WASTEWATER REUSE FOR POTABLE AND NONPOTABLE PURPOSES: A REGULATORY VIEWPOINT

James Crook
Senior Sanitary Engineer

California Department of Health Services
2151 Berkeley Way
Berkeley, CA 94704

Presented at
American Water Works Association Annual Conference
Kansas City, Missouri
June 14-18, 1987

WASTEWATER REUSE FOR POTABLE AND NONPOTABLE PURPOSES: A REGULATORY VIEWPOINT

James Crook
Senior Sanitary Engineer

California Department of Health Services
2151 Berkeley Way
Berkeley, CA 94704

INTRODUCTION

The reuse of domestic wastewater has been practiced for many years in the United States and elsewhere in the world. In the past, the majority of the reuse occurred in arid or semi-arid regions having limited water supplies. In recent years, however, reclaimed water has been recognized as a valuable resource, and, as water demands increase and environmental and public health concerns make effluent disposal less acceptable, the reuse of wastewater will increasingly be viewed as an attractive alternative to disposal in areas not subject to existing water shortages.

There are no federal regulations or guidelines pertaining to wastewater reclamation: hence, the regulatory burden rests with the individual states. This has resulted in widely differing standards, and many states do not have any standards for the use of reclaimed water. California has had regulations governing wastewater reuse for over 50 years, and this paper discusses the current health-related regulations and other policies and guidelines pertaining to various types of wastewater reuse.

Untreated sewage contains both microbiological and chemical agents, generally in higher concentrations than found in natural waters. The two major factors affecting wastewater reuse are economics and health protection. Therefore, health agencies play an important role in wastewater reuse in an effort to assure that wastewater treatment, effluent quality, and use practices are sufficient to adequately protect public health. It is not uncommon for health agencies to be viewed as hindering or preventing various types of reuse due to their regulations or policies. This paper will address some of the common criticisms and misconceptions pertaining to health agencies, particularly as they relate to the California situation. Some of the criticisms leveled against health agencies in the past have been valid, while some are misconceptions that may be based, in part, on poor communication between health officials and reuse advocates. Some of these criticisms are as follows:

- o Health agencies do not support wastewater reuse.
- o Health-related standards represent "barriers" to reuse.
- o Health-related regulations are overly conservative, represent a zero risk, and have no rational basis.
- o Health-related standards represent a "moving target" and tend to become more restrictive with time.
- o Health agencies oppose all forms of potable reuse.

IMPETUS FOR REUSE

There are many reasons why water reuse is increasing in the United States. Factors include: opportunity; need; availability and reliability of supply; economics; acceptance (both public and regulatory agency); pollution abatement; and successful experiences at existing reuse operations. A more detailed discussion of these factors is as follows:

Opportunity - Historically, most reuse operations were located in areas close to the existing treatment plants for uses not requiring additional treatment and where the need for extensive transmission pipelines was unnecessary. Under such conditions, reuse is more opportunistic in nature than the result of a well-planned program to supplement or replace the use of potable water for nonpotable purposes. Of course, such opportunistic reuse is dependent on other factors, such as availability of supply, economics, acceptance by regulatory agencies, etc.

Need - Reclaimed water may be the only feasible way of supplementing water resources in areas where additional freshwater resources are not available. Health-related regulatory agencies are more likely to approve high-order types of reuse, that is, uses involving ingestion or intimate contact with the reclaimed water, if there is a demonstrated need for the water. It is prudent public health practice not to expose the public to additional (and, perhaps, undetermined) risks in the absence of a demonstrated need to do so.

Economics - With the ever-increasing costs of treating and distributing potable water, reclaimed water is often the most economical option for increasing water resources in a community. The incremental cost of upgrading wastewater treatment, if any, and providing reclaimed water for many nonpotable uses is generally lower than the cost of providing the same quantity of potable water.

<u>Pollution abatement</u> - Population increases, identification of environmentally sensitive areas, public awareness, and more restrictive state and federal discharge standards all contribute to costly treatment for discharge to receiving waters. In some cases, discharges are being prohibited. Reuse may be less costly than treatment for disposal of the effluent and often offers an expedient approach to pollution abatement. Under such conditions, reuse has the advantage of not only providing an additional water supply, but it also reduces overall costs to the community and eliminates a source of contamination in surface waters.

<u>Availability and reliability of supply</u> - Neglecting minor interruptions in service due to breakdowns at sewage treatment plants, inability to meet water quality standards, etc., reclaimed water customers are assured of receiving their allocation of water. Interruptions in the production of reclaimed water are usually very short-term and can be overcome by providing adequate treated water storage facilities or by having an alternative source of water for emergency situations. In fact, the reclaimed water supply may be more reliable than the freshwater supply in times of water shortage.

<u>Public and regulatory acceptance</u> - Public acceptance is closely related to acceptance by regulatory agencies. The public strongly supports wastewater reuse for many nonpotable purposes if they are assured that the reuse will not present unreasonable health risks. Consequently, they rely heavily on the regulatory agencies' determination of the safety of the various types of reuse. Public awareness of the advantages and risks associated with wastewater reuse is crucial for widespread acceptance and implementation of wastewater reuse.

<u>Successful experiences</u> - While research and pilot studies provide useful and necessary information on many types of reuse, the ultimate test is a full-scale operation. Long-term projects answer many questions that can't be otherwise answered. (For example - Are there any long-term adverse effects of agricultural reuse? Has the public accepted the reuse project? Is the reclaimed water supply reliable and consistently of adequate quality? Have their been any measurable adverse health effects?) Successful experience at existing reuse operations in California and elsewhere has undoubtedly led to the implementation of many new projects and will continue to do so in the future.

