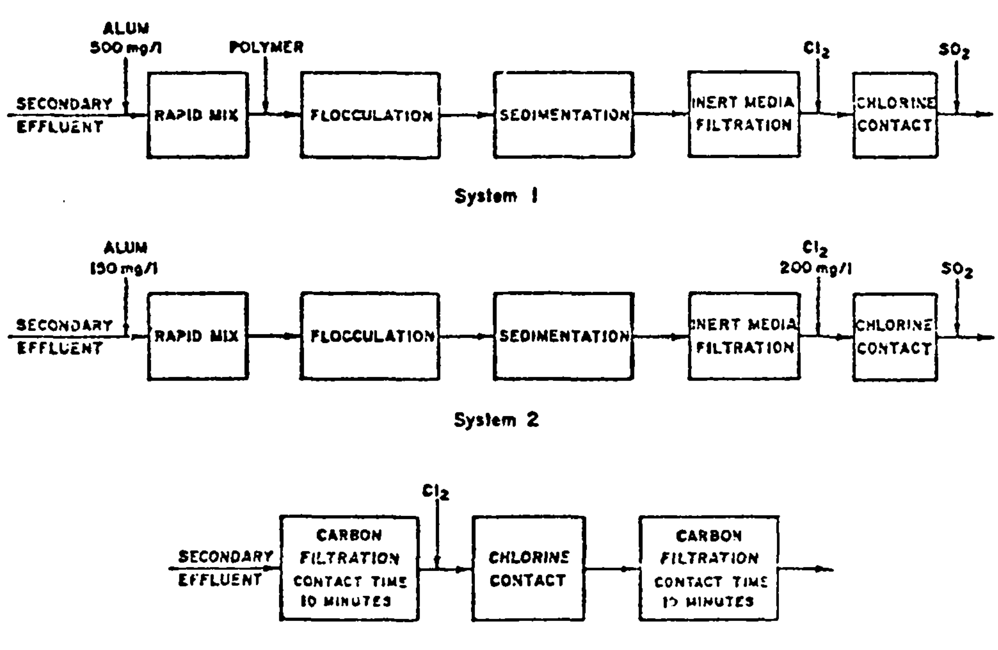


FIGURE 13

SCHEMATIC DIAGRAM

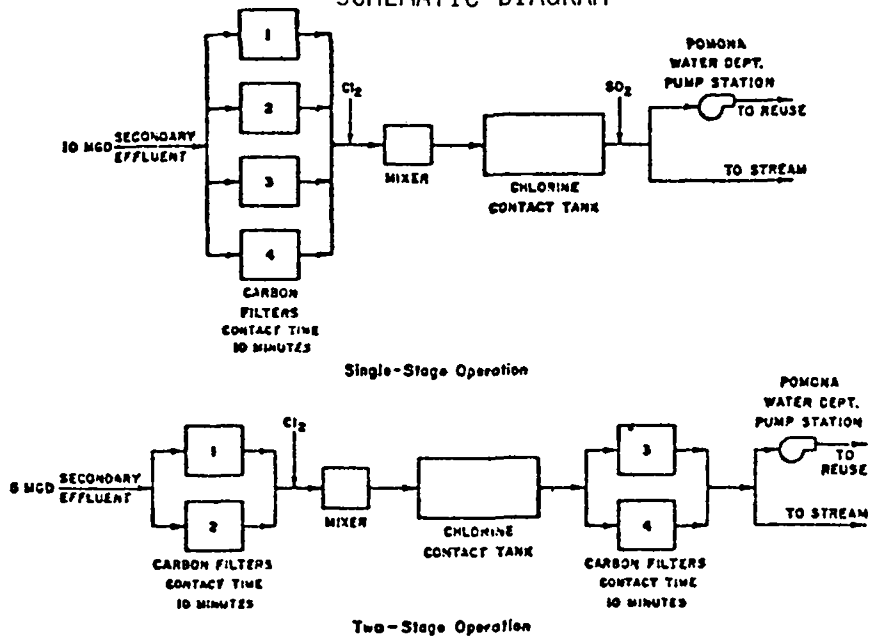


TABLE 5

POMONA, CALIFORNIA POTENTIAL REUSE

Consumer	Potential Use	Water Demand (MGD) 1973 Average Day	Water Demand (MGD) 1973 Max. Day	Water Demand (MGD) 2000 Average Day
1. Regional Park	Landscape Irrigation	1.25	3.10	1.25
2. Cal-Poly University at Pomona	Agricultural and Landscape Irrigation	0.35	4.30	1.07
3. State Hospital	Landscape Irrigation	0.40	1.20	0.40
4. Paper Company	Process Water	3.00	3.00	3.00
5. Cemetary	Landscape Irrigation	0.15	0.30	0.34
6. Paper Company	Process Water	2.50	3.70	2.50
7. Water District	Irrigation, Cooling Water, Groundwater Recharge	1.71	1.70	11.0
8. Water Company	Irrigation	0.15	0.60	0.15
TOTAL		9.51	17.90	19.80

TABLE 6

COST ANALYSIS

Alternative	Capital	Operation & Maintenance	Annual O & M	Annual Capital Cost(7%-20 yrs.)	Total Annual Cost
No.1-Coagulation at 500 mg/l alum	$\$3.1\times10^6$	18¢/1000 gal.	$656,000	$293,000	$949,000
No.2-Coagulation at 150 mg/l alum + bkpt Cl_2	$\$3.3\times10^6$	21¢/1000 gal.	$765,000	$311,000	$1,076,000
No.3-Carbon Filters	$\$3.4\times10^6$	7.0¢/1000 gal.	$256,000	$324,000	$580,000

TABLE 7

TYPICAL EFFLUENT QUALITY

Constituent	Units	Raw Sewage	Primary Effluent	Secondary Effluent	Final Effluent
Suspended Solids	mg/l	250	85	6	< 1
COD	mg/l	480	300	50	27
BOD_5	mg/l	240	170	-	> 2
Coliform	MPN/100 ml	--	--	--	2
Residual Chlorine	mg/l	--	--	--	0.1
Turbidity	TU	--	--	4.0	1.4
Color	Units	--	--	27	7

****

20. Researchers at the University of Illinois presented a paper at the 1976 WPCF Convention on tertiary treatment of secondary effluent for water reuse application requiring high qualities. Dr. Edward S.K. Chian and Associates described the use of sand filtration, reverse osmosis and ozonation in both laboratory and field studies on activated sludge effluent. The operating parameter which varied in the particular study was the food to microorganism ratio (F/M) to observe the effects of loading on the molecular weight (MW) distribution of soluble organics reaching the AWT processes.

The most chlorine-resistant indicator microorganism-mycobacterium fortuitum-was selected for the ozone disinfection studies because of its higher survival rates than poliovirus and E.coli.

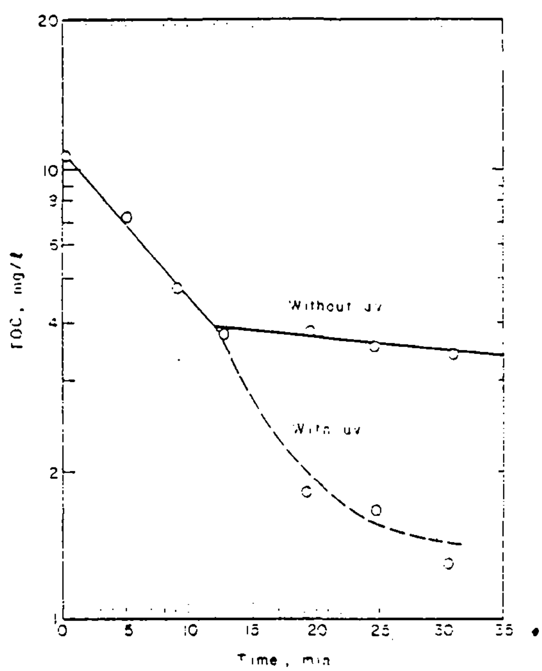
One of the most significant findings in the study was that the operational parameter F/M in the activated sludge process is closely related to the quality of effluent that can be produced by the subsequent R.O. step. The rejection of organics increased when the loading rate F/M decreased from 0.69/day to 0.33/day. In addition, the soluble TOC in the secondary effluent decreased from 18 mg/l to 11 mg/l as the loading decreased. At the lower secondary treatment loading rate and at 90% product water recovery from the R.O. system, the effluent TOC was 2.2 mg/l.

To determine the value of the product water for potential reuse, the R.O. permeates were analyzed for organics to identify the nature of the TOC contributing compounds. Approximately 0.7 mg/l of acetic acid, 1.3 mg/l of 2-butanol and 0.2 mg/l of aromatic compounds were found. GC/MS analysis of the aromatics showed they consisted of components similar to benzyl-ethyl ether, dichloroethoxy-phenol, ethoxy-methyl hydroxy-propyl ether, etc. having molecular weights between 136 and 165.

Ozone studies were then conducted for disinfection and further organic removals. Ozone inactivation rates were not affected by F/M ratios. A conclusion was

FIGURE 14

ORGANIC REMOVAL BY OZONE



reached that any effort to reduce the gross organic matter in R.O. permeate by ozonation would result in more than sufficient inactivation of the most resistant microorganisms. At a 98% product water recovery, 65% of the remaining TOC was removed through O_3 within the first fifteen minutes. After that time, as shown in Figure 14, an ozone resistant fraction appeared consisting mainly of oxalic and formic acids. UV radiation increased the TOC removal to the lower detectable limit. The product water also contained 6 mg/l of TDS.

It was the author's conclusion that a potable water can be produced from secondary effluent but is not cost effective.

****

21. Before closing the EPA Blue Plains, Washington, D.C. pilot plant in the Fall of 1977, a 36 gpm AWT treatment train was evaluated (see Figure 15). Over the 1½-year reliability testing period, 107 water quality parameters were measured, including virus, pathogens, metals, radioactive particles, pesticides and trace organics with no existing drinking water standard being exceeded. The results also showed that AWT reuse technology could produce a water from sewage effluents equivalent to many of the nation's finished drinking waters derived from present surface supplies on a consistent and reliable basis. A side stream ion exchange unit was evaluated for further removal. Some of the results are shown in Figures 16, 17, 18 and Tables 8, 9, 10, 11, 12 and 13.

FIGURE 15

EPA BLUE PLAINS AWT TREATMENT TRAIN

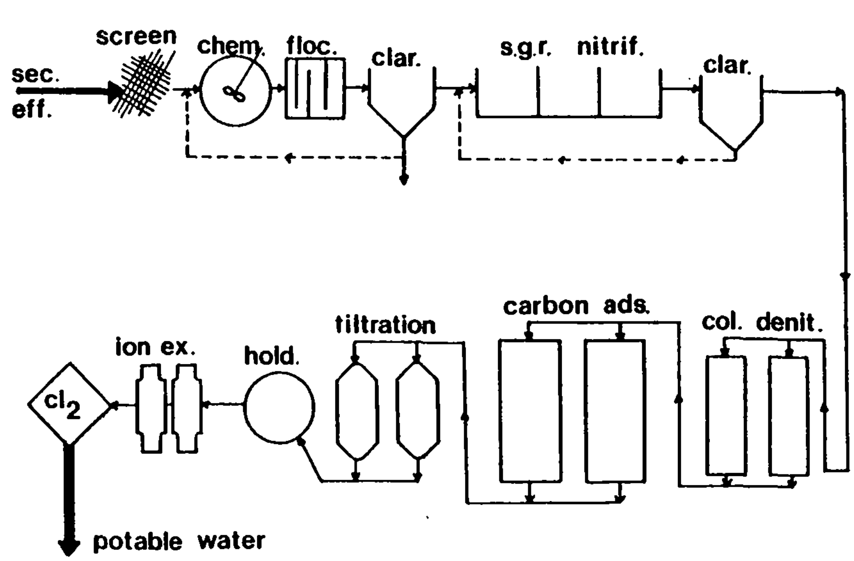


FIGURE 16

BLUE PLAINS REUSE SYSTEM RESULTS OF BACTERIAL ENDOTOXIN TESTING*

SOURCE	ENDOTOXIN EQUIVALENTS (Ng/ml)
BLUE PLAINS REUSE SYSTEM	2.5 - 12.5
PUBLIC DRINKING WATER SYSTEMS	
1	1.25
2	12.5
3	12.5
4	12.5
5	$<$0.625
6	500
7	125
8	10
9	2.5
10	2.5

* LIMULUS ASSAY PROCEDURE-JORGENSEN, J. H., etal, APPLIED AND ENVIRON. MICROB. SEPT. 1976

FIGURE 17

BLUE PLAINS REUSE SYSTEM MUTAGENICITY OF ORGANIC CONCENTRATES

R.O. MEMBRANE AND SOLVENT FRACTION	*MUTAGENIC POTENTIAL
CELLULOSE ACETATE	
• PENTANE	** N.D.
• METHYLENE CHLORIDE NEUTRAL	N.D.
• METHYLENE CHLORIDE ACIDIC	N.D.
NYLON	
• PENTANE	N.D.
• METHYLENE CHLORIDE NEUTRAL	N.D.
• METHYLENE CHLORIDE ACIDIC	N.D.
COMPOSITE	N.D.

* IN VITRO WITH STRAINS OF SALMONELLA TYPHIMURIUM TA98 & TA100
**N.D. - NONE DETECTED

FIGURE 18

BLUE PLAINS REUSE SYSTEM RESULTS OF 80 ELEMENT SURVEY*

ELEMENTS DETECTED IN EFFLUENT (mg/l)

Na – 37.8	ZN – 0.017	Ba – 0.034
K – 7.08	Cd – 0.002	As – 0.006
Ca – 54.0	I – 0.013	Ni – 0.004
V – 0.003	Pb – 0.003	Cu – 0.013
Cr – 0.001	Ga – 0.001	Sr – 0.151
Fe – 0.031	Br – 0.100	Sn – 0.002
Co – TR.	Rb – 0.007	S – 2.85

ELEMENTS NOT DETECTED

Mn, Mo, Ag, Sc, Ti, Ge, Y, Pd, In, Sb, Te, Cs, La, W, Pt, Tl, Bi, Si, P, Ar, Se, Kr, Zr, Nb, Ru, Rh, Xe, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, Re, Os, Ir, Au, Hg, Po, At, Rn, Fr, Ra, Ac, Th, Pa, U, Np, Pu.

*PROTON – INDUCED X-RAY EMISSION PROCEDURE

TABLE 8

BLUE PLAINS REUSE SYSTEM Performance of Ion Exchange Process

PARAMETER (units-mg/l)	INFLUENT Filter Effluent	EFFLUENT	REMOVAL Percent
Flow (GPM)	3.84	-	-
pH	7.52	4.94	-
Alkalinity (as $CaCO_3$)	106	15.3	86
TOC	3.39	1.70	50
BOD	3.51	1.00	72
COD	7.25	3.55	51
TPO_4	0.17	0.11	35
TKN	0.23	0.37	-
NH_3N	0.061	0.56	-
NO_3+NO_2-N	4.82	2.95	39
SS	1.13	0.54	52
TDS	343	43.3	87
Calcium	55.4	1.80	97
Magnesium	5.52	0.42	92
Chloride	64.7	3.85	94
Sulphate	47.7	0.52	98
Sodium	33.3	7.40	78
Potassium	9.30	2.40	74

TABLE 9

BLUE PLAINS REUSE SYSTEM
Pesticides

Pesticide Unit - μg/l	Effluent	*EPA Standards
Aldrin	4	
DDT	10	
Dieldrin	1	
Endrin	5	200
Heptaclor	0.7	
Heptaclor Epoxide	1	
Lindane	2	4000
Methoxychlor	40	10^5
Diazin	5	
Guthion	200	
Malathian	10	
Parathian	10	

*EPA Interim Drinking Water Standards

TABLE 10

BLUE PLAINS REUSE SYSTEM
General Organics

PARAMETER (units - mg/l)	INFLUENT Arithmatic Mean	INFLUENT Standard Deviation	EFFLUENT Arithmatic Mean	EFFLUENT Standard Deviation
TOC	74.1	11.0	2.79	1.35
COD	240	30.5	6.53	3.12
BOD	106	15.7	3.12	2.15
MBAS	8.92	1.71	0.14	0.08
CCE	-	-	0.75	0.64
CAE	-	-	2.25	0.64
Phenol (mg/l)	12.9	4.02	3.66	1.52
UV @ 290 mμ (%T)	-	-	96.9	0.87

TABLE 11

BLUE PLAINS REUSE SYSTEM
Metals

Metal (Unit-μg/l)	Influent	Effluent	*D.C. Drinking Water	**EPA Standards
Mercury	0.723	0.666	<0.5	2
Cadmium	1.92	0.143	<2	10
Selenium	4.76	4.76	<5	10
Chromium	15.7	2.24	<5	50
Lead	18.6	0.308	<5	50
Manganese	152	7.96		
Arsenic	2.48	2.25	<5	50
Iron (mg/l)	1.28	0.0599		
Barium	111	82.3	<50	1000
Copper	53.2	4.86		
Zinc	132	10.6		
Boron	0.250	0.313		
Flouride (mg/l)	0.698	0.722	1.0	1.8 @ 65°F
Silver	2.71	0.134	<10	50
Cyanide	5.80	4.23	<20	
Aluminum (mg/l)	-	0.251		

* Washington, D.C. Aqueduct, Dalecarlia Plant
** EPA Interim Drinking Water Standards

TABLE 12

BLUE PLAINS REUSE SYSTEM
General Inorganics

PARAMETER (unit - mg/l)	INFLUENT Arithmatic Mean	INFLUENT Standard Deviation	EFFLUENT Arithmatic Mean	EFFLUENT Standard Deviation
pH	7.20	0.118	7.34	0.146
Total Alkalinity	125	15.1	102	12.1
Conductivity	-	-	514	36.0
TDS	283	28.6	357	31.6
Hardness	115	7.65	162	7.18
$CaCo_3$ Stability	-	-	0.198	0.394
Chloride	-	-	68.6	4.56
Sulphate	-	-	50.1	3.83
Calcium	31.2	2.73	56.6	4.40
Magnesium	6.47	0.579	5.49	0.481
Sodium	-	-	34.1	2.94
Potassium	-	-	8.23	0.318

TABLE 13

BLUE PLAINS REUSE SYSTEM
VOLATILE ORGANICS

COMPOUND (UNIT mg/l)	INFLUENT	NITRIFICATION	DENITRIFICATION	CARBON	CHLORINATION	** DRINKING WATER
ACETALDEHYDE	*TR.		TR.	TR.		✓
METHANOL	TR.					✓
ACETONE	TR.	TR.	TR.	TR.	TR.	✓
DICHLORO-METHANE	4		TR.	1	TR.	✓
ACROLEIN	TR.		TR.		TR.	
CARBON DISULFIDE	TR.			TR.	TR.	✓
CHLOROFORM	10	3	2	5	7	✓
BROMODICHLOR-OMETHANE	1	TR.			4	✓
1,1,1-TRICHLOR-OETHANE	TR.					✓
CHLORODIBROM-OMETHANE	4	TR.		TR.	2	✓
BENZENE	2	1	1	1	2	✓
DIMETHYL DISULFIDE	3					✓
TOLUENE	2	TR.	TR.	TR.	TR.	✓
N-HEXANOL			TR.	TR.		
TETRACHLORO-ETHYLENE	3					✓
XYLENE	TR.		TR.	TR.	TR.	✓
ALKYL BENZENE	TR.	TR.				
BENZALDEHYDE			TR.		2	
CARBON TETRACHLORIDE	2	TR.		TR.	TR.	✓

*TR.=TRACE (<1 mg/l)
** NORS REPORT, DEC. 1975

CONFERENCE CALENDAR

1. This section contains a list of conferences, conventions, workshops, seminars, training courses and expositions related to the water reuse field which were held during the 1976-77 period or will be convened in the future. The sponsoring associations' addresses are included below if more information, the technical program or results of the meeting are needed.

AIChE
American Institute of Chemical Engineers
United Engineering Center
345 East 47th St.
New York, NY 10017

ASCE
American Society of Civil Engineers
345 East 47th St.
New York, NY 10017

AWRA
American Water Resources Association
St. Anthony Falls Hydraulic Lab
Mississipp R. at 3rd Ave., S.E.
Minneapolis, MN 96822

AWWA
American Water Works Association
6666 West Quincy Ave.
Denver, CO 80235

Association of Environmental Engineering Professors
Professor T.M. Keinath
Dept. of Environmental Engineering
Clemson University
Clemson, SC 29678

Association of Metropolitan Sewerage Agencies
Suite 200
1015 18th St., N.W.
Washington, D.C. 20036

Battelle Columbus Labs
505 King Avenue
Columbus, OH 43201

Clemson University
College of Engineering
Box 1607
Clemson, SC 29631

CWC
Culp, Wesner, Culp Engineers
P.O. Box 40
El Dorado Hills, CA 95630

ICE
Institution of Civil Engineers
Great George Street
Westminster
London, SWIP 3 AA, ENGLAND

AIDIS
Inter-American Association of Sanitary Engineering
Associacion Interamericana de Ingeniera Sanitaria
Apartado 88-2 Feria
Santo Domingo, Distrito Nacional
Republica Dominicana

IAWPR
International Association for Water Pollution Research
Chichester House
278 High Holborn
London, WCIV 7HE, ENGLAND

IDEA
International Desalination and Environmental Association
1000 River Road
Teaneck, NJ 07666

IOI
International Ozone Institute
Richard S. Croy, Exec. Director
14605 Detroit Avenue, Suite 206
Lakewood, OH 44107

IWRA
International Water Resources Association
Executive Secretary
Av. Paulista, 2073 Conj. 1910/11
Sao Paulo, BRAZIL

IWSA
International Water Supply Association
1 Queen Anne's Gate
London, SW1H 9BT, ENGLAND

ICPRB
Interstate Commission on the Potomac
River Basin
4350 East West Highway
Bethesda, MD 20014

National Bureau of Standards
Materials Bldg., B-348
Washington, D.C. 20234

National Institute for Water Supply
P.O. Box 150
Parkweg 13
Leidschendam, THE NETHERLANDS

National Sanitation Foundation
NSF Bldg.
P.O. Box 1468
Ann Arbor, MI 48106

National Water Resources Association
955 L'Enfant Plaza North, S.W.
Washington, D.C. 20024

NWSIA
National Water Supply Improvement
Association
P.O. Box 8300
Fountain Valley, CA 92708

National Water Well Association
500 West Wilson Bridge Road
Worthington, OH 43085

New York University
SCENYU Registrations
New York Conference Management Center
360 Lexington Avenue
New York, NY 10017

Oak Ridge National Lab
P.O. Box X
Oak Ridge, TN 37830

Society of Chemical Industry
14 Belgrave Square
London, SW1X8PS, ENGLAND

U.S. Environmental Protection Agency
401 M Street, N.W.
Washington, D.C. 20460

U.S. EPA
26 West St. Clair St.
Cincinnati, OH 45268

U.S. Water Resources Council
2120 L Street, N.W.
Washington, D.C. 20037

University of Texas at San Antonio
Center for Applied Research & Technology
San Antonio, TX 78285

WATERCARE
California Association of Reclamation
Entities of Water
Lloyd C. Fowler, President
5750 Almaden Expressway
San Jose, CA 95118

WPCF
Water Pollution Control Federation
2626 Pennsylvania Avenue, N.W.
Washington, D.C. 20037

Weston Environmental Engineers
Weston Way
West Chester, PA 19380

CONFERENCE CALENDAR

SPONSOR(S)	TITLE	FIELD	LOCATION	DATES
WATERCARE	3rd Annual Conference	wastewater reclamation and reuse	Malibu, CA	6/76
National Water Supply Improvement Association (NWSIA)	3rd Annual Conference	water reclamation	Oklahoma City, OK	7/14/76
National Well Water Association	National Groundwater Quality Symposium.	groundwater quality, recharge	Las Vegas, NV	9/76
Water Pollution Control Federation (WPCF)	49th National Conference	water resources, reuse	Minneapolis, MN	10/3-8/76
International Association for Water Pollution Research(IAWPR)	8th Biannual Conference	AWT, recharge, reuse	Sydney, AUSTRALIA	10/17-22/76
Culp, Wesner, Culp Engineers	3rd Annual Seminar on Wastewater Treatment and Reuse	land treatment, sludge handling, AWT	So.Lake Tahoe, NV	10/27-28/76
National Sanitation Foundation (NSF) and EPA	3rd Annual Conference on Individual Onsite Wastewater Systems	on-site reuse, gray water	Ann Arbor, MI	11/16-18/76
International Ozone Institute (IOI) and EPA	Workshop on Oxidation Products of Organics in Water	organics, ozone/UVozone/sonics, health	Cincinnati, OH	11/17-19/76
		1977		
American Institute of Chemical Engineers (AIChE)	Training Courses	AWT	Houston, TX	3/19-20/77
U.S. Environmental Protection Agency (EPA)	National Conference on Treatment & Disposal of Industrial Wastewaters and Residues	water reuse	Houston, TX	4/26-28/77
IOI	3rd International Symposium and World Congress	ozone technology, AWT	Paris, FRANCE	5/4-6/77
American Water Works Association (AWWA)	National Convention	water reuse, resources, health	Anaheim, CA	5/9-12/77
U.S. Water Resources Council	National Conference on Water	resources, reuse	St. Louis, MO	5/23-25/77
IOI	Advanced Methods for Water Treatment	electrolysis and recent ozone advances	Montreal, CANADA	5/29-6/2/77
IAWPR	Conference	Advanced treatment and wastewater reclamation	Johannesburg, SOUTH AFRICA	6/13-17/77
WATERCARE	4th Annual Conference	water conservation and reuse in drought	Concord, CA	6/27-28/77

SPONSOR(S)	TITLE	FIELD	LOCATION	DATES
National Water Supply Improvement Association (NWSIA)	5th Annual Conference	desalination, AWT, reuse	San Diego, CA	7/17-21/77
American Society of Civil Engineers (ASCE)	National Conference On Environmental Engineering	water reuse, resources	Nashville, TN	7/13-15/77
State of California	Drought Conference: Industrial Water Allocation & Conservation	reuse paper	Concord, CA Los Angeles, CA	7/15/77 7/28-29/77
Association of Metropolitan Sewerage Agencies	Conference on Energy Conservation and Wastewater Managements,	reuse paper	Hartford, CT	8/16-19/77
Clemson University	Membrane Separation Technology	AWT	Clemson, SC	8/17-19/77
AIChE	Training Courses	advanced wastewater treatment	Denver, CO	8/27-28/77
Society of Chemical Industry and Chemical Society of London	New Processes of Wastewater Treatment and Recovery	AWT	London, ENGLAND	9/5-8/77
IOI and EPA	Current Status of Wastewater Treatment and Disinfection with Ozone	AWT	Cincinnati, OH	9/15/77
National Institute for Water Supply	2nd International Symposium on Aquatic Pollutants	Environmental behavior and biological effects, AWT, reuse	Amsterdam, the NETHERLANDS	9/26-28/77
EPA, Hoffman-LaRoche, Inc. and Battelle		polynuclear aromatic hydrocarbons	Columbus, OH	9/28-30/77
WPCF	50th Annual Conference	resources, AWT, reuse	Philadelphia, PA	10/2-7/77
New York University	Water Recycle Systems	courses	New York, NY Los Angeles, CA Chicago, IL	10/12-14/77 12/14-16/77 2/27-3/1/78
NSF	4th National Conference	individual onsite wastewater systems	Ann Arbor, MI	10/18-20/77
National Water Resources Association	Convention	reuse papers	Boise, ID	10/23-27/77
Culp, Wesner and Culp, Engineers	Wastewater Treatment Seminar	water reuse, sludge alternatives	So.Lake Tahoe, NV	10/26-27/77
ICPRB	The Potomac Estuary Supply	indirect reuse, AWT	Washington, D.C.	10/27-28/77
American Water Resources Association (AWRA)	13th Annual Conference	assessment, management and politics of water, reuse	Tucson, AZ	10/31-11/3/77
Oak Ridge National Laboratory	Water Chlorination: Environmental Impact and Health Effects	biomedicine, toxicology and modeling disciplines	Gatlinburg, TN	10/31-11/4/77
Weston Engineers	Dual Water Supply Workshop	reuse via dual distribution, models	West Chester, PA	11/4/77
AIChE	AWT courses	water reuse	New York, NY	11/12-13/77
IOI	Symposium on Advance Ozone Technology	AWT	Toronto, CANADA	11/16-18/77

SPONSOR(S)	TITLE	FIELD	LOCATION	DATES
International Desalination and Environmental Assn. (IDEA)	1st International Congress on Desalting and Water Reuse	desalination, AWT, reuse	Tokyo, JAPAN	11/28-12/3/77
University of Texas	Risk Assessment and Health Effects of Land Application of Municipal Wastewater and Sludges	pathogens, AWT, reuse	San Antonio, TX	12/12-13/77
Association of Environmental Engineering Professors	Fundamental Research Needs for Water and Wastewater Treatment Systems	AWT, reuse, research	Arlington, VA	12/15/77
		1978		
AIDIS	16th Inter-American Congress of Sanitary & Environmental Engineering	AWT, reuse	Santo Domingo, DOMINICAN REPUBLIC	2/19-24/78
National Bureau of Standards	9th Research Symposium	Trace Organic Analysis: A new frontier in Analytical Chemistry	Gaithersburg, MD	4/10-13/78
IAWPR	5th International Sewage and Reuse Engineering Exhibition	technical exhibition	Munich, GERMANY	6/5-10/78
IAWPR	9th Annual Conference	AWT systems and reuse	Stockholm, SWEDEN	6/12-16/78
NWSIA	6th Annual Conference	desalination, reuse	Sarasota, FL	6/16-20/78
AWWA	Annual Conference	reuse sessions	Atlantic City, NJ	6/25-29/78
WATERCARE	6th Annual Conference	reuse	San Diego, CA	6/78
IWRA	3rd World Congress on Water Resources	Water for Human Survival	Sao Paulo, BRAZIL	6/29-7/5/78
WPCF	Annual Conference	reuse sessions	Anaheim, CA	10/1-6/78
International Water Supply Assn.	12th International Water Supply Congress and Exhibition	several aspects of water supply	Kyoto, JAPAN	10/2-6/78
IAWPR, Royal Society of Tropical Medicine and the Institution of Civil Engineers	Engineering, Science and Medicine in the Prevention of Tropical Water-Related Disease		London, ENGLAND	12/12-14/78

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HEALTH EFFECTS RESEARCH

1. The possibility of domestic reuse emphasizes the need for medical research into the possible toxicological effects of ingestion. At present however, there are no accepted guidelines for direct reuse.

   The College of Medicine at the University of Cincinnati has, for the last few years, been developing technology for using cultured cells as a toxicity indicator. The in vitro (out-of-living-host) studies involved growing cells in specialized nutrients, then subjecting them to various concentrations of suspected toxicants. Growth, protein, synthesis or morphological changes can then be noted. The advantages of the bioassay system includes:

   1. Cells are the smallest self-sustaining units of life and perform most of the metabolic functions of whole organisms.

   2. Cell culture assays require a small amount of space and are relatively inexpensive.

   3. During the course of a test, cell numbers may double 3 or 4 times, repeatedly exposing all aspects of cell metabolism to the contaminants.

   Two separate experiments were run using concentrated Cincinnati tapwater and then effluent from a synthetic hospital waste treated by ultrafiltration, reverse osmosis and ozone. Unconcentrated tapwater did not inhibit cell synthesis but at a 64-fold concentration, cytotoxic response was noted.

   The distilled effluent did not create a toxic response in the cells, but as low as a 2-fold concentration did. Slight toxicity from a group of sixteen alleged non-toxic compounds was reflected throughout the experiment.

   Although the synthetic waste was considerably more toxic in the concentrations used, it was felt that further development of the AWT processes would reduce the problem.

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2. The U.S. Army Medical BioEngineering R & D Laboratory in Fort Detrick, Maryland, U.S.A., is involved in the development of non-potable and potable water reuse criteria for field hospitals employing wastewater renovation and recycling.

   To develop the data for chronic and acute effects analysis, health related research is mandatory but the program is somewhat overwhelming with currently available techniques.

   Extensive research is needed in the field to refine toxicology methodologies. The National Institute of Health is sponsoring a massive program in the area of dose-response mathematics and extrapolation of animal data to human situations. There is every likelihood that the NIH work will be applicable to water reuse standards.

   Development of mathematics for extending dose-response or dose-risk information from acute and chronic studies to very low level chronic exposures experienced by human populations is an extremely difficult task. NIH is supporting a large multi-university statistical research program to determine how dose-response curves might be extended from massive dose experimental results to the trace contaminants region.

The likelihood that statistical methods will be available is slim. The fall-back position in this kind of work is the mega-mouse experiment which is too costly to perform for most chemicals. A second fallback position is the execution of massive epidemiological investigations which are probably more expensive than mega-mouse research.

Extrapolation of animal test results to humans has been historically tenuous and will likely continue. A feeling in the Army is that animal experiments conducted to date are essentially worthless for attempts to predict human effects.

The Army would like to be able to use individual cells as the indicator of life effects. Three research contracts have been supported to use cells as an on-line toxicity indicator.

They also suggested continuation of research for developing rapid screening methods for toxicological hazards. No federal agency has sufficient funds to perform a complete toxicological analysis on even a small fraction of the chemicals of interest. The need for a screening method to replace the standard costly tests is evident.

One of the immediate Army tasks has been as follows:

a. Review the available literature concerning acute and long-term health effects of ingestion of the identified components in potable water and the occular and dermal effects in the case of non-potable applications such as bathing, laundry and recreational uses in which human contact is likely. Document the knowledge, identify areas in which the necessary information is lacking and recommend studies to obtain that information.

b. Propose the adoption of existing standards for water reuse based upon the uses to which they are to be put, the duration of exposure and the military mission involved which may cause more emphasis to be placed upon short-term or semi-acute effects than the chronic ones.

A sub-committee of the National Academy of Sciences Committee on Military Environmental Research will be established to review this research. The Army is coordinating this work with the Navy, NASA, EPA and OWRT while maintaining liaison with the Food and Drug Administration, Department of Health, Education and Welfare, AWWA and the WPCF.

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3. Rapid evaluation of the potential hazards posed by new chemicals can now be performed with a sequence of bioassay methods developed by Battelle's Columbus laboratories.

Battelle, an independent, non-profit research laboratory, uses a sequence of five rapid and easily repeated cell tests conducted outside of living organisms in an artificial environment to predict toxic or carcinogenic activity.

In a series of evaluations, the Ames assay for initial spot screenings is used in conjunction with the Battelle-developed series designated "rapid mammalian cell toxicity and prescreen confluency assays".

The basis for both types of assays is the way in which bacteria or animal-cell tissue cultures react to various chemicals. The methods used are:

a. Ames bacterial mutagenesis assay
b. Battelle-Columbus prescreen toxicity assay
c. Balb/c 3T3 clinical transformation assay
d. C3H 10T1/2 mouse prostate cell assay
e. Syrian hamster embryo cell clonal transformation assay

The sequence is expected to approach 95-100% certainty in identifying hazardous chemicals when combined with corroborative evaluations, including sophisticated lab animal experiments.

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4. As reported in the April 1977 issue of <u>Environmental Science and Technology</u>, trace organics in water require considerably more research according to EPA's William T. Donaldson.

