AGRICULTURAL AND MUNICIPAL WASTEWATER HANDBOOK

STATE OF CALIFORNIA—HEALTH AND WELFARE AGENCY

PETE WILSON, Governor

DEPARTMENT OF HEALTH SERVICES/DEPARTMENT OF INDUSTRIAL RELATIONS
HAZARD EVALUATION SYSTEM AND INFORMATION SERVICE (HESIS)
2151 Berkeley Way, Annex 11, Third Floor
Berkeley, CA 94704
(510) 540-2115
FAX (510) 540-3472

March 31, 1998

TRS #18-581

John Stroh
Mosquito Vector Control District
San Joaquin County
7759 South airport Way
Stockton, CA 95206

Dear Mr. Stroh,

Here are the materials we discussed in relation to your inquiry about occupational health hazards of contact with treated municipal wastewater.

Municipal wastewater which has undergone secondary treatment still contains disease organisms and should be handled with the same precautions that are recommended for handling raw sewage. Immunization against Hepatitis A and Tetanus is recommended for employees.

Although the Bloodborne Pathogens standard does not apply, several other Cal/OSHA regulations do apply. Employees should be trained regarding the hazards and safe practices for handling wastewater, and the necessary safe handling practices should be required and enforced by the employer. All necessary personal protective equipment should be provided, and all water outlets should be posted as non-potable. The IIPP (Injury and Illness Prevention Program) for this facility should contain documentation of the above measures.

Please phone me at 510-540-3482 should you have additional questions after reviewing these materials. For questions regarding wastewater treatment standards, you may call Dave Spath at the Drinking Water Technical Programs Branch of the California Department of Health Services (916-323-4344). For questions regarding the IIPP and other Cal/OSHA regulations, you may call the Consultation Service in Fresno (209-454-1295).

Sincerely,

Elizabeth Katz, MPH, CIH
Associate Industrial Hygienist
Acting Chief, HESIS

Enclosures:
General Industry Safety Order 3363
Infectious Disease Hazards of Wastewater - HESIS
Biological Hazards at Wastewater Treatment Facilities - Water Pollution Control Federation

NOTE: Authority cited: Section 142.3, Labor Code. Reference: Section 142.3, Labor Code.

HISTORY

1. New Article 9 (Sections 3361–3376) filed 7-16-76; effective thirtieth day thereafter (Register 76, No. 29).
2. Amendment filed 7-16-76; effective thirtieth day thereafter (Register 76, No. 29).
3. Amendment of subsection (h) filed 9-19-80 as procedural and organizational; effective thirtieth day thereafter (Register 80, No. 38).
4. Repealer and new section filed 1-23-81; effective thirtieth day thereafter (Register 81, No. 4).
5. Amendment filed 1-17-86; effective thirtieth day thereafter (Register 86, No. 3).

§ 3362. General Requirements.

(a) To the extent that the nature of the work allows, workplaces, storerooms, personal service rooms and passageways shall be kept clean, orderly and in a sanitary condition. The interiors, exteriors and environs of buildings that contribute to a hazard to which these orders apply shall be cleaned and maintained in such conditions as will not give rise to harmful exposure, as defined in Section 5140.

(b) Cleaning and sweeping shall be done in such a manner as to minimize the contamination of the air and, insofar as is practicable, shall be performed at such time and in such a manner that will avoid harmful exposures as defined in Section 5140.

(c) To facilitate cleaning, every floor, workroom, personal service room and passageway shall be kept free from protruding nails, splinters, loose boards and unnecessary holes and openings.

(d) All putrescible waste or refuse shall be stored in a receptacle so constructed that it does not leak and may be conveniently and thoroughly cleaned. Such a receptacle shall be maintained in a sanitary condition and shall be equipped with a tight fitting cover if it cannot be maintained in a sanitary condition without one. (This provision does not prohibit the use of receptacles which are designed to permit the maintenance of a sanitary condition without regard to the above requirements.)

(e) All sweepings, putrescible wastes, refuse and garbage shall be removed in such a manner as to avoid creating a nuisance and shall be removed as often as necessary to avoid creating a menace to health through the development of unsanitary conditions.