REGULATORY ROLE

Health agencies support reuse for many of the above reasons. Properly designed and operated reuse facilities have many advantages and, if an adequate level of health protection is provided, it would be irrational not to support wastewater reuse. However, reluctance of health agencies to actively promote or support reuse through research or economic assistance is often incorrectly viewed as an opposition to reuse. These activities are properly the responsibility of water quality control and water resources agencies. In California, the Department of Health Services (DOHS) does not have the authority or economic resources to fund research or projects but is an active participant in the planning and evaluation process.

The absence of definitive regulations for a particular type of reuse may be interpreted as a prohibition of that type of reuse. This may be a correct interpretation in some cases. For example, the absence of regulations addressing direct potable reuse accurately indicates current opposition to this type of reuse by regulatory agencies. On the other hand, lack of regulations addressing many types of nonpotable reuse, e.g., industrial uses, construction uses, fire protection, and snow-making, is not meant to imply that those types of reuse are not acceptable. It is not practical to address every type of reuse in the regulations. Due to the variable nature of some types of reuse, it may be more appropriate to evaluate specific proposals on a case-by-case basis. However, as specific types of reuse not currently included in the regulations become more widespread, discrete criteria likely will be developed. The fact that wastewater reclamation criteria exist in many states and that planned reuse is occurring in other states not having discrete reclamation standards implies that regulatory acceptance is growing for many types of reuse.

California has long recognized the benefits associated with wastewater reuse. The State Legislature has declared that "a substantial portion of the future water requirements of this state may be met economically by beneficial use of reclaimed water", and that "it is the intention of the Legislature that the state undertake all possible steps to encourage development of water reclamation facilities so that reclaimed water may be made available to help meet the growing water requirements of the state" (1).

Many agencies may be involved in regulating water reuse, including: U.S. Environmental Protection Agency; state and local health departments; state, regional, and local water pollution control agencies; water resources agencies; air pollution agencies; fish and game agencies; state and local water conservation districts; and food and agriculture-oriented agencies. While each of these agencies may have policies or regulations affecting proposed wastewater reuse projects, the acceptability of specific projects often is determined by the overriding need to assure that the public is not exposed to unnecessary or unreasonable risks as a result of the reuse operation. It logically follows that, since regulatory controls for health protection in the water area fall under the purview of health agencies, it is the health agencies that play a major role in assessing the acceptability of the various types of water reuse.

It is difficult to quantify the health risks associated with reuse. For nonpotable reuse, the principal concern is pathogenic organisms (bacteria, protozoa, helminths, and viruses) in the reclaimed water, while the principal concern associated with potable reuse is organic constituents and treatment reliability. The inability to justify criteria with definitive risk assessments based on hard data results in public health officials imposing criteria that often are viewed as being overly conservative and unnecessarily costly. It should be realized that sound public health policy dictates prudence in the face of uncertainty. It would be inappropriate and irresponsible for health agencies not to take a conservative approach.

It is true that health-related reuse standards do not specifically address economic feasibility. Conventional public health philosophy reasons that the level of health protection should not be determined strictly by economics. Health departments are unlikely to make reclamation criteria less restrictive merely to make projects cost-effective. Unfortunately, there are projects that are not implemented due to the economic infeasibility of meeting appropriate treatment, quality, or use area standards or controls. As a result, the unwillingness of regulatory agencies to compromise health in order to make a project cost-effective is often incorrectly called a "barrier" to reuse. Reclamation criteria could more properly be called "barriers" to misuse.

It is commonly assumed that the health-related regulations pertaining to water reuse always represent the most conservative public health viewpoint. This is not true. As with any organization, there is a wide range of opinions and views within health agencies, and water reclamation criteria represent compromises and balanced positions based on input from a wide variety of experts. For example, the California Department of Health Services' wastewater reclamation regulations were developed with input from the Department's Sanitary Engineering Branch, Sanitation and Radiation Laboratory, Infectious Disease Section, Viral and Rickettsial Disease Laboratory, Epidemiological Studies Section, Microbial Disease Laboratory, and Food and Drug Branch, in addition to extensive input from other technical experts and engineering professionals.

NONPOTABLE REUSE

The early history of public health in the environmental field has been one of efforts to provide safe water supply and safe disposal of sewage. With sewage disposal, the first efforts were directed at eliminating indiscriminate discharge of raw sewage to the environment and at providing sewage treatment. These efforts progressed to providing higher degrees of treatment; in particular, biological oxidation to restore receiving waters to aerobic conditions and chlorination of effluents to protect against the grossest health hazards from public contact with recreational waters.

Standards for acceptable performance evolved from these practices - standards which represented good practice, which could be attained by well designed and operated plants, and which were validated by indications that the resulting conditions were no longer producing epidemic disease. Therefore, standards evolved as a part of the process of cleanup of major public health hazards associated with domestic water supply and community waste disposal.

The evolution of regulations pertaining to sewage reclamation in California followed the same pattern. The first standards adopted by the State Board of Health in about 1918 prohibited the use of raw sewage for crop irrigation and limited the use of treated effluents to irrigation of non-food crops. As wastewater reclamation became more prevalent both in the number and type of reuse applications, more restrictive standards were established for more critical kinds of use. In 1933 the regulations were modified to allow sewage to be used on food crops. In each instance the standards were developed on the basis of attainability and "good practice" and, in each case, was associated with efforts to strictly limit public health risks from sewage reclamation. The standards represented a response to reducing existing or potential risks.