Increased interest in organics has resulted from the improved capability for identification and measurement of large numbers of compounds at trace levels and from recognition that serious health effects are possible in lab animals. Unfortunately, very little is known about the human health effects. More than 2 million organic compounds have been identified with the number in one sample related to the sensitivity of the measurement technique.

Based on the number of compounds detected by current methods, one would expect to find every known compound at a concentration of 10^{-12} g/l or higher in a sample of treated drinking water. Therefore, to discuss the composition of water in a purely qualitative sense is meaningless, although many compounds have been tested without concentration values.

For the "zero tolerance" proponents, it should be noted that 10^{-12} g/l is approximately 10^{10} molecules per liter; most water treated for domestic consumption contains about 10^{19} molecules of organic matter per liter. Drinking water will probably always contain large numbers of organic compounds and the problem is to determine which ones are in significant concentrations to pose a hazard to humans.

A U.S. Department of Health, Education and Welfare Directory of toxic compounds lists 1500 suspected carcinogens without a dose-response relationship. To date, toxicologists are unable to determine no-effect levels of carcinogens in man by extrapolation from the no-measureable-effects in animals. Neither can they prove from an animal experiment that a substance is not carcinogenic to man.

The epidemiology of carcinogens and chemicals that are only toxic when present chronically is also difficult to delineate. Most relationships between human exposure to chemical and development of cancer have been observed following occupational contact at much higher levels than those encountered normally. As the exposure concentrations approach levels encountered in non-occupational activities, the relationships begin to get lost in the "noise" created by other factors.

The author describes the inconsistencies and error in using statistical or predictive analysis for determining suspected chemicals in the environment. Another often overlooked factor in measuring trace organics is the analytical method itself. In nearly all cases, only those compounds that are volatile enough to pass through a gas chromatograph are identified and measured. In addition, the group of compounds usually is further restricted to those that can be extracted from water by a non-polar solvent or adsorbed by carbon. With those limitations, only 10-20% of the total mass of organics in most waters are analyzed.

Dr. Donaldson calls for a program to measure all organics, amenable to analysis, in all media and for selected geographic areas, in which a specific human health problem is significantly higher or lower than normal. However, the base normality has not been established from epidemiology or other studies. A highly comprehensive analysis is required, but the detection levels adopted must be carefully selected. The level must be low enough to reveal all important compounds, but not so low that it makes analysis unduly difficult. In drinking water, those compounds at the highest concentrations are usually present at 10^2 µg/l or less. Therefore a detection limit of 10^{-2} or 10^{-1} µg/l is usually selected.

Weaknesses are evident in the analytical procedures themselves with surrogate methods needed. It was the author's intention to point out the need for extensive research in analytical and monitoring capabilities, but a survey with known techniques could begin now.

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5. In the April 1977 issue of New Engineer Magazine, the Ames bacterial test for carcinogenic screening was discussed by Aileen M. Smith, freelance writer, as to its relevancy and usefulness in the environmental hazard field. Several points in the article are summarized as follows:

   a. Animal bioassays are presently considered the only definitive methods of carcinogenicity testing, but they are time-consuming and expensive.

   b. One alternative is to derive the possible health effects from the known molecular structure. But, knowledge is limited and not enough information can be provided for a final answer.

   c. There is a need for a quick, inexpensive screening test that is reliable and easy to perform. In order to be accurate, such a test must actually incorporate, or mimic, specific attributes of the cancer process that occurs in humans. To be of real use, the test must produce very few false positives and no false negative results.

   d. The Salmonella-microsome test, developed over the past decade by Dr. Bruce Ames, a biochemist at the University of California in Berkeley, comes close to fulfilling those criteria. Once a lab is set up, a test on one chemical costs only a few hundred dollars and takes only a few days to complete.

e. The test measures not the carcinogenic potential (tumor formation) but rather, the mutagenic (potential to produce genetic changes) of a chemical. Almost all known carcinogens turn out to be mutagens and hence, register positive in the Ames test.

f. In addition to being cheap, bacteria have a number of other advantages. Complicated genetic procedures are much easier to perform on bacteria, and bacteria are easily malleable. Through experimentation, they can be gradually molded to simulate patterns of mammalian cell behavior.

g. In the Ames test, bacteria and the chemical are put together on a petri dish and incubated. If the chemical is a mutagen, it will mutate the bacteria which would be difficult to detect. Thus, reverse mutation is utilized. Bacteria were developed that already have mutations in the genes that govern the ability to make histidine which allows growth.

h. If the chemical being tested is a mutagen, and if it acts on the bacteria, the already mutated bacteria are mutated once again. The bacteria returns to normal, makes histidine and begins to grow. After 48 hours, the colonies are visible.

i. Ames screened hundreds of known mutants of Salmonella typhimurium before an appropriate strain was found. Tested strains are continually being added to and refined to increase the accuracy and versatility of the test.

j. One of the shortcomings of the test is the false positive results. A few classes of chemicals that contain known or suspected carcinogens are difficult to pick up. The chlorinated hydrocarbons, carbon tetrachloride and dieldrin, have registered negative. 109 chemicals considered to be non-carcinogens, but close relatives of known carcinogens, were tested. 87% registered negative. Among the "false positives", several chemicals had only limited animal tests which leaves some doubt as to their non-carcinogenic classification. There is also the possibility that mammals may have detoxified some of the "false positive" through normal metabolic processes rendering them harmless to humans, but mutagenic to bacteria.

k. Another shortcoming is the test's inability to provide quantitative answers about the potency of substances that register as mutagens. Because dosage is important in the actual causal relationship, the detriment is a serious drawback.

l. But, most researchers agree that the Ames test is suggestive evidence of carcinogenicity which requires backup by bioassay methods. It must be used with discretion. Apparently, many carcinogens are mutagens, but not all mutagens are demonstrable carcinogens.

m. False negatives also worry some researchers because the reverse mutation step does not provide a guarantee. It would not be advisable to market a particular chemical product only on the basis of a negative Ames test. Others are concerned that it is impossible for a bacterial system to fully mimic the human system. Validation tests have shown only 70-90% accuracy.

n. One researcher felt that the argument over the test was moot because its validity as a pre-screen was based on the invalid assumption that there was a shortage of bioassay laboratories in the country.

o. Another suggested that instead of using an imperfect short-term method like the Ames test to screen everything, labs should selectively perform bioassays on chemicals on the basis of the extent of exposure to the public, the length of exposure, persistence of the chemical and the structure-activity relationship. An enormous financial burden could be reduced in this manner.

p. There is another argument in favor of animal tests. The Ames method, because the medium is bacteria, does not carry the political clout that creation of a tumor in a test animal does.

q. The Ames test does have a useful role looking for trouble (positive where they were not expected) rather than confirming safety (negatives where they were expected). The method seems to have a good ability to hunt out carcinogenicity in complex chemical mixtures.

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6. Dr. Robert C. Cooper, Associate Professor in the Department of Biomedical and Environmental Health Sciences at the University of California, Berkeley, reported at the 1976 ASCE National Water Resources Convention on "Health Considerations in the use of Tertiary Effluents". As the author described in this paper, the public health significance of wastewater reuse must be considered in terms of the disease agent involved and the dose to a susceptible population.

The agents present in wastewater can be conveniently divided into two groups, biological (infectious) and chemical compounds.

Biological agents can be of bacterial, viral and parasitical origin. The most important wastewater-borne enteric pathogens in the U.S. are members of the genera Salmonella and Shigella from which frequent outbreaks occur. The viruses of potential concern include (1) the enteroviruses (polio, coxsackie, Echo); (2) the adenoviruses; (3) the reoviruses; and (4) the agent of infectious hepatitis. All together there are at least 101 identified virus strains among those four groups. Internal parasites and associated diseases in sewage effluents include amoebic dysentery, giant roundworm and giardiasis.

The second large category of health-affecting agents includes those of either an inorganic or organic chemical nature which may be either acutely or chronically toxic to an exposed population. Chemical agents arise from a number of sources, both natural and as a result of man's activities. Their variety and distribution are widespread with new compounds continually being formulated and discharged. It is expected that the toxic substance registry will ultimately include 500,000 entries.

Table 1 gives an indication of inorganic chemicals which are listed as of concern in public water supplies. Limit concentrations were derived from available toxicological data and established tolerable dose levels.

Table 2 is a representative list of organic compounds found in finished drinking water in the U.S. Very little is known concerning the public health impact, and allowable concentrations are just now being formulated. The toxicological and epidemiological data concerning organics are relatively sparse and inconclusive. The few studies available relate quality parameters in an indirect way.

A study in 1947 in London showed that four boroughs which were supplied with well water had lower cancer mortalities than those areas whose supply was from river water. In Holland, studies indicated the same results in indirect reuse situations. Recently, statistical analysis were performed in which the correlation between cancer mortality and water supply sources was determined among residents of the Parishes in Louisiana. The rate study was limited to white males only and correlations were made for all malignant neoplasms, urinary cancers, gastrointestinal cancers, pulmonary cancers and cancers of the liver. The results indicated a significant correlation between surface water (Mississippi River) and total cancer mortality. The authors estimated that a parish that changed from 100% river water to ground water would decrease its cancer rates in white males by 33 per 100,000 population.

TABLE 1

A SELECTED LIST OF POTENTIALLY TOXIC CHEMICAL AGENTS FOUND IN DRINKING WATER AND RECOMMENDED LIMIT CONCENTRATIONS

Chemical Agent	Recommended Maximum Standard mg/l
Arsenic	0.05
Barium	1.0
Cadmium	1.01
Chromium	0.05
Cyanide	0.20
Lead	0.05
Mercury	0.002
Nitrate	10.0*
Nitrite	1.0*
Selenium	0.01

*mg Nitrate or Nitrite-Nitrogen

TABLE 2

ORGANIC COMPOUNDS IDENTIFIED FROM FINISHED DRINKING WATER

Compound	Compound
Acetone	Hexachloro Benzene
Acetophenone	Hexachloro Ethane
Acetylene Dichloride	Hydroxy Adiponitrile
Benzene	Isoborneol
Benzo Thiazole	Isocyanic Acid
Bromo Benzene	Isopropanyl Isopropyl Benzene
Bromo Chlorobenzene	Isopropyl Benzene
Bromo Dichloromethane	p-menth-1-en-8-pl
Bromoform	o-methoxy Phenol
Bromo Phenyl Phenyl Ether	2-Methoxy Biphenyl
Butyl Benzene	Methyl Benzothiazole
Camphanol	Methyl Biphenyl
Camphor	Methyl Chloride
Caprolactam	Nitroanisole
Carbon Tetrachloride	Nitrobenzene
Chloro Benzene	Octane
Chloro Dibromo Methane	Pentane
Chloro Ethoxy Ether	Propylbenzene
Chloro Ethyl Ether	Tetrachloroethylene
Chloroform	Toluene
Chloro Hydroxy Benzophenone	Trichloroethane
Bis-Chloroisopropyl Ether	Triglycodichloride
Chloromethyl Ether	Thiomethylbenzothiazole
Chloronitro Benzene	Vinyl Benzene
Chloropyridine	Dimethyl Naphthalene
Chloromethylethyl Ether	Dimethyl Sulfoxide
Dibromo Benzene	Dinitrotoluene
Dichloroethane	Ethyl Benzene
Dichloroethyl Ether	Ethylene Dichloride
Dimethoxy Benzene	Exo-2-Camphanol

Applicable dose-response data are needed for the agents found in wastewater. Ideally, if such data were known, then limits on concentrations allowed in tertiary treatment plant effluents could be established, and engineers could use the quality limitations as design targets for process efficiency. The efficiency requirements might be based on an assessment of the risk of disease to the population consuming the treated wastewater. Perhaps an acceptable risk of contracting disease through the use of reclaimed water should be one chance in 1 million gallons of water consumed.

The development of dose-response data for all agents which may be suspected of being in water,although most useful is a utopian goal. This is particularly the case when working with those agents to which the host response is of a chronic nature and developed over a long period of exposure. In the case of many carcinogenic compounds, there may well be no threshold dose, and thus, no level can be maintained in which there would be no measurable response over time.

Because of the difficulties involved in the isolation, identification and determination of the health significance of every agent apt to be in wastewater, it will not only be important to continue to identify specific problems, but also to carefully examine the health status of the population as it relates to water quality. The major problem is the absence of an adequate index of the general health of a population, the inadequate reporting of many diseases, and the uncertainty as to what are the significant parameters in evaluating quality. From such studies, water quality criteria may be derived. At present, there seems to be a dichotomy of thinking in that water quality standards for AWT effluents are expected to be of some different order than those placed upon water taken from a polluted source. It would seem advisable to develop criteria that would be applicable to both, a formidable task.

If reuse is to be practiced, the strictest surveillance will most certainly be required. Realistically, one cannot speak in terms of zero concentration of organism; thus, it is important to know as much about dose-response relationships as is possible.

Dose contact should be considered. Obviously, the manner in which a susceptible host comes into contact with an infectious agent or toxic agent will affect the occurrence of disease. Direct reuse certainly holds the most potential as a health hazard as compared to industrial, recreational or agricultural reuse.

Dr. Cooper also spoke at the 6th Annual CWC-Lake Tahoe Reuse Seminar in October of 1977. His presentation centered on:

a. the possible hazardous agent
b. the agent dose
c. the dose response
d. the dose contact

Water borne disease potentials from biological to chemical contaminants were then reviewed under the above four health considerations. The least area of knowledge is in dose response or the acceptable levels of risk which need to be determined for environmental insults.

"Because little is known in the first three areas of concern, control has to be made and is possible on dose contact. This means limitations on potable reuse, etc., until more is known. It also means we do not know how many excess cancers are caused in the U.S. because of indirect reuse."

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7. The World Health Organization International Reference Centre for Community Water Supply (IRC/CWS), located in the Netherlands has assumed the role of an international coordinating agent for the study of health effects of direct and indirect reuse of wastewater for human consumption, including research and practical studies. The emphasis is to stimulate and promote new worldwide cooperative studies and avoid duplication of work. Proposed research will include analytical-chemistry, toxicology, epidemiology and the technology to treat the water to a level of purity that is economically feasible and safe for human use.

   New techniques predicting the availability of certain quantities of surface and groundwater of a certain quality will be a part of the investigation. Cooperation will include regular meetings of the experts concerned and the establishment of data banks for organics identified in drinking water and their toxicological significance.

   In January 1975, the IRC/CWS convened in Amsterdam an international group of experts in the health effects relating to potable reuse. The objectives were to review existing knowledge, formulate research needs, exchange information and consider international cooperation. Dr. Shuval, of Israel, acted as a consultant to the group in the formulation of a program to meet the objective.

   Dr. Arthur W. Garrison of EPA's Environmental Research Lab in Athens, Georgia, continued the effort with an extensive report on the analysis of organics in water. That work is now available as IRC Technical Paper Series (No. 9), "Analysis of Organic Compounds in Water to Support Health Effect Studies" - Dec., 1976 and is available from:

   World Health Organization
   International Reference Centre for
   Community Water Supply
   P.O. Box 140
   Leidschendam, THE NETHERLANDS

   An earlier publication, Technical Paper Series (No. 7), "Health Effects Relating to Direct and Indirect Reuse of Wastewater for Human Consumption", Dec., 1975, is also available from the same source.

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8. The U.S. Environmental Protection Agency (EPA) has been involved in several health related studies under the auspices of its Municipal Environmental Research Lab (MERL), Health Effects Research Lab (HERL) and Office of Water Supply. These programs are summarized as follows:

   a. In 1976, Oak Ridge National Lab was funded to identify non-volatile organics in typical municipal effluents upstream of drinking water intakes. The 2-year study would evaluate the effect of disinfection (Cl_2, O_3, UV) on organics with some toxicological screening and mutagenic work.

Sixty liters of secondary effluent from the Oak Ridge, Tennessee Wastewater Treatment Plant were ozonated to a total dose of 22.8 mg/l and concentrated 3000-fold by vacuum distillation. A high resolution liquid chromatogram of the concentrate was prepared and the eluate fractions representing the large peaks were collected, frozen and lyophilized. One-half of the residue from each peak is being processed through the multi-compartment identification procedure and the remainder is being stored at -10^{o}C in a dessicator and will be tested for mutagenic activity.

b. Syracuse Research Corporation began work in 1976 to monitor polynuclear aromatic hydrocarbons (PAH) in several New York state waters. Several PAH compounds are known carcinogens with the WHO setting limitations on six specific ones without any adequate means of measurement. The funded research work will examine new extraction methodologies and isolation techniques. In the EPA 80-cities survey, PAH was indicated in several waters, but was below detectable limits. A portable field sampler was constructed and field tested. No sampling problems were encountered but during elution of PAH, considerable impurities were also eluted which interfered with the GC analysis. Solvent selection followed by chromatography on a florisil column gave encouraging results.

Flexible polyurethane foam plugs were successful in concentrating the trace quantities. Analyses were performed on 10 selected water supplies in the Eastern U.S. with PAH compounds detected in the ppt range in all samples. In many cities, all six with standards were found. While the concentration in the finished drinking water was small (0.9-15 ppt), the values found in raw waters were as high as 600 ppt but still well below the WHO recommended limits. The new method is 10,000 times more sensitive than previous systems.

c. The University of Colorado Chemistry Department received HERL funds to evaluate the effects of ozone on organics at the recently completed Estes Park, Colorado sewage plant which uses ozone as the final disinfection step.

Procedures for handling, sampling, concentrating, separating and identifying the organics were standardized. The principle volatile products of the ozone disinfection process used are n-heptanal, n-octanal and n-nonanal. Some of the halocarbon loading is caused by chlorination of the drinking water and the compounds reaching the wastewater plant. Ozonation does not change the concentration of the two major chlorinated constituents - chloroform and tetrachloroethylene.

Caffeine was found to be a major component with ozonation resulting in a complex mixture of products such as dimethylparabanic acid and a previously undescribed compound with a molecular formula of $C_7H_{10}N_4O_3$. The acid was found to be non-mutagenic in testing.

A combination of a dynamic headspace sampling system and high resolution gas chromatography has been used successfully to determine qualitative and quantitative information about volatile wastewater components before and after chemical disinfection with ozone and chlorine. The major new products formed in the reaction of wastewater with ozone are n-heptane, n-octane, n-hexanal, n-heptanal, n-octanal and n-nonanal in the low and sub-ppb range. Significant increases in the concentration of toluene, o-, m-, p-xylenes, and styrene have been observed after chlorination of wastewater, in addition to chlorinated hydrocarbons.

Some of the halocarbon loading is caused by chlorination of the drinking water supply and the compounds reaching the wastewater treatment plant. Ozonolysis does not change the concentration of chloroform and tetrachloroethylene, the two major chlorinated constituents in the Estes Park effluent.

d. Cytotoxicity - The University of Colorado Medical School was awarded a grant in 1976 to develop a rapid screening procedure for checking the impairment of metabolic and phagocytic functions of blood cells by trace water contaminants. Phagatosis is the ability of white blood cells to digest foreign matter and is an important part of the body's immune system. Any reduction of that ability usually results in disease. Essentially the project is attempting to develop a new toxicity measurement technique. Preliminary dose response curves from polluted river and effluent samples have shown increasing impairment with increasing concentrations of contaminants.

   It was concluded that multiple cellular response tests were practical and could be completed within 9 hours after receipt of a sample. In the ppb range, research showed little or no effect of identified organic substances on human neutrophile function, but the compounds will be tested in higher concentrations to determine possible toxicity.

   Additional work showed that powdered activated carbon following secondary treatment adsorbs the solutes of low polarity but leaves highly polar and ionic materials in solution. Reverse osmosis eliminates these ionic and highly polar materials but lets pass the materials of low polarity. Both processes remove humic materials and both pass some material of medium polarity.

   Preliminary testing of combined scintillation spectrometry and high performance liquid chromatography systems for on-line evaluation of water samples was begun. It is hoped that the measurements will be able to provide a continuous indication of toxicity.

e. Inorganics - Purdue University received a contract for evaluating 80 out of the 106 known elements in AWT effluents. Rare earths are measured in the parts per trillion range with the use of the proton induced x-ray emission procedure. Few facilities are available for such work because of the necessity for a cyclotron to provide protons. Initial work uncovered surprisingly high concentrations of strontium and other elements never measured before. This work is also being applied to the water supply field and its relationship to cardiovascular diseases.

f. Grant monies were awarded to Texas A & M University for research in trace metal, virus removal and UV disinfection studies at the Dallas AWT pilot plant. A final manuscript, "Characterization for Potable Reuse and Ultraviolet Disinfection of Municipal Effluents", has been prepared and is under review prior to publication.

g. Texas A & M has also received research funds to evaluate pyrogenic materials or endotoxins which pass carbon filters. After injection of effluent samples into guinea pigs and rabbits, the pyrogenic response is noted in terms of fever and potential temperature rise. An aerosal exposure chamber was fabricated and calibrated to measure that type of response with the Veterinary School aiding in the studies.

   In the second year of work, endotoxin and bacteria levels from three disinfection processes (Cl_2, UV, O_3) are being evaluated by animal response research.

h. SCS Engineers in Long Beach, California contracted to prepare a state-of-the-art document on health effects associated with direct and indirect reuse of renovated wastewaters for potable purposes. A draft version of the volume has been submitted to EPA with publication expected in early 1978.

   A new contract has been awarded to the consulting firm to study the proportion of wastewater in receiving waters at water supply abstraction points. The primary objective is to determine how much wastewater and wastewater-derived materials from municipal and industrial discharges are to be found in the surface supplies of U.S. cities over 25,000 population, and to develop and utilize a procedure that will take into account alterations of residuals between discharge and intake point.

i. Syracuse Research Corporation (SRC) received a grant in 1976 to assess the toxicology of several AWT effluents from eastern sewage plants incorporating physical-chemical, biological and land treatment. In January of 1977, SRC began work on the mutagenic/carcinogenic potential of mixtures of organic substances in treated wastewaters. Three test systems were used:

   (1) Salmonella microsomal mutagenesis assays
   (2) Saccharomyces mutagenesis assays
   (3) An <u>in vitro</u> carcinogenesis assay method involving the use of baby hamster kidney fibroblasts which is said to be 91% positive with known carcinogens and negative in 97% of the tests with known non-carcinogens.

   Salmonella microsomal mutagenesis assay (Ames test) worked well on unconcentrated reclaimed wastewater. The saccharomyces system worked well with mutagens not requiring metabolic activation. Samples are being obtained at the Lake George Village, New York sewage plant.

j. A $55,000 grant was awarded in late 1977 to the Orange County Water District for evaluation of Water Factory 21's effluent which completed the third and final year of the planned $200,000 support. An interim report on the first two years of operation and organic monitoring is being prepared and plans call for publishing it in the EPA Environmental Technology Series.

k. Prior to the closure of the EPA Blue Plains, Washington, D.C. pilot plant in October of 1976, 120,000 gallons of AWT effluent was collected, concentrated to 100 gallons using dinandialysis membranes and forwarded to Gulf South Research Institute in New Orleans for organic work. Further concentration and deionization were necessary prior to toxicological evaluation in animal feeding studies.

A pilot study was initiated with the concentrated organics incorporated into an agar base diet to determine palatibility and gross signs of toxicity. Groups of mice were exposed to either purina meal, control agar base diet, or agar base diet containing the TOC mixture. The results indicated that the animals did not reject any of the test substance, nor did chemical signs of toxicity or change in body weight appear over a 7-day exposure period.

The principle investigator, Nachman Gruener, has broadened the scope of his work to include an in vivo mutagenicity test (mice), a behavorial toxicity test (mice) and in vitro mutagenicity tests with bacteria (Ames test) and mammalian cells (L 929), as well as the range-finding, reproduction and 90-day feeding experiments with AWT concentrates. All of the research will be finished in November of 1977 with analysis completed by early 1978.

Other than the range-finding experiments, only the results of the reproduction experiments have been analyzed thus far. Litter size and birth weights are not significantly affected by the concentrate eaten by the mothers. After 28 days however, there was a significant reduction in the mean weight of the young of the mothers fed higher amounts of the concentrate, even though these mothers showed no difference in body weight or food consumption.

l. A first draft of the final report on "Evaluation of AWT Systems at the Blue Plains Pilot Plant for Potable Reuse Purposes" is being prepared. Results from the 18-month potable reuse treatment sequence evaluation have shown reliability and the safety of effluent discharge upstream of water supply intakes.

Viruses were absent in the product water, with radioactivity, trihalomethane, other volatile organics, heavy metals, pesticides, TOC, turbidity, general inorganics, and pathogens similar to those found in finished drinking waters during the 1975 EPA NORS Study.

Effluent organic concentrates did not exhibit mutagenic properties, no significant trace element was noted and endotoxin levels were comparable to public drinking water supplies.

m. Samples from six AWT plants in the U.S. were collected by Gulf South in 1975 and 1976, concentrated and delivered to HERL for evaluation.

One-half of the sample was sent to Stanford Research Institute for toxicological analysis and mutagenic research. The standard Ames Test was used in lieu of more expensive and time-consuming animal studies. As there is an 85% correlation between mutagenic results and carcinogenicity, the Ames Test was considered sufficient for short-term results.

Mutagenic testing of wastewater concentrates from the AWT plants at Dallas(2), Pomona(3), Tahoe(2), Blue Plains(2), Escondido(1) and Orange County(2) was completed in 1977. With the exception of the Orange County samples, all other concentrates were divided into 6 fractions prior to testing: Cellulose acetate - pentane extract, cellulose acetate - methylene chloride-neutral, cellulose acetate - methylene chloride-acidic, nylon concentrate - pentane extract, nylon concentrate - methylene extract - neutral, nylon concentrate - methylene chloride extract - acidic. Each of the samples was tested using the in vitro microbiological assays with strains of salmonella typhimurium TA 98 and TA 100.

The following samples contained at least one fraction with mutagenic activity:

Dallas 1 and 2, Pomona 1, Lake Tahoe 1 and 2 and Blue Plains, 1. No mutagenic activity appeared in Pomona 2 and 3, Blue Plains 2, Escondido and Orange County.

For groups which were mutagenic, activity was always observed in the cellulose acetate - methylene chloride extract - acidic. In general, methylene chloride seemed to extract more mutagens than pentane, and cellulose acetate membranes concentrated more mutagens than nylon membranes.

It is recommended that aliquots of the fractions which demonstrated mutagenic activity be submitted to chemical characterization to obtain some indication of the active agents. Perhaps some chemical commonality existed, since most of the activity was found in the same subfraction after membrane concentration.

Aliquots of those fractions which demonstrated mutagenesis will be submitted to chemical characterization to obtain some indication of the active agents within.

The remaining sample portions were sent to Battelle-Columbus Laboratories to make a detailed analysis of the 20 most prevalent organics plus other selected compounds. A relationship between chemical contaminants and mutagenic properties will hopefully be found.

The objective of the task is to provide a state-of-the-art capillary column GC/MS analysis of the mutagenic concentrates. Because of the complexity of the concentrate samples, it is essential to use glass capillary GC columns even after fractionation and derivatization. In order to obtain a clean mass spectrum for every prominent component, each fraction is analyzed on both a polar and a non-polar column. These components are identified by their electron impact mass spectra using a computer search technique and manual interpretation, and then confirmed by comparison with authentic reference samples. Quantitation is accomplished by addition of internal standards and comparison of the integrated extracted ion currents corresponding to each of the components and the internal standards. In preparation for a three-year program in capillary GC/MS analysis of water concentrates, commercially available columns have been evaluated to set specifications for both polar and non-polar columns. The test mixture used for the polar column was slightly different from that for the non-polar column. The tests were performed on a GC with predetermined column conditions. The GC column performance of the capillary GC/MS system was examined with a tested column and found to be comparable to that of the GC. 26 compounds of potential health hazards were used to test the concept of using a polar and non-polar column in the analysis of complex mixtures. The non-polar column permitted more of the 26 compounds to be identified, while the polar column provided better separation for some of the compounds.

A partitioning scheme has been developed to separate these complex AWT concentrates into groups of potentially toxic compounds. This is necessary even though all concentrates are analyzed on both polar (SP 1000) and non-polar (SP 2100) capillary columns. This partitioning scheme will be further tested by analyzing a test mixture of model compounds with various functional groups. A concentrate of the Lake Tahoe AWT plant will be evaluated in the last quarter of 1977.

The contract also provides for the concurrent systematic analysis of organics in concentrates of five U.S. water supplies.

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9. Israeli epidemiological investigations on spray irrigation of effluents has indicated significant increases in diseases among populations exposed to the aerosal virus hazard. Dr. Hillel Shuval, principle investigator, compared agricultural communities practicing spray irrigation with partially treated, non-disinfected oxidation pond effluent with 130 communities without that form of water reuse.

As shown in Figure 1, the mean incidence of Shegellosis, Salmonellosis, typhoid fever and infectious hepatitis is 2-4 times higher. No significant differences were found in strep infections, tuberculosis and influenza.

Test results have spurred strong treatment measures including effective bacterial and viral inactivation when sewage irrigation is to be practiced near exposed populations.

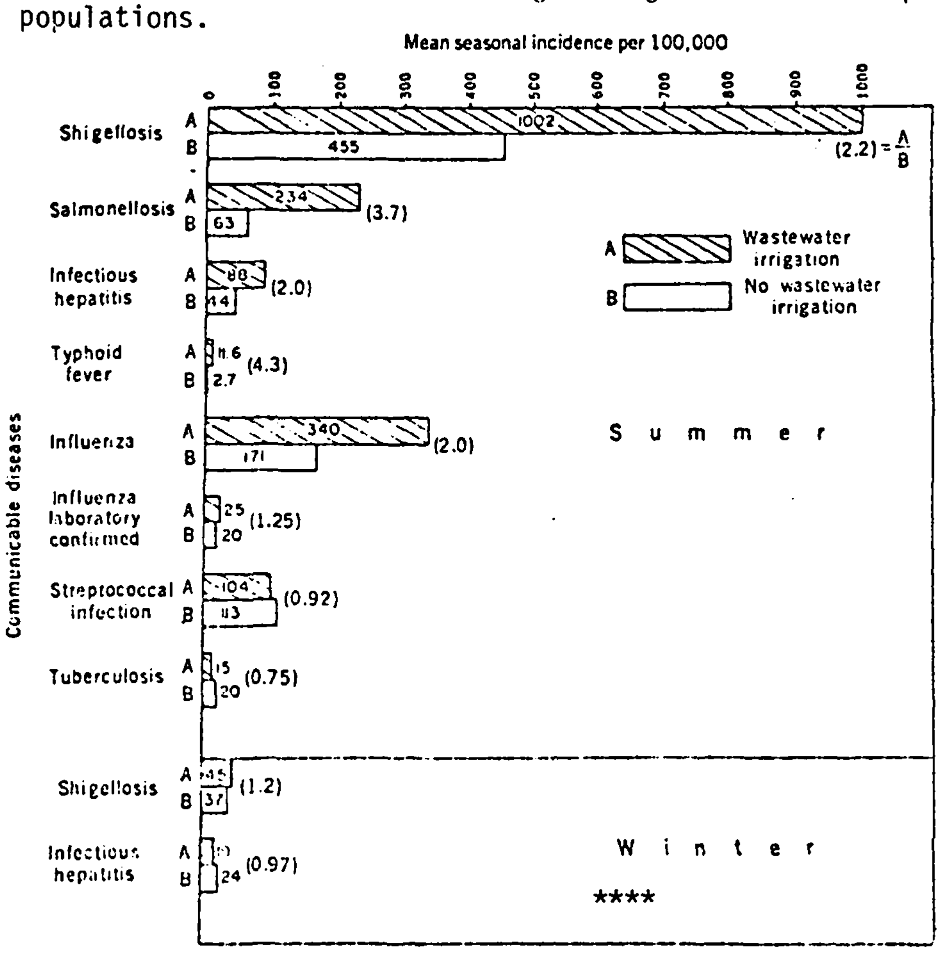

FIGURE 1

MEAN SEASONAL INCIDENCE OF COMMUNICABLE DISEASES IN COMMUNITIES WITH AND WITHOUT WASTEWATER SPRAY IRRIGATION.

10. Dr. B.C.J. Zoeteman of the National Insitute of Water Supply in the Netherlands is involved in the overall planning and management aspects of water reuse in his country. Health aspects are an important consideration and different methodologies will be examined. According to Dr. Zoeteman, there are two approaches to the toxicological evaluation of renovated water to be used as drinking water or drinking water produced from polluted sources as shown in Figure 2 (page 45). The first approach requires the establishment of maximum allowable concentrations for each potentially hazardous substance that may be found in renovated water. Although it will take a long time to establish proper tolerance levels, this kind of research is of great important as it is essential, that full toxicological information is available for each one of the pollutants on the black and grey list. In case the pollutant appears on a regular basis or accidentally, a data bank for the rapid retrieval of such toxicological data is an essential tool in water quality management for reuse systems.

The second approach would consist of experiments of exposing animals to water containing the complete mixture of water pollutants at different concentrations. Although this approach does not indicate the substances responsible for toxic effects, it can give information about the total toxic properties of the renovated water, including the combined and possible antagonistic or synergestic effects resulting from the exposure to a mixture of toxic and non-toxic compounds.

From a health point of view, the detected levels of contaminants in drinking water derived from heavily contaminated sources are the most relevant data in relation to the water reuse for human consumption. Information on the concentration of contaminants in wastewater, surface and drinking water, although still limited, reveals that an enormous amount of organic as well as inorganic compounds are present, of which the toxicity is not understood very well and so this has to be studied further. Furthermore, in the evaluation of the toxicological data, the applied safety factor is an essential aspect since there are problems in extrapolating results from animal experiments to men.

First of all, it should be realized that drinking water is a rather unique food product as it is universally consumed daily by the total population at all ages and in all stages of health and disease during an entire life span. Furthermore, by stating maximum acceptable concentrations of pollutants in drinking water, the total body burden to which the individuals are exposed must be taken into consideration. The intake of chemicals from air and food may in many cases, be more important than the intake from water.

For all these reasons it will be clear that there is a great need for intensive toxicological research, consisting of studies to establish maximum acceptable concentrations of individual chemicals as well as studies on renovated water plants for domestic consumption to identify the presence of toxic effects before any project for recycling of water is envisaged.