(f) Every enclosed workplace and personal service room shall be equipped and maintained, insofar as is practicable, to prevent the entrance or harborage of insects, rodents or other vermin. An effective program of extermination and control shall be instituted whenever their presence is detected.

NOTE: Authority and reference cited: Section 142.3, Labor Code.

HISTORY

1. Amendment filed 7-16-76; effective thirtieth day thereafter (Register 76, No. 29).
2. Amendment of subsections (a) and (b) filed 10-2-81; effective thirtieth day thereafter (Register 81, No. 40).
3. Amendment of subsection (f) filed 1-17-86; effective thirtieth day thereafter (Register 86, No. 3).

§ 3363. Water Supply.

(a) Potable water in adequate supply shall be provided in all places of employment for drinking and washing and, where required by the employer of these orders, for bathing, cooking, washing of food, washing of cooking and eating utensils, washing of food preparation or processing premises, and personal service rooms. (Title 24, Part 5, Section 5-1001; Exception No. 2 (b))

(b) All sources of drinking water shall be maintained in a clean and sanitary condition. Drinking fountains and portable drinking water dispensers shall not be located in toilet rooms. (Title 24, Part 5, Section 5-1001; Exception No. 2 (c))

(c) Portable drinking water dispensers shall be equipped with a faucet or drinking fountain, shall be capable of being tightly closed and shall be otherwise designed, constructed and serviced so that sanitary conditions are maintained. Such dispensers shall be clearly marked as to their contents.

(d) The dipping or pouring of drinking water from containers, such as from barrels, pails or tanks, is prohibited regardless of whether or not the containers are fitted with covers.

(e) The common use of a cup, glass or other vessel for drinking purposes is prohibited.

(f) Nonpotable water shall not be used for drinking, washing, or bathing, washing of clothing, cooking, washing of food, washing of cooking or eating utensils, washing of food preparation or processing premises or other personal service rooms. (Title 24, Part 5, Section 5-1012 (a))

(g) Outlets for nonpotable water, such as water for industrial or fire fighting purposes, shall be posted in a manner understandable to all employees to indicate that the water is unsafe and shall not be used for drinking, washing, cooking or other personal service purposes. (Title 24, Part 5, Section 5-1012 (c))

(h) Nonpotable water systems or systems carrying any other nonpotable substance shall be installed so as to prevent backflow or back siphonage into a potable water system. (Title 24, Part 5, Section 5-1012 (b))

NOTE: Authority cited: Section 142.3, Labor Code. Reference: Section 142.3, Labor Code.

HISTORY

1. Amendment filed 7-16-76; effective thirtieth day thereafter (Register 76, No. 29).
2. Repealer of subsections (c), (e), (h) and consecutive relettering of subsections (d)–(k); effective thirtieth day thereafter (Register 81, No. 4).
3. Amendment filed 1-17-86; effective thirtieth day thereafter (Register 86, No. 3).

§ 3364. Sanitary Facilities.

(a) Separate toilet facilities shall be provided for each sex according to the following table:

Number of Employees	*Minimum Number of Water Closets**
1 to 15	1
16 to 35	2
36 to 55	3
56 to 80	4
81 to 110	5
111 to 150	6
over 150	1 additional for each additional 40 employees or fraction hereof.

*Urinals may be installed instead of water closets in toilet rooms to be used only by men provided that the number of water closets shall not be less than two-thirds of the minimum number of toilet facilities specified. The length of trough urinals to equivalent number of individual urinals shall be based on the following:

Length of Trough Urinal	*Equivalent Number of Individual Urinals*
24"	1
36"	2
48"	[illegible]
60"	[illegible]
72"	4

EXCEPTIONS:
(1) When there are less than five employees, separate toilet rooms for each sex are not required provided toilet rooms can be locked from the inside and contain at least one water closet. (Title 24, Part 5, Section 5-910 (a)(1))
(2) Employees engaged in hand-labor operations at agricultural establishments are subject to the sanitation provisions of Section 3457.

(b) Toilet facilities shall be kept clean, maintained in good working order and be accessible to the employees at all times. Where practicable, toilet facilities should be within 200 feet of locations at which workers are regularly employed and should not be more than one floor-to-floor flight of stairs from working areas. (Title 24, part 5, section 5-910(a)(1))

(c) All water-carried sewage shall be disposed of by means of either a public sewage system or by a sewage disposal system in conformance with applicable State and local laws, ordinances, and regulations. The sewage disposal method shall not endanger the health of employees.