With an increasing demand for water, wastewater began to be viewed as a valuable resource, and it became necessary to develop wastewater reclamation standards on the basis of assuring a reasonable degree of health protection. In the declaration of policy of the Wastewater Reclamation and Reuse Law of 1967 (2), the State Department of Public Health (now Department of Health Services) was given the authority and responsibility to establish statewide reclamation standards and did so for uses involving irrigation and impoundments. The Department's regulations, which are entitled "Wastewater Reclamation Criteria" (3), were most recently revised in 1978.

Wastewater Reclamation Criteria

Clearly, most wastewater reclamation and reuse operations impose a greater risk than would the use of unpolluted waters of non-sewage origin. The health concern is in proportion to the expected degree of human contact with the water, the quality of the effluent, the reliability of the treatment processes, and controls at the reuse sites. A basic objective of the Wastewater Reclamation Criteria is to assure health protection without unnecessarily discouraging wastewater reclamation.

The literature is replete with information on pathogenic organisms that may be present in wastewater, their associated diseases, their survival times in the natural environment, and suspected or confirmed waterborne disease outbreaks. Disease can be transmitted to humans either directly by contact, ingestion, or inhalation of infectious agents in reclaimed water, or indirectly by contact with objects or ingestion of food previously contaminated with reclaimed water. For the purposes of this paper, it is sufficient to state that many types of bacteria, parasites, and viruses are capable of surviving for extensive time periods in water, soil, and on vegetation, and such pathogens present a health risk during the reuse of water if they are not controlled or, in some cases, eliminated.

The regulations specify wastewater reuse standards for uses involving irrigation, impoundments, and groundwater recharge. As previously stated, it should not be inferred that types of reuse not mentioned in the regulations are not acceptable. Other types of reuse are evaluated on a case-by-case basis. The Wastewater Reclamation Criteria include water quality standards, treatment process requirements, sampling and analysis requirements, operational requirements, and treatment reliability requirements. The treatment and quality criteria for irrigation and impoundments are shown in Table 1. The reliability requirements address the need for alarms, standby power supply, emergency storage or disposal, standby replacement equipment, unit process reliability, elimination of bypassing, and flexibility of design. The reclamation criteria are directed at disease transmission and do not address potential adverse effects of reclaimed water on crops, soil, or aquatic habitats.

As indicated in Table 1, there are four levels of wastewater treatment specified in the reclamation criteria. The required degree of treatment increases as the likelihood of human exposure to the reclaimed water increases. If there is no expected contact with the reclaimed water, the regulations are very liberal and allow the use of primary effluent. Uses for which primary effluent is acceptable include fodder, fiber, and seed crop irrigation and the surface irrigation of orchards and vineyards. Primary treatment has been allowed for these types of irrigation for many years without demonstrable adverse health effects, although information from other countries indicates that the use of low quality effluent has, in some cases, resulted in increased levels of parasitic infections in grazing animals.

If a negligible degree of direct contact, or infrequent indirect contact, is expected, such as at golf courses, cemeteries, or freeway landscapes, the effluent should not contain high numbers of pathogens. Hence, DOHS determined that an oxidized wastewater not exceeding a 7-day median total coliform concentration of 23/100 ml would not impose undue health risks. The total coliform bacteria group is used as the indicator of disinfection effectiveness for several reasons: total coliform bacteria are present in municipal wastewater in greater numbers than pathogens; total coliform bacteria are more resistant to disinfection than many (but not all) pathogens; the test for total coliform bacteria is simple and inexpensive; and the concentration of total coliform bacteria in domestic wastewater roughly parallels the hazard.

A criticism of the use of total coliform organisms as an indicator of fecal contamination is that the intestine of warm-blooded animals is not the sole source of the organisms - they are found in large numbers in nature from sources unrelated to domestic wastewater or human activity. This is not a particular drawback when total coliforms are used in domestic wastewater to measure disinfection effectiveness. Fecal coliform bacteria typically comprise 30-35 percent of the total coliform content, although individual treatment results may vary greatly. While fecal coliforms are a better indicator of sewage contamination in rivers and streams, the total coliform level in wastewater is a more conservative measurement of disinfecton effectiveness.

If casual contact with the reclaimed water is expected, such as at recreational lakes allowing boating and fishing, or if there is occasional contact between the wastewater or contaminated soil and food crops sold or eaten raw, a higher level of disinfection is necessary. An oxidized wastewater not exceeding a 7-day median coliform concentration of 2.2/100 ml, while not assuredly pathogen-free, is unlikely to contain significant concentrations of pathogens _if_ a high quality secondary effluent is produced prior to disinfection. It is noteworthy that viruses have been detected in disinfected secondary effluent when both fecal and total coliform organisms were not detected (4). It cannot be argued that these two intermediate levels of treatment were selected somewhat arbitrarily. They were based on attainability, experience, and the judgment of public health and engineering professionals that the coliform levels assured an adequate level of protection for the intended uses of the reclaimed water. The specific numbers, 2.2 and 23/100 ml, were selected because they are reportable numbers using the Most Probable Number (MPN) test. They are not definitive threshold levels justified by rigorous documentation and evaluation of illness rates.

If intimate direct contact with the reclaimed water is expected, such as swimming, or indirect contact is likely, such as eating produce spray irrigated with reclaimed water, the regulations specify treatment and water quality requirements intended to produce an effluent that is free of measurable pathogens, including viruses. A fundamental decision was made that the standard to be applied was to be the total absence of any enterovirus, based on the assumptions that very low numbers of virus can initiate infection and wastewater treatment processes assuredly controlling enterovirus would without question be free from any human pathogen and thus be a safe water for the intended use.