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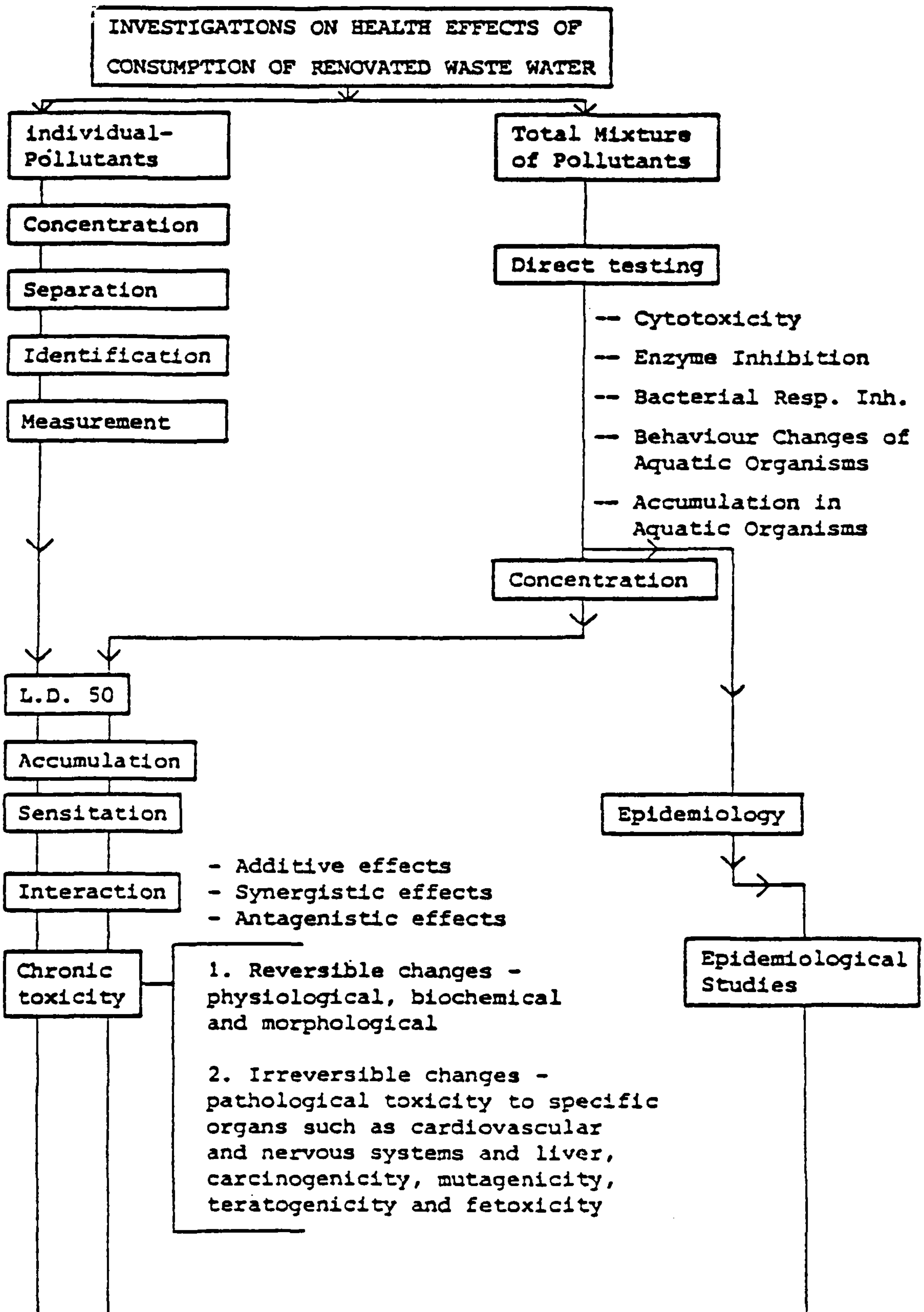
11. In the April 1977 issue of Water - South Africa, Dr. W.H.J. Hattingh of the National Institute for Water Research wrote an article entitled "Reclaimed Water: A Health Hazard", which described the comparison of AWT effluents with surface water supplies in his country from eight years of data.

FIGURE 2

POSSIBLE APPROACHES TO THE TOXICOLOGICAL EVALUATION OF RENOVATED WATER TO BE USED AS DRINKING WATER



The 1 mgd Windhoek Reclamation Plant in Southwest Africa has been producing a very high quality effluent on an intermittent basis since 1969. Comparisons between the Windhoek product and local sources is shown in Table 3 and 4 with the constituents regarded as being detrimental to human health shown as criteria in Table 5.

TABLE 3

THE AVERAGE CHEMICAL QUALITY OF THE DIFFERENT SOURCES OF POTABLE WATER IN WINDHOEK OVER THE PERIOD 1971 TO 1975

		Goreangab Dam		**Von Bach Dam**	**Pahl Quelle**	**Re-claimed**
		Raw	**Treated**	**Treated**	**Boreholes**	**water**
	Conductivity (mS/m)	34	41	25	86	110
mg/ℓ	Alkalinity*	98	96	91	273	89
	COD**	33	32	40	28	33
	MBAS***	0,4	0,4	0,4	0,5	—
	Ammonia-N	0,9	0,4	3,6	0,7	0,1
	Organic-N	1,2	0,6	2,7	0,6	0,6
	Nitrate-N	0,9	0,7	1,1	1,4	25,0
	Nitrite-N	<0,1	<0,1	<0,1	<0,2	<0,1
	Ortho-P	0,4	<0,2	0,9	0,6	<0,2
	Organic-P	1,3	0,3	0,7	0,3	<0,2
	Organic-C	14	15	14	13	8
	Fluoride (F^-)	0,2	0,2	0,2	0,8	0,1
	Chloride (Cl^-)	20	27	5	27	130
	Sulphate ($SO_4^{=}$)	36	40	34	104	210
	Sodium (Na)	28	29	2	101	154
	Potassium (K)	7	7	4	13	29
	Calcium (Ca)	27	36	32	58	57
	Magnesium (Mg)	4	4	2	18	5
μg/ℓ	Aluminium (Al)	699	309	903	247	—
	Arsenic (As)	—	—	—	—	—
	Boron (B)	147	96	112	176	—
	Barium (Ba)	<250	<250	<250	<250	<250
	Beryllium (Be)	<50	<50	<50	<50	<50
	Cadmium (Cd)	<25	<25	<25	<25	<25
	Cobalt (Co)	<25	<25	<25	<25	<25
	Chromium (Cr)	<25	<25	<25	<25	<25
	Copper (Cu)	<25	<25	<25	<25	<25
	Iron (Fe)	813	59	156	250	<25
	Manganese (Mn)	92	70	25	40	<25
	Nickel (Ni)	<25	<25	<25	<25	<25
	Lead (Pb)	<25	<25	<25	<25	<25
	Strontium (Sr)	122	127	88	381	225
	Zinc (Zn)	54	82	54	57	<25

*Alkalinity at pH 4,3 ($CaCO_3$)
**COD = Chemical oxygen demand
***MBAS = Methylene blue active substances

TABLE 4

THE AVERAGE MICROBIOLOGICAL QUALITY OF THE DIFFERENT SOURCES OF POTABLE WATER IN THE WINDHOEK AREA OVER THE PERIOD 1970 TO 1975

		Goreangab Dam		Purified Von Bach Dam	Pahl Quelle boreholes	Re-claimed water
		Raw	Purified			
1 mℓ	Total plate count	292 x 10^2	20	400	600	<100
/100 mℓ	Coliforms (37°C)	23 x 10^2	0	0	14	0
	Faecal coliforms (44,5°C/18h)	5 x 10^2	0	0	6	0
	Confirmed *E. coli I*	3 x 10^2	0	0	<1	0
	Pseudomonas aeruginosa	4 x 10^2	0	0	2	-
	Clostridium perfringens	17 x 10^2	0	1	<1	-
	Staphylococci	34	0	0	<1	-
Percentage of samples positive for enterovirus		6	3	<1	0	0

TABLE 5

DRINKING WATER QUALITY CRITERIA WHICH MIGHT AFFECT PUBLIC HEALTH AS PROPOSED BY THE WORLD HEALTH ORGANIZATION (WHO), US PUBLIC HEALTH SERVICE (USPHS), SOUTH AFRICAN BUREAU OF STANDARDS (SABS), RUSSIA (USSR), USA NATIONAL ACADEMY OF SCIENCES (NAS), THE BRITISH MINISTRY OF HEALTH (UK), AUSTRALIA, JAPAN AND ENVIRONMENTAL PROTECTION AGENCY (EPA) OF THE USA.

All concentrations in μg/l unless otherwise stated

	Quality criteria proposed by									
					WHO					
Parameter	**USPHS (1962)**	**Japan (1968)**	**UK (1969)**	**USSR (1970)**	**European (1970)**	**International (1971)**	**SABS (1971)**	**NAS (1972)**	**Australia (1973)**	**EPA (1975)**
Arsenic	10	50		50	50	50	50	100	50	50
Barium	1 000			4 000	1 000	—	—	1 000	1 000	1 000
Cadmium	10			10	10	10	50	10	10	10
Chromium	50	50		100	50	—	50	50	50	50
Copper	1 000	10 000		100	50	50	1 000	1 000	10 000	—
Cyanide	10	10		100	50	50	10	200	10	—
Lead	50	100		100	100	100	50	50	50	50
Mercury	—	1		5	—	1	—	2	—	2
Phenolic compounds	1	5		1	1	1	1	1	—	—
Selenium	10	—		1	10	10	—	10	10	10
Silver	50	—		—	—	—	—	—	50	50
Zinc	5 000	1 000		1 000	5 000	5 000	5 000	5 000	5 000	
Organic Matter (CCE)	200	—		—	200 - 500	—	—	300	700	—
Pesticides										
Total chlorinated hydrocarbon	—	—		—	—	—	—	1 066	—	1 092
Total organo phosphorus and carbamates	—	—		—	—	—	—	100	—	—
Total chlorophenoxys	—	—		—	—	—	—	52	—	110
Nitrate-Nitrogen (mg/ℓ)	10	10		10	<11,5	10	10	10	10	10
Fluoride (mg/ℓ)	0,6 - 1,7	0,8		1,5	0,7 - 1,7	0,6 - 1,7	1,0 - 1,5	1,4 - 2,4	1,5	1,4 - 2,4
Coliforms/100 mℓ	<1[1]	0	<10	—	—	0	<10	—	0	<1
E. coli I/100 mℓ	—	0	0	—	—	0	0	—	0	—
Total plate count/mℓ	—		—	—	—	—	<100	—		—
Virus/ℓ	—		—	—	—	1[2]	—	—		—

(1) Less than 10% of samples should be positive in any one month
(2) 1 Plaque forming unit on testing 10ℓ sample

Average chemical and biological qualities from potable waters and the Stander Wastewater Reclamation Plant in Pretoria are shown in Tables 6, 7, 8 and 9 respectively.

It was the author's conclusion that reclaimed effluent is a safe water supply and would not present a health hazard when proper treatment and safeguards are present.

TABLE 6

THE AVERAGE CHEMICAL QUALITY OF THE DIFFERENT POTABLE WATERS IN THE PRETORIA AREA OVER THE PERIOD 1972 to 1975

		Rietvlei Dam		Rietvlei Fountains	Erasmia Borehole	Pretoria Fountains	NIWR Laboratory Tap water	Vaal River at Vereeniging	
		Raw	Treated					Raw	Treated
	Conductivity (mS/m)	54	58	27	55	49	44	52	37
mg/ℓ	Alkalinity*	160	140	98	196	162	71	84	86
mg/ℓ	COD**	30	34	18	18	20	47	22	22
mg/ℓ	MBAS***	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,2
mg/ℓ	Ammonia-N	0,4	0,3	0,3	0,3	0,3	0,4	0,4	0,5
mg/ℓ	Organic-N	0,7	0,6	0,5	0,5	0,4	2,0	0,7	0,8
mg/ℓ	Nitrate-N	0,1	<0,1	0,6	2,1	2,1	0,7	1,3	1,0
mg/ℓ	Nitrite-N	0,5	0,3	0,2	0,1	<0,1	0,2	0,1	0,2
mg/ℓ	Ortho-P	0,5	0,6	0,2	<0,2	<0,2	0,2	0,4	<0,2
mg/ℓ	Organic-P	0,4	0,2	0,1	0,1	0,1	0,2	0,2	0,4
mg/ℓ	Organic-C	17	12	7	6	7	7	10	8
mg/ℓ	Fluoride (F^-)	0,3	0,3	0,1	0,1	<0,1	0,2	0,4	0,2
mg/ℓ	Chloride (Cl^-)	31	51	15	46	25	53	36	21
mg/ℓ	Sulphate ($SO_4^=$)	60	76	10	12	10	44	111	58
mg/ℓ	Sodium (Na)	58	63	10	15	15	46	39	22
mg/ℓ	Potassium (K)	8	8	1	1	2	3	7	4
mg/ℓ	Calcium (Ca)	27	28	24	53	44	33	56	42
mg/ℓ	Magnesium (Mg)	15	15	13	31	24	11	30	7
µg/ℓ	Silver (Ag)	<25	<25	<25	<25	<25	<25	<25	<25
µg/ℓ	Aluminium (Al)	154	192	145	154	137	149	263	171
µg/ℓ	Arsenic (As)	2	3	1	1	1	1	2	2
µg/ℓ	Boron (B)	188	174	109	107	107	103	259	139
µg/ℓ	Barium (Ba)	<250	<250	<250	<250	<250	<250	<250	<250
µg/ℓ	Beryllium (Be)	<5	<5	<5	<5	<5	<5	<5	<5
µg/ℓ	Cadmium (Cd)	<5	<5	<5	<5	<5	<5	<5	<5
µg/ℓ	Cobalt (Co)	<25	<25	<25	<25	27	<25	<25	<25
µg/ℓ	Chromium (Cr)	<25	26	<25	<25	25	<25	28	<25
µg/ℓ	Copper (Cu)	27	<25	<25	<25	<25	40	28	29
µg/ℓ	Mercury	2	1	1	1	1	1	1	1
µg/ℓ	Iron (Fe)	1939	26	26	25	26	71	1534	<25
µg/ℓ	Manganese (Mn)	25	<25	<25	<25	<25	<25	29	<25
µg/ℓ	Nickel (Ni)	28	27	<25	26	27	<25	30	<75
µg/ℓ	Lead (Pb)	<25	<25	<25	27	<25	<25	27	<25
µg/ℓ	Strontium (Sr)	69	65	24	33	28	67	148	85
µg/ℓ	Zinc (Zn)	39	29	28	61	32	41	35	26
µg/ℓ	Phenol	68	56	73	72	61	54	<50	71
µg/ℓ	Cyanide (CN^-)	<50	<50	<50	<50	<50	<50	<50	<50

*Alkalinity at pH 4,3 ($CaCO_3$)
**COD = Chemical oxygen demand
***MBAS = Methylene blue active substances.

TABLE 7

THE AVERAGE MICROBIOLOGICAL QUALITY OF THE DIFFERENT SOURCES OF POTABLE WATER IN THE PRETORIA AREA DURING THE PERIOD 1972 to 1975

		Vaal River at Vereeniging		Rietvlei Dam		Rietvlei Fountains		Erasmia Borehole	Pretoria Fountains		NIWR Laboratory tap water
		Raw	Treated	Raw	Treated	Before Cl_2	After Cl_2		Before Cl_2	After Cl_2	
/mℓ	Total plate count (37 °C/24 h) x 10^2	33	0,12	44	9	8	12	5	8	12	10
/100 mℓ	Coliforms* (37 °C)	35	0	30	35	10	3	5	1	10	5
	Faecal coliforms* (44,5 °C/18 h)	17	0	12	5	4	<1	4	<1	1	50
	Confirmed *E. coli I**	12	0	0	0	0	0	—	—	0	6
	Pseudomonas aeruginosa	9	0	<1	<1	<1	<1	0	0	0	1
	*Clostridium perfringens**	17	0	113	87	6	<1	<1	<1	<1	7
	Staphylococci*	9	0	<1	<1	0	0	0	0	0	0
/litre	Total enterovirus	0	0	<1	0	0	0	0	0	0	0
	Total parasite ova	0	0	0	0	0	0	0	0	0	0

*By membrane filtration.

TABLE 8

AVERAGE MICROBIOLOGICAL QUALITY OF RAW WATER TO AND FINAL WATER FROM THE STANDER WATER RECLAMATION PLANT, PRETORIA, DURING CONTINUOUS OPERATION IN 1975

		Raw	Final
/mℓ	Total plate count (37 °C/24 h) x 10^2	19 000	9
/100mℓ	Coliforms* (37 °C) x 10^5	13	0
	Faecal coliforms* (44,5 °C/18 h) x 10^5	6	0
	Pseudomonas aeruginosa	1	1
	*Clostricium perfringens**	8	1
	Staphylococci*	64	0
	Enterococci*	91	0
/litre	Total enterovirus x 10^3	24	0
	Total parasite ova	1	0
	Ascaris ova	1	0
	Hookworm ova	0	0
	Taenia ova	0	0
	Other ova	0	0

*By membrane filtration

TABLE 9

CHEMICAL QUALITY OF RAW WATER TO THE STANDER WATER RECLAMATION PLANT AND THE FINAL WATER PRODUCED DURING CONTINUOUS OPERATION IN 1975

		Raw	Final
	Conductivity (mS/m)	66	60
mg/ℓ	Alkalinity*	158	35
	COD**	36	19
	MBAS***	0,8	0,6
	Ammonia-N	7,6	0,4
	Organic-N	4,6	1,1
	Nitrate-N	11,3	15,3
	Nitrite-N	0,5	0,1
	Ortho-P	6,0	0,4
	Organic-P	1,4	0,4
	Organic-C	18	8
	Fluoride (F^-)	0,1	0,1
	Chloride (Cl^-)	46	90
	Sulphate ($SO_4^{=}$)	45	46
	Sodium (Na)	46	63
	Potassium (K)	13	12
	Calcium (Ca)	41	35
	Magnesium (Mg)	20	4
µg/ℓ	Silver (Ag)	<25	<25
	Aluminium (Al)	109	102
	Arsenic (As)	2	2
	Boron (B)	260	164
	Barium (Ba)	<250	<250
	Beryllium (Be)	<5	<5
	Cadmium (Cd)	<5	<5
	Cobalt (Co)	<25	<25
	Chromium (Cr)	<25	<25
	Copper (Cu)	<25	<25
	Mercury (Hg)	4[1]	22[1]
	Iron (Fe)	161	59
	Manganese (Mn)	<25	<25
	Nickel (Ni)	<25	<25
	Lead (Pb)	<25	<25
	Strontium (Sr)	75	52
	Zinc (Zn)	32	<25
	Phenol	93	92
	Cyanide (CN^-)	<50	<50

*Alkalinity at pH 4,3 ($CaCO_3$)
**COD = Chemical oxygen demand
***MBAS = Methylene blue active substances.

(1) See text for explanation of these high figures.

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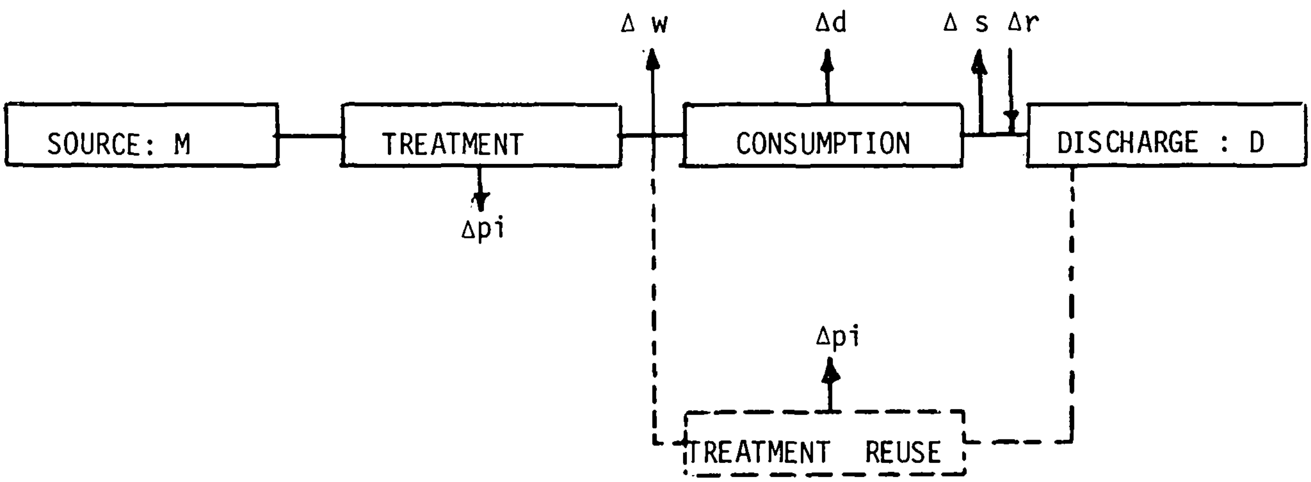
12. The Netherlands National Institute for Water Supply has developed a theoretical consideration for possible health effects in water reuse situations as well as organics monitoring and international research cooperation.

The scheme for introduction of reuse in a water supply system is given in Figure 3.

FIGURE 3

DRINKING WATER BALANCE OF A CITY



Water losses in the system (Δ) are given by:

Δ_{pi} :Losses during water treatment i

Δ_d :Losses during consumption

Δ_w :Losses during transport and distribution

Δ_s :Losses in the sewer system

Δ_r :Introduction of rain

(Δ) :Σ^Δ (pi, d, w, s, r)

M :Total quantity of water abstraction from the source

D :Wastewater discharge

When a city is confronted with water shortages the decision to reuse must be weighted against economics, health risks, type and amount of recycling.

The degree of reuse is commonly expressed by the reuse factor R, the ratio between the quantity of reclaimed water (Q) and the available quantitiy of raw water (M). (R = Q/M)

The percentage of effluent for reuse is dependent upon the actual changes in the water volume in the system and can be expressed as a recovery percentage.

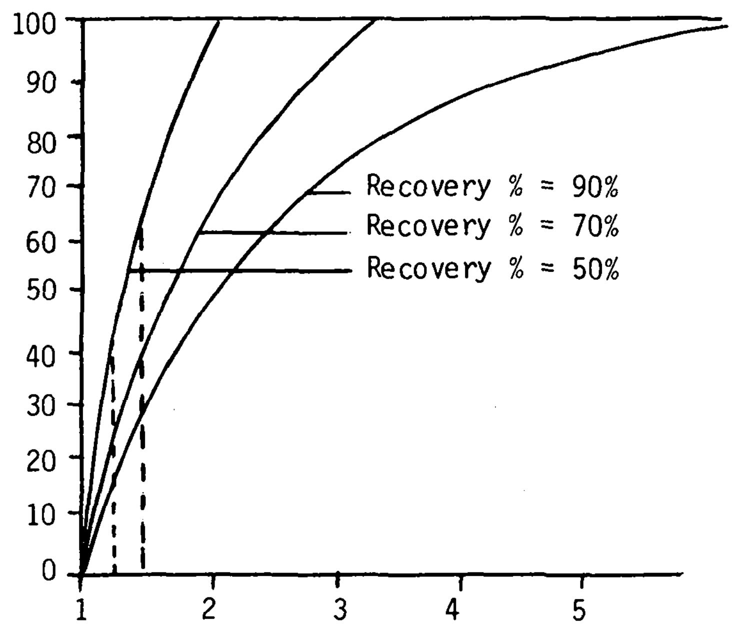
The percentage of the wastewater, which has to be recycled can be expressed mathematically as a function of the recovery and the reuse factor or a water scarcity index and is graphically given in Figure 4.

The water scarcity index is by definition, the ratio of the water demands over the available raw water.

FIGURE 4

Relation between effluent recycling percentage and water scarcity index at different recoveries.

$$\text{Effluent Recycling \%} = \frac{1}{(\text{Recovery \%})} \cdot \frac{R}{R+1}$$



$$\text{Water scarcity index} = \frac{\text{quantity demand}}{\text{quantity available}} = R + 1$$

A sewer system in Europe is assumed to have a recovered effluent percentage of 40-60% with 50% considered as a realistic figure.

The reuse factors will then be 0, 25, and 50 with these figures used in further calculations, because only the reuse factor is responsible for typical reuse effects due to repeated recycling of pollutants.

In such a closed or semi-closed system, contaminants will show a tendency to accumulate. The level of accumulation can be described with simple models and with worst-case simulations. From the simplified equation for the equilibrium concentration (1) a second equation can be drawn up, the so-called equilibrium concentration under worst condition, e.g. when the treatment efficiency is zero, or no treatment for the contaminant is available.

$$Ceq = \frac{1}{1-A} (A \cdot \Delta_C + B \cdot C_m) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

in which:

- Ceq :equilibrium concentration, of a considered pollutant
- Δ_C :use increment concentration of a considered pollutant
- C_m :concentration of a considered pollutant in raw water
- A + B :factors dependent on waterbalance and treatment efficiency

$$Ceq = R \cdot \Delta_C + C_m \quad \text{worst-case condition} \ldots\ldots\ldots\ldots(2)$$

When wastewater reuse is considered it is necessary to know whether or not the new situation will create an increased health risk for the consumer and to what extent. For this purpose the water quality in both cases can be compared.

Before reuse of wastewater becomes a part of the water supply system, the concentration of pollutant A in drinking water is called C_{me}.

Due to water recycling, the equilibrium concentration of pollutant A under steady state conditions changes.

The ratio between the concentration of constituent A in the case of reuse and without reuse is called the potential health risk (K).

The nature of the considered contaminant and increased concentration will lead to potential health risks. (ratio water quality at reuse - water quality without reuse) The mathematical expression for the potential health risk factor K is given by equation 3.

$$K = \frac{C_{eq\ reuse}}{C_{me}} = \frac{R \frac{\Delta_C}{C_{me}} + S_{pl}}{(R+1)\ S_{pl}\ -R} \quad \ldots\ldots\ldots\ldots(3)$$

(S_{pl} = treatment efficiency)

This rather complicated formula can be simplified when no treatment effect is assumed (S_{pl} = 1).

This situation is called the worst-case situation and Equation 3 can be written as:

$$Kwc = R \frac{\Delta_c}{Cme} + 1 = R \frac{\Delta_c}{Cm} + 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Kwc represents the potential health risk factor under the worst conditions.

The factors K and Kwc were calculated for some carcinogenic components based on water quality data for the Dutch city of Dordrecht and with pollutants increasing by a factor of 1.5, a recovery factor of 60% and a recycling percentage of 55%.

Table 10 shows the relevant data for three carcinogenic contaminants.

TABLE 10

The potential health risk calculation related to 3.4. benzofluoranthene, 11.12 benzofluoranthene and 3.4. benzopyrene in case of wastewater reuse.

Contaminant	Max. reported concentration in μ/l in: River Rhine	Drinking water Dordrecht	Domestic sewage Dordrecht	Separation factor s	Use increment concentration c	R = 0,5 K	R = 0,5 Kwc
3.4 benzo-fluoranthene	0,21	0,044	0,30	4,8	0,30	1,4	4,4
11.12 benzo-fluoranthene	0,23	0,005	0,34	46	0,34	1,2	35
3.4 benzo-pyrene	0,15	0,004	0,31	38	0,31	1,4	40

Normal treatment will reduce the concentration of the carcinogenic contaminants by a factor of 5-50%. If reuse is considered, the potential health risk can be calculated with the help of Equation (3).

Figure 5 shows that to avoid unnecessary health risks the reuse factors have to be chosen as small as possible. The effect of treatment is very large. When the purification effect is limited, the potential health risk can be high.

To illustrate that fact, it can be shown that a non-removable chemical in sewage, when 80% is directly reused, is at a 10 times higher concentration than if the tap water was derived from an indirect reuse situation with river discharge, dilution and abstraction.

If 85% of the sewage is directly recycled, a factor of 100 times the pollutant concentration is possible as compared to tap water derived from river water containing 5% of the sewage effluent.(see Table 11) These calculations indicate the great importance for detailed studies of health effects of present indirect

FIGURE 5

The increasing K_{wc} and K-value as a function of the reuse factor.

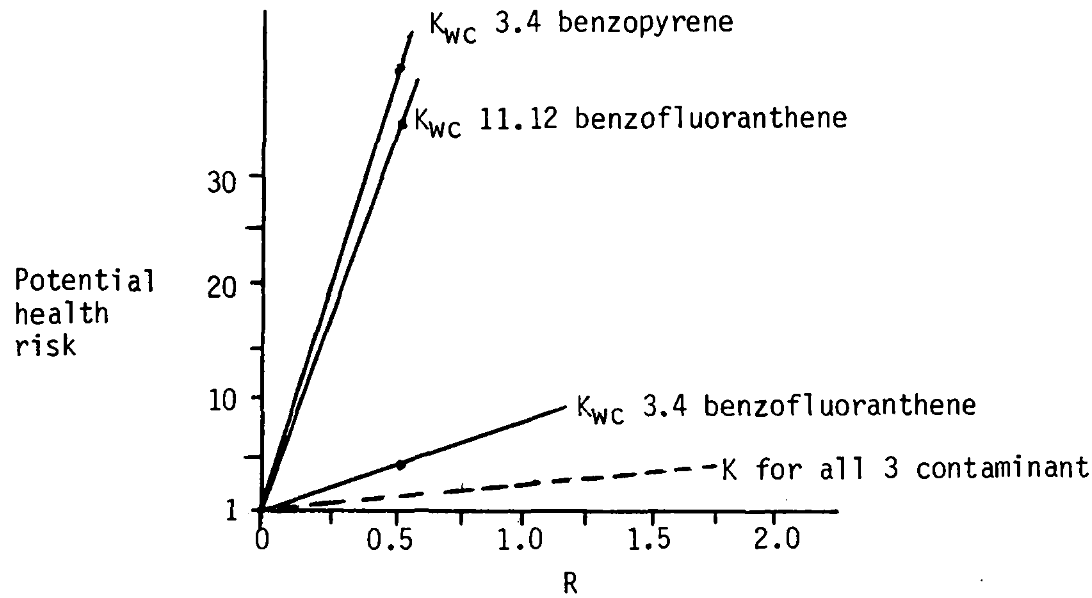


TABLE 11

Potential increased levels of exposure to a persistent chemical in domestic effluent via directly reused wastewater compared with indirect wastewater reuse.

Percent Directly Recycled wastewater	Ratio* of potential exposure for direct/indirect reuse	
	River with 50% effluent	River with 5% effluent
25	1.5	6
50	3	21
75	7	61
80	9	81
85	12	115
90	19	181
95	39	381

* (Exposure ratio) direct/indirect $= 1 + \frac{Q_{recycled}}{Q_{normal}} \cdot \frac{\Delta C_{cycle}}{C_{river}}$

and planned direct reuse of wastewater for human consumption. By the use of mathematical models, it will further be possible to extrapolate the health risk of present indirect reuse situations to those encountered in future projects of direct reuse.

13. The question related to the health effects of heavy metals and organics in drinking water supplies is complex. First, is there an effect of each of the many elements and compounds, and if so, what effect, present at which concentration? Further, are the effects symptomatic as mutagenic, carcinogenic or teratogenic? Before these questions can be answered, the proper questions must be formulated.

Part of the difficulty in assessing the health effects of heavy metals and trace organics has been in the lack of coordination in data gathering and subsequent reporting. Clinical epidemiological data, while present, is widely scattered, making analysis difficult. Research aimed at alleviating the situation by gathering the pertinent results into one place was published in the Journal of Environmental Health, Volume 39, No.2, as "Physiological Effects of Trace Elements and Chemicals in Water". The authors, M.M. Varma and H.M. Katz, of Howard University, Washington, D.C., and S.G. Serdahely of WHO, compiled a comprehensive literature survey of the occurrence, sources, concentration and health effects of heavy metals including: mercury, cadmium, arsenic, lead, beryllium, chromium and manganese, the trace elements; fluoride and nitrates and organic compounds too numerous to mention. Concern is voiced, in respect to the potable reuse of treated wastewater, about the accumulation and concentration of these contaminants through conventional treatment processes. The significant results are presented in Table 12, while the original document should be consulted for more information.

TABLE 12

PHYSIOLOGICAL EFFECTS OF TRACE ELEMENTS & CHEMICALS IN WATER
JEH, SEPT/OCT 1976

A - HEAVY METALS

SOURCE OF POLLUTION	FORMS OCCURRING IN	HEALTH EFFECTS	CONCENTRATION
MERCURY Manufacture of lamps, controls, batteries, Dental use, pesticides, fungicides, mildew proofing agents in paints, chloro-alkali Released from land disposal, incineration.	1. Most Toxic: alkyl mercury compounds methylmercury (MM) 2. Toxic: elemental mercury compounds mercuric ions 3. Less Toxic: inorganic mercury salts Phenyl and methoxyethyl compounds	90% of (MM) ingested is adsorbed in the gastro-intestinal tract-accumulates in blood cell concentrates in brain and nervous system; can cross placental barrier and cause irreversible damange to fetus at levels that cause no symptoms to mother; elemental mercury accumulates in brain and central nervous sytem; 75-85% adsorbed excreted more rapidly; phenyl and methoxyethyl concentrate in kidney and liver excreted much more rapidly.	Methyl mercury causes neurological symptoms at a blood level of 02 ug/g corresponding to daily intake of 300 ug/day. FDA Regulations - 30 ug/day WHO Regulations - 33ug/day MM 50ug/day total mercury
CADMIUM Electroplating, zinc ore mining, pigments, stabilizer in PVC, released in industrial waste discharge, waste incineration, melting scrap steel	Cd^{++}	In high concentration Cd is a deadly poison. 5-6% adsorbed through oral ingestion; 30% inhaled; concentrates in kidney (renal cortex); cardiovascular disease possibly; affects lung, kidney, liver.	At 200 ppm concentration, chronic kidney disease begins
ARSENIC Pesticides, detergent made from phosphate rock, also fertilizers from phosphate.	1. Highly Toxic: Arsenites, dimethyarsine 2. Toxic: Arsenates, inorganic arsenicals, arsenic trioxide, organic arsenicals 3. Non-Toxic: Elemental Arsenic	Exposure to arsenic trioxide has caused dermatitis, hyperkeratosis, gastro-intestinal disorders, peripheral neuropathy, muscular weakness, degenerates lung, liver, kidney, pancreas, stomach, heart and blood. Correlation with skin cancer.	
LEAD Gas additive, storage batteries, pigments automobile exhaust, land disposal, highway paint leaching	Children: Mental retardation, cerebral atrophy, kidney tumors, nervous system		Man retains 200-400ug/day Over 0.8 mg/kg concentration causes lead poisoning
MANGANESE Fertilizers, catalyst	manganese, ethylene-bis-dithio-carbamide	Primary effect on central nervous system, hallucination, insomnia & mental confusion	

(continued on next page)

Table 12 cont.

B - ORGANIC COMPOUNDS

SOURCE OF POLLUTION	FORMS OCCURRING IN	HEALTH EFFECTS	CONCENTRATION
POLYCHLORINATED BIPHENYLS (PCB'S) Electrical Industry		Fat soluble stored in lipids-increase susceptibility to infectious diseases. animal results: liver enzyme activity increased, bladder cancer, chloracne, blindness, gastro-intestinal diseases, skin discoloration in newborn infants	
PHTHALATE ESTERS Plasticizers in PVC manufacture, insect repellent	Di-2-ethyl-hexyl and di-n-butylphthalates Phthalic acid esters (PAE)	PAE's have low order of acute toxicity-have produced teratogenic effects in rats.	
1-NAPHTHYLAMINE Agricultural chemicals, food colors, dyes, petroleum anti-oxidants, effluents from dye manufacture and agricultural runoffs.	1-naphthylamine 2-naphthylamine	Malignant tumors of bladder, methemoglobemia 2-naphthylamine is a known carcinogen	
ARYL PHOSPHATES Flame retardants, plasticizers for PVC manufacture	Tri-orthotolyl phosphate (TOTP) Tri-orthocresyl phosphate Tri-ethylphenyl phosphate	Intestinal cramps, vertigo, blurred vision headache, diarrhea, vomiting, muscular weakness, coma, pulmonary edema. TOTP is highly toxic. Tri-orthocresyl affects the neuromuscular system, as does tri-ethyl-phenyl	
ACRYLONITRILE Industrial intermediate in manufacture of plastics and elastomers	Vinyl cyanide,propenitrile, cyanothylene, acetonitrile	Mutagen-interferes with RNA	LD50 in mice is 26-43 mg/kg 2 mg/l causes behavioral changes

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LEGISLATIVE & FUNDING ACTIVITIES

1. On November 8, 1977, the President signed into law, PL95-155, the EPA Research and Development Authorization Act of 1978, which requires the EPA to spend $25 million on water reuse research. Background information on this important legislation follows.