(d) An adequate supply of toilet paper shall be provided for every water closet.

NOTE: Authority cited: Section 142.3, Labor Code. Reference: Section 142.3, Labor Code.

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DEPARTMENT OF HEALTH SERVICES/DEPARTMENT OF INDUSTRIAL RELATIONS
HAZARD EVALUATION SYSTEM AND INFORMATION SERVICE (HESIS) Jim Cone
151 BERKELEY WAY, ANNEX II
BERKELEY, CA 94704
(415) 540-211

INFECTIOUS DISEASE HAZARDS OF WASTEWATER

Wastewater in the sewer systems contains human urine and feces which may contain disease-causing microorganisms. Workers in sewers may be exposed to a variety of parasites, bacteria and viruses. When the proper safety precautions are taken, the risk for infection among workers appears to be low.

Cholera or AIDS cases have not been reported as job-related infections for sewer workers in the U.S. There is no evidence that AIDS can be spread through feces or urine. The AIDS virus is present in low concentrations in the blood of infected persons. However, scientific evidence indicates that the virus can not survive in waste water.

Although uncommon, there have been reported cases of infectious disease in sewer workers attributed to their job. Enclosed is a copy of *Biological Hazards at Wastewater Treatment Facilities*, published by the Water Pollution Control Federation, which describes the infectious diseases which may be a risk to workers who come into direct contact with sewage and measures to prevent infection.

There are three basic routes that may lead to infections:

1. Ingestion: eating, drinking or accidentally swallowing a disease causing organism. This can occur if workers forget to wash their hands before eating or smoking. Even when not in direct contact with sewage, workers may unknowingly handle objects which are contaminated. Ingestion is the major route of wastewater infection.
2. Inhalation: breathing spray or mist containing disease causing organisms.
3. Direct Contact: Disease causing agents can enter the body through cuts or breaks in the skin.

The following practices will help prevent infection in workers:

1. Wash hands with soap and water before eating, drinking, or using tobacco products. Wash hands immediately after any contact with wastewater.
2. Avoid touching face, mouth, eyes, or nose while working.
3. Do not eat in an area nearby to wastewater.
4. Do not smoke or use chewing tobacco while working.
5. Clean contaminated tools after use.
6. Shower and change clothing before going home. Keep and wash work clothes separately from other clothes.

In addition, protective equipment is recommended to help prevent infection.

1. Wear heavy duty gloves and boots that are waterproof and puncture resistant.
2. Use a face shield (or goggles with a surgical-type mask) to protect your eyes and mouth from splashes.

Vaccinations are available which can protect workers against some diseases. The following immunizations are available against wastewater born diseases:

1. Hepatitis A. Recommended for workers exposed to wastewater
2. Hepatitis B. Not recommended since the risk of infection is low in wastewater.
3. Tetanus. All adults should be immunized every ten years and after puncture wounds or cuts.
4. Polio and typhoid. Not recommended unless there is a regional outbreak of these diseases. Normally the primary vaccination one receives as an infant is sufficient protection.
5. Leptospirosis. Not recommended since there are very few cases of this disease in the U.S.

An important infection, cryptosporidiosis, is not listed in *Biological Hazards at Wastewater Treatment Facilities* and which may pose a hazard to sewer workers. Cryptosporidiosis is a parasitic infection transmitted through human feces. This infection is characterized by diarrhea, stomach cramps, and possibly vomiting. There is no recommended treatment for the disease except for rehydration when needed. Most healthy individuals recover fully within 30 days. People suffering from AIDS may be unable to clear the parasite from their body and as a result suffer more serious health problems.

Studies of sewer workers have found that they suffer from higher than normal rates of diarrhea, eye inflammation, skin disorders, and other gastrointestinal disorders. Other studies have found that sewage system cleaning workers experience short-term and long-term respiratory problems such as chronic cough, phlegm, bronchitis, and chest tightness. Closed channel workers have reported excess eye irritation, headache, dizziness, and throat irritation.

The cause of these excess health problems is likely the presence of infectious agents and various chemicals in the sewers. Drains from industries may carry chemicals hazardous to human health.