Selection of the treatment chain specified in the Wastewater Reclamation Criteria to produce a pathogen-free effluent was predicated on studies conducted several years ago to determine the virus removal capability of advanced wastewater treatment processes. More recent studies (5,6) have verified the effectiveness of the treatment chain, which includes oxidation, chemical coagulation, clarification, filtration, and disinfection to a coliform level not exceeding 2.2/100 ml. These studies also indicated that equivalent virus removal can be achieved by direct filtration of high quality secondary effluent, using low coagulant and/or polymer dosages, thereby eliminating the need for high dosages of chemical coagulants and discrete flocculation/clarification unit processes. This abbreviated treatment chain, in conjunction with specific design and operational controls, is acceptable to DOHS even though it is not strictly equivalent from an effluent quality and treatment reliability standpoint to the full treatment chain specified in the regulations.

The Wastewater Reclamation Criteria do not require virus monitoring. The identification and enumeration of viruses in wastewater is hampered by the lack of standardized sampling and analytical procedures, relatively low virus recovery rates, the complexity and high cost of laboratory procedures, and the limited number of facilities having the personnel and equipment necessary to perform the analyses. Furthermore, the laboratory culturing procedure to determine the presence or absence of viruses in a water sample takes about 14 days, and another 14 days are required to type (identify) the viruses. A more complete discussion of the Wastewater Reclamation Criteria is provided in an article by Crook (7), entitled "Water Reuse in California", in the July 1985 Journal of the American Water Works Association.

In the absence of an ability to make definitive risk assessments based on specific levels of indicator organisms, the reclamation criteria were based on the capability of well-designed and operated wastewater treatment plants to consistently attain specific effluent quality limits, experience at existing wastewater disposal and reuse operations, and the desire not to allow unreasonable or unknown risks due to the use of reclaimed water.

It is not possible to ascribe numerical risk estimates to the reclaimed water use with any degree of confidence. Factors that influence risk estimates include: treatment provided; treatment reliability; concentration of indicator organisms; estimate of pathogen concentration in the reclaimed water; pathogen die-off rates in the environment; degree of human exposure to the reclaimed water; and the mechanisms of disease transmission, e.g., infective dose, organism virulence, and susceptibility of host. There are information gaps and limitations associated with most of these factors. No indicator organism or group exhibits all of the desirable characteristics to accurately predict the presence of pathogens. There are few data available documenting the ratio of pathogens to indicator organisms in the environment. For some organisms there is virtually no dose-response data, and there is little agreement on the risk associated with the low concentrations of pathogens that are most likely to be present in reclaimed water that has received secondary or tertiary treatment, including disinfection. In addition, the degree of exposure may vary widely among individuals at use areas.

Epidemiological studies of the exposed population at water reuse sites would be of limited value because of the mobility of the population (and, hence, the ability to obtain meaningful data), the small size of the study population, the difficulty in determining the actual level of exposure of each individual, the low illness rate - if any - resulting the reuse practice, and insufficient sensitivity of the current epidemiological techniques to detect low level disease transmission. It is particularly difficult to detect low level transmission of viral disease because many of the viruses cause inapparent infections that are difficult to recognize as waterborne, and most enteric viruses cause such a broad spectrum of disease syndromes that scattered cases of acute illness would probably be too varied in symptomology to be attributed to a single etiological agent. A person with an inapparent infection may exhibit only mild symptoms or none at all, yet can be an effective carrier and transmit the virus to others, who may then develop acute symptoms of the disease.

One of the common criticisms of DOHS's Wastewater Reclamation Criteria is that the requirements are too restrictive and overly conservative. It cannot be argued that the treatment and quality standards, for the most part, are conservative. However, they do not attempt to represent a zero risk. They are not overly conservative for the following reasons:

- o The infective dose of some pathogens may be as low as one organism, and medical experts within DOH recommend that contact with wastewater containing pathogenic agents should be avoided, yet casual contact with reclaimed water that is not pathogen-free is allowed for some types of use.

- o The coliform group is known to be less resistant to chlorine disinfection than some pathogenic organisms.

- o There have been instances where the total coliform test has not indicated the presence of waterborne pathogens.

- o The coliform limits are based on a running 7-day median value, which allows for a considerable fluctuation in the degree of disinfection.

- o The precision of the MPN coliform test is not of a high order. For example, the lower and upper 95 percent confidence limits for an MPN of 23/100 ml are 9/100 ml and 86/100 ml, respectively.

- o All treatment plants are subject to fluctuations in treatment and, since coliform sampling is required only once a day, it is likely that substandard water is reused at one time or another at almost every reuse operation - even when sampling indicates that the appropriate requirements are being met.

- o The standards are based on proper use area controls-controls which are not always implemented by the operating agency.

There have been instances when criteria have been recommended that are more restrictive than those specified in the Wastewater Reclamation Criteria. In those cases, reclaimed water used for landscape irrigation could not be confined to the designated use areas, and direct or windblown spray reached populated areas or property not controlled by the user. Therefore, DOHS has taken the position that an effluent free of measurable pathogens is necessary in such situations. This position does not apply if it is determined that reclaimed water spray or runoff not confined to the use area will not result in significant human exposure to the water.

The argument has been made that nonpotable reclaimed water should be acceptable if it meets a geometric mean fecal coliform level of 200/100 ml, as previously recommended by the U.S. Environmental Protection Agency for recreational (bathing) waters (8). The added gastrointestinal illness rate at this fecal coliform level has been calculated to be 8 illnesses per 1000 swimmers at freshwater beaches and 19 illnesses per 1000 swimmers at marine beaches (9). It has been stated that the public has accepted this illness rate. This public acceptability is inferred, perhaps incorrectly. There is no indication that the public has knowledge of the illness rate in such situations, and the public may consider 8 illnesses/1000 swimmers to be an excessive rate. Illness rates of this magnitude resulting from the use of reclaimed water would, in DOHS's opinion, present an excessive, unreasonable, and unacceptable risk. Similarly, the use of the 200 fecal coliform level as a disinfection standard can be questioned regarding its ability to provide an assured level of protection from viral pathogens.