Included in the Safe Drinking Water Act of 1974 (PL93-523) was Section 1444, which authorized the expenditure of $25 million for potable reuse research. Those monies, earmarked by Congress for needed reuse research, were to expire at the close of fiscal year 1977 (September 30, 1977).

Working against that dealine, Representative James P. Johnson (R-CO), early in 1977, brought to the attention of the House, that no positive action was taken to request the use of the authorized funds.

Confronting the EPA on the issue, Johnson was informed that the EPA had failed to ask for those monies or have them appropriated because of "many technical uncertainties concerning reuse....which would make assessing current demonstration projects very difficult".

However, on the floor of the House, Rep. Johnson pointed out that "these technical uncertainties as well as related health questions are precisely the areas of concern which can only be fully investigated and resolved through a practical demonstration size facility which would qualify for cost-sharing grants under the provisions of the SDWA". In response to his perception of the problem, Johnson introduced a bill, on February 22, 1977, to provide for a "simple amendment" to SDWA to remove the optional wording and require that EPA grant $10 million in FY1978 for potable reuse demonstration projects.

The amendment (HR5101) to the EPA R & D Legislation went to the House HUD and independent sub-agencies and sub-committees for committee study. With committee approval, and additional support on the floor from California, New Mexico and New York, the required amount was increased to $25 million. On April 19, 1977 the amendment was approved in the House by a vote of 358 to 31, with 41 abstentions.

When taken to the Senate, the reuse provision was removed from their version of the EPA legislation and placed in the Senate Safe Drinking Water Act (S.1528) which was subsequently passed. In a compromise move, an attempt was made to insert the same wording into the House version of the SDWA. Opposition was encountered and the amendment was dropped entirely because it would have jeopardized passage of the entire bill.

With the reuse monies stranded in S.1528 and HR5101, a conference between representatives of both legislative branches was held to resolve differences in wording.

U.S. House of Representatives and Senate Conferees concluded discussion in October of 1978, and after successful House ballot, the bill went to the President, becoming PL95-155.

In the language of the conference report, the $25 million will be offered as 65-75% cost-sharing grants for the purpose of:

a. Assisting in the development and demonstration (including construction) of any project which will demonstrate a new or improved method, approach or technology for providing a dependable safe supply of drinking water to the public; and

b. Assisting in the development and demonstration (including construction) of any project which will investigate and demonstrate health and conservation implications involved in the reclamation, recycling and reuse of wastewaters for drinking and the processes and methods for the preparation of safe and acceptable drinking water.

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MODELING FOR REUSE

1. In order for wastewater reuse to realize its true potential, it must be considered as part of a regional water resources management plan. Such comprehensive planning required the capability for planners to "step back" from the situation and assess the consequences of various allocation schemes. Digital computer models, and linear programming techniques have been applied successfully as aids to resource planning, but their use in the field of wastewater reuse is in its

infancy. The references in this section begin to explore the utility of modeling as a powerful tool for water resources planning.

In a recent EPA publication, EPA-600/2-76-058, entitled "Future Direction of Urban Water Models", the state of the art of urban water modeling since 1968 was reviewed. As pertaining to the subsystem category of reuse, six specific models were mentioned. These include:

1. Bishop, A.B., D.W. Hendricks, and J.H. Milligan, "Assessment Analysis for Water Supply Alternatives", Water Resources Bulletin, AWRA, Vol. 7, No. 3, June 1971, pp. 542-553.

2. Kugelman, I.J., "Water Reclamation and Reuse", WPCF Journal, Vol. 46, No. 6, June 1974, pp. 1195-1199.

3. Mallory, C.W., The Beneficial Use of Storm Water, Final Report to U.S. EPA, EPA-R2-73-139, Hittman Associates, Inc., Columbia, Maryland, January 1973, 266 p.

4. Mulvihill, M.E., and J.A. Dracup, "Optimal Timing and Sizing of a Conjunctive Urban Water Supply and Waste Water System with Nonlinear Programming", Water Resources Research, Vol. 10, No. 2, April 1974, pp. 170-175.

5. Water Resources Engineers, Systems Analysis for Urban Water Management, prepared for the Office of Water Resources Research through the ASCE Water Resources Research Program, Walnut Creek, California, September 1970, 78 p.

6. Weddle, C.L., S.K. Mukherjee, J.W. Porter, and H.P. Skarheim, "Mathematical Model for Water-Wastewater Systems", AWWA Journal, Vol. 62, No. 12, December 1970, pp. 769-775.

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2. A computer program, PROCS, has been developed by Moore, Gardner and Associates, Consulting Engineers, to perform preliminary cost estimates in AWT plants for comparative purposes. The program selects a treatment sequence to meet the required effluent limitations, but does not produce detailed design information.

Ten unit operations are included in PROCS: preliminary treatment and activated sludge, nitrification - denitrification, chemical precipitation, filtration, carbon adsorption, reverse osmosis, ozonation, chlorination and post aeration.

Removal efficiencies are calculated which take into account different qualities of wastewater.

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3. Dr. G.C. Hall of South Africa's National Institute for Water Research (NIWR) has reported on the development of linear programs to optimize direct reuse in a

community. The article, as it appears in the June 1977 NIWR issue of Water Report, states that a system approach is required to balance stream augmentation and reclamation. A rather simplistic model could be used as an initial thrust at determining the economical balance and screen possible flow systems.

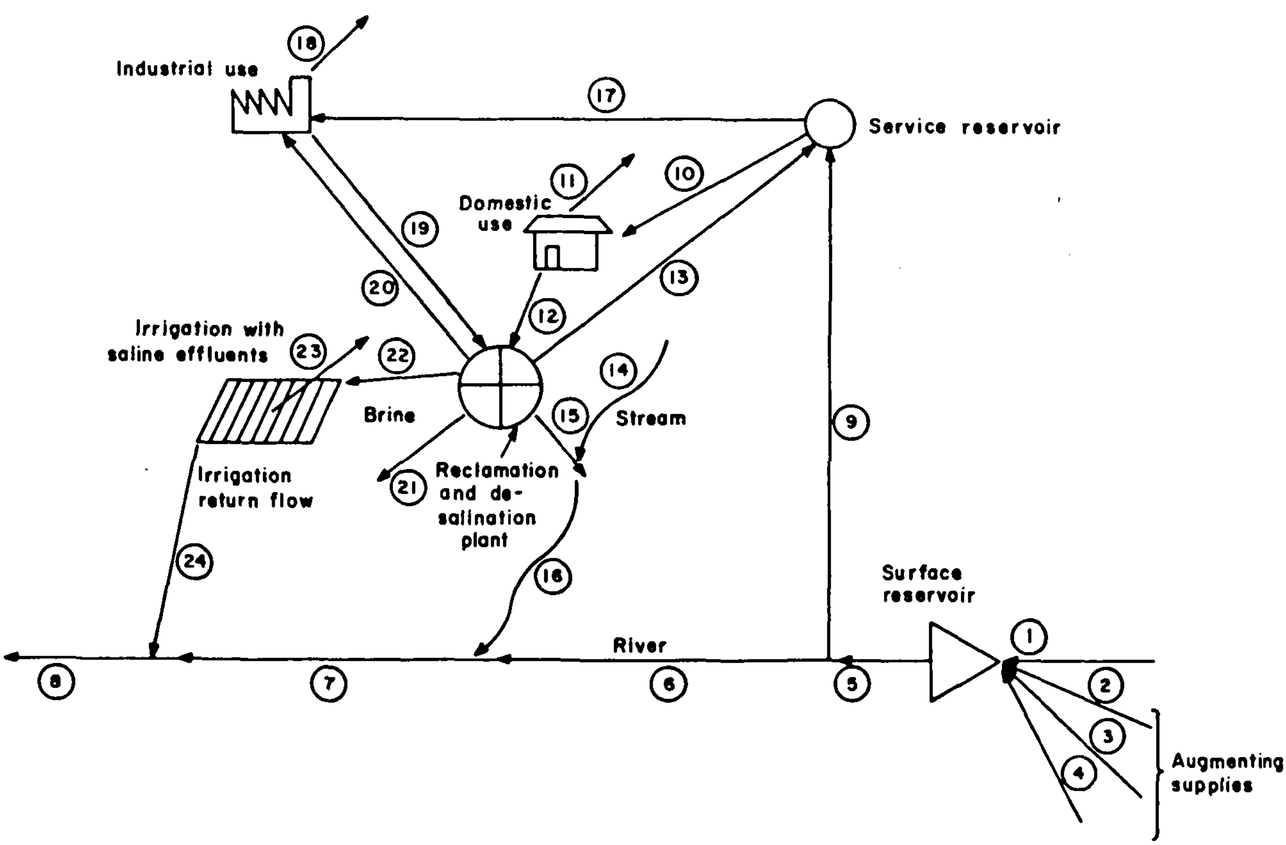
An example of a possible circulation system is shown in Figure 1 which consists of 24 directed flows that join at 10 nodes. A cost coefficient (cost per unit of water conveyed including treatment) is associated with each flow.

For example, the cost coefficient for flow #9 would include the unit cost of treating raw water to potable standards. Decision variables in the model are the magnitude of flow with the objective to minimize the total cost of water supply subject to demand satisfaction and quantities available. Other constants include the physical capacities of the carriers and concentration build-ups.

Linear programming techniques are a suggested method to solve the model even though some of the constraints are not amenable to linear solutions. It is possible to modify the constraints permitting an approximate linear program which can then be adjusted manually to satisfy the deviations. The basic method suggested appears in South Africa's research to be satisfactory for problems involving fewer than 100 decision variables.

FIGURE 1

SIMPLIFIED LINEAR MODEL FOR REUSE



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4. In "The Decision to Reuse Water", a paper presented at the 1977 AWWA Anaheim Convention, Drs. Baumann and Dworkin of Southern Illinois University provide a good introduction to the wastewater reclamation and reuse field with emphasis on decision criteria and modeling factors. Three types of models for evaluating reuse economics are identified.

   1. Projected costs of treating wastewater to a suitable level are contrasted with the costs of providing the water from an alternative source.

   2. Various supply alternatives are evaluated to optimize or determine the least cost alternative under given conditions.

   3. A municipal system is simulated through the interaction of supply and demand components and the waste treatment and reuse systems.

   Through analysis of the strengths and weaknesses of the three categories of models, the more comprehensive supply-demand alternate is selected for further investigation. Model development is discussed, with each specific component expanded to illustrate its relation and significance in the decision-making process.

   The authors contend that water reuse is a viable, attractive and economically more efficient method of providing municipal supplies. However, they ask:

   > If recycled renovated wastewater can be safe to drink, and under specific qualifications the concept is a socially acceptable and economically efficient alternative for municipal water supply planning, then why has the rate of adoption been so low? The answer may be related to the existence of two problems: the unavailability of a methodology to assess the relative value of reuse, and the professional biases of consulting engineers, public health officials and municipal water managers. An effort has been made to correct the first deficiency: a simulation model has been developed to evaluate the relative merits of specific water reuse systems. The second problem has been only defined and awaits additional research.

   In summary, and to demonstrate the feasibility of the model as a water resources management tool, the applicability of reuse to the Colorado Springs, Colorado municipal water supply was investigated.

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POSITION STATEMENTS

1. On June 18, 1971, the Board of Directors of the AWWA issued a position statement on the "Use of Reclaimed Wastewater as a Public Water Supply Source". At that time, the AWWA encouraged increased reclamation of wastewaters for non-public water supply needs, specifically industrial cooling and processing, crop irrigation,

recreation and groundwater recharge. While acknowledging that the full potential of reclaimed water should be developed, AWWA felt that the state of scientific knowledge and wastewater treatment technology was not sufficiently advanced to support use as a public water supply source. In response to the situation, AWWA called upon its Research Foundation and the U.S. EPA to sponsor sustained, intensive research and development to that end.

Policy statements such as the one issued are subject to review every five years. In order to get a broader range of input, the original one-page policy was submitted to the Water Resources and Water Quality Divisions of AWWA for comments. The latter Division requested rather sweeping changes in content from the recognition of indirect reuse to the support of a full-scale, multi-disciplinary research program in potable water reuse.

After unanimous approval in the Divisions, the revised policy statement, Figure 1, still presses for support from the Federal sector of needed research. The language is similar, and the content identical to that expressed in a joint American Water Works Association - Water Pollution Control Federation Resolution issued in November, 1973.

FIGURE 1

AWWA POLICY STATEMENT REVISION

Use of Reclaimed Wastewaters as a Public Water Supply Source

The American Water Works Association recognizes that properly treated wastewaters constitute an increasingly important element of the total available water resources. In relation to this situation several factors are important. These are as follows:

1. Ever increasing amounts of treated wastewaters are being discharged to the waters of the Nation and constitute an increasing proportion of many existing drinking water supplies;

2. More and more proposals are being made to introduce reclaimed wastewaters directly into various elements of domestic water supply systems in certain water short areas;

3. The sound management of our total available water resources may include consideration of the potential use of properly treated wastewaters as part of drinking water supplies in certain instances;

4. Insufficient information exists concerning acute and long-term effects on human health resulting from such uses of wastewater;

5. Fail-Safe technology to assure the removal of all potentially harmful substances from wastewater is not available.

Based on these factors the policy of the American Water Works Association is to urge the Federal Government to support an immediate and sustained multi-disciplinary national research effort to provide the scientific knowledge and technology relative to the future use of reclaimed wastewaters as a public water supply source in order to assure the full protection of the public's health, and further, that any advocacy of such direct use of reclaimed wastewaters as a public water supply source await the development of the needed scientific knowledge and treatment technology.

Prior to adoption, the policy statement will be balloted at two further organizational levels, and then be presented to the Board of Directors, possibly as early as June, 1978.

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2. Established in 1973, the National Water Supply Improvement Association (NWSIA) is dedicated to the improvement of community water supplies through desalting, wastewater reclamation and other water sciences. Representing a small (200) but highly qualified membership composed of national and international manufacturers, consulting firms, engineers, municipal water officials, government representatives and firms which supply equipment for water and wastewater treatment, positions endorsed by NWSIA carry considerable weight. The general membership of NWSIA in July, 1976, adopted the following resolution which is appropriate for entities involved in wastewater reclamation.

Only relevant reuse sections have been reproduced here.

> WHEREAS, the membership of the NWSIA has again reviewed the present desalination, wastewater reclamation and new water science programs in the U.S.; and
>
> WHEREAS, de-emphasis by agencies of the Federal Government of desalting research and demonstration continues to shock the members of the NWSIA, who also find disappointing the leisurely approach taken to research in the area of water recycling, especially that involving health aspects of reclaimed water; and
>
> WHEREAS, approaches under the Safe Drinking Water Act of 1974 to research into the health aspects of reuse of reclaimed wastewater has continued slowly and has delayed application of this technology as a water conservation measure, at a time when conservation is an increasingly recognized factor in water resources development and environmental enhancement programs.
>
> BE IT HEREBY RESOLVED, that the NWSIA calls to the attention of the President of the United States and of the U.S. Congress, the sad state of water resources research programs of the Federal Government. NWSIA urges that the EPA, the Department of the Interior, NSF, ERDA & OMB be held to strict account for these programs. NWSIA urges that the Congress take up soon the consideration of reorganization of the Federal Agencies in order to insure that adequate timely attention be given to the resources crises that impends, and that water resources research demonstration and development programs for all purposes and particularly for improved water supplies be developed, funded and activated. NWSIA petitions the Federal Government to provide the technological support needed by water agencies in the U.S. in meeting their requirements...
>
> WHEREAS, the policy statement of the California Association of Reclamation Entities of Water (WATERCARE) regarding water quality criteria having been presented for review of general NWSIA membership; and

WHEREAS, NWSIA emphasizes the need to protect all communities through the development and application of adequate water quality standards to water supplies; and

WHEREAS, NWSIA declares that there are no pristine waters, since stable organics and trace elements that may have an adverse effect on human life are found in rainwaters, lakes, streams, rivers and groundwaters; and

WHEREAS, NWSIA finds that community wastewaters make their way into most of the water supplies of the world, thus requiring water quality standards that adequately consider this contribution.

BE IT HEREBY RESOLVED, that the NWSIA believes in and encourages the adoption of water quality standards that protect the public health, and endorses the Concept of Uniform Standards applicable to water supplies according to use <u>regardless</u> of the source of the water.

RESOLVED FURTHER, that in preparing legislation for reorganization of water resources research in 1977, the Congress carefully consider the critical needs for inclusion of desalination and wastewater reclamation in research programs; and, further, the need to place construction and operation functions related to nationwide programs in an action and program oriented Federal Agency, such as the Bureau of Reclamation if its scope be broadened.

The resolutions were placed before Congress to offer, according to NWSIA, "needed guidance as to which agencies will administer research programs, what new directions those programs will take, and whether demonstration projects will be funded."

****

3. As indicated in a memorandum presented at the WPCF Philadelphia Convention on October 3, 1977 by Douglas Costle, EPA Administrator, there has been a major shift in that Agency's policy on water reuse. In pursuit of the national goals of conserving water and eliminating the discharge of pollutants to navigable waters by 1985, as articulated in PL92-500 (the Federal Water Pollution Control Act Amendments of 1972)..."the Agency (EPA) will press vigorously for publicly owned treatment works to utilize <u>land treatment</u> processes to reclaim and recycle municipal wastewater."

The following excerpts from the memorandum convey the scope, justification and impact of the new position:

At the time P.L. 92-500 was enacted, it was the intent of Congress to encourage to the extent possible the development of wastewater management policies that are consistent with the fundamental ecological principle that all materials should be returned to the cycles from which they were generated. Particular attention should be given to wastewater treatment processes which renovate and reuse wastewater as well as recycle the organic matter and nutrients in a beneficial manner.

...Land treatment systems involve the use of plants and the soil to remove previously unwanted contaminants from wastewaters. Land treatment is capable of achieving removal levels comparable to the best available advanced wastewater treatment technologies while achieving additional benefits. The recovery and beneficial reuse of wastewater and its nutrient resources through crop production, as well as wastewater treatment and reclamation, allow land treatment systems to accomplish far more than most conventional treatment and discharge alternatives.

The application of wastewater on land is a practice that has been used for many decades; however, recycling and reclaiming wastewater that may involve the planned recovery of nutrient resources as part of a designed wastewater treatment facility is a relatively new technique. One of the first such projects was the large scale Muskegon, Michigan, land treatment demonstration project funded under the Federal Water Pollution Control Act Amendments of 1966 (P.L.84-660), which began operations in May 1974.

...Because land treatment processes contribute to the reclamation and recycling requirements of P.L. 92-500, they should be preferentially considered as an alternative wastewater management technology. Such consideration is particularly critical for smaller communities. While it is recognized that acceptance is not universal, the utilization of land treatment systems has the potential for saving billions of dollars. This will benefit not only the nationwide water pollution control program, but will also provide an additional mechanism for the recovery and recycling of wastewater as a resource.

EPA currently requires each applicant for construction grant funds to make a conscientious analysis of wastewater management alternatives with the burden upon the applicant to examine all available alternative technologies. Therefore, if a method that encourages water conservation, wastewater reclamation and reuse is not recommended, the applicant should be required to provide complete justification for the rejection of land treatment.

Imposition of stringent wastewater treatment requirements prior to land application has quite often nullified the cost-effectiveness of land treatment processes in the past. EPA must ensure that appropriate Federal, State and local requirements and regulations are imposed at the proper point in the treatment system and are not used in a manner that may arbitrarily block land treatment projects. Whenever States insist upon placing unnecessarily stringent preapplication treatment requirements upon land treatment, such as requiring EPA secondary effluent quality in all cases prior to application on the land, the unnecessary wastewater treatment facilities will not be funded by EPA.

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PUBLISHED LITERATURE

1. The references listed in this section are drawn from many sources, but unified by their reuse-related subject matter. For easier access, the material is organized as follows:

I. TECHNICAL REPORTS

With the exception of one, as noted, all of the references in the Technical Reports section may be obtained from the National Technical Information Service (NTIS), U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia, U.S.A. 22161.

A. Processes

1. "Ammonia Removal from Wastewater: A Review of the State of the Art"- John H. Whiting, A. Paul Adams & Milton Roth, Picatinny Arsenal, Dover, N.J. Jan 1976.
   AD A020 698/7PSP P.C. $4.50

2. "Water Treatment by Reverse Osmosis and Membrane Processes"-Bibliography, August 1976, 150 pages.
   NTIS/PS-76/0652/8WP $25.00

3. "UV-Ozone Water Oxidation/Sterilization Processes" December 1975, 102 pages
   AD-A026 571/0WP $5.50

4. "Waste Treatment by Reverse Osmosis and Membrane Processes. Part 1. Sewage", August 1976, 69 pages. Citations from the Engineering Index Data Base. Contains 62 abstracts from worldwide research efforts, plus studies on design and performance.
   NTIS/PS-76/0653/6WP $25.00

5. "Ozonation Used in Water & Sewage Treatment" from NTIS Data Bank, August 1976, 52 pages.
   NTIS/PS-76/0655/1WP $25.00

   This published search contains a bibliography of federally funded research in the use of ozone to treat industrial wastes, sewage and drinking water. 48 abstracts.

6. "Ozonation Used in Water & Sewage Treatment" from Engineering Index Data Base, August 1976, 152 pages.
NTIS/PS-76/0656/9WP $25.00

Contains 145 abstracts on worldwide research reports covering design, operation and costs.

7. "Nitrogen Removal in Sewage Treatment Systems" (A bibliography with abstracts), September 1976, 146 pages.
NHS/PS-76/0692 4 WP $25.00

All aspects of nitrogen removal in sewage treatment systems from federally funded reports is covered including breakpoint chlorination, bio-denitrification, ammonia stripping, design aspects and microbiology.

8. "Evaluation of Membrane Separation Processes, Carbon Adsorption, and Ozonation for Treatment of MUST Hospital Wastes", Abcor, Incorporated, August 1976, 456 pages.
AD - A030 057/4WP $12.00

Treatment sequence evaluations, quality specifications and operating criteria.

9. "Wastewater Treatment Using Flocculation, Coagulation and Flotation (A Bibliography with Abstracts)", October 1976, 212 pages.
NTIS/PS-761 0790/6WP $25.00

207 abstracts on processes and performance of federally funded research in the field.

10. "Sewage Filtration", November 1976,
Volume 1, 170 pages, NTIS/PS-76/0890/4WP $25.00
Volume 2, 58 pages, NTIS/PS-76/0891/2WP $25.00

A 2-Volume published search from the Engineering Index Base covering the periods of 1973-1975 and January-August, 1976 respectively. 214 abstracts from the worldwide literature are available.

11. "Evaluation of new R.O. Membranes for the Separation of Toxic Compounds from Wastewater", Edward Chian, Illinois University, June 1976, 323 pages.
AD-A030 884/1WP $9.75

Results of a 3-year study on membranes and wastewater with reliability and computer programming data.

12. "Packed-Bed Reactors for Nitrification and Denitrification of Secondary Effluents", James C. Young, Iowa State Water Resources Research Institute, June 1976, 151 pages.
PB-259 607/OWP $6.75

Upflow pack-bed reactors (PBR) in laboratory and pilot scale experiments were used as a tertiary process for BOD, SS and nutrient removal research.

Granular medias were examined with a treatment sequence selected which was comparable in results to PCT systems employing carbon.

13. "A Feasibility/Development Study for the Removal of Ammonia from Wastewater using Biologically Regenerated Clinoptilolite", Michael J. Semmens, Illinois University Water Resources Center, August 1976, 153 pages.
PB-260 512/9WP $6.75

Results of a study to reduce costs of resin regeneration using nitrifying bacteria.

14. "Naval Stores Wastewater Purification and Reuse by Activated Carbon Treatment", Hercules, Inc., October 1976, 45 pages.
PB 261-168/9WP $4.00

Report describes PCT process removing 80% of the COD and 85% of the TOC at 31.4¢/1000 gallons from Naval Stores Manufacturing plant with subsequent reuse.

15. "Disinfection Efficiency and Residual Toxicity of Several Wastewater Disinfectants", PB-262 245/AS $4.00

16. "Wastewater Treatment Using Flocculation, Coagulation and Flotation", published literature search from NTIS data base, February, 1977, 227 pages, 222 abstracts.
NTIS/PS-77/0056/0WP $25.00

17. "Wastewater Treatment Using Flocculation, Coagulation and Flotation", published literature search from American Petroleum Institute Data Base, February 1977, 115 pages, 104 abstracts.
NTIS/PS-77/0057/8WP $25.00

18. "Conventional Tertiary Treatment", Blue Plains Pilot Plant, November, 1976, 43 pages.
PB-262 522/6WP $4.00

19. "Backwash of Granular Filters Used in Wastewater Filtration", Cleasby and Baumann, Iowa State University, April 1977, 384 pages.
PB 266 693/1WP $10.75

A study of alternatives to water backwashing of deep granular wastewater filters. The most effective backwash was provided by air scour and water simultaneously at subfluidization velocities. The other methods, surface, subsurface wash auxilliary and prior air scour were evaluated in coarse sand, dual and tri-media filters with design data presented.

20. "Physical-Chemical Treatment of a Municipal Wastewater Using Powdered Carbon. No 11", Envirotech, November 1976, 349 pages.
PB 263 134/9WP $10.00

Results of a 100 gpm pilot plant with 90% carbon recovery.

21. "The Removal of Organic Matter from Water Supplies by Ion Exchange", Minnesota University, February 1977, 59 pages.
PB-266 022/3WP $4.50

A study on the use of anion exchange resins for organic removal. Test organics were removed to the lower limit of TOC analysis with high basic resins which were easily regenerated by Na Cl. Selectivity and kinetics was briefly investigated.

22. "UV-Ozone Water Oxidation/Sterilization Process", Westgate Research Corporation, November 1976, 214 pages.
AD-A038 609/4WP $7.75

A report describing the 2nd and 3rd year efforts in developing a UV-ozone system for the Army MUST project and NASA manned spacecraft. Mathematical models were derived.

23. "Processing of Raw Sewage by Ultra-Filtration", David W. Taylor Naval Ship Research & Development Center, Annapolis, Maryland, April 1977, 18 pages.
AD-A041 607/3WP $3.50

Evaluation of microfiltration and ultrafiltration systems for naval wastewater discharges including pretreatment and maintenance requirements.

24. "Wastewater Disinfection: A State-of-the-Art Summary" by Dr. C.M. Sawyer is a five-section report dealing with the advantages and disadvantages of chlorination and alternative methods. It is available as Bulletin #89 at no cost from Water Resources Research Center, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24601 U.S.A.

B. Testing, Monitoring and Chemical Contaminants

1. "Development of Techniques for Detection of Low Molecular Weight Contaminants in Product Water from Waste Purification on Water Reuse Systems", Amicon Corporation, August 1976, 87 pages.
AD-A038 148/3WP $5.00

Evaluation of a lab-scale permanganate colorimeter instrument to monitor organics from the Army's MUST system. The hardware is judged low-cost, rugged, simple and reliable.

2. "The Development of a Test for the Potability of Water Treated by a Direct Reuse System", Cincinnati University.
AD-A025 143/9WP $7.50

3. "Development of an On-Line Biological Detector", Gulf South Research Institute, July 1976, 58 pages.
AD-A034 493/7WP $4.50

4. "Instrumentation and Automation Experiences in Wastewater Treatment Facilities", Raytheon Corporation, October 1976, 378 pages.
PB-262 232/2WP $10.75

Nationwide survey of plant automation and instrumentation-successes and needs.

5. "Research Needs for Automation of Wastewater Treatment Systems. Proceedings of a Workshop held at Clemson, South Carolina in 1974", Clemson University, January 1977, 134 pages.
PB-262 816/2WP $6.00

Research needs plus the effect of automation on design of wastewater recycle systems.

6. "Selected Applications of Instrumentation and Automation in Wastewater-Treatment Facilities", Raytheon Company, December 1976, 315 pages.
PB-263 777/5WP $9.75

Control strategies for operation of wastewater plants including automation, direct digital and computerized control.

7. "Technology Transfer Potential of an Automated Water Monitoring System", Battelle Columbus Labs, May 1976, 89 pages.
N 77 - 25006/6WP $5.00

The nature and characteristics of the potential economic need (markets) for a highly integrated water quality monitoring system.

8. "Analysis of Organic Compounds in Water to Support Health Effect Studies", The World Health Organization International Reference Centre for Community Water Supply, Technical Paper Series #9, December 1976, 90 pages.

May be obtained from the W.H.O. - I.R.C., P.O. Box 140, Leidschendam, the Netherlands.

Organic identification and characterization are stressed by the project's consultant, and author Dr. A.W. Garrison of the U.S. EPA.

C. Virus and Bacteria

1. "Virus Elimination in Water and Wastewater"
AD A021 773/7WP $4.00

The report emphasizes treatment technology for disinfection, particularly virus removal, economics and new processes.

2. "Disinfection of Wastewater: Task Force Report", EPA, March 1976,67 pages.
PB-257 449/9WP $4.50

Several issues concerning wastewater disinfection and alternatives.

3. "New Microbial Indicators of Disinfection Efficiency", Illinois University, July 1975, 88 pages.
AD A030 547/4WP $5.00

Examines the use of yeast organisms as a more reliable indicator of disinfection for viral pathogen work.

4. "Development of a Chemiluminescent and Bioluminescent System for the Detection of Bacteria in Wastewater Effluent", R.R. Thomas, Boeing Company, Houston, Texas, 1975, 50 pages.
   N76-23824/5WP P.C. $4.00

D. Reuse and System Management

1. "Fresh Water from Sewage on Long Island", Brookhaven National Laboratory, April 1976, 17 pages.
   BNL - 21371 $3.50

   Describes small sewage treatment systems for recycling wastewater into potable groundwater aquifers.

2. "Recreational Reuse of Municipal Wastewater Phase II", Texas Tech University, Lubbock Water Resources Center, April 1976, 93 pages.
   PB 261-256/2WP $5.00

   Modeling of recreational reuse potential in Lubbock, Texas water quality analyses and health aspects.

3. "Renovated Wastewater as a Supplementary Source for Municipal Water Supply: An Economic Evaluation", EPA, October 1976, 133 pages.
   PB-262 203/3WP $6.00

   Cost analysis of two wastewater renovation and reuse projects.

4. "Select Minerals and Potable Reuse of Reclaimed Wastewaters", Harold Wolf, Texas A & M, March 1977, 86 pages.
   PB-265 203/0WP $5.00

   Analysis of relationship of drinking water mineral content and heart-circulatory deaths.

5. "Cost-Effectiveness Analysis of Municipal Wastewater Reuse", SCS Engineers.
   PB 252 932/9WP $8.00

6. "MIUS Wastewater Technology Evaluation", NASA, May 1976, 127 pages.
   N76 - 30120/9WP $6.00

   Capital, operating and maintenance costs are provided for the wastewater treatment part of MIUS.

7. "Estimating the Reliability of AWT", EPA, June 1976, 9 pages.
   PB-265 254/3WP $3.50

   Complete analysis of Tahoe data.

8. "Developments at International Conference on Water Pollution Research (8th) held in Sydney, Australia, October 17-22, 1976", Delaware University, June 1977, 229 pages.
   PB-268 365/4WP $8.00

   Critical analysis of Conference with several reuse papers.

E. Economic Factors

1. "Feasibility Study of a Nuclear Power-Sewage Treatment System for the Conservation and Reclamation of Water Resources", 1976.
   PB-255 630/6WP $3.50

2. "An Analysis of the Market Potential of Water Hyacinth-Based Systems for Municipal Wastewater Treatment", Battelle Columbus Labs, January 1976, 250 pages.
   N76 - 28679/8WP $8.00

   Baseline design and market study of tertiary sewage treatment.

3. "Energy Costs of Wastewater Reuse", Arizona University, September 1976, 14 pages.
   PB-257 518/1WP $3.50

   Regression techniques to relate cost and energy for application to Arizona reuse projects.

4. "Municipal Wastewater Recycling: A Strategy for Meeting the Zero Discharge Goal of PL 92-500", University of California-Davis, February 1976, 139 pages.
   PB-261 912/0WP $6.00

   Justification and need for water reuse paper.

5. "An Economic Appraisal of Reuse Concepts in Regional Water Supply Planning", Utah State Research Lab, April 1976, 62 pages.
   PB-268 093/2WP $4.50

   A mathematical programming model is applied to reuse potential for optimum allocations.

II. BOOKS

A. The book, Advanced Wastewater Treatment, by Culp and Culp is still available for $16.95 from Van Nostrand Reinhold Co., 450 West 33rd Street, New York, New York 10001. The 310-page volume describes several tertiary sewage treatment processes used in the reclamation and reuse of effluents. Costs and reliability factors are included.

B. Introduction to Wastewater Treatment Processes, R.S. Ramalho, 409 pages, Academic Press, Inc., 111 Fifth Avenue, New York, New York 10003, 1977, $22.50. Tertiary Treatment.

C. A new book, Handbook of Water Resources and Pollution Control, as edited by Harry W. Gehm and Jacob I. Bregman contains several chapters on the subject of water quality, AWT, water reclamation and reuse and solids handling. It is available for a 10-day free examination or $39.50 from Van Nostrand Reinhold Company, 300 Pike Street, Cincinnati, Ohio 45202.

III. CONFERENCE PROCEEDINGS

A. The proceedings from a three-day workshop in Boulder, Colorado in March of 1975 are still available. The report entitled "Research Needs for the Potable Reuse of Municipal Wastewater" describes the research priority needs in health effects work, treatment reliability and technology, and the socio-economic area. Report number PB-249 138/9WP can be purchased for $7.75 from the National Technical Information Service (NTIS), U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia, 22161.

B. The 192-page proceedings of the 7th International Water Quality Symposium (1975) held in Washington, D.C. is available for $10.00 from the Water Quality Research Council, 477 East Butterfield Road, Lombard, Illinois 60148. The report contains several papers on the health effects of water contaminants, environmental concerns and water reuse.

C. At the 1975 AWWA Minneapolis Conference, a seminar on water reuse was conducted. The proceedings, 75-20109, are available from the American Water Works Association, Publications Order Department, 6666 West Quincy Avenue, Denver, Colorado 80235. Members: $2.00 Non-members:$4.00.

D. Proceedings from the 3rd National Conference on Complete WateReuse, held June 27-30, 1976 in Cincinnati are now available for purchase from the American Institute of Chemical Engineers, 345 East 47th Street, New York, New York 10017. The 628-page booklet includes a variety of topics from in-plant industrial recycling, AWT research and potable reuse. This volume, P-13 and the Proceedings of the Second Conference, May 1975 in Chicago, P-14 are priced at $55.00 each. They may be obtained as a set for $90.00. The proceedings of the First Conference are out of print.

E. Proceedings of the June, 1976 WATERCARE Conference in Malibu, California (reuse) are available in limited numbers for $5.00 from the present WATERCARE office at 5750 Almaden Expressway, San Jose, California 95118.

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R E G U L A T I O N S

1. Under the Porter-Cologne Water Quality Control Act, the California State Department of Health was charged to establish "reclamation criteria for each varying type of use of reclaimed water where such use involves the protection of public

health". Having previously established criteria for irrigation and recreational reuse, the Department of Health, in June 1976, issued the first draft of proposed criteria for groundwater recharge with reclaimed water. The stated intent of the regulations was to control organics being introduced into groundwater aquifers used as potable supply. The regulations would apply to new demonstration projects, which until additional information on the quality and health effects was obtained, would be the only projects allowed involving groundwater recharge through spreading with reclaimed wastewater. A summary of the extensive scope of the proposed regulations appears in Table 1. Informal public meetings were held during June with some broad-based comments as follows:

--Water Districts felt that the standards were unnecessary, demanding and unattainable.

--The protection of the public health is imperative, but regulations which most drinking water supplies cannot meet were termed unrealistic.

--If the regulations are enforced, they should be applied to all waters for domestic use, including surface supplies.

--There should be a single standard for suitability of domestic water, regardless of the source.

--The standard should be applied to the groundwater at point of extraction, not to influent. Treatment processes are designed to produce an acceptable effluent quality.

--Water used for groundwater recharge need not have potable water quality assigned to it. Regulations should recognize moderating effects of underground detention.

--The regulations should apply to groundwater recharge in general and not only to demonstration projects.

--The water conservation values of reuse need to be recognized.

In November, 1976 the Department of Health issued a second draft of the proposed regulations. Significant changes were made: the requirement of R.O. treatment was dropped, the total nitrogen requirement was deleted, the COD limit was changed to less than 5.0 mg/l, the sampling programs were relaxed and the requirement of biomonitoring for toxic compounds and source pollution control were deleted. While retaining the required activated carbon treatment (30 minute detention time), the definition of adequate treatment was expanded to include percolation through an unsaturated zone of undisturbed soil for 10 feet, and the amount of recharge by reclaimed wastewater was limited to 20% of the total water entering a groundwater basin.

A third draft of the proposed regulation was issued in January, 1977. A limit on TOC was established at less than 3.0 mg/l with daily sampling requirements and increases in organics sampling frequency. The source pollution control program was reinstated and a hydrogeologic study was required prior to beginning a demonstration project. In response to comments from water reclamation entities,

SUMMARY OF CALIFORNIA REGULATION ON WASTEWATER RECLAMATION THROUGH GROUNDWATER RECHARGE

TABLE 1

JUNE 1976 VERSION

Required Treatment:

Secondary Treatment
Activated Carbon
Reverse Osmosis

Physical & Chemical Quality Parameters:

Total N less than 10 mg/l
COD median less than 2.0 mg/l per 7 days
less than 5.0 mg/l per 1 sample

Required Monitoring & Quality Requirements:

Daily
COD

Semi-Monthly
Total N
Organics:

benzene	3,4-benzophyrene
carbon tetrachloride	indeno(1,2,3-cd) pyrene
p-dichlorobenzene	chloroform
vinyl chloride	bromodichloromethane
1,2,4-trichlorobenzene	bromoform
bis-(2-chloroethyl) ether	1,2-dichloroethane
11,12-benzofluoranthene	polycholorinated biphenyls
1,1,2-trichloroethylene	pentachlorophenol
2,4-dichlorophenol	3,4-benzofluoranthene
fluoranthene	1,12-benzoperylene

Monthly

Inorganic Chemicals Constituent	Limiting Concentration, mg/l
Arsenic	0.10
Barium	1.0
Cadmium	0.01
Chromium	0.05
Cyanide	0.2
Lead	0.05
Mercury	0.005
Nitrate-N + Nitrite-N	10.
Selenium	0.01

Organic Chemicals Constituent	Limiting Concentration, mg/l
Carbon-alcohol extract(CAE-m)	3.0
Carbon-chloroform extract(CCE-m)	0.7
Foaming agent(MBAS)	0.5
Pesticides:	
Aldrin	0.017
Chlordane	0.003
DDT	0.042
Dieldrin	0.017
Endrin	0.001
Heptachlor	0.018
Heptachlor epoxide	0.018
Lindane	0.056
Methoxychlor	1.0
Organophosphorous & Carbamate compounds	0.1*
Toxaphene	0.005
Herbicides:	
2,4-D plus	
2,4,5-T plus	
2,4,5-TP	0.1

*As parathion in cholinesterase inhibition

Fluoride Concentration

Annual Average of Maximum Daily Air Temperature	Fluoride Concentration, mg/l Lower	Optimum	Upper
50 - 54	0.9	1.2	1.7
55 - 58	0.8	1.1	1.5
59 - 64	0.8	1.0	1.3
65 - 71	0.7	0.9	1.2
72 - 79	0.7	0.8	1.0
80 - 81	0.6	0.7	0.8

Radioactivity

Gross Beta	1000 pc/l
Radium-226	3 pc/l
Strontium-90	10 pc/l

Semi-Annually

Constituents	mg/l
Color-Units	15.0
Copper	1.0
Iron	0.3
Manganese	0.05
Odor-Threshold	3.0
Zinc	5.0

Constituents	mg/l
Total Dissolved Solids	1000
or	
Specific Conductance	1600 micromhos
Chloride	500
Sulfate	500

Additional Required Studies & Reports:

Continuous Biomonitoring for Toxic Substances
Health Monitoring
Groundwater Monitoring
Hydrogeologic Study
Spreading Area Practices
Source Pollution Control

TABLE 2

SEPTEMBER 1977 VERSION

Required Treatment:

Secondary Treatment
Activated Carbon

Physical & Chemical Quality Parameters:

COD median less than 5.0 mg/l per 1 sample
TOC less than 3.0 mg/l

Required Monitoring & Quality Requirements:

Daily
COD
TOC

Quarterly
Organic Chemical Monitoring

benzene	3,4-benzophyrene
carbon tetrachloride	indeno(1,2,3-cd) pyrene
p-dichlorobenzene	chloroform
vinyl chloride	bromodichloromethane
1,2,4-trichlorobenzene	bromoform
bis-(2-chloroethyl) ether	1,2-dichloroethane
11,12-benzofluoranthene	polycholorinated biphenyls
1,1,2-trichloroethylene	pentachlorophenol
2,4-dichlorophenol	3,4-benzofluoranthene
fluoranthene	1,12-benzoperylene

Inorganic Chemicals Constituent	Limiting Concentration, mg/l
Arsenic	0.05
Barium	1.0
Cadmium	0.010
Chromium	0.05
Lead	0.05
Mercury	0.002
Nitrate (as NO_3)	45.
Selenium	0.01

Organic Chemicals Constituent	Limiting Concentration, mg/l
Endrin	0.0002
Lindane	0.004
Methoxychlor	0.1
Toxaphene	0.005
2,4-D	0.1
2,4,5-TP Silvex	0.01

Fluoride

Annual Average of Maximum Daily Air Temperature (Degrees) Fahrenheit	Celsius	Limiting Concentration, mg/l
53.7 and below	12.0 and below	2.4
53.8 to 58.3	12.1 to 14.6	2.2
58.4 to 63.8	14.7 to 17.6	2.0
63.9 to 70.6	17.7 to 21.4	1.8
70.7 to 79.2	21.5 to 26.2	1.6
79.3 to 90.5	26.3 to 32.5	1.4

Additional Required Studies & Reports:

Health Monitoring
Groundwater Monitoring
Hydrogeologic Study
Spreading Area Practices
Source Pollution Control

the quality requirements for reclaimed wastewater for recharge and that of the groundwater at the point of extraction were separated. Also, the amount of recharge water permitted in a groundwater basin was increased to 50%.

The latest version of the proposed groundwater recharge regulations, as issued in September, 1977 are summarized in Table 2 (previous page). Minor changes appeared, primarily redefining the Department of Health's position. Health monitoring, if required, will be performed by the recharger, and the required hydrogeologic study must be reviewed and approved by the Department of Health, prior to beginning a project. The percentage of reclaimed water entering a groundwater basin may be greater than 50% if it can be shown that the concentration of reclaimed wastewater at the abstraction well is less than 50%.

The present regulations were to undergo a formal hearing by Health Department and state personnel, then be submitted to the Attorney General's office for enforcement proceedings. But in November, 1977, a proposal was submitted to review reuse projects entirely on a case-by-case basis and eliminate the proposed regulations. That proposition was received favorably and is expected to be adopted as the course of action in California.

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WATER REUSE PLANS & DEMONSTRATIONS

A tertiary wastewater treatment process involving flocculation with alum, sedimentation, filtration and disinfection has been successfully put into operation to serve the Apollo Park recreational lakes near Lancaster, California. In a recent EPA report on the project, the 0.5 mgd plant successfully demonstrated wastewater reuse for recreational purposes meeting all water quality requirements and being comparable in cost to other water sources.

The County Park itself was constructed because of the reclaimed water resource available in an arid area. The lakes proved to be an excellent fish environment, well-suited for growth and reproduction. However, due to an unforeseen natural soil condition, a mercury contamination problem resulted with the levels in the fish exceeding maximum allowable levels for human consumption but no adverse health effect on the fish were noted.

Public acceptance of the park has been well established with over 90,000 visitor-days in the second year of operation. The overall treatment sequence is shown in Figure 1 with the tertiary schematic in Figure 2. Figure 3 indicates the recreational lake development following the space program theme. As shown in Table 1, the quality of the effluent in the lake deteriorates because of soil conditions. Algae has been a problem in the oxidation ponds prior to the chemical nutrient removal process.

FIGURE 1

DIAGRAMATIC LAYOUT OF TREATMENT FACILITIES AND PROCESSES

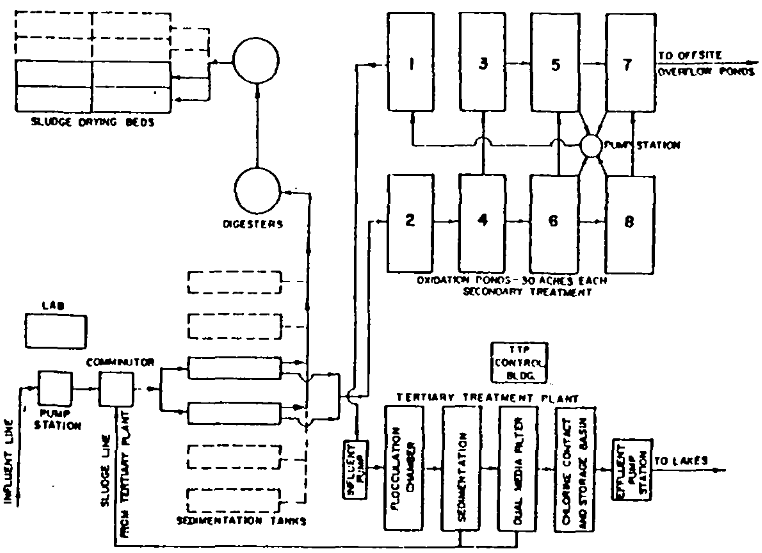


FIGURE 2

TERTIARY TREATMENT PROCESS FLOW DIAGRAM

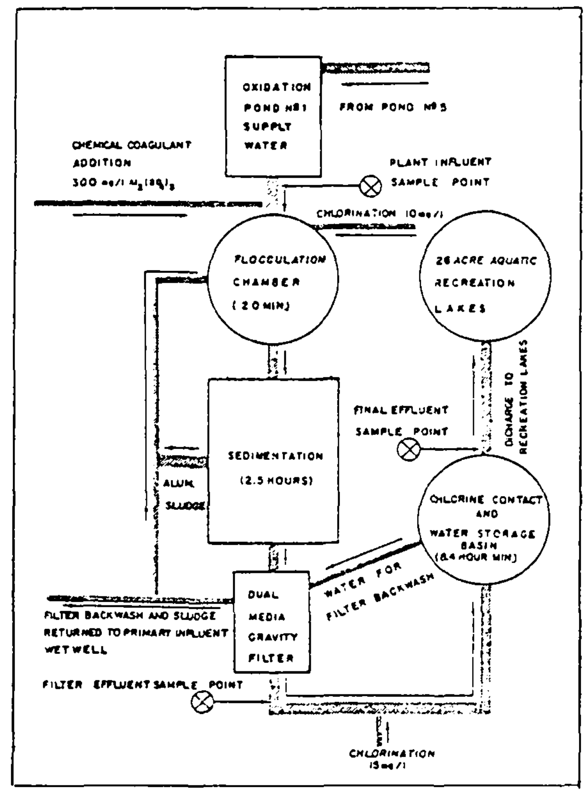


FIGURE 3

DEVELOPMENT PLAN APOLLO COUNTY PARK

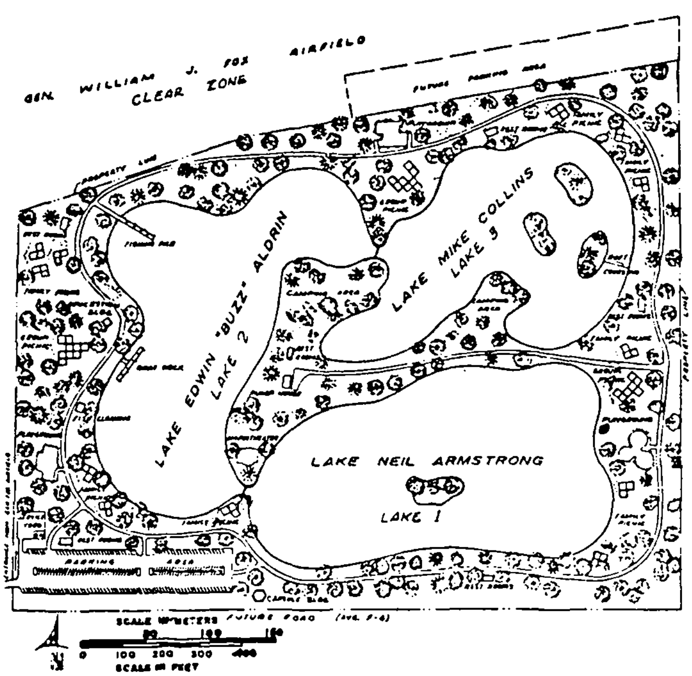


TABLE 1

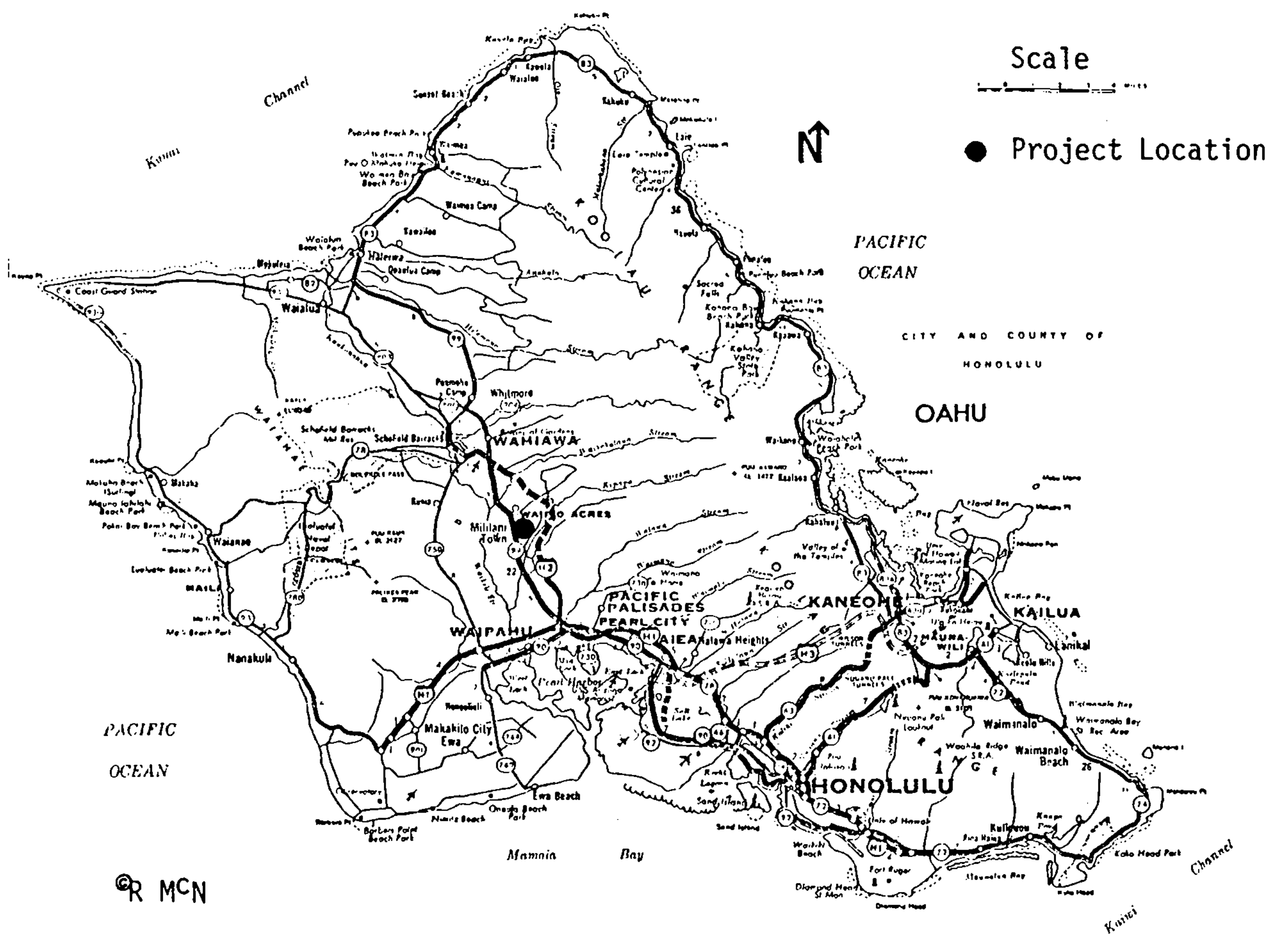
LANCASTER AVERAGE WATER QUALITY CHARACTERISTICS

CONSTITUENT	UNITS	TERTIARY INFLUENT	TERTIARY EFFLUENT	APOLLO LAKES
Temperature	^oF	55	57	56
Turbidity	JTU	45	1.8	14
pH	pH	9.4	6.5	8.3
TDS	mg/l	636	638	910
Susp. Solids	mg/l	100	1.9	22
Alkalinity	mg/l $CaCO_3$	245	83	153
Boron	mg/l	.99	.90	1.3
CO_2	mg/l	0	54	2
Hardness	mg/l $CaCO_3$	63	62	118
MBAS	mg/l	0.11	0.1	0.12
NH_3-N	mg/l	.29	0.22	.63
Org-N	mg/l	11.8	2.1	1.7
NO_3-N	mg/l	0.51	0.53	2.1
BOD	mg/l	32	1.9	1.8
COD	mg/l	182	36	44
DO	mg/l	10	9.2	8.9
Total PO_4	mg/l	30.4	0.23	0.45
Potassium	mg/l	17	16.5	19.5
Sodium	mg/l	183	176	210

2. The Water Resources Research Center at the University of Hawaii has, for the last five years, been investigating the agricultural reuse potential of secondary sewage effluents. A small 0.85 mgd treatment plant near the Mililani Town Development provides the effluent for the Central Oahu Project site, Figure 4.

FIGURE 4

CENTRAL OAHU PROJECT SITE



Specific project objectives were to: (1) Evaluate, by field lysimeters and pilot plots and augment by laboratory studies, the feasibility of utilizing reclaimed effluent for irrigation under Hawaiian conditions; (2) assess the probable effects of surface-applied wastewater on groundwater quality, particularly in terms of potential viral transmission and long-term buildup of solids; (3) evaluate the effects of various water quality parameters on the soil, percolation and vegetative growth especially grassland and sugarcane; (4) explore any problem in sugarcane culture, either in technology or in crop quality.

Typical effluent quality prior to irrigation is shown in Table 2. There was no apparent evidence of significant surface clogging of the soil or of soil chemical properties impairment resulting from sewage irrigation during the first full two-year sugarcane crop cycle. Under a no-moisture stress condition, a 1 mgd

TABLE 2

WEIGHTED COMPOSITE MILALANI STP ANALYSES

CONSTITUENT*	RAW SEWAGE (26 AUGUST 1974†)	CHLORINATED EFFLUENT (26 AUGUST 1974†)	CONSTITUENT REDUCTION (%) (26 AUGUST 1974†)
pH RANGE	6.7-8.1	6.4-7.0	--
CONDUCTIVITY RANGE (μmhos/cm)	460-700	440-540	--
DISSOLVED OXYGEN RANGE	0	2.7-3.4	--
OXYGEN-REDUCTION POTENTIAL RANGE (mv)	(-230)-(+75)	150-285	--
SUSPENDED SOLIDS	159	6	96
TOTAL DISSOLVED SOLIDS	411	333	19
TOTAL VOLATILE SOLIDS	252	65	74
VOLATILE SUSPENDED SOLIDS	135	3	98
BOD_5	241	12	95
CHLORIDE	48	55	-15
SULFATE	76	33	57
MBAS RANGE	1.5-19.0	0.3-0.9	--
TOTAL KJELDAHL NITROGEN	36.4	13.9	62
NO_2 + NO_3 NITROGEN	0.02	3.62	18000
TOTAL NITROGEN	36.42	17.52	52
ORTHOPHOSPHATE PHOSPHORUS	15.9	13.5	15
SODIUM	50	55	-10
POTASSIUM	10.0	9.2	8
CALCIUM	10	11	-10
MAGNESIUM	6.6	7.9	-20
ALKALINITY ($CaCO_3$)	52	60	-15
SILICA (SiO_2)	84	81	3.6
RESIDUAL CHLORINE RANGE	--	0.7-3.0	--
TOTAL COLIFORM RANGE (/100 mℓ)	1.3×10^7- 1.3×10^9	52-650	--
FECAL COLIFORM RANGE (/100 mℓ)	2.4×10^6- 1.0×10^8	0-260	--
FECAL STREPTOCOCCUS RANGE (/100 mℓ)	3.0×10^5- 4.0×10^8	0-62	--

*All units in mg/ℓ unless noted otherwise.
†16-hr composite samples.

HEAVY METAL	SAMPLING DATE: 22-23 OCT 1971[1] raw	22-23 OCT 1971[1] effl.	2 OCT 1973[2] raw	2 OCT 1973[2] effl.	13 JAN 1975[2] raw	13 JAN 1975[2] effl.
	mg/ℓ					
CADMIUM	0.004	0.005	ND	ND	ND	ND
LEAD	0.028	0.047	0.003	ND	--	--
MERCURY	ND[3]	ND[3]	ND[3]	ND[3]	ND	ND
COPPER	--	--	0.021	0.010	ND	0.00024
ZINC	--	--	0.025	0.027	ND	0.0037
NICKEL	--	--	0.015	0.015	ND	0.0065
IRON	--	--	0.432	0.164	--	--
ALUMINUM	--	--	0.592	0.532	--	--
CHROMIUM	--	--	--	--	ND	ND

NOTE: ND = nondetectable.
[1] 24-hr composite sample.
[2] 16-hr composite sample.
[3] Nondetectable below 0.003 mg/ℓ.

supply is sufficient to irrigate 150-200 acres of sugarcane by the furrow method.

Application of the effluent for the first year of the two-year cycle increased the sugar yield by about 6% as compared with control plots. However, when applied for the entire two-year cycle, sugar yield was reduced by about 6% and cane quality by 16% even though the total cane yield increased by 11%. This was due to the sensitivity of sugarcane to nitrogen loadings.

The quality of the percolate recovered from field lysimeters was of acceptable quality. Phosphorus, potassium, suspended solids, BOD, TOC and boron were effectively removed. Both chlorides and TDS remained unaffected but were still below drinking water standards.

Human enteric viruses were present even in the chlorinated effluent. But the absence of these in all sugarcane and grass percolates suggest strongly that the possibility of contaminating deep underground water sources is <u>extremely remote</u>. Survival of poliovirus was minimal in an open field area which was exposed to direct sunlight, high temperature and dessication. In contrast, the viability of the virus was maintained for up to two months in a field of mature sugarcane where the virus was protected from environmental elements.

Thus, the possible health hazard posed by viruses in the fields cannot be ignored. Fortunately, they are not transmitted by physical contact but must be ingested before infection can occur. Thus, the following precautionary measures were developed for field workers to minimize the risk of contact:

a. Posted warning signs

b. Thoroughly washing hands and outer garments

More research is taking place in the use of ozone or bromine for beter disinfection prior to irrigation.

****

3. The Flushing Meadows Project in the Salt River Bed west of Phoenix, Arizona was installed in 1967 to study renovation of secondary sewage by groundwater recharge with rapid infiltration basins. Several years of testing and research into quality aspects has resulted in a very successful U.S. Department of Agriculture (USDA) program under the direction of Dr. Herman Bouwer.

Current emphasis is on maximizing nitrogen removal by denitrification in the soil. With a loading rate of 200 ft. per year and careful management of the flooding and drying periods, 50% nitrogen removal has been achieved. In 1974, virus were detected in the effluent but not in test wells 20-30 feet below the infiltration basins. Human viral pathogens do not appear to move through the soil into the groundwater but are apparently absorbed and degraded.

The USDA is expanding its research to include the new Phoenix 23rd Avenue project where infiltrated effluent is recovered for unrestricted irrigation use. However, careful management of the system is required to protect the potable aquifer from the renovated sewage.

A third aspect of the western region water conservation lab is the use of renovated water for recreational lakes under the Rio Salado Project. That is a master plan to convert a 40-mile stretch of the normally dry Salt River bed in the Phoenix area into a greenbelt with recreational, commercial and wildlife benefits.

Additional data from the research is as follows:

1. While wastewater is greatly improved in quality as it percolates through soil, the quality of the resulting renovated water may not be as good as that of the local native groundwater, whose quality is thus degraded.

2. To take advantage of the beneficial aspects of land application without trading a surface water pollution problem for a groundwater contamination situation, the spread of wastewater in the aquifer must be restricted.

3. This can be accomplished by removing the reclaimed water from the aquifer at some point away from the application area. The land between them provides additional treatment.

4. Such zoning of only part of an aquifer as a tertiary treatment facility is not necessarily new. The difference between conventional zoning (separation

of a well and septic tank) and zoning for land treatment is that, for the latter, the wastewater is removed from the aquifer after it is renovated.

5. The renovated water may be discharged into surface supplies for indirect reuse, or directly for unrestricted agriculture, recreation and industry.

6. Using renovated water for drinking is not yet encouraged because the possible health effects of the refractory organics and other compounds in low concentrations are not yet completely understood.

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4. South Australia, the state lying northwest of Victoria, Figure 5, has been described

FIGURE 5

SOUTH AUSTRALIA

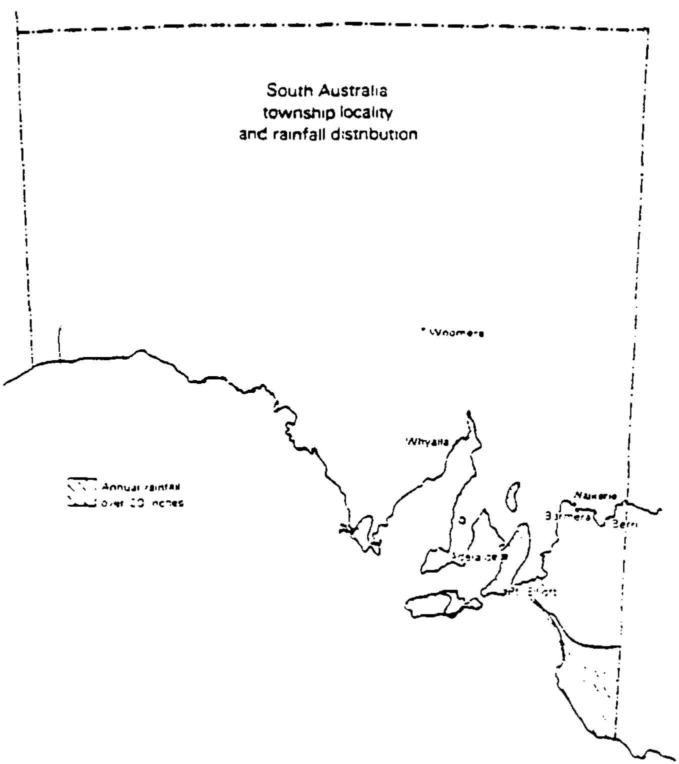
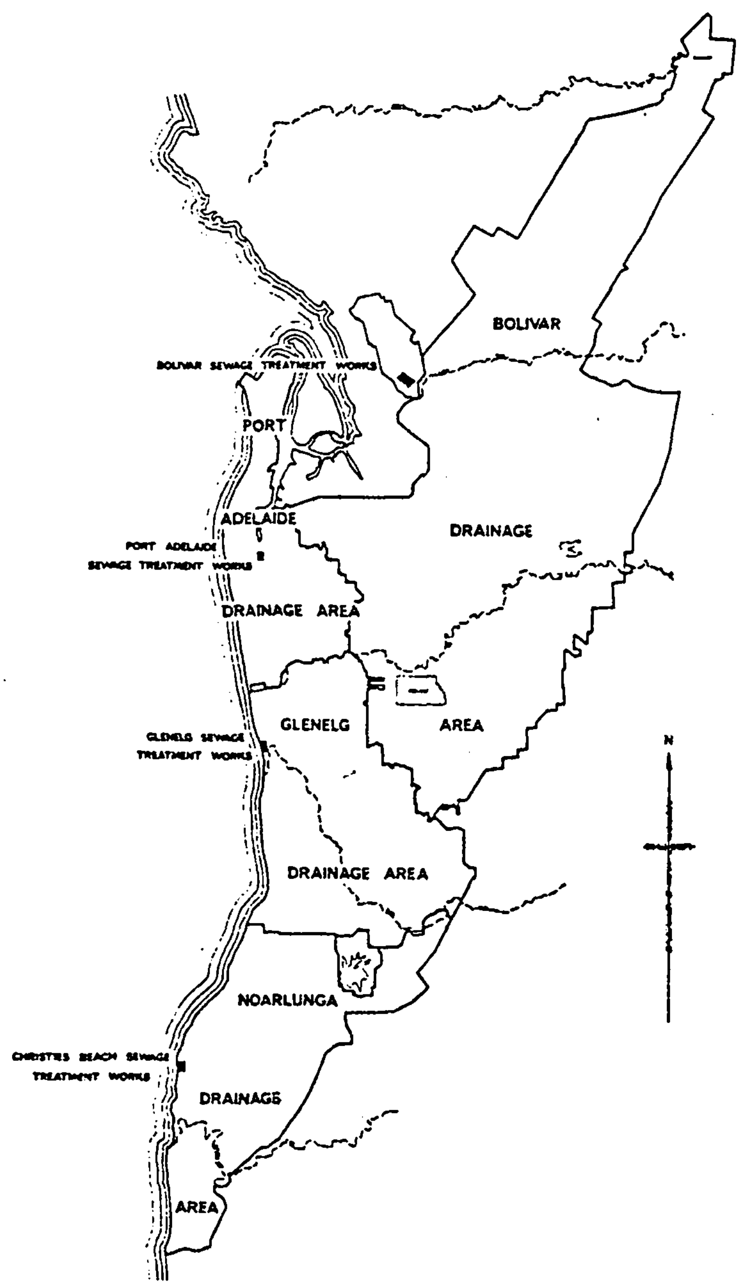


FIGURE 6

METROPOLITAN ADELAIDE
DRAINAGE AREA



as the driest region in the driest continent of the world. To fully conserve valuable water resources, the various organizations involved in sewage collection and treatment have tried to promote effluent reuse wherever practicable. More than one-half of the state's population of 1.5 million live in Metropolitan Adelaide, Figure 6, where reclamation and reuse have been a necessity for 35 years.

Two major sub-potable systems are evident.

a. The Glenelg Treatment Works, an activated sludge plant, Figure 7, with an average daily flow of 15 mgd has been providing secondary effluent for a variety of purposes. In 1933, the water was first used to irrigate lawns, shrubs and trees on the grounds proper. TDS levels approached 2750 mg/l because of saline groundwater infiltration into the sewers. Lawns would be watered for a 2-3 week period, then regular city water would be used to leach out the excess salts. TDS has been reduced to 1500 mg/l with sewer improvements.

   90% of all the effluent is now used for two championship golf courses, two public courses, driving ranges, a public caravan park, bowling greens and ovals, tennis courts, public lawns, sport and recreation areas and the Adelaide airport.

b. The Bolivar Treatment Works, another secondary plant but with polishing ponds, Figure 8, treats approximately 25 mgd.

   Following a 3-year appraisal of bacteriological and virological results of Bolivar effluent, approval was given to irrigate potatoes, orchards, vineyards, fodder grasses, tomatoes, flowers, onions, cucumbers and seed crops, as well as stock watering under controlled conditions. Few problems have occurred with soil and quality testing continuing by health and agricultural officials.

The Port Adelaide Plant, 8 mgd, with an effluent TDS of 3730 mg/l uses its secondary effluent for plant beautification after some blending with city water.

The new Christies Beach Works (0.5 mgd) provides secondary effluent through a dual distribution system to several city parks, nature strips and scenic ovals. High winds in the area removed most of the topsoil and made living conditions undesirable. To soften the harsh environment, trees, shrubs and perennials were offered free to residents which were watered by the effluent at a low cost.

The most important future use of effluent for irrigation is in the planned city of Monarto. Wastewater would be used 12 months of the year in a spray irrigation and land treatment scheme. The Department of Mines is currently investigating the movement of possible reclaimed water into the potable aquifer. South Australians have expressed a willingness to fully utilize their water resources in a variety of ways.

In additional research work on agricultural reuse of effluents at Braeside, Victoria, Australia, the following facts were evident:

a. Nine vegetable crops were sown and planted with 2 crops on each plot using city and reclaimed wastewater on lettuce, cabbage, beets, turnips, beans, radishes, carrots, celery and cucumbers.

b. The yield was better with reclaimed water when fertilizer was not used. But, when fertilizer was applied, the yield with city water was better.