The Wastewater Reclamation Criteria include a requirement that an engineering report be prepared prior to implementation of a project. The report requires detailed information documenting measures to insure compliance with the criteria and DOHS use area guidelines, and it requires certain management aspects of the reuse operation to be addressed. Management is a critical factor and has a strong influence on regulatory decisions. Unfortunately, management is a neglected aspect of many reuse operations, and comprehensive guidelines are needed in this area. Publications such as AWWA's "Dual Distribution Systems" manual (10) can be an effective vehicle in addressing management needs and disseminating information on a national level.

POTABLE REUSE

Indirect Potable Reuse

Unintentional indirect potable reuse has been occurring for many years in the United States and elsewhere. Unplanned reuse results from the discharge of wastewater into watercourses used as sources of drinking water, disposal of wastewater via percolation ponds to potable water supply aquifers, migration of septic tank leacheate to surface or groundwater, etc. However, it should not be assumed that no harmful effects are resulting from these practices. The fact that unplanned potable reuse is occurring does not signify that it is a desirable situation without risk. Definitive health effects studies have not been conducted in those areas where incidental reuse is occurring, and sound scientific data do not exist to support the contention that there are no resultant adverse health effects. Certainly any effects would be subtle and difficult to detect.

The California Department of Health Services recommends against wastewater discharges to freshwater streams used for domestic water supply. However, DOHS recognizes that there are situations where it is not possible to prevent discharges to streams and has developed guidelines (11) to address such situations. Wastewater disposal to domestic water supply sources is acceptable under certain conditions because: a high degree of dilution (the minimum acceptable ratio of diluting water to effluent is 20:1) reduces but does not eliminate the risks; natural stream purification processes provide some benefit; extensive treatment of the raw water, which would be required, provides a further barrier to pathogenic organisms and reduces the concentration of sewage-associated organics; and there are no economically feasible wastewater disposal alternatives. It is important for regulatory agencies to consider water resources planning and management when evaluating wastewater discharge proposals and fully consider all risks and benefits during the decision-making process.

Indirect potable reuse via groundwater recharge is a different matter. In California, DOHS has the responsibility to develop criteria for reclaimed water used to recharge potable water supply aquifers through planned groundwater recharge operations. Ideally, regulations directed at groundwater recharge would include provisions for septic tank systems, community land disposal systems (pond or spray), irrigation with wastewater, and wastewater discharges to rivers or dry stream beds which recharge groundwater basins. While these operations may affect drinking water supplies, they generally result in a very limited amount of wastewater entering the groundwater, e.g., septic tank systems, or wide dispersion within the underground basin, e.g., agricultural irrigation. Conversely, effluent discharges to dry stream beds could result in relatively high quantities of wastewater being recharged. Unfortunately, DOHS does not have the authority to regulate incidental or unplanned recharge resulting from effluent disposal, and an inconsistency becomes apparent. Planned groundwater recharge operations may be subject to more stringent regulatory control than unplanned recharge that also may result in significant quantities of wastewater percolating into potable water supply aquifers. The inconsistency relates to the issue of regulatory control of the different types of recharge and is not indicative of a lack of concern for unplanned recharge that is occurring.

In 1973, the Department of Health Services prepared a position statement (12) directed at augmentation of domestic water sources with reclaimed water. The rationale for the position statement stated, in part, that "Health risks from the use of renovated wastewater may arise from pathogenic organisms and toxic chemicals. The nature of the phenomenon associated with pathogens and heavy metal toxicants are well enough understood to permit setting limits and creating treatment control systems. This is not the case, however, with regard to some organic constituents of wastewater. In particular, the ingestion of water reclaimed from sewage may produce long-term health effects associated with the stable organic materials which remain after treatment. This is an area of unknowns - unknowns involving the composition of the organic materials, the types of long-term effects, synergistic effects, metabolite formations, treatment effects, methods of detection and identification, and ultimately, the levels at which long-term health effects are exerted." In regard to groundwater recharge by surface spreading, the position statement recommended that large-scale recharge should be deferred until more definitive health data were forthcoming.

In 1975, the Department of Health Services, Department of Water Resources (DWR), and State Water Resources Control Board (SWRCB) jointly prepared a state-of-the-art report (13) on the health aspects of wastewater reclamation for groundwater recharge and convened a consulting panel of recognized health and water experts. The panel concluded, among other things, that: (a) there were uncertainties regarding health effects associated with groundwater recharge using reclaimed wastewater which could not be resolved because basic scientific knowledge was lacking, with the principal concern being stable organic materials; and (b) research was needed in several areas to resolve the uncertainties concerning the health aspects of groundwater recharge, including characterization of the contam-inants in reclaimed water and extracted water, assessment of toxicological risks, and epidemiological studies of exposed populations (14).