FIGURE 7

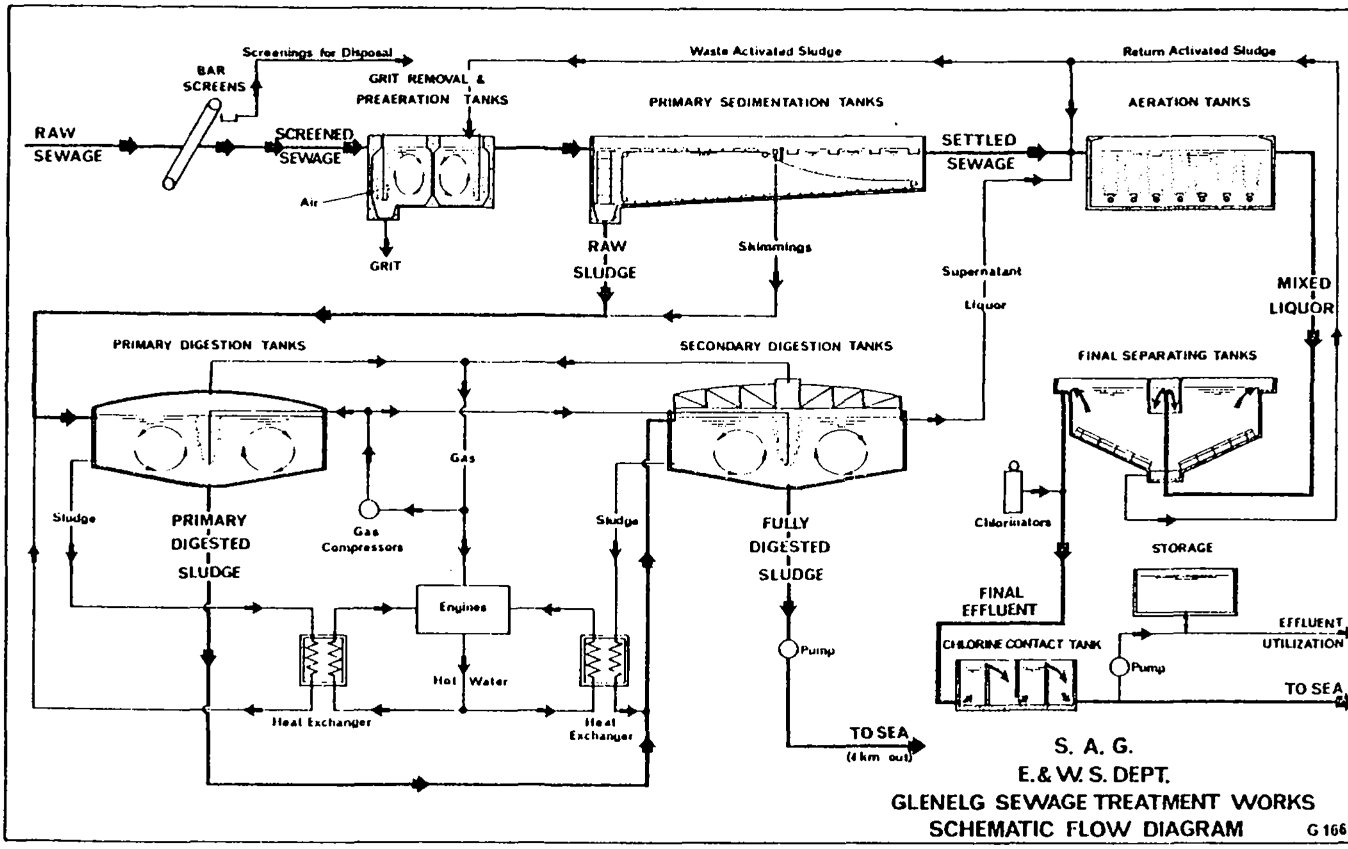
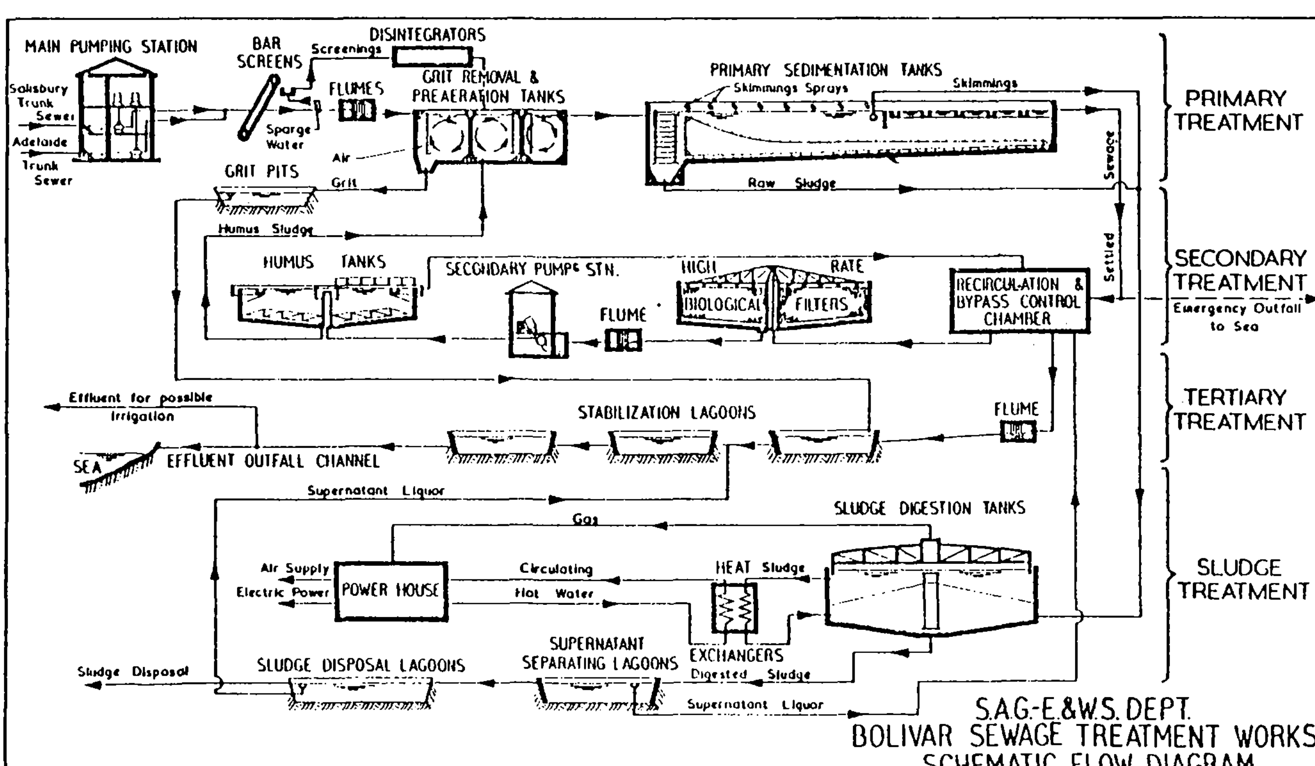


FIGURE 8



By adjusting fertilizer application to a level generally well below those normally used commercially, reconditioned water was best.

c. The harvested crops of radishes and turnips were sent to the Keith Turnbull Research Laboratories at Frankston as rabbit feed, but the rabbits declined to eat either foodstuff.

d. Seventy-two fruit trees were planted and maintained according to normal orchard practice. Early death amongst the trees followed the toxic accumulation of ammonia after the application of chemical nitrogen fertilizer. No fruit was obtained and few significant conclusions could be drawn. Those trees using city water were higher than those on chlorinated effluent.

e. The production of forage crops with effluents was higher, but weeds were a problem.

f. Cattle, after grazing on wastewater-irrigated pastureland, were examined for beef measles with no conclusions drawn.

g. The field tests on crops and pasture indicated that the nutrients in the effluent could be used to advantage. If allowance was made for the type and quantity of the nutrient in the wastewater, and a fertilizer was applied to give the balance of nutrient requirements of the crop, the yield could be superior to that obtained from market-gardens irrigated with city waters. The cost of necessary fertilizer could also be reduced and in one case was shown to be one-fourth of the normal amount.

h. Coliform organisms were counted on Braeside effluent vegetables and compared with those purchased from commercial markets. The Braeside samples were, if anything, better quality than those bought from stores. Future work is needed however, in measuring E. coli or strep organisms.

i. The Chief Health Officer from the Commission of Public Health expressed the view that the examination and evaluation of the health aspects of using reclaimed wastewater for growing vegetables would be a major project requiring full scale investigation, and that at present, it was not possible to state what criteria should be applied in evaluating any test results. Because of the lack of applicable criteria, the acceptability of the produce for human consumption could not be satisfactorily determined.

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5. At the Manufacturing Service Center of Eaton Corporation in Willoughby Hills, Ohio, a 10,000 gpd system for complete recycling of sanitary wastes has been operating since January of 1975. It employs batch biological-PCT treatment processes with sand filters, activated carbon and chlorination. Solids are aerobically digested with the effluent used for everything but drinking and kitchen purposes. In the restrooms, reclaimed effluents are used for toilet flushing and hand and face washing in the sinks. The product water, with 99.6% of the BOD removed, has an SS of less than 1 and a zero fecal coliform count.

Excess water goes to lawn irrigation year-round which also serves as a bleed-off, eliminating the need for demineralization.

The 125 employees have fully accepted the recycling system after some orientation. No signs are posted indicating reclaimed water, but the quality is monitored by the local health department.

****

6. At the Langeley Research Center in Hampton, Virginia, the National Aeronautics and Space Administration (NASA) has been evaluating the application of space technology to the homebuilding industry. What has resulted is a "Tech House" concept which utilizes energy conservation, solar heating and water recycling.

FIGURE 9

Plans for the home shown in Figure 9 are available for $10.00 from:

North Carolina Science and
Technology Research Center
P.O. Box 12235
Research Triangle Park,
North Carolina 27709
U.S.A.
(919) 549-0671

Details of the water recycling system are shown in Figure 10 with grey water being treated and reused for toilet flushing purposes. Material for the system is commercially available and was purchased at a cost of $450.00

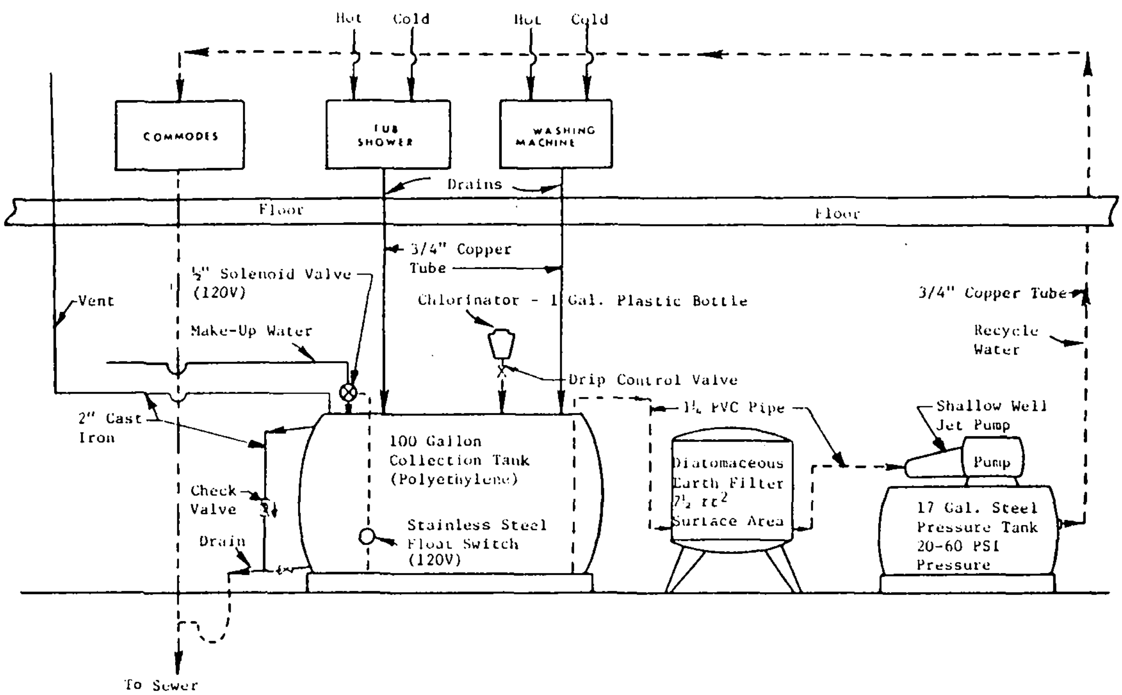
For evaluation, a simulated living pattern was created over a three-week period during February and March of 1977. Water use was recorded and microbiological characteristics determined.

Performance results were as follows:

1. 92% of the required flush water was provided from the reclaimed source.
2. Overchlorination resulted in a total kill of all organisms.
3. Energy consumption was 0.07 kwh per day.
4. No degradation in filter performance was noted.
5. Overall household water use was reduced by 70%.

FIGURE 10

NASA TECH HOUSE TREATMENT SCHEMATIC



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7. Treated Effluents from the water reclamation plants in Lubbock, Texas have been reused for beneficial purposes since 1938. In that year, a local farm contracted with the city to use effluents for irrigation of 200 acres southwest of this town. That farm has now increased to 2500 acres and uses 10-12 mgd for watering cotton, milo, grains, corn and pasture grasses. Runoff from the land is controlled by dams but the water table over the years has risen to within 4-10 feet of the surface.

In 1970, a power company contracted to use from 4-12 mgd of secondary effluent for cooling tower water in the electric generating plant. When the power plant has cycled the reclaimed water about four times, it is mixed with well water, then used again for irrigation.

In January of 1968, the City Planning Department proposed that consideration be given to beautifying a local canyon with a series of dams to form small recreational lakes. In dry seasons, the lakes would be maintained by pumping water from wells on the 2500 acre farm nearby, thus lowering the water table and allowing for more storage. Extensive tests have shown the aquifer under the farm to be free of bacteria and virus. Although bacteriologically safe for primary human contact, only secondary or indirect contact like fishing, boating, etc. will be allowed. The "Canyon Lakes Project", as it is appropriately titled, is making every attempt to recycle wastewater in a classical cascading sense.

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8. In May of 1973 a Water Reuse Promotion Center was incorporated in Tokyo, Japan with the object of encouraging the development and practical application of water reuse technology, by reclamation of wastewater and seawater desalination, in order to cope with acute water demands.

The main activities of the Center are:

1. Construction and operation of test plants for water reuse.
2. Promotion of R & D technology.
3. Provide consulting services on construction of reclamation plants.
4. Establish standards for reuse facilities and certification of performance.
5. Provide an information service on reuse technology.
6. Survey water reuse status in Japan.
7. Promote international cooperation in reuse.

The organization is sponsored heavily by Japanese industries, banks, water utilities and foundations.

Several sub-potable demonstrations are currently in operation in Japan as indicated in Table 3.

TABLE 3

STATUS OF JAPANESE REUSE PROJECTS

CITY	SEC.TRT. PLANT	PUBLIC UTILITY	VOLUME M^3/DAY	USE	AWT TREATMENT	SELLING COST ¢/M^3	PURPOSE OF REUSE
Tokyo	Mikawashina-Sunamachi	Tokyo Metropolitan Water Works	76,190	Industry, domestic-non-consumption	Chemical Coag, Filtration, Cl_2	3	Countermeasure against ground subsidence from ground water usage
"	Shibaura	"	311	Railroad car washing-National Railway	rapid sand filtration	1.1	Water shortages
"	"	"	110	car - floor wash, Metro whsle.market	Strainer	1.1	"
"	Morigasaki	"	1,758	inplant wash, Metro Refuse Disposal Bureau	-	1.1	"
"	Sunamachi	"	1,491	digested sludge washing	-	1.4	"
"	Mikawa-shina Sunamachi	"	1,100	home flushing, air cond, fire fighting, lawns	Chemical coag, filtration Cl_2	5	-
Kawasaki	Iriezaki	Kawaski Municipal Water Works	4.7	industrial cooling sprinkling	Cl_2	0.6	-
Nagoya	Sennen	Nagoya Municipal Water Works	103	industrial process w/cooling	Chemical coag, filtration, Cl_2	0	against ground subsidence
Ohsaka	Nakahama	Ohsaka City	1.5	water source Ohsaka Castle's moat	filtration Cl_2	0	-
Kitakyusyu	Kougouzeki	Municipal Sewage Works	11	industrial cooling, Mitsubishi Corp.	Cl_2	0.5	-

****

9. From correspondence with Mr. V. Raman, Secretary of the Indian Association for Water Pollution Control, the following water reuse projects are currently operating in India.

Several small villages and district towns employ raw sewage for irrigation purposes, but with a high incidence of parasitic infections in farm workers.

Metcalf and Eddy, under the auspices of the World Bank, are doing the feasibility study for agricultural reuse in Bombay, the largest city. They are being assisted by the National Environmental Engineering Research Institute of Nagpur in finding suitable agricultural sites for the 400 mgd of flow. Several multi-storied commercial buildings in Bombay tap domestic sewage from nearby city sewers for use in air conditioning systems.

The city of Madras is building a 15 mgd plant for effluent usage in nearby industries. Additional agricultural reuse is being implemented in the cities of Delhi and Bhilai.

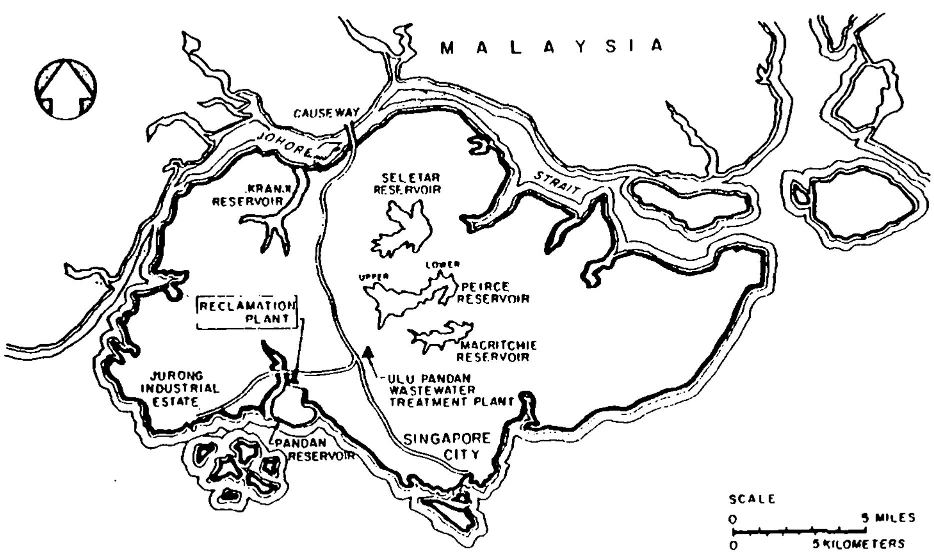
Severe water shortages will necessitate more reuse demonstrations in the future.

****

10. The City of Singapore, with an area of 225 square miles and a population of 2.25 million, is one of the more densely populated areas in the world. Insufficient water supply has led the Public Utilities Board to investigate water recycling and reuse.(Figure 11)

FIGURE 11

SINGAPORE - LOCATION MAP



As early as 1915, treated effluent was used for general wash water and irrigation of flowers and gardens.

In the mid-1960's, the Jurong Industrial Estate was constructed with 5.4 mgd of reclaimed wastewater being used in paper and textile manufacturing as well as for rinsing and cooling purposes with the user costs in the range of $0.076 to $0.24 per 1000 gallons. Secondary effluent from the nearby Ulu Pandan Plant receives prechlorination, dual media filtration, cascade aeration and post-chlorination before reuse by the industries, or in irrigating public parks and roadway landscaping. No use is made of the water in vegetable gardens or for watering livestock.

In June of 1971, six high rise residential apartments were selected for a dual plumbing system and the use of Jurong reclaimed wastewater for toilet flushing. Visible pipes are colored yellow with the only complaint from users being slight foaming when flushing or odors after long periods of stagnation. Heavier chlorine doses have combated the problem. The acceptance and success of the pilot work has led the government to extend the program to an additional 4000 apartments.

It became apparent that a higher quality effluent would foster even more reuse. A 100,000 gpd AWT plant was designed by Camp, Dresser & McKee in 1972, constructed in 1973 and placed in operation in September, 1974.

Secondary effluent undergoes chemical treatment, ammonia stripping, filtration, carbon adsorption and demineralization by three methods and disinfection with chlorine or ozone. The process flow schematic is shown in Figure 12. Typical effluent quality and removal characteristics are shown in Table 4.

FIGURE 12

DEMONSTRATION PLANT - PROCESS FLOW SCHEMATIC

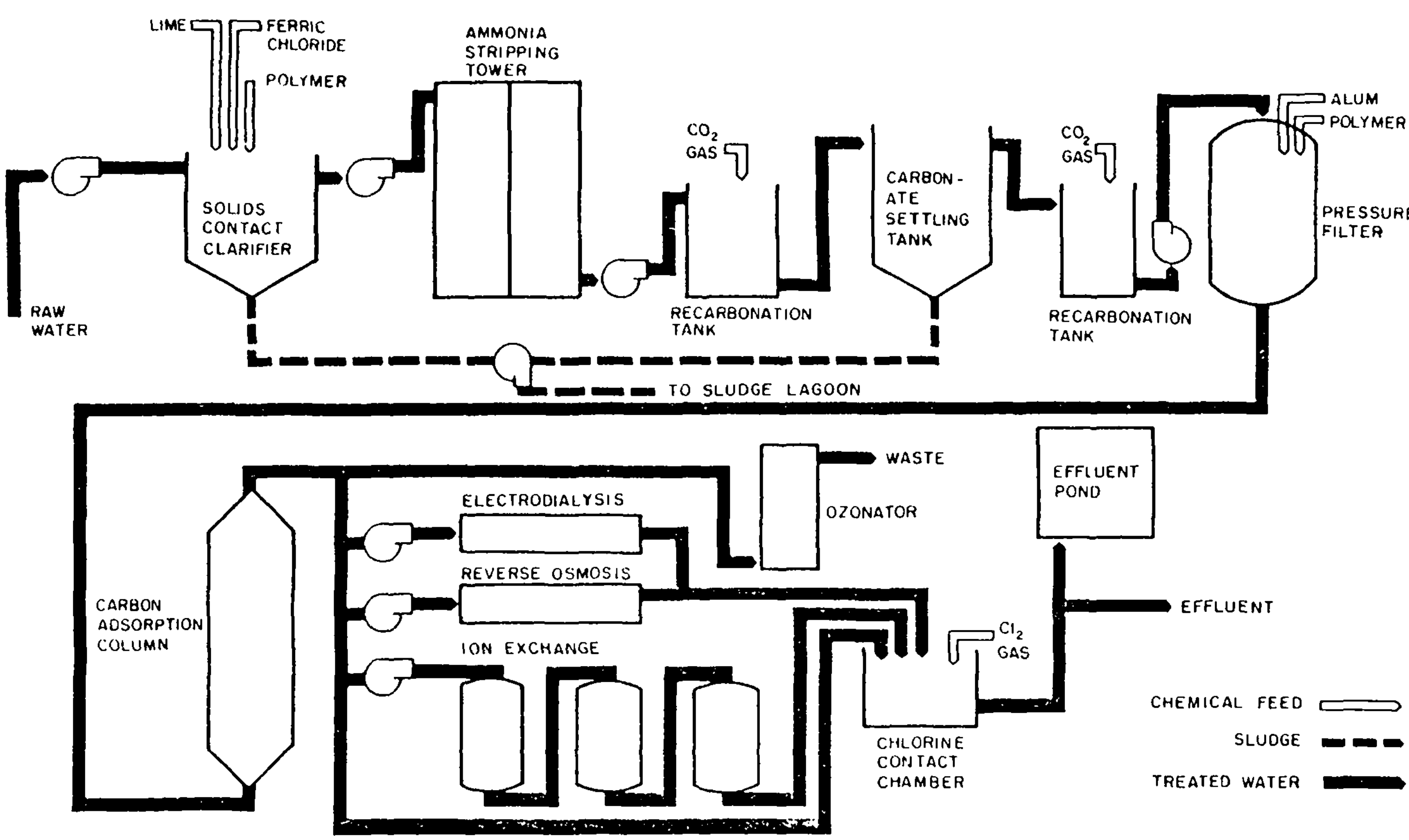


TABLE 4

SINGAPORE AWT DEMONSTRATION PLANT RESULTS

PARAMETER	SECONDARY EFF. RANGE mg/l	AWT EFF. RANGE mg/l	AVG. REMOVAL RANGE %
Alkalinity	190-340	30-116	80
Turbidity	3-750	0.5-4.8	93
SS	16-535	0.4-7.2	95
BOD_5	8-58	0.2-4.6	95
COD	47-645	2-29	89
TOC	9-170	2-24	70
PO_4-P	2-15	0.01-1.65	92
TKN-N	16-46	0-6.4	93
NH_3-N	15-44	0-5.6	94
NO_2-N	0-0.35	0-0.08	85
LAS	0.14-1.9	0-0.78	85
Fe	0-1.64	0-0.09	95
Zn	0-0.6	0-1.6	50

The demo plant is being used to determine the feasibility of treating wastewater to potable water standards within practical economic constraints.

Overall treatment reliability has been demonstrated with the R.O. process proving superior to the electrodialysis and ion-exchange methods for demineralization.

Virus recovery by the University of Singapore has been negative but this is not to imply their absence because new concentration techniques are needed. Fish bioassays are being performed to determine organic uptake in selected organs.

Based on operational data developed to date, it was the consultants opinion that reuse could provide a viable means for the Government to augment the water supply.

****

11. Toups Engineering Consultants has completed a report for the Goleta County Water District on wastewater reclamation by irrigation. Located in the water-short coastal area north of Los Angeles, the county has evaluated several alternatives for increasing available supply. Initial studies in 1975 indicated that imported waters would cost $302.00 per acre-foot, while reclaiming local wastewater would run $205.00 per acre-foot. The decision then became what was the optimum method to utilize available sewage effluents. As groundwater recharge standards were not expected to be developed for a 5-year period, the decision to irrigate existing agricultural areas and landscaping projects was reached. Approximately 3300 acres of avocados and lemon groves, plus 800 acres of golf course, park, highway and campus landscaping was available.

Typical chemical characteristics of the existing water supply and primary effluent available are shown in Table 5. One interesting factor was the very high use-increment of TDS. An additional 386 mg/l of TDS over the normal expected range was due to sewer discharge of brines from home water softeners. Several plans to alleviate the situation were discussed. The effluent was further compared to several other successful wastewater irrigation projects in California as indicated in Table 6 and the criteria for good agricultural reuse in Table 7.

The California Department of Health has established additional treatment criteria for reuse as shown in Table 8. To meet the quality and irrigation requirements, secondary treatment and more effective disinfection is planned. The facilities are scheduled to be constructed and operating by 1978. But the future depends upon successful bond issues, definition of legal responsibilities, environmental impacts and contracts for sale of the reclaimed water.

TABLE 5

CHEMICAL CHARACTERISTICS OF GCWD WATER SUPPLY AND GSD WASTEWATER

Constituent[(a)]	Water Supply	Projected Wastewater	Actual Wastewater
Cations			
Calcium(Ca)	88	108	124
Magnesium(Mg)	32	52	44
Sodium(Na)	50	120	262
Potassium(K)	3	15	19
Ammonium(NH_4)	na	30	40
Anions			
Bicarbonate(HCO_3)	198	318	na
Sulfate(SO_4)	228	258	308
Nitrate(NO_3)	1	2	4
Phosphate(PO_4)	na	30	74
Chloride(Cl)	29	104	354
Fluoride	0.5	1.2	0.8
Boron	0.4	0.8	0.8
Total Hardness	350	485	485
Total Dissolved Solids (TDS)	690	990	1,376
Hydrogen Ion(pH)	7.9	6.9	na

na - Data not available

(a) Milligrams per liter unless otherwise noted.

TABLE 6

EXISTING AREAS USING RECLAIMED WASTEWATER FOR CITRUS OR AVOCADO IRRIGATION

AGENCY	CROP	IRRIGATED AREA (acres)	AVERAGE WATER-USE (ac-ft/yr)	IRRIGATION SYSTEM	RECLAIMED WATER QUALITY (mg/l)		LEVEL OF TREATMENT
					TDS	B	
Irvine Ranch W.D. (Irvine Co.)	Avocados Citrus	1,200	4,200	Furrow	1,100 (10)	0.75	Secondary
Fallbrook, S.D.	Avocados Citrus	16	50	Sprinkler	1,200 (10)	0.5-1.0	Secondary, Filtration plus Chlorination
Strathmore PUD	Citrus	2	55	Furrow	na	na	Primary plus oxidation ponds
Chino Basin MWD (Fontana)	Citrus	72	675	Furrow	400	0.5	Primary
LACSD-Pomona (Cal Poly, Pomona)	Avocados Citrus	na	600	Furrow	500	0.7	Secondary
Exeter	Citrus	na	785	na	na	na	Primary plus oxidation ponds

TABLE 7

COMPARISON OF MINERAL AND BACTERIOLOGICAL WASTEWATER QUALITY WITH IRRIGATION WATER CRITERIA FOR REUSE

Constituent (a)	Existing Wastewater	Projected Wastewater with Upgraded Facilities	Irrigation Criteria		
			Landscape	Agriculture	
				Spray	Drip
Total Dissolved Solids (TDS)	1,376	1,376	2,000	1,000	1,000
Boron (B)	0.8	0.8	2.0	1.0	1.0
Chloride (Cl)	354.	354.	350.	100.	100.
Sodium (Na)	262.	262.	350.	120.	120.
Percent Sodium - %	54.	54.	65.	50.	50.
Coliform-MPN/100 ml	ns	200.	23.	2.2	ns

ns - Not specified.

(a) Milligrams per liter

TABLE 8

CDH RECLAMATION CRITERIA FOR WASTEWATER REUSE

REUSE	REQUIRED TREATMENT	ALLOWABLE COLIFORMS (MPN/100 ml)
Food Crops		
Spray Irrigation	Bio-oxidation, coagulation/ clarification, filtration, disinfection	2.2
Surface irrigation		
General	Bio-oxidation, disinfection	2.2
Orchards and vine-yards with no fruit contact with water or ground	Primary sedimentation	ns
Exceptions	Considered on individual basis if crop undergoes pathogen destroying processing	ns
Fodder, Fiber & Seed Crops		
Fodder, fiber and seed crops	Primary sedimentation	ns
Pasture for milking animals	Bio-oxidation, disinfection	23
Landscape Irrigation	Bio-oxidation, disinfection	23
Recreational Impoundments		
Nonrestricted	Bio-oxidation, coagulation/ clarification, filtration, disinfection	2.2
Restricted to non-bodily contact	Bio-oxidation, disinfection	2.2
Landscape-non-contact	Bio-oxidation, disinfection	23

ns-Not specified

12. In the December, 1976 issue of Water and Wastes Engineering was a description of a reuse project in Woodlands, Texas, a new, fully planned community being developed in a heavily forested area 30 miles north of Houston. When completed in 1977, the new town will provide work, recreation and living facilities for 150,000 people.

To preserve the forested environment, the owners have incorporated ecological planning into the development process which is reflected in the selected wastewater treatment plant, Figure 13.

Treated wastewaters will be recycled into Lake Harrison, a 60 mg recreational facility in the village which also serves as a reservoir for irrigation demands. Overflows from the lake are discharged into Lake Houston watershed which is the source of domestic water for Houston. Quality requirements are BOD - 5 mg/l, SS - 5 mg/l and a P of 2.0 mg/l on a monthly average.

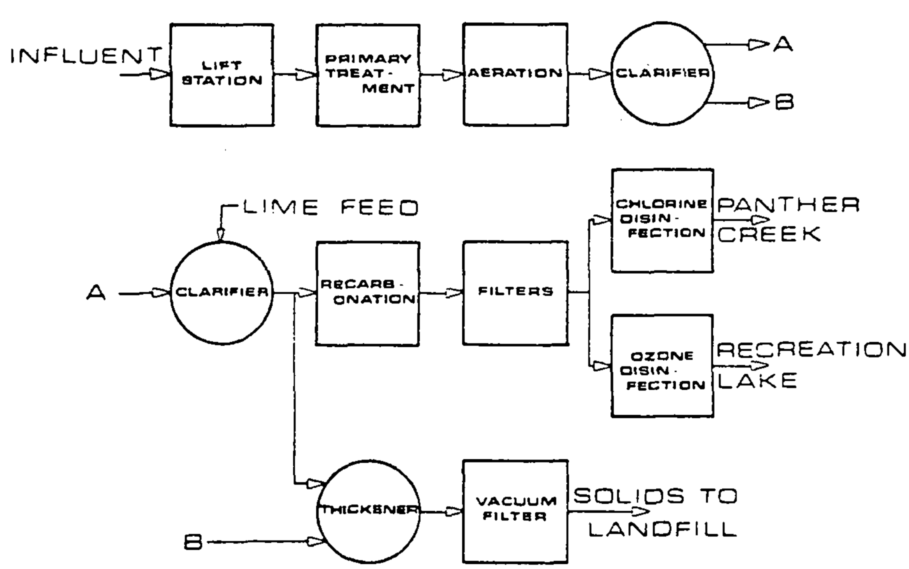
The plant, to be developed in 4 incremental stages, has a present capacity of 0.5 mgd with an ultimate 6 mgd rating. Should nitrogen removal become a future requirement, ammonia stripping will be employed. Dual media filters are employed with the ozone contact tower being a vessel 5 feet in diameter and 12 feet high filled with 3-inch polypropylene packing with a liquid detention time of 30-60 seconds.

Initial tests have resulted in the following effluent characteristics:

Parameter	Influent	Effluent
BOD	200	1
COD	330	6
SS	40	4
P	20	1.9
Fecal Coli		0

FIGURE 13

LAYOUT OF WOODLANDS SEWAGE TREATMENT PLANT



13. The city of Aurora, Colorado on Denver's eastern border, is investigating the possibility of municipal wastewater reuse. For many years, filtered secondary effluent has been used for golf course irrigation, but the new plans call for eventual potable reuse. In a preliminary report prepared by CH_2M-Hill Engineers for the city, a 20 mgd AWT plant would be constructed and be operating by the early 1980's. Conventional primary and secondary treatment for 20 mgd is to be followed by disinfection and filtration steps for 12.5 mgd only. This water would then be used via a secondary distribution system for agricultural purposes (parks, greenbelts, golf courses, etc.) and industry. The remaining 7.5 mgd of flow would undergo further treatment and eventually be discharged into a terminal water supply reservoir to be followed by conventional water treatment and public use. The direct pipe-to-pipe link is missing but the potable reuse acronym is still evident. The preconceptual treatment sequence for the higher grade water consists of lime clarification, two-stage recarbonation, filtration, ammonia removal with ion exchange, breakpoint chlorination, carbon adsorption, reverse osmosis and chemical oxidation. Estimated costs for the industrial/irrigation portion of the project approach $12.1 million, with an additional $43 million for the potable quality plant. Additional information about this ambitious program can be obtained by contacting Mr. C.A. Wemlinger, Director of Utilities, Municipal Building, Aurora, Colorado 80010.