In 1976, DOHS developed draft regulations for groundwater recharge of reclaimed water by surface spreading that were extremely controversial and were not adopted as statewide criteria. The absence of regulations addressing groundwater recharge was viewed by many as an indication that this type of reuse was unacceptable to the regulatory agencies under any circumstances. In order to alleviate this concern, but at the same time recognizing the inability to set meaningful definitive groundwater recharge standards, DOHS revised the Wastewater Reclamation Criteria in 1978 to include a section addressing groundwater recharge as follows:

> "60320. Groundwater Recharge. (a) Reclaimed water used for groundwater recharge of domestic water supply aquifers by surface spreading shall be at all times of a quality that fully protects public health. The State Department of Health Services' recommendations to the Regional Water Quality Control Boards for proposed groundwater recharge projects and for expansion of existing projects will be made on an individual case basis where the use of reclaimed water involves a potential risk to public health.
>
> (b) The State Department of Health Services' recommendations will be based on all relevant aspects of each project, including the following factors: treatment provided, effluent quality and quantity; spreading area operations; soil characteristics; hydrogeology; residence time; and distance to withdrawal.
>
> (c) The State Department of Health Services will hold a public hearing prior to making the final determination regarding the public health aspects of each groundwater recharge project. Final recommendations will be submitted to the Regional Water Quality Control Board in an expeditious manner."

In an attempt to answer some of the health-related issues associated with groundwater recharge, a Health Effects Study (15) was initiated in 1978 as part of the Orange and Los Angeles Counties Water Reuse Study. The focus of the study, conducted by the Los Angeles County Sanitation Districts (LACSD), was the Whittier Narrows groundwater recharge project, located in the Montebello Forebay area of Los Angeles County. The primary goal of the five-year $1.4

million study was to develop a data base which will enable health and regulatory authorities to determine whether the use of reclaimed water for groundwater replenishment at Whittier Narrows, which began in 1962, should be maintained at the present level, cut back, or expanded.

A wide range of research tasks were undertaken to meet these objectives, including water quality characterizations, toxicological studies, percolation studies, hydrogeological studies, health surveys, and epidemiological studies. The final report of the Health Effects Study was published in March 1984. LACSD concluded that the Whittier Narrows groundwater replenishment project did not demonstrate any measurable adverse impact on the area's groundwater or the health of the population ingesting the water. Although the Health Effects Study represents the most comprehensive research performed to date pertaining to the health aspects of indirect potable reuse via groundwater recharge, questions remain regarding the possible impact on health.

An argument could be made against the Health Effects Study recommendation that expansion of the use of reclaimed water should be implemented at the present level of treatment for the following reasons:

- The validity of some of the study's findings and conclusions is based on the estimated amount of reclaimed water in the groundwater. This, in turn, was based on an empirical model which used sulfate in Colorado River water as the tracer of groundwater movement. The model was based on data obtained from 1954 to 1970. Therefore, the percentage of reclaimed water extracted at the wells was estimated using indirect methods and may or may not be accurate.

- The 20-year average percentage of reclaimed water in the extracted well water was estimated to range from 0 to 11 percent, with most wells having a long-term average of less than 5 percent. Any health effects resulting from such a low level of consumption of reclaimed water may not be detectable using present epidemiological techniques.

- Concentrated organic residues derived from reclaimed water (and other replenishment waters) elicited mutagenic responses in bacterial tests.

- Approximately 10 percent of the organic material present in the reclaimed water and groundwater was identified. The data do not permit an unambiguous judgment regarding whether or not the organic compounds of greatest concern were identified.

- o The use of soil as an effective treatment method during percolation is questionable. As stated in the report: "Results from a pilot percolation study and literature review showed that percolation did not consistently remove trace organics from reclaimed water."

- o It is not clear that the genotoxic assay data, in the absence of other toxicological data, are adequate to serve as a basis for risk assessment. The traditional basis for evaluating safety of specific organic constituents or fractions is the two-year oncogenicity protocol in rodents. More study is needed on the Ames Salmonella Microsome Assay and the mammalian cell transformation assay to establish credibility for the subsequent conclusions regarding the safety of the reclaimed water source.

- o Less than 50 percent of the study population have resided there for more than 10 years, complicating interpretation of health survey and epidemiological study data.

- o Most cancers take 15 years or more to manifest themselves. Extracted water from many of the wells did not contain any reclaimed water until several years after recharge began, and very few wells have received significant quantities of reclaimed water for an extended time period.

- o If any risk did exist, it would be small. It is not surprising, then, that the epidemiological study and health survey did not correlate disease with consumption of reclaimed water. It is stated in the Health Effects Study report that "While the results suggest there have been no dramatic changes in disease patterns due to water reuse, it cannot be said that potable reuse has had no effect. Rather, it can only be said that the study design and the power of the statistical test were such that no significant difference was detected."

In April 1985, a proposal was made to increase the amount of reclaimed water used for groundwater recharge in the Montebello Forebay by 50 percent - from 33,700 acre-feet per year to 50,000 acre-feet per year. An argument could be made that additional treatment should be required to remove organic constituents prior to recharge to alleviate lingering health concerns or doubts. In fact, an inter-agency health effects advisory committee, which was previously formed by DOHS and SWRCB to advise the state agencies on various matters involving wastewater reuse, recommended that any increased use of reclaimed water for recharge should receive the additional treatment of carbon adsorption. They also recommended increased water quality monitoring.

Recognizing the uncertainties that will always remain, even after the most intensive scientific investigations have been conducted, DOHS concluded that the Health Effects Study data do not indicate that the reclaimed water has had a measurable impact on the groundwater, and that the proposed increase should not have a measurable impact on domestic wells down-gradient from the spreading area. The Department subsequently commented on the proposal and, contrary to the findings of its advisory committee, stated that additional treatment was not necessary but did recommend a greatly expanded monitoring program. It should be noted that more restrictive requirements can be imposed in the future. DOHS's position on the Whittier Narrows project represented a radical departure from its past policies and has been attacked by some individuals as a weak public health position not consistent with the conventional philosophy of not exposing the public to potential health risks in the absence of a demonstrated need.