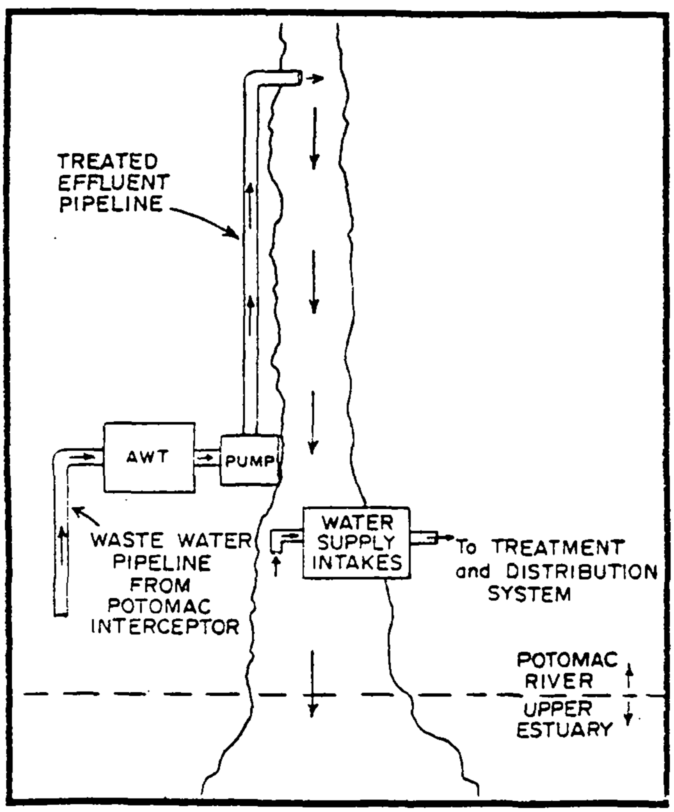
****

14. In the U.S. Army Corps of Engineer's evaluation of water supply alternatives for the Washington, D.C. area, three indirect reuse projects were examined. Their purposes being to supplement the base flow of the Potomac River by making highly treated wastewater available for use during drought conditions. Two of the projects considered - (1) Fairfax County Plant, Figure 14, and (2) the 60 mgd Montgomery County Plant, Figure 15 - would also serve to reduce the wastewater management plant in the Washington Metropolitan area. The third project would employ AWT at Blue Plains, pumping the effluent upstream of the water intakes, Figure 16. Corresponding cost estimates are indicated in the respective figures.

The advantage of piping highly treated effluents upstream was to reduce the potential health hazard with dilution and utilize the so-called "instream purification processes". As indicated in previous Planning Reports, the Montgomery Plant effluent would have been considerably better than the river quality itself. The Corps, in an effort to find the answers needed, has decided to test estuary waters and Blue Plains effluent in what has been nicknamed the "Six-Million Dollar Plant".

FIGURE 14

REPRESENTATION OF FAIRFAX COUNTY AWT OPERATION

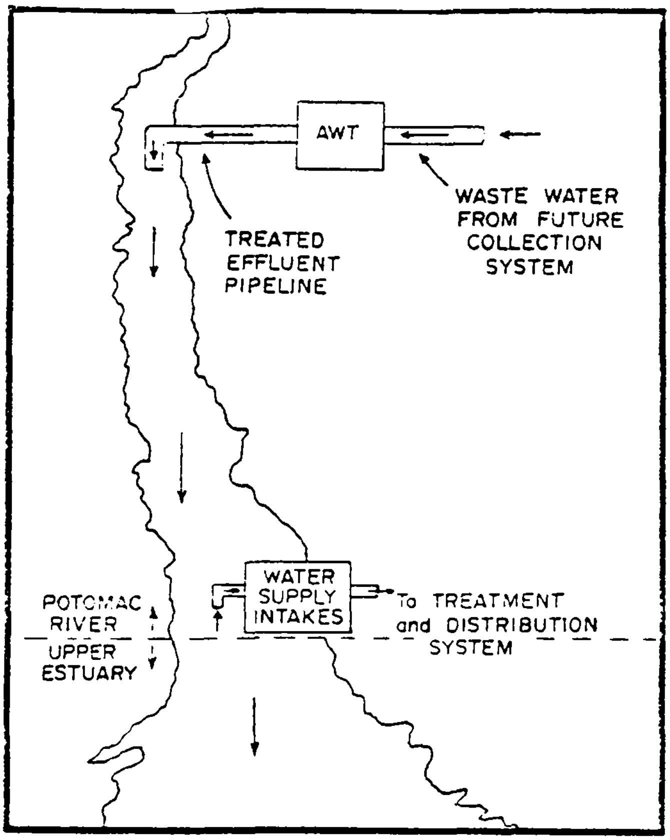


Loudoun County (25 mgd yield to the Potomac River from April through October)

Initial construction cost (does not include the cost of land) $201,114,000

FIGURE 15

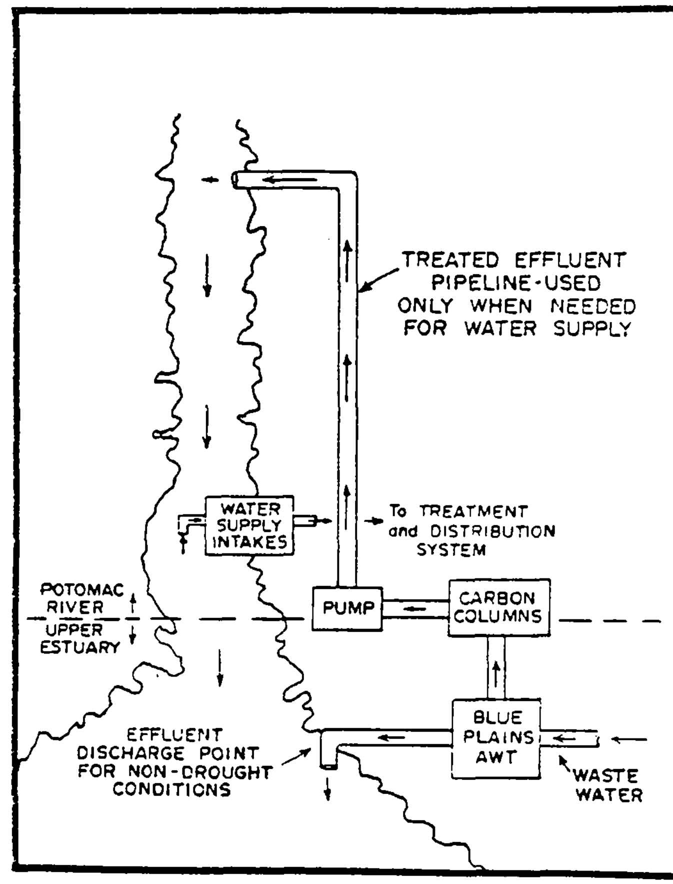
REPRESENTATION OF MONTGOMERY COUNTY AWT OPERATION



Project/Size	Unstaged Construction Cost ($ millions)	Staged Construction Cost ($ millions)
Montgomery County AWT/75 MGD	134.3	134.3
Montgomery County AWT/150 MGD	221.4	123.7
Fairfax County AWT/35 MGD	98.5	115.2
Fairfax County AWT/70 MGD	153.2	61.3
Blue Plains AWT/100 MGD	164.7	N/A
Blue Plains AWT/150 MGD	212.3	N/A
Blue Plains AWT/200 MGD	252.6	N/A

FIGURE 16

REPRESENTATION OF BLUE PLAINS RIVER MIX OPERATION



Project/Size	Unstaged Construction Cost ($ millions)	Staged Construction Cost ($ millions)
Plant Mix/50 MGD	40.3	45.6
Plant Mix/100 MGD	72.4	35.0
River Mix/100 MGD	165.5	207.7
River Mix/150 MGD	216.2	N/A
River Mix/200 MGD	269.6	67.8

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15. A U.S. Army Corps of Engineers' November 1975 interim report entitled "Critical Choices for Critical Years" contains information on the water supply needs for the northeastern United States, including several references on wastewater reuse.

Initial findings clearly showed that three metropolitan areas - New York, Eastern

Massachusetts-Rhode Island, and Washington, D.C. - have the most critical and immediate need to develop water supply sources to meet growing water demands. Studies of the 200,000 square mile region indicates a population of 50 million persons, but with an increase by the year 2020 to 80 million. A severe drought in the northeast in the 1960's caused Congress to pass PL89-298 directing the Corps to work with appropriate federal, state and local officials to insure against future drought-related water shortages.

Since the drought, no major water supply projects have been built in the three most critical areas and the general purpose of the interim report is to briefly present a wide range of available alternatives based on a separate and ongoing major water supply survey.

As a planning premise it was generally assumed that direct wastewater reuse would not be generally acceptable during the time frame of the study. However, deliberate indirect reuse was acknowledged as impacting available supply. Planned indirect reuse in the east (AWT effluents into water supply reservoirs) is considered direct reuse in several western states.

The statement was made that indirect reuse could be made safe by employing carefully controlled AWT methods or land treatment. "AWT plants, whether using biological or PCT processes, can produce effluent that is eminently suitable for indirect water supply use. The effluent can be safely discharged into a stream or surface water body that is used as a water supply source. While the emphasis and interest in AWT has in the past centered on their role as a pollution control tool, their usefulness as a viable source of water supply cannot be overlooked.

Basic plans for the three areas are summarized as follows:

The Washington D.C. Metropolitan Area: One of the Corps' alternatives concerns construction of a pilot estuarine water treatment plant to determine the technical feasibility of full scale use of the Potomac estuary for water supply and to answer the health-related questions. Formal plans include the treatment of sewage effluents from the Blue Plains facility as well. In many cases, the secondary effluent is of a higher quality than the Potomac itself. Additional references were given to the planned Montgomery and Occoquan AWT plants.

The New York Metropolitan Area: Emphasis was given to surface water sources in that complex region but groundwater recharge programs in two Long Island counties, Nassau and Suffolk, merited considerable attention. Surface water augmentation with treated wastewaters also received consideration. The Connecticut plan of conservation and development contained a rather limiting policy of not even considering streams within the watershed which might contain sewage discharges.

Eastern Massachusetts and Rhode Island: While surface water development and conservation were stressed, some interest in land treatment and recovery of effluent was shown.

Since public works projects normally take many years to plan, authorize, design and build, it is critical that all parties involved in the water supply decision-making process be made aware of the choices available to avert shortages. With rapidly increasing technology, reuse may come to the forefront as a viable solution.

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16. Dr. H. Sontheimer of the University of Karlsruhe in West Germany is involved in a Berlin Project to recharge aquifers with treated wastewater. Within the next 12 months, a pilot plant will be constructed to remove nutrients and biological soil clogging organisms. Early research has indicated that ozonation prior to recharge changes the non-biodegradable organics in such a way that there is complete biological oxidation within the ground. Other tests have shown that when ammonia and nitrates are in a stoichiometric correlation, biological oxidation in the ground lead to nitrogen formation and removal of all inorganic nitrogen compounds.

Extraction for potable purposes is not expected until much more is known about the combination treatment and ground processes.

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17. In the 1976 Annual Report from the South African Water Research Commission (WRC) two on-going reuse research projects in the Cape Town region are described. The first involves treatment research at the Athlone Sewage Works on a 300 m^3/day pilot plant which is operated by the municipality while the National Institute for Water Research (NIWR) provides specialist services. The process design incorporates an aerated biological stage after lime treatment and ammonia stripping to insure quality equalization and higher efficiency in the removal of organic carbon and NH_3. Subsequent physical-chemical units include secondary clarification, sand filtration, disinfection and carbon adsorption.

Proposals have been made that the siting of future sewage treatment and reclamation plants should be planned on a regional basis for optimum reuse, so as to obtain the benefit of scale and allow segregation of domestic and industrial effluents.

The reclamation and reuse of purified sewage effluent in the Cape Peninsula could substantially relieve the critical water supply problem in the region. The main purpose of the second contract is to evaluate the technical and economic feasibility of full scale water reclamation and its storage in and abstraction from the sand beds of the Cape Flats, and to develop the required design criteria.

During the year 1976-77, extensive studies were undertaken on the hydraulic suitability of the sand beds for storage, infiltration and withdrawal of natural waters or treated effluents. Geohydrological studies showed a daily subterranean flow to an ocean bay of 75 Ml or approximately 3m^3/day per meter of coastline. This fresh water could be intercepted and used but at the expense of sea water intrusion. To create a hydraulic barrier against the saltier source, artificial recharge by covered infiltration channels or ponds appeared feasible with 220 Ml per day of treated domestic sewage as the source. After one year of storage in the coastal aquifer it too would be abstracted for all uses.

A preliminary mathematical model has been developed for simulating the behavior of the groundwater resource under a wide range of conditions.

Three sewage purification works, with an eventual combined capacity of 400 Ml per day are currently under construction along the bay coast. In two of the three installations, provision is being made for nutrient removals which simplifies the subsequent reclamation plant. The Cape Flats plant, which will replace the oxidation pond system, will be commissioned by the end of 1978, offering an improved effluent to the proposed 4.5 Ml per day demonstration AWT plant. A new agreement between the WRC and municipality will postpone the full reclamation plant until the Cape Flats facility becomes operational. In the mean time, only a portion of the demo plant will be built to enable infiltration studies.

****

18. Plans have been developed in Marin County, California, north of San Francisco, to implement wastewater reuse via irrigation in newly developed parks. Responsibility for the program comes under the auspices of the Marin Municipal Water District which serves 181,000 consumers in a 140 square-mile area.

In 1974 the District proposed to integrate four water supply activities: reuse, conservation, desalination and importation to meet future water demands. One of the goals was to provide 2000 acre-feet of reclaimed wastewater annually by 1995. The District, with the refreshing attitude of viewing reclamation not in terms of disposal, but in support of the domestic supply, has evaluated the treatment requirements, user potential and environmental impacts for reuse in the Las Gallinas Valley Area.

A 1.0 mgd filtration and chlorination plant is to be built for $500,000. The proposed steps following the existing trickling filter process will produce an effluent superior to the prescribed reuse quality limitations of:

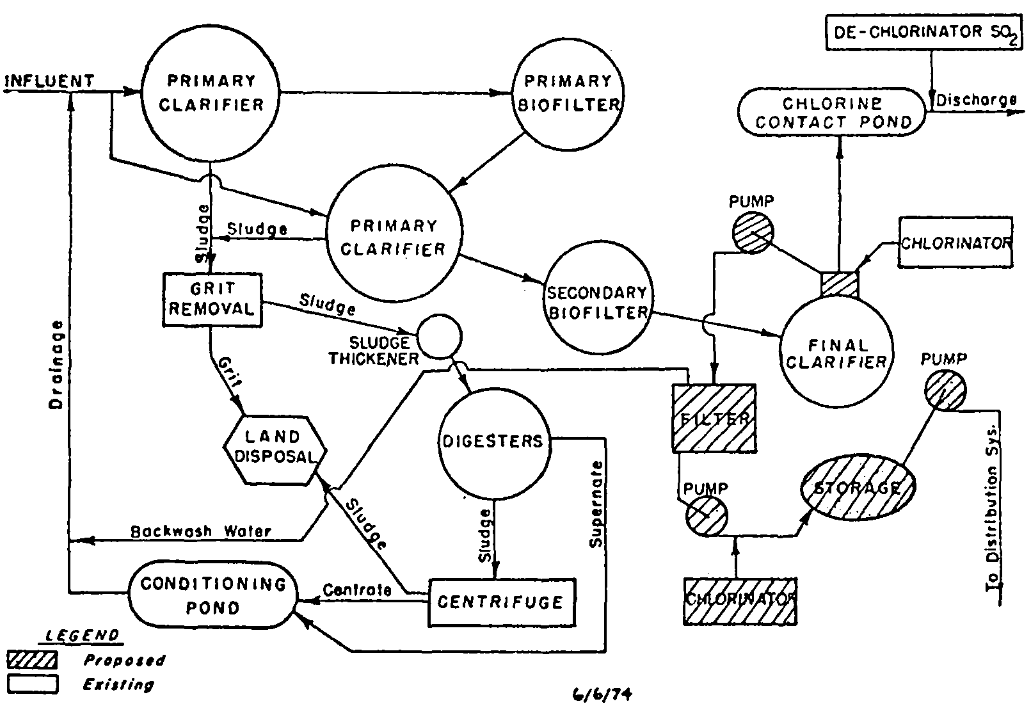
BOD	40 mg/l
D.O.	2 mg/l
Dissolved Sulfide	0.1 mg/l
Total Coliform	23/100 ml

In conjunction with the plant, an experimental R.O. process will be sponsored by the District, UCLA and the California Department of Water Resources. The overall facility and storage units will be sized to accommodate landscape irrigation needs for the proposed Marin County McInnis Park, Civic Center and Fairgrounds.

District policy will require the use of reclaimed water within the use area, as it becomes available for consumers. Thus, the project will accommodate growth rather than induce it. Figure 17 indicates the selected treatment sequence and Table 9, the irrigation quality requirements as compared to raw water supply and exisiting effluent.

FIGURE 17

WASTEWATER AND RECLAIMED WATER FLOW DIAGRAM



Two other documents are enclosed for interest. These include Table 10 - State Guidelines for Landscape Irrigation with Reclaimed Effluent - and Table 11 - an example of the user-seller contract for reclaimed water.

TABLE 9

LAS GALLINAS VALLEY - WATER QUALITY CHARACTERISTICS

Metals	MMWD Domestic Water Northern Area 7/1/75 to 12/21/75 mg/l	LGVSD Effluent mg/l	Class 1 Irrigation Water mg/l
Aluminum	.013	.1	5.00
Arsenic (As)	.001	.00-.001	.10
Boron (B)	.1	.40-.60	.5
Cadmium (Cd)	.001	0-.025	.010
Calcium (Ca)	16.4-21.2	5.4-45.6	
Chromium (Cr)	.005	0-.04	.10
Copper (C)	.02	.01-.11	.20
Cyanide (CN)	.01	.01	
Fluoride	.87		1.0
Iron (Fe)	.06	.47	5.0
Lead (Pb)	.01	.02-.04	5.0
Magnesium (Mg)	7.7-10.0	16.3-33	
Manganese (Mn)	.05	.34-1.0	.20
Mercury (Hq)	.0005	.001-1.0	
Nickel (Ni)		.0-.05	.2
Phenols	.001	.14-.3	
Silver	.005	.0-.044	
Sodium	8.2	95-133	
Zinc	.01	.06-.07	2.0
Nutrients			
Nitrate (N)	.1	.06-.35	
Nitrite (N)	.01	.05-.26	
Ammonia (N)		17-50	
Total Organic Nitrogen		.9-5.4	
Total Phosphate (PO_4)		23-33	
Potassium (K)		13	
Miscellaneous			
Total Hardness	84.5	137-155	
TDS	130	424-600	
EC	199	841-1260	
Ph	8.2	6.8-7.6	6.56-8.4
Bicarbonate (HCO_3)		79-239	90
Sulfate (SO_4)	15.8	55-93	
Cloride (Cl)	15.2	102-213	142

TABLE 10

GUIDELINES FOR USE OF RECLAIMED WATER FOR LANDSCAPE IRRIGATION

STATE OF CALIFORNIA DEPARTMENT OF HEALTH

1. Reclaimed water shall meet the Regional Water Quality Control Board requirements and the quality requirements established by the State of California Department of Health for health protection.

2. The discharge shall be confined to the area designated and approved for disposal and reuse. Irrigation should be controlled to minimize ponding of wastewater and runoff should be contained and properly disposed.

3. Maximum attainable separation of reclaimed water lines and domestic water lines shall be practiced. Domestic and reclaimed water transmission and distribution mains shall conform to the "Separation and Construction Criteria" (see attached).

   a. The use area facilities must comply with the "Regulations Relating to Cross-Connections," Title 17, Chapter V, Sections 7583-7622, inclusive, California Administrative Code.

   b. Plans and specifications of the existing and proposed reclaimed water system and domestic water system shall be submitted to State and/or local health agencies for review and approval.

4. All reclaimed water valves, outlets and/or sprinkler heads should be appropriately tagged to warn the public that the water is not safe for drinking or direct contact.

5. All piping, valves, and outlets should be color-coded or otherwise marked to differentiate reclaimed water from domestic or other water.

   a. Where feasible, differential piping materials should be used to facilitate water system identification.

6. All reclaimed water valves, outlets, and sprinkler heads should be of a type that can only be operated by authorized personnel.

   a. Where hose bibbs are present on domestic and reclaimed water lines, differential sizes should be established to preclude the interchange of hoses.

7. Adequate means of notification shall be provided to inform the public that reclaimed water is being used. Such notification should include the posting of conspicuous warning signs with proper wording of sufficient size to be clearly read. At golf courses, notices should also be printed on score cards and at all water hazards containing reclaimed water.

8. Tank trucks used for carrying or spraying reclaimed water should be appropriately identified to indicate such.

9. Irrigation should be done so as to prevent or minimize contact by the public with the sprayed material and precautions should be taken to insure that reclaimed water will not be sprayed on walkways, passing vehicles, buildings, picnic tables, domestic water facilities, or areas not under control of the user.

   a. Irrigation should be practiced during periods when the grounds will have maximum opportunity to dry before use by the public unless provisions are made to exclude the public from areas during and after spraying with reclaimed water.

   b. Windblown spray from the irrigation area should not reach areas accessible to the public.

   c. Irrigated areas must be kept completely separated from domestic water wells and reservoirs. A minimum of 500 feet should be provided.

   d. Drinking water fountains should be protected from direct or windblown reclaimed water spray.

10. Adequate measures should be taken to prevent the breeding of flies, mosquitoes and other vectors of public health significance during the process of reuse.

11. Operation of the use area facilities should not create odors, slimes, or unsightly deposits of sewage origin in places accessible to the public.

TABLE 11

AGREEMENT FOR THE PURCHASE AND SALE OF RECLAIMED WASTEWATER

THIS AGREEMENT, made and entered into this _____ day of ________________, 19____, by and between ______________________________ ____, its successors and assigns, and hereinafter referred to as "User", and Marin Municipal Water District, a public corporation of the State of California, and its successors and assigns, and hereinafter referred to as "Water District".

W I T N E S S E T H:

WHEREAS, the parties hereto recognize that it is for the benefit of the community and in the public interest that wastewater be reclaimed and used for landscape irrigation whenever practical; and,

WHEREAS, Water District has constructed a wastewater treatment facility, hereinafter referred to as "reclamation facility", the effluent from which will be suitable for landscape irrigation purposes; and,

WHEREAS, User has existing and/or future landscape areas which can utilize reclaimed water for landscape irrigation in lieu of using potable water supply; and,

WHEREAS, User is willing to enter into an agreement with Water District for the purchase of water for irrigation purposes; and,

WHEREAS, Water District has obtained a Waste Discharge Permit, Order No. _________, from the Regional Water Quality Control Board on behalf of listed Users to enable them to use treated wastewater for specific purposes.

NOW, THEREFORE, IT IS HEREBY AGREED:

1. As a condition of potable water service, User agrees to install piping on his property necessary to accommodate the use of reclaimed wastewater.

2. This agreement is conditioned on obtaining necessary permits relating to the use of reclaimed water for landscape irrigation. Water District and User will jointly obtain and maintain all necessary permits as required by the Regional Water Quality Control Board, San Francisco Bay Region, and other authorized agencies. Water District will act as lead agency in obtaining, complying with, and maintaining these permits; however, both Water District and User are responsible, where applicable, to comply with regulations set forth in these permits.

3. Responsibility for building, managing and operating the reclamation facility belongs to the Water District.

4. Reclaimed water shall be used solely for landscaping irrigation as the term applies in Section 8046, Title 17 of the California Administrative Code, and only upon the property approved in the Waste Discharge Permit, Order No. ________. User may use water delivered to it by Water District at and for such other uses as it may desire, subject to the approval of obtaining necessary permits as required by the Regional Water Quality Control Board, and other authorized agencies.

5. Water District undertakes and agrees that the quality of water delivered hereunder shall conform to the requirements prescribed by the Regional Water Quality Control Board, and other authorized agencies.

6. Water District will, at its own cost and expense, construct necessary mains and lines from Water District's reclamation facility to the property of User, according to Water District's wastewater policy and procedures.

7. Water District is responsible for installing and maintaining any metering devices used in connection with the delivery of reclaimed water to User.

8. Water District and User are jointly responsible for water monitoring, sampling, analyses, and observations required by the Regional Water Quality Control Board or other authorized agency. Water District will be the lead agency in such monitoring programs.

9. User agrees to properly maintain any required backflow device, as specified in Section 11.14.076 of the Water District Code.

10. User agrees to comply with guidelines contained in the State of California Guidelines for Use of Reclaimed Wastewater for Landscape Irrigation.

11. User agrees to pay for reclaimed wastewater at the rate established by Water District, said rate not to exceed the rate set for domestic water.

12. As User's failure to meet requirements may lead to suspension of the Waste Discharge Permit, Water District reserves the right to discontinue User's water service should User violate the terms of this agreement.

13. Water District will endeavor to satisfy all demands for treated wastewater; however, Water District is not responsible for its failure to do so.

14. Water District shall, and does hereby agree to indemnify User against and to hold User harmless from any and all damages, claim for damages or liabilities of any nature whatsoever arising out of, or in connection with, Water District's operation hereunder.

USER ______________________________

By ______________________________

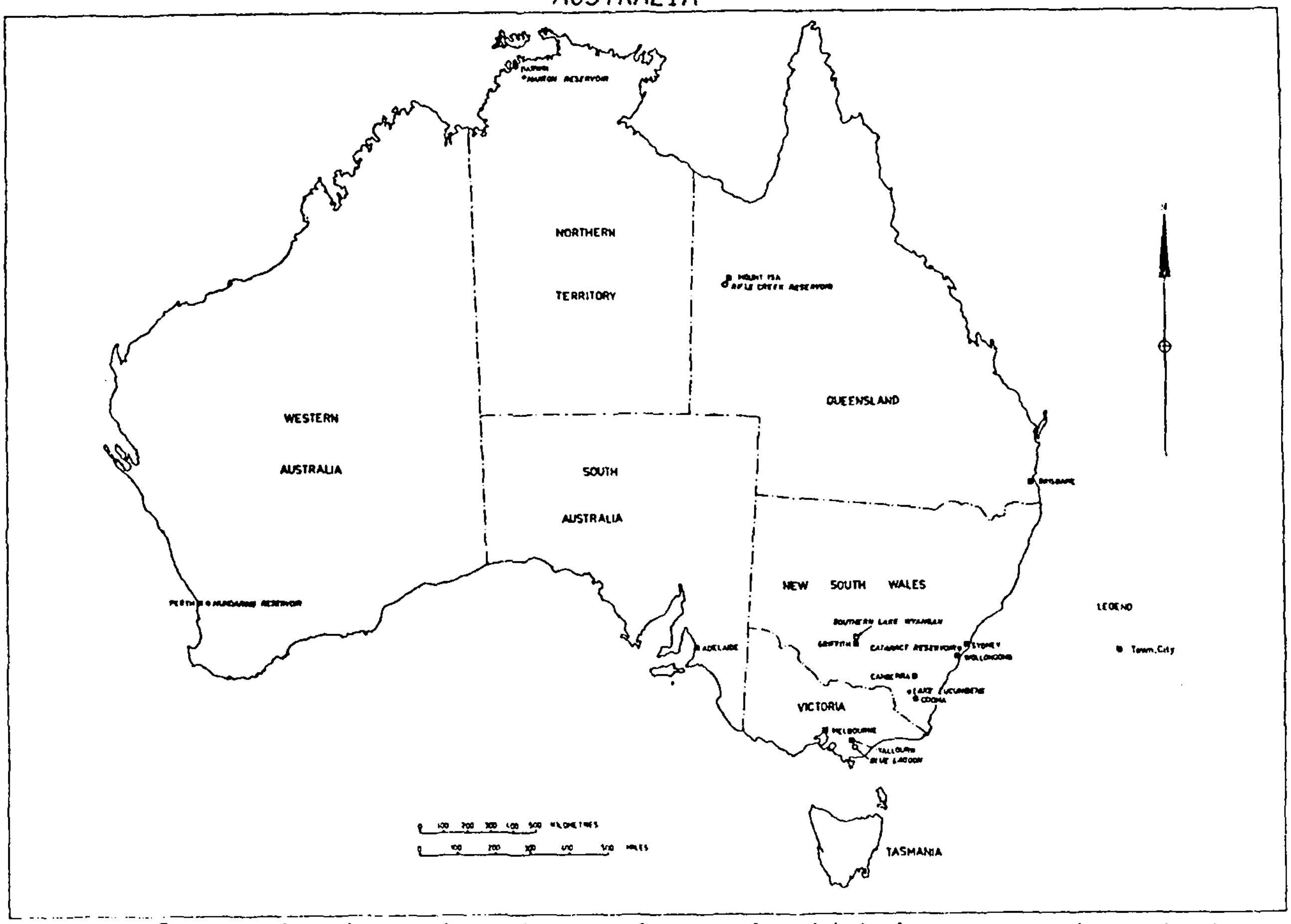
MARIN MUNICIPAL WATER DISTRICT

By ______________________________

19. Aquifer recharge is being considered as a water supply alternative in the Victoria State of Australia. (Figure 18) The Koo Wee Rup Plain, an extremely productive farmland area, lies southeast of the city of Melbourne. The primary

FIGURE 18

AUSTRALIA



source of water has been the sub-artesian basin which is connected to the bay at the city of Western Port. Drawdown due to pumping has caused a reversal of flow and contamination of the aquifer with salt water.

Two proposals were suggested to remedy the situation:

a. Piping reconditioned wastewater from the Board of Works Southeastern Purification Plant at Carrum, 25 miles to the plains and thence reticulating it to farms in order to reduce or eliminate the dependence on groundwater. Nutrients would be effectively absorbed, but the peak water demand which occurs in summer does not coincide with peak supply which occurs in winter.

b. Piping the reconditioned water to Koo Wee Rup and charging it directly into the aquifer which would obviate the complex farm distribution system and overcome problems created by varying supply and demand. It would, however, introduce the problems of the complex physical, chemical and biological reactions between the natural groundwater, the aquifer medium and the charging water.

An initial testing program has been undertaken by the Department of Mines on charging and discharging a similar sedimentary aquifer at Carrum. In other research performed at the University of Melbourne, a computer model was developed that purports to predict aquifer response to given input conditions.

An entirely separate proposal for the employment of all or part of the 5 million cubic feet per day flow from the Southeastern Plant has been made by Australian Groundwater Consultants Pty. Ltd. In that proposal, it is envisioned that a substantial part of the water requirements of Mornington and Western Port could be met by a scheme entailing the spreading of effluent over the dune limestone deposits of the Nepean Peninsular south of Rosebud.

Modeled on schemes overseas at Santee and Tel Aviv, effluent would be injected into the ground and pumped out some distance away, having been relieved of its BOD, bacterial and phosphate loads. The water would mix with the natural groundwater and, when removed, be blended with waters from the Tarago and Bunyip Rivers north of the Mornington Peninsula to produce a potable supply.

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20. The Naval Civil Engineering Laboratory at Port Hueneme, California is developing a wastewater reclamation system for producing potable water at water-short bases world-wide that presently rely on desalination for water supply.

Pilot investigations have been completed with a 25,000 gpd demonstration plant to be completed in 1978.

The objectives of the demo work will be:

a. to investigate fail-safe characteristics and reliability of the systems operation

b. to determine the cost-effectiveness

c. to establish on-line real time system efficiency monitoring methods

d. to demonstrate to prospective consumers, as well as management, the safety, economics and reliability of direct reuse

New development in unit processes/operations for water purification, water quality monitoring equipment, sample concentrations, and virus and toxic chemical analyses methods are of significant interest to the Navy.

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21. Community utility service at the present time involves independent large-scale facilities for the generation of electricity, water and wastewater treatment and solid waste disposal. The customers are usually served through extensive and costly transmission and distribution systems while space heating, space cooling and potable water heating are normally accomplished at the home level. In contrast, the Modular Integrated Utility System (MIUS) which is being researched by the U.S. Housing and Urban Development Department (HUD), provides a single facility on a community basis.

In a long-range program to develop, demonstrate and encourage integrated facilities, HUD has set the following performance goals for the MIUS system:

1. Conserve fuel and other natural resources
2. Reduce environmental degradation
3. Reduce total public cost
4. Match the reliability of existing service
5. Be capable of installation in phase with community development
6. Permit greater flexibility in intensive land development

Studies of multi-family housing demand indicate that 16-35% of new residential/commercial construction is a candidate for application of an MIUS.

Mass production of MIUS components also offers modern utility service to isolated communities that cannot afford conventional technology. Perhaps the largest market lies in the new cities of developing countries.

The MIUS program is now a multi-agency effort under the direction and sponsorship of HUD. Other program participants are ERDA, NASA, HEW, EPA, FEA and the Department of Defense. The National Bureau of Standards serves as technical program advisor and lead agency for review and evaluation of the proposed MIUS demonstration.

The MIUS system would be located near the center of a medium density residential community with perhaps 2500 dwelling and associated commercial units. Thermal energy from the internal combustion engines on the electrical generators and auxilliary boilers is used for space and potable water heating throughout the community. It also serves as a heat source for an absorption chiller in the air conditioning cycle. Excess heat from the steam loop could be used to warm the influent wastewater.

Solid waste handling may consist of vacuum collection and incinerator with heat recovery.

Early MIUS modeling studies indicated a 50% savings in fuel energy over conventional methods. Energy is the key which ties the electrical, thermal and solid waste elements into an integral entity. Wastewater and potable water treatment are more loosely bound and it is unlikely that those systems will be energy producers. Anaerobic sludge digestion appears viable economically only for communities of more than 10,000 people, but new techniques of methane production are being investigated. Both water and wastewater treatment systems will become integral elements and contribute to effective energy utilization by serving as controllable electric loads. This will be evident in the proposed ozonation process.

Probably the most salient feature of the MIUS concept is the potential for water conservation through reuse. Wastewater receiving AWT will be reused in applications compatible with the protection of public health and welfare. The possible applications via a dual-distribution system include home lawn watering, fire fighting, industrial uses and recreational purposes. Potable reuse may be considered as technology advances.

An actual demonstration of the MIUS concept will take place on an 130-acre planned development in southern Maryland in the late 1970's. The specific wastewater treatment sequence is being developed at this time.

HUD announced, in 1976, a $400,000 grant to Interstate Land Development, Inc. for preliminary planning and design work on installing an MIUS in the Company's new town of St. Charles in Charles County, Maryland, 25 miles southeast of Washington D.C. Two thousand dwelling units have been completed with a goal of 24,000 by 1990.

Interstate has contracted with United Technologies Corporation for a 6-12 month study to determine how many housing units and what size shopping center one MIUS unit could serve.

A companion program, IUS, funded by the National Bureau of Standards and administered by HEW is moving ahead rapidly. Under a $136,000 contract, Reynolds, Smith and Hills, Inc., is completing a feasibility study on installing IUS at the University of Florida, Gainesville, and Central Michigan University, Mt. Pleasant for the U.S. Department of Health, Education and Welfare (HEW).

IUS provides the same basic utility service as MIUS, but is designed for use where expansion is expected to be slight.

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22. A similar yet further advanced concept is being developed in Canada for the Central Mortgage and Housing Corporation. The system, entitled CANWEL, refers to Canadian Water Energy Loop with the basic research being conducted by the Ontario Research Foundation.

Again, as in MIUS, the broad objectives of CANWEL are to conserve natural resources, reduce the cost of urban development and reduce pollution of water, soil and air. Reclamation of wastewater has taken precedence over energy research and recycling for sub-potable use is planned.

The three sub-systems are for sewage treatment, water polishing and solid waste handling. The sewage system consists of an absorption bio-oxidation (A-B) reactor where raw sewage is contacted with activated sludge and powdered carbon. Following nitrification and denitrification in the same tank, the flow reaches a sludge separator for recirculation back to the A-B. In the following chemical reactor, phosphorus compounds and excess biological solids are removed. Sludge is then thickened and combined with municipal solid waste for incineration. Thermal recovery allows for heating a development or apartment complex of perhaps 500 persons. An interim ozonation step oxidizes residual organics in the effluent and makes the water suitable for surface discharge or utility usage.

Higher orders of reuse will require additional treatment as provided in the water polishing sub-system. Mixed media filtration will remove the remaining suspended solids. Where required, the two optional processes of pH control and reverse osmosis can be incorporated. Additional ozonation will be used to destroy pathogens. The polished water would then meet the Canadian Drinking Water Standards.

A working prototype of the sewage unit at 90 kiloliters per day has been operating for more than a year. But a full scale unit (250 KPD) for 500 persons will be operating in a Toronto apartment building in 1977 to demonstrate the long-term efficiency and reliability of the system.

Design work is also complete on another 250 KPD experimental unit for exposed environment municipal wastewater plants to be installed near Montreal. That system will supply information required for scale-up to an initial community plant size of 5000-person capacity and for the conversion of existing conventional plants to the CANWEL technology. By designing components modularly, these units could be linked together to service communities of about 20,000 people.

In terms of cost and economics of the recoverable water product, CANWEL is expected to be less than any conventional system.

Again, the direct potable reuse option is left open while sub-potable demonstrations are made and technology advances.

Dr. Besik of the Ontario Research Foundation was one of the pioneers in the CANWEL water reclamation system. His years of pilot plant work with the following treatment sequence (see Figure 19) yielded the results as shown in Tables 12, 13, 14 and 15. That data was used to develop the present recycling system.

FIGURE 19

PILOT TREATMENT PROCESS

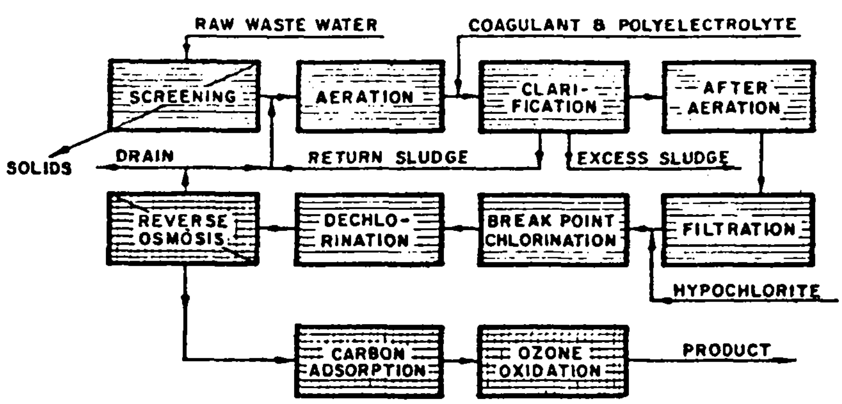

TABLE 12

WATER QUALITY AT VARIOUS POINTS OF THE TREATMENT
(minimum-maximum values)

Quality parameter	Raw waste water 1	Clarifier effluent 2	Filter bed effluent 3	Break-point chlor.eff. 4	Dechlor. effluent 5	R.O. effluent 6	Final effluent 7
T.O.C.(mgl^{-1})	64-110	13-38	6-15	6-13	2-7	<1.0	<1.0
S.O.C.(mgl^{-1})	27-49	9-17	5-12	6-11	2-5	<1.0	<1.0
PO_4(mgl^{-1})	22-42	2-9	<1.0	<1.0	<1.0	<1.0	<1.0
Kjeldahl N(mgl^{-1})	20-50	14-30	5-27	1.0-13	0.5-12	0-3	0-3
Ammonia N(mgl^{-1})	13-30	13-30	13-30	0.0-12	0.0-13	0.0-5.0	0.0-5.0
NO_2 + NO_3N(mgl^{-1})		0.1-1.2	0.4-1.8	1.3-2.7	0.1-1.1	0.1-0.3	0.0-0.8
S.S.(mgl^{-1})	96-236	16-73	0.5-5.0	0.6-5.0	---	0.0	0.0
D.S.(mgl^{-1})	413-530	440-560	460-560	690-1020	690-980	55-140	65-140
Turbid(mgl^{-1})	57-95	12-40	1.0-5.0	1-5	1-3	<0.2	<0.2
Coliforms per 100 ml	15×10^6	8×10^6	0.5×10^6-1.5×10^6	0	---	---	0

TABLE 13

TOTAL REMOVAL EFFICIENCY AT VARIOUS POINTS OF TREATMENT (maximum achieved)

Parameter	Clarification (%)	Filtration (%)	Break-point chlorination (%)	Dechlorination (%)	Reverse Osmosis (%)
T.O.C.	82.5	91.8	91.8	97.5	99
S.O.C.	73.4	81.6	86.0	88.4	99
PO_4	93.7	97.2	97.2	98.5	99.6
Kjeldahl N	3.7	45.0	94.2	97.9	98.5
Ammonia	20*	27*	100	--	--
S.S.	84.9	98.9	98.9	98.9	100
D.S.	5.2*	7.0	49*	49*	77.8
Coliform	46.6	96.6	100	--	--

*Concentration increased by %.

TABLE 14

TRACE ELEMENT ANALYSIS OF THE RENOVATED WATER

Element	Method of analysis (AAS)	Detection limit (ppm) flameless AA	Element concentration in samples (ppm) Ren. water (15/5/73)	Ren. water (23/5/73)	Tap water (23/5/73)	Permissible levels
Ag	Flameless	0.0006	ND*	ND	ND	0.05
As	Flameless	0.006	ND	ND	<0.04	0.05
B	Flameless	0.300	<0.5	<0.5	<2.5	1.00
Ba	Flameless	0.02	<0.075	<0.075	<0.075	1.00
Ca	Flame		1.5	1.5	40.0	200.00
Cd	Flameless	0.00003	<0.0001	<0.0003	<0.0002	0.01
Cr	Flameless	0.0008	<0.003	<0.002	<0.005	0.05
Cu	Flameless	0.005	<0.150	<0.175	<0.015	1.00
Fe	Flame		--	--	--	0.30
Mg	Flame		0.35	0.70	8.3	150.00
Mn	Flameless	0.00004	<0.002	<0.002	<0.005	0.05
Pb	Flameless	0.0005	<0.002	<0.002	<0.004	0.05
Se	Flameless	0.001	<0.005	<0.003	<0.007	0.01
Zn	Flame		0.47	0.20	<0.05	5.00

*Not detectable.

TABLE 15

BIOCIDES IN THE RENOVATED WATER

Biocide	Detection limit (ppb)	Biocide concentration in samples (ppb) Ren. water (23.5.1973)	Tap Water (24.5.1972)	Permissible levels
Aldrin	0.03	ND	ND	17
DDT	0.03	ND	ND	42
DDD	0.03	ND	ND	*
DDE	0.03	ND	ND	*
Dieldrin	0.03	ND	ND	17
Endrin	0.03	ND	ND	1
Heptachlor	0.03	ND	ND	18
Heptachlor epoxide	0.03	ND	ND	18
Lindane	0.03	ND	ND	56
Methoxychlor	0.03	ND	ND	35
PCBs	0.03	ND	ND	*
Disyston	0.05-0.8	ND	ND	*
Diazinon	0.05-0.8	ND	ND	*
Ronnel	0.05-0.8	ND	ND	*
Dursban	0.05-0.8	ND	ND	*
Malathion	0.05-0.8	ND	ND	*
Sumithion	0.05-0.8	ND	ND	*
Parathion	0.05-0.8	ND	ND	*
Ethion	0.05-0.8	ND	ND	*
Methyl parathion	0.05-0.8	ND	ND	*
Trithion	0.05-0.8	ND	ND	*
Dasanit	0.05-0.8	ND	ND	*
Acid herbicides	0.09	ND	ND	100

* Not listed in Canadian Drinking Water Standards.

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23. The Ministry of Water Resources and Water Supply of the Victorian State Government, Melbourne, Australia, established a Reclaimed Water Committee to promote and coordinate reuse throughout Victoria.

Since its establishment in 1973, the Committee has concentrated its attention on investigations relating to health aspects, agricultural trials and aquifer recharge studies.

The object of the Committee is to insure that, by the end of this century, the necessary knowledge and expertise is available to enable reclaimed water to be used for any purpose (including domestic use) if required.

Notwithstanding this basic aim, it is the general philosophy of the Committee that in the foreseeable future, reclaimed water should be used for "secondary" purposes wherever possible, thus releasing high quality surface and groundwater to meet domestic requirements.

Apart from carrying out investigations into various aspects of the reuse of water, the Committee believes that it has an important role to play in informing interested individuals and organizations of the latest developments in the field of research and also of investigations being carried out by other groups. To this end, a number of reports have been produced and circulated widely throughout the State. Attempts are currently being made to reach more people by publishing articles in technical journals, etc., but this work is restricted due to a lack of staff.

While the Committee was originally set up to carry out investigations, etc. in Victoria, it is obvious that the results of many of the investigations can be applied to other areas of Australia. Much interest has been generated in other states, in particular Western Australia, South Australia and New South Wales, and close liaison is maintained with experts from these states. Efforts are currently being made to make more formal arrangements with these organizations and to expand the role of the Committee to encompass other states of Australia.

Some 20 reports on reuse activity have been completed or are being planned by the Committee composed of eight senior representatives from state governmental departments.

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24. At its Plenary Session in Dusseldorf, Germany on February 8-9, 1977, the NATO committee on the Challenges of Modern Society (COMS) approved a proposal submitted by the U.S. for a new pilot study on drinking water. The objective of the comprehensive study would be to achieve a better understanding of the drinking water problems that industrialized countries share and to seek solutions to them. The research would include evaluation of existing technology and practice from the point of view of effectiveness, public health protection, practicality, costs, general availability and associated by-product hazards.

The work program to develop a state-of-the-art document includes the following areas:

a. analytical chemistry and data handling

b. advanced treatment technology

c. microbiological assessments

d. health effects

e. groundwater considerations

f. energy conservation

g. data sources

With respect to water reuse, the project will look at epidemiological aspects, appropriate treatment technology and the composition of recycled waters.

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25. The California State Water Resources Control Board (SWRCB) is sponsoring several water reclamation projects in that state with plans to increase needed research demonstration and monitoring activities. Highlights of the seven programs from 1976-78 are as follows:

a. A $1.3 million, 3-year project will be completed by December 31, 1978 on groundwater injection of reclaimed wastewater in Palo Alto, California. The study by the Santa Clara Valley Water District and Stanford University will look at the effects of recharge on groundwater quality with emphasis on trace organics, bacteria, virus, hydraulics and treatment plant performance.

b. In a $36,000, 6-month project, the SWRCB is assisting the Los Angeles County Sanitation Districts in evaluating the feasibility of an epidemiological study in the Montebello Forebay area of Southern California which has been receiving recharged effluents for the last 15 years. The preliminary study, to be completed in December of 1977, will evaluate the feasibility of toxicology, monitoring and health effects research.

c. Orange County Water District received $60,000 in 1977 to evaluate the effectiveness of its new 5 mgd reverse osmosis plant in removing stable organics, reliability of the equipment, and long-term performance. The work will be completed in April of 1979.

d. The University of California at Berkeley will receive $57,000 for a 1-year study of the mutagenic and carcinogenic potential of selected wastewaters in the state using the Ames test.

e. A $100,000, 1-year grant was given to the State Department of Health to establish capability and technical expertise in water virology including occurrence, health significance and treatment removals.

f. To be completed in 1984 is a 7-year, $2.4 million study on food crop irrigation with wastewater in Castroville, California. The benefits and problems of agricultural reuse will be analyzed along with monitoring, soil degradation and epidemiological work.

g. An 8-month, $15,000 feasibility study of agricultural reuse in the Morro Bay Area of California in 1977 indicated the lack of a suitable market for reclaimed water.

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26. Estimates are that by the year 2000, Californians will have a water deficit of 4.6 million acre-feet a year requiring an increased overdraft of groundwaters. In Orange County, a recent report indicated that in 1976, an all time high amount of groundwater was pumped from the basin, levels dropped 5.1 feet during the year to 0.8 feet below sea level and storage decreased by 94,000 acre-feet.

To ease the expected shortage, a comprehensive policy statement and plan of action for encouraging the development of water reuse was adopted on January 6, 1977 by the State Water Resources Control Board (SWRCB). California will implement the program through the administration of the State and Federal Clean Water Grant Program and State Board's authority over water right allocations.

A 55- member task force was formed to assist the SRWCB in the development of the policy and action plan which met over a one-year period to establish the necessary guidelines. The policy states specifically that the State and Regional Boards shall encourage and consider or recommend for funding, water reclamation projects which meet the three conditions below and which do not adversely impact vested water rights or unreasonably impair instream beneficial uses:

1. Beneficial use will be made of wastewaters that would otherwise be discharged to marine or brackish receiving waters;

2. Reclaimed water will replace the use of freshwater or better quality water;

3. Reclaimed water will be used to preserve, restore, or enhance instream beneficial uses, which include but are not limited to, fish, wildlife, recreation and aesthetics associated with any surface water or wetlands.

The Boards will also encourage other agencies to assist in implementing the policy, recognize public health aspects and recommend legislation.

With respect to action, expansion of 208 grants will be encouraged to emphasize water reclamation in planning studies. In reviewing applications for state monies, the SWRCB shall give added consideration to reuse projects. As the SWRCB administers the Water Rights Program, it may, after evaluation of a supply contract, approve or disapprove it subject to conditions requiring reuse.

The State Board could also adopt guidelines for regulating water reclamation in order to assist Regional Boards in the adoption and enforcement of reuse requirements. A combination of research, demonstration and monitoring projects shall be initiated to provide information necessary to develop reclamation criteria and guidelines, evaluate concerns regarding health and environmental impact, and to assess the statewide marketability of reclaimed water.

Public involvement and reuse information is to be stressed with close coordination by the state agencies.

Copies of the formal Policy and Action Plan may be obtained from:

Office of Public Affairs
Calif. State Water Resources Control Board
P.O. Box 100
Sacramento, California 95801

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27. Located on the arid south rim, the Grand Canyon Resort Village has always had a critical water supply. Potable water (0.3 mgd) is lifted 3200 feet over a distance of 12 miles from springs at the Canyon's bottom as no natural source exists at the 7000 foot rim.

In 1926, a rather innovative approach by the Atchison, Topeka and Santa Fe Railway led to the construction of a dual distribution system which served reclaimed wastewater to the community. Dual media filtration and heavy chlorine doses following secondary treatment now result in a product water as follows:

BOD	10 mg/l
SS	10 mg/l
TDS	616 mg/l
Chlorides	200 mg/l
Coliforms-MPN	0
pH	6.9-7.2

Effluent is stored in a 300,000 gallon and 100,000 gallon tank for use. An average of 30,000 gpd of wastewater is used which represents only 7% of the total water demand. The remaining secondary effluent goes to evaporation ponds or is sold to farmers for cattle watering.

The largest single use of the effluent is for flushing public toilets in the older lodges, motels, dorms and cafeterias within the village. This is followed by landscape irrigation, watering of the high school football field, vehicle washing and occasional construction work. Warning signs are posted wherever reclaimed water is available and high chlorine residuals are maintained to discourage human consumption.

The major problem with the dual system has been the deterioration of the now 50-year old distribution piping. If funds become available, the National Park Service is planning to expand its tertiary system and replace the dual piping to serve even a greater area. Last year Grand Canyon experienced a record 3 million visitor-days with a full-time population increase of 6% per year.

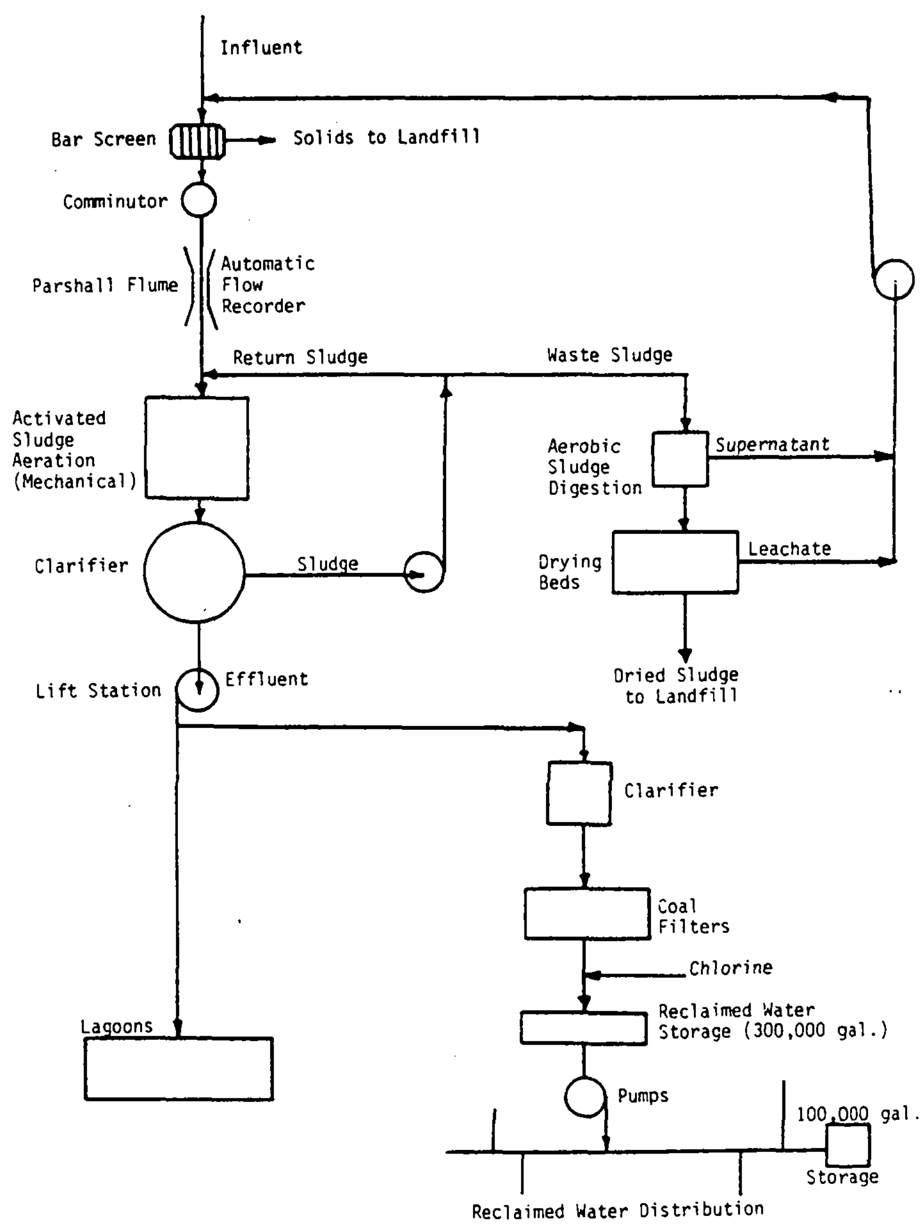
Economics has become an important factor with potable water costing $2.45 per 1000 gallons. Charges for the reclaimed water are $1.00 per 1000 gallons when piped to a point of use where potable water is also available, and $1.75 per 1000 gallons in all other areas. Treatment cost of the wastewater is about $2.77 per 1000 gallons with reclaimed water sales reducing that figure by only 5%.

The National Park Service is aware that its sanitary facilities and designs are always for the most extreme conditions. That is, for the hottest desert, coldest climate, highest point, or inaccessible points on the globe. Thus, conservative approaches have been abandoned to individual systems with unusual characteristics. Water reuse is a necessity at the Grand Canyon and innovative approaches are expected. Figure 20 indicates the simple treatment sequence.

On the north rim of the Grand Canyon, which is only open in the warmer months, a new treatment plant and dual system have been completed to serve growing water demands. The plant employs secondary treatment, chemical clarification in tube settlers and centrifugation to produce an effluent for use in public restrooms, irrigation and fire hydrants.

FIGURE 20

SCHEMATIC DIAGRAM OF WASTEWATER TREATMENT AND RECLAMATION SYSTEM
GRAND CANYON VILLAGE, ARIZONA



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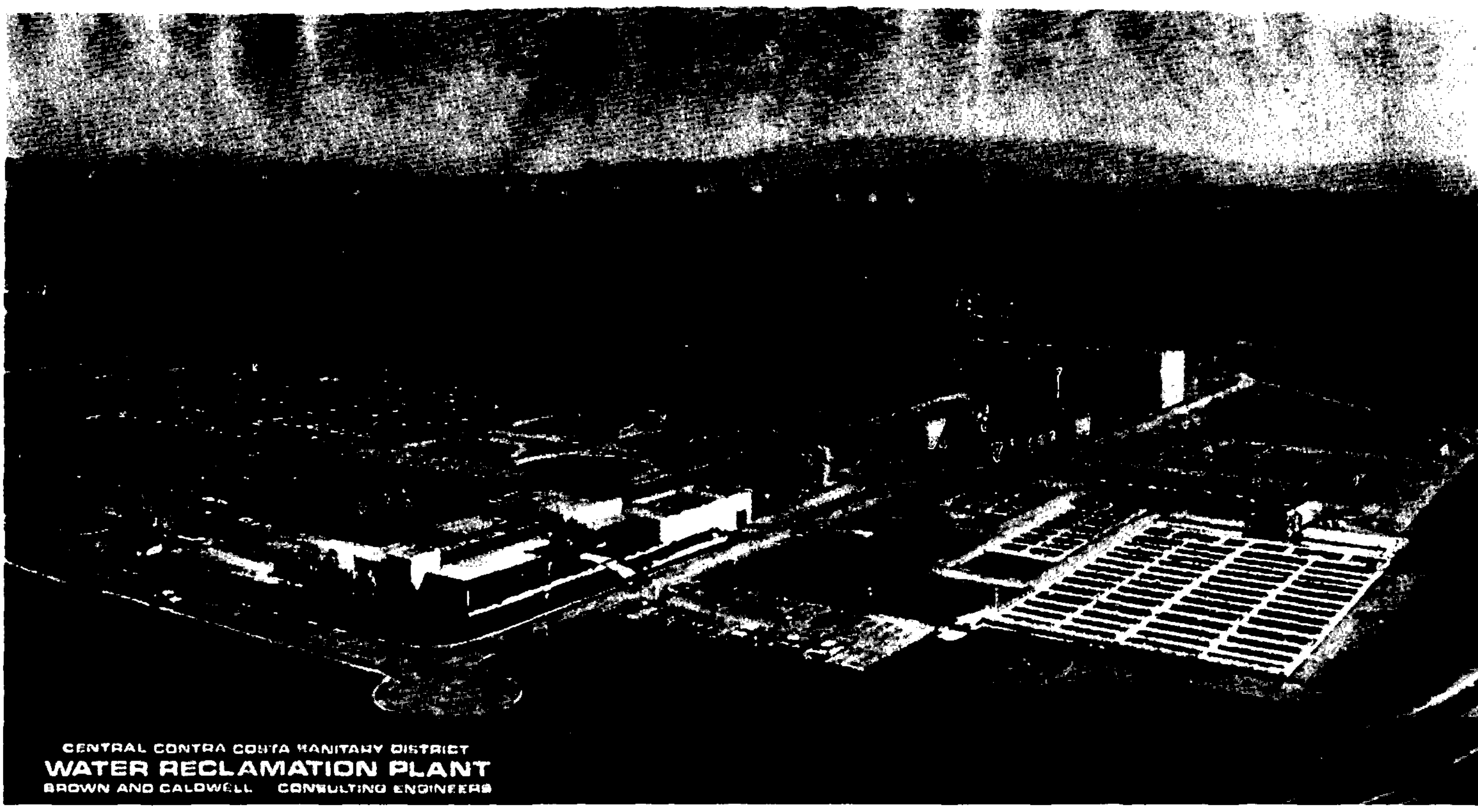
28. Scheduled for completion in 1978, the Central Contra Costa Sanitary District's new AWT plant near Concord, California (see Figure 21) will be the largest water reclamation plant of its kind in the far West, recycling 30 mgd of domestic sewage as cooling and process water for major industries in the San Francisco Bay area. The $47 million plant was designed by Brown and Caldwell Engineers, following two years of extensive research using a full scale test

FIGURE 21

CENTRAL CONTRA COSTA SANITARY DISTRICT'S WATER RECLAMATION PLANT



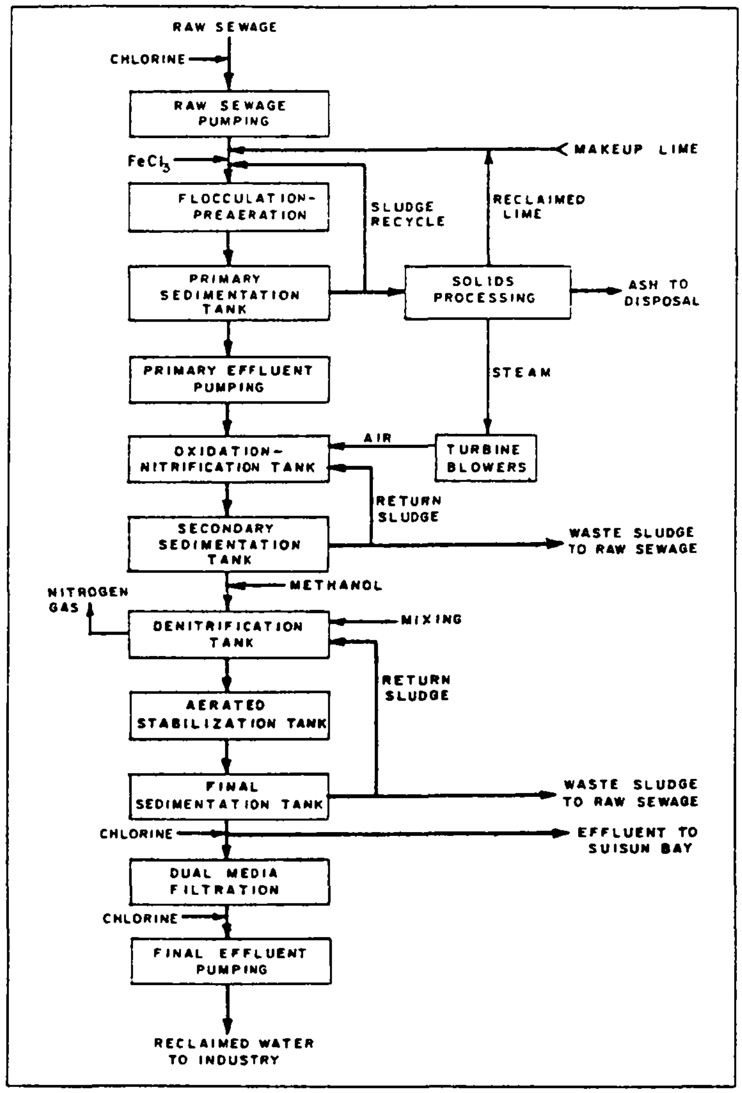
facility at the site. As shown in Figure 22, the new plant was to feature lime clarification, biological nitrification, denitrification, filtration and chlorination. The denitrification requirement was lifted so methanol addition will not be used.

Lime is added to the primary system for phosphorus removal. Dual media filters will provide a polished product to the water district at $4.00 per acre-foot. The CCCSD Water District is currently building a 15 mgd strong-acid-sodium-exchange (SANEX) plant to soften some of the effluent prior to use. Calcium and magnesium will be removed because of the scaling problem. In the spring of 1978, 15 mgd of unsoftened AWT effluent will be served to the following industries:

Lion Oil Company	Stauffer Chemical	Pacific Gas & Electric
Shell Oil	Monsanto Chemical	(2 plants)

FIGURE 22

CCCSD AWT FLOW SCHEME



Eventual expansion of the ion exchange plant to 30 mgd is envisaged with full use of the contracted effluent.

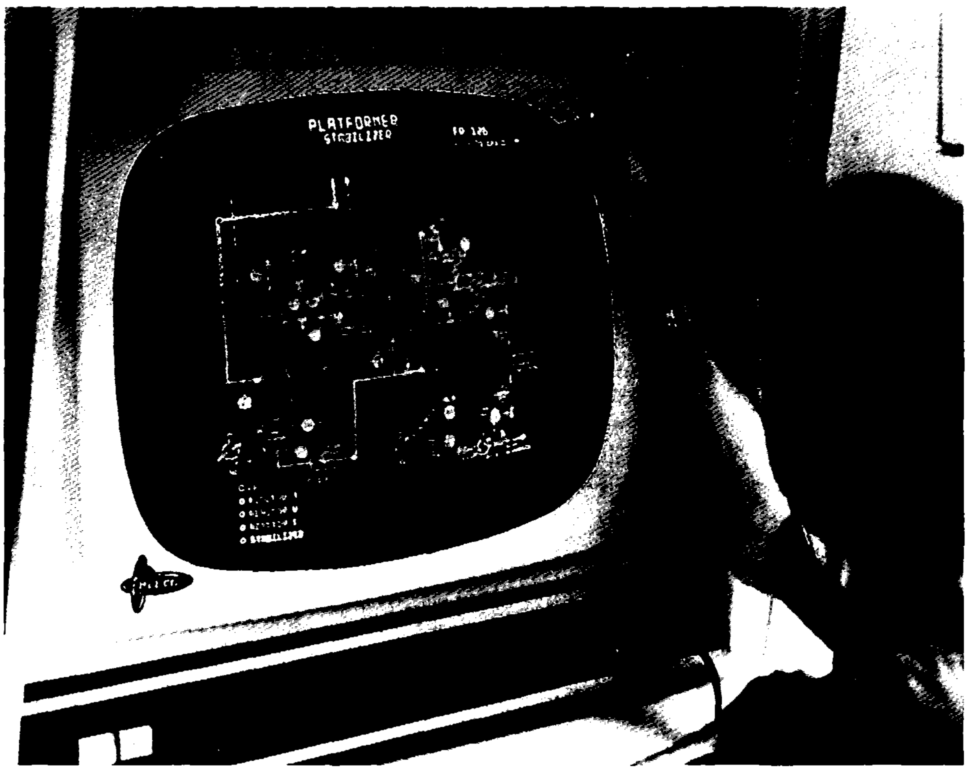
Two large BSP furnaces will incinerate organic sludges and recalcine lime for recycling. Heat recovery as steam is used for the complete heating and cooling requirements of the plant and, in addition, to drive the aeration tank blowers. There are plans and space for four new pyrolysis incinerators for future energy self-sufficiency.

Counter-current vertical bowl centrifuges will classify and dewater the chemical sludges.

Important to the plant operation is the computer control technology employed. Operators have access to an interactive color graphic light pen control system which displays flow schematics on a CRT unit shown in Figure 23. Directing the light pen to specific points on the diagram results in a blow-up and detail of the desired section. Primary and secondary computer control handles plant control and data acquisition, process malfunctions and provides a list of possible causes and recommended action. Direct-digital-control provides for fast retrieval of needed information and the optimization of unit processes is available.

FIGURE 23

ELECTRONICALLY DISPLAYED SCHEMATICS



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29. In order to minimize the launch weight requirements for water, future long-term space flights will reuse water reclaimed from various onboard sources including urine, feces, wash water and/or humidity condensate. NASA's Johnson Space Center in Houston, Texas has the responsibility of developing that recycling hardware and accompanying health effects research.

A Space Station Prototype Environmental Thermal Control and Life Support System (SSP) research program was conducted by NASA from 1970 to 1974 to determine process selection for recycling of water on manned space flights. The program imposed upon the evaluated process techniques strict requirements of materials selection, component commonality, maintainability, fail-safe operational modes, reliability and modular design. Subsystems were also required to interface with an onboard data management system.

The processes selected were of key importance because of the major regenerative systems needed on extended space missions. Water recycling offered the largest potential weight savings. All previous flights have used either stored or in-flight water produced from fuel cells.

Vapor compression distillation (VCD) was selected for the task of water recovery from crew urine, urinal flush water, atmospheric revitalization subsystem condensate and wash water concentrate. The projected flight version treatment unit for a 3-man crew weighs 150 pounds, consumes 10.5 cubic feet of space and uses 130 watts of power.

A small waste tank can receive up to 40 pounds of wastewater before the system is automatically activated. Metering pumps feed the liquid at a rate of 16 pounds per hour into the still for boiling. Condensation takes place on a wall common with the evaporation for greater heat efficiencies. Remaining evaporator waste is removed to the recycle tank.

Condensed water leaves the still, passes through the conductivity sensor, the combined bacteria and activated carbon filter, the silver chloride column and enters a potable water storage tank. If conductivity of the product water exceeds 50 μmhos/cm, it is recycled for reprocessing.

Post-treatment is actually accomplished through a series of three beds; a 0.5 micron pore size bacteria filter protected from backgrowth with AgCl a double pass carbon column and a packed bed of AgCl to provide a sterilization dose of 1.0 to 1.4 ppm Ag^+. Replacement intervals for the multi-bed system is 30 days or more.

A series of tests were run on an actual pilot system to reproduce the spacecraft waste fluid production profile over a 10-day period. The treated water production rate from urine and flush water showed a decreasing rate with increasing solids concentration. The distillation unit was operated at 59.7% solids concentration which corresponded to a 98% water recovery.

NASA has also contracted with Spectrix Corporation to perform the following tasks:

1. Develop a program leading to the formulation of Reuse Water Quality Standards for aerospace applications that will qualify the water for human consumption, with particular emphasis on trace organics and potential toxicological significance.

2. Continue to characterize, identify and quantify potentially toxic and adverse taste producing organics in the reclaimed water.

The water produced by the treatment system is typically analyzed to determine its acceptability as compared to existing water specifications. Those specifications, however, were developed for finished waters whose sources are relatively free of organics. As a result, the existing terrestrial standards do not sufficiently consider organics. In particular, a gross total such as TOC or COD is stated rather than specific compounds which leaves a deficiency for space application.

Spectrix is proposing that a different approach be used in the formulation of reuse water standards since the program schedule will not permit either the time or the cost of the development of years of real use experience.

Several background facts are evident in the overall picture. Water supplies for long duration spaceflights need to be as wholesome and acceptable as those provided municipalities conforming to existing standards which are not applicable to NASA.

Interim aerospace standards were proposed in 1964. Prior to that, the only standards available were those developed by the USPHS in 1946 and 1962. In 1967 an Ad Hoc Committee of the Space Science Board of the National Academy of Sciences recommended a set of water standards for space applications.

All of the previous standards are insufficient because they were not the product of a comprehensive program based on the most thorough and up-to-date knowledge available.

The quality of the raw feedstock for space flight water reclamation systems is obviously different from municipal supplies. The water will be recycled through the human body many times providing opportunity for concentration of trace materials.

On the other hand, a number of EPA or USPHS limits have been based on considerations of potential lifetime accumulated doses or have had reference to complete populations including infants, aged or infirm persons with minimal resistance. Presumably, space travelers will be healthy, robust adults and the period of ingestion will not exceed a few years. The relaxation of a number of existing requirements for chemical quality can therefore be considered without significant deterioration of wholesomeness.

Another important distinction is that municipal standards are operating standards to be employed on water as it is being distributed. In these circumstances, it is possible to allow occasional failure and still meet requirements fully, provided the failure is not of great magnitude and prolonged in time. Possible adjustments in space flight will be limited, and the same source of water must be used whether it meets standards or not.

Performance testing of an actual system is required over extended periods to note any deteriorations in quality or to achieve a steady-state operation.

The severe stresses of a long space voyage in closely confined quarters should not be increased by any objectionable appearance, odor or flavor in the water supply. Lack of adequate palatability will tend to discourage normal intakes of water and subsequently decrease health and vigor.

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INDEX TO WATER REUSE HIGHLIGHTS

AWWA Research Foundation
6666 West Quincy Avenue
Denver, Colorado, 80235