It is interesting to note that public attitude studies consistently find that somewhat more than 50 percent of the public is opposed to potable reuse (16), yet there has been no public outcry opposing groundwater recharge at Whittier Narrows. Possible reasons for this apparent lack of concern are as follows: there is a "loss of identity" of the wastewater when it percolates into the underground and mixes with groundwater and, thus, the psychological repugnance associated with drinking treated wastewater is eliminated; the public assumes that groundwater recharge is safe because it is occurring with the knowledge of health officials; the public is aware that there is a potential risk asociated with drinking reclaimed water and accepts the risk; many households drink bottled water because of taste or other reasons and, therefore, are relatively unconcerned about the potable quality of the groundwater; or the public does not know that they are drinking reclaimed wastewater. Whatever the reason, public policy cannot be ignored in any consideration involving potable reuse, and the public should be informed of any potential risks imposed on them.

Faced with an increasing need for water and the optimism generated by the Health Effects Study, it became apparent that more definitive guidance and policies by regulatory agencies were necessary. As a consequence, in 1986 the three agencies most involved in water use in the state, SWRCB, DWR, and DOHS jointly formed a "Scientific Advisory Panel on Groundwater Recharge with Reclaimed Wastewater". The panel was made up of recognized experts in the areas of environmental engineering, groundwater hydrogeology, microbiology, toxicology, epidemiology, risk assessment, organic chemistry, and regulatory functions. The major objectives of the panel were: (a) to define the health significance of using reclaimed water for groundwater recharge to augment domestic water supply; (b) to evaluate the benefits and risks associated with groundwater recharge with reclaimed water,; and (c) to provide detailed background information needed for the establishment of statewide criteria for groundwater recharge with reclaimed water. The final report of the consulting panel is due to be completed this summer, and publication and distribution is scheduled for November of this year. It is hoped that the conclusions and recommendations of the panel will be specific enough to aid the regulatory efforts of DOHS.

The earlier attempt to develop statewide criteria for groundwater recharge with reclaimed water was aborted due, in part, to the fact that the proposed regulations were directed at the worst case situation and it would be virtually impossible for any individual project to comply with all of the requirements. Each recharge area has unique conditions and circumstances, and it would be inappropriate to neglect this fact during the regulatory process. It is anticipated that, upon review and evaluation of the Scientific Advisory Panel's final report, criteria will be developed that are flexible enough to consider site-specific conditions and at the same time contain water quality limits and other requirements that must be met by all recharge operations.

DIRECT POTABLE REUSE

It has always been the policy of the Department of Health Services that public water supplies should be derived from the most protected source, and lower quality water used for less demanding purposes. The drinking water standards are intended to apply to water supplies that have been obtained from the most desirable source and are not intended for application to wastewater used directly as a raw water source.

Application of drinking water standards to reclaimed water in the absence of an ability to adequately define the nature of chemicals present and in the absence of proven treatment reliability is potentially very dangerous, and it is apparent that requirements for constituents not contained in the drinking water standards may be necessary to insure that the water is "pure, wholesome, and potable". It would be inappropriate to suggest that potable water is completely defined by the drinking water standards. Standard setting is difficult, and it is becoming clear that the U.S. Environmental Protection Agency and the States are finding it increasingly difficult to develop meaningful drinking water standards - a situation which will only intensify as analytical techniques become more sophisticated.

It is often stated that reclaimed water can be produced that is superior to many existing treated drinking waters. This comparison is misleading and implies that wastewater is a desirable source of drinking water. The comparison should be made between the sources, e.g., river water vs. raw sewage, and not the final product. It would appear to be more practical and safer to treat relatively unpolluted source waters than to encourage the deliberate use of source waters known to contain significantly greater levels of contaminants.

All waters are subject to contamination. The contaminants can be classified into four general groups: radionuclides; microbiological agents; inorganic constituents; and organic constituents. Quality standards have been established for most inorganic constituents and radionuclides, and treatment and analytical technology has demonstrated the capability to identify, quantify, and control these substances to an acceptable degree. It is generally accepted that available technology is capable of eliminating pathogenic agents from reclaimed water, although reliability is still of concern. However, many unanswered questions remain with organic constituents, due mainly to their potential large number and unresolved human risk potential resulting from long-term exposure to extremely low concentrations.

While it is possible to determine risk and maximum contaminant levels for many individual organic chemicals, the majority of the organic fraction in treated wastewater remains unidentified. In addition, there is a paucity of information regarding synergistic or additive effects of low levels of organics. Clearly, the health effects of a given array of contaminants are the same regardless of their source. However, there are important differences in the circumstances. Chemical contaminants should be identified in existing raw water sources and their effects understood and mitigated as promptly as resources and public policy will allow. Conversely, since direct potable reuse is not yet occurring and should not occur until there is a demonstrated need, research directed at potable reuse should proceed at a deliberate pace, and the possible ramifications associated with such reuse should be fully evaluated.

Extensive research is being conducted in Denver, San Diego, and elsewhere to address some of the unanswered questions. The concentration and health significance of trace organics in drinking water is receiving most of the attention, but equally important are microbiological quality and treatment reliability. Raw sewage contains a wide range of pathogenic organisms, and it is essential that the final effluent be free of all pathogens if it is intended for ingestion. While pilot-plant data indicate that advanced treatment processes can produce reclaimed water that is free of measurable pathogens and contains extremely low levels of organic constituents, it has yet to be proven that full-scale facilities can consistently produce water of that quality. If closed-loop potable reuse systems are to be considered, research should address the possibility of constituent buildup to health-significant levels in the water.

In consideration of the present unknowns associated with potable reuse (including reliability), it would not be prudent to implement direct potable reuse projects unless there is an absolute necessity to do so. Necessity implies that there is a need for additional drinking water, that alternative freshwater sources are not available, and that all feasible measures have been taken to conserve the highest quality water for domestic use.

Typically, the amount of water actually used for drinking is a small percentage of the total water usage in a community. Water conservation measures and wastewater reuse for nonpotable purposes should be encouraged and increased. An advantage of this approach is that less sewage effluent would be discharged to environmentally sensitive areas and rivers, streams, or other bodies of water used as domestic water supply sources. If nonpotable reuse, water conservation, and other measures are fully integrated into water planning and management in water-short areas, the need to consider potable reuse can be delayed for many years.

SUMMARY

Substituting reclaimed water for a wide range of uses that were formerly met by freshwater helps preserve high quality sources for drinking water and decrease the demand for new sources of potable water. Regulatory agencies support nonpotable reuse where public health is not compromised. The many variables associated with disease risk assessment make it virtually impossible to base nonpotable reuse standards on specific risk levels. Reclamation criteria developed in California are intended to mitigate health risks but are not "zero risk" standards.

Reclaimed water has been used successfully to augment underground aquifers via groundwater recharge, and properly designed and operated projects have not been shown to have demonstrable adverse health consequences. Data from recent water quality research and health effects studies are encouraging but inconclusive, and questions remain regarding the long-term health effects of this type of indirect potable reuse. It has not been confirmed that the organic constituent levels present in the reclaimed water used for groundwater recharge at existing operations do not result in chronic health effects.

Direct potable reuse is the subject of intense investigation and many of the health concerns associated with ingestion of reclaimed water are still unresolved. Health agencies support the water quality, treatment process reliability, and health effects research directed at potable reuse, but maintain that such reuse should be deferred until there it has been demonstrated that direct potable reuse will not present unreasonable health risks and there is a necessity to resort to such low quality source waters. Regulatory agencies must err on the side of caution in any consideration involving the possible introduction of contaminants into a public water supply.

REFERENCES

1. California State Water Resources Control Board. "The Porter-Cologne Water Quality Control Act". California Water Code, Division 7, Chapter 7, California State Water Resources Control Board, Sacramento, Ca 1985.

2. California State Water Resources Control Board. "Wastewater Reclamation and Reuse Law". California Water Code, Chapter 6, Division 7, California State Water Resources Control Board, Sacramento, CA, 1967.

3. California Department of Health Services. "Wastewater Reclamation Criteria". Calif. Admin. Code, Title 22, Div. 4, California Department of Health Services, Sanitary Engineering Section, Berkeley, CA, 1978.

4. Vaughn, J.M., et al. "Survey of Human Virus Occurrence in Wastewater-Recharged Groundwater on Long Island". Applied & Environ. Microbiol., 36(1), 47, 1978.

5. County Sanitation Districts of Los Angeles County. "Pomona Virus Study - Final Report". California State Water Resources Control Board, Sacramento, Ca, 1977.

6. Engineering-Science. "Monterey Wastewater Reclamation Study for Agriculture - Final Report". Prepared for Monterey Regional Water Pollution Control Agency, Engineering-Science, Berkeley, CA, 1987.

7. Crook, J. "Water Reuse in California". Jour.AWWA, 77(7), 60-71, 1985.

8. U.S. Environmental Protection Agency. Quality Criteria for Water". U.S. Environmental Protection Agency, Washington, D.C., 1976.

9. U.S. Environmental Protecion Agency. "Ambient Water Quality Criteria for Bacteria - 1986". EPA A440/584-002, U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Washington, D.C., 1986.

10. American Water Works Association. "Dual Water Systems". AWWA Manual M24, American Water Works Association, Denver, CO, 1983.

11. California Department of Health Services. "Uniform Guidelines for Sewage Disinfection". California Department of Health Services, Sanitary Engineering Branch, Sacramento, CA, 1987.

12. California Department of Health. "Position on Basin Plan Proposals for Reclaimed Water Uses Involving Ingestion". California Department of Health, Water Sanitation Branch, Berkeley, Ca, 1973.

13. California State Water Resources Control Board, Department of Water Resources, and Department of Health. "A 'State-of-the-Art' Review of Health Aspects of Wastewater Reclamation for Groundwater Recharge. California Department of Water Resources, Sacramento, CA, 1975.

14. State of California. "Report of the Consulting Panel on Health Aspects of Wastewater Reclamation for Groundwater Recharge". Prepared for the State Water Resources Control Board, Department of Water Resources, and Department of Health Services, Sacramento, CA, 1976.

15. County Sanitation Districts of Los Angeles County. "Health Effects Study - Final Report". Prepared for the Orange and Los Angeles Counties Water Reuse Study, County Sanitation Districts of Los Angeles County, Whittier, CA, 1984.

16. Bruvold, W.H., and J. Crook. "Public Evaluation of Wastewater Reuse Options". OWRT/RU-80/2, U.S. Department of the Interior, Office of Water Research and Technology, Washington, D.C., 1980.

TABLE 1

WASTEWATER RECLAMATION TREATMENT AND QUALITY CRITERIA

Treatment Level	Coliform Limits	Type of Use
Primary		Surface Irrigation of Orchards and Vineyards
		Fodder, Fiber and Seed Crops
Oxidation and Disinfection	23/100 ml	Pasture for Milking Animals
		Landscape Impoundments
		Landscape Irrigation (Golf Courses, Cemeteries, etc.)
	2.2/100 ml	Surface Irrigation of Food Crops
		Restricted Recreational Impoundments
Oxidation, Coagulation, Clarification, Filtration, and Disinfection	2.2/100 ml	Spray Irrigation of Food Crops
		Landscape Irrigation (Parks, Playgrounds, etc.)
		Nonrestricted Recreational Impoundments