In addition to the document on infectious diseases, enclosed a section on the hazards and safety measures recommended for work in sewers from the *Encyclopedia of Occupational Health and Safety*.

INDEX

ADDITIONAL SOURCES OF INFORMATION

Publications

"Operation of Municipal Wastewater Treatment Plants." Manual of Practice No. 11, Water Pollut. Control Fed., Alexandria, VA (1990).

"Safety & Health in Wastewater Systems." Manual of Practice N o. 1, Water Pollut. Control Fed., Alexandria, VA (1983).

"Wastewater Aerosols and Disease." EPA-600/9-80-028, Pahren, H. and Jakubowski, W. (Eds.), U.S. EPA, Cincinnati, Ohio (1980).

"Wastewater Biology: The Microlife." Water Pollut. Control Fed., Alexandria, VA (1990).

Agencies and Organizations

Centers for Disease Control
U.S. Department of Health & Human Services
5600 Fishers Lane
Rockville, MD 20852

National Institutes of Health
U.S. Department of Health & Human Services
9000 Rockville Pike'
Bethesda, MD 20814

National Institute for Occupational Safety & Health
Robert A. Taft Laboratories4676 Columbia Parkway
Cincinnati, OH 45226

Occupational Safety and Health Administration
U.S. Department of Labor
200 Constitution Avenue, N.W.
Washington, DC 20001

Water Pollution Control Federation
601 Wythe Street
Alexandria, VA 22314

see also State and Local Health Departments

12. Gerardi, M.H., *et al.*, "An Operator's Guide to Wastewater Viruses." *Public Works*, **50** (1988)

13. "Safety & Health in Wastewater Systems." Manual of Practice No. 1, Water Pollut. Control Fed., Washington, D.C. (1983).

14. Centers for Disease Control, "Adult Immunizations, Recommendations of the Immunizations Practice Advisory Committee (ACIP)." *Morbid. and Mortal. Wkly. Rep.*, **33**, 15 (1984).

15. Metcalf & Eddy, Inc.,"Wastewater Engineering: Treatment, Disposal and Reuse." 2nd Ed., McGraw-Hill Book Company, New York, N.Y. (1979).

16. Hurrell, D.J., "High Risk Safety Technology: Biological Hazards." A.E. Green (Ed.), John Wiley & Sons, Ltd., London (1982).

17. Clark, C.S., *et al.*, "Biological health risks associated with the composting of wastewater treatment plant sludge." *J. Water Pollut. Control Fed.*, **56**, 1269 (1984).

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2. Clark, C.S., "Potential and actual biological related health risks of wastewater industry employment." *J. Water Pollut. Control Fed.*, **59**, 999 (1987).
3. Ottolenghi, A.C., and Hamparian, V.V., "Multiyear Study of Sludge Application to Farm Land: Prevalence of Bacterial Enteric Pathogens and Antibody Status of Farm Families." *Appl. Environ. Microbiol.*, **53**, 1118 (1982).
4. Niederinghaus, L., "Biological Hazards at Treatment Plants." *Oper. Forum*, **3**, 2, 16 (1986).
5. "Microbiology: An Introduction." G.J. Tortora *et el.* (Eds.), Benjamin/Cummings Publ. Co., Inc., Menlo Park, Calif. (1982).
6. Carter, A.M., *et al.*, "Seasonal Occurrence of Campylobacter spp. in Surface Waters and Their Correlation with Standard Indicator Bacteria." *Appl. Environ. Microbiol.*, **53**, 523 (1987).
7. Hunter, R.M., *et al.*, "Operator Exposure to the AIDS Virus." Am. Water Works Assoc./Water Pollut. Control Fed. Joint Conf., Montana Section (1987).
8. "Wastewater Biology: The Microlife." Water Pollut. Control Fed., Alexandria, VA (1990).
9. Kowal, N.E., "Health Effects of Land Application of Municipal Sludge." EPA/600/52-85/142, U.S. EPA, Washington, D.C. (1986).
10. Hejkal, T.W., *et el.*, "Seasonal Occurrence of Rotavirus in Sewage." *Appl. Environ. Microbiol.*, **47**, 558 (1984).
11. Jawetz, E., *et al.*, "Review of Medical Microbiology." 15th Ed., Lang Medical Publ., Los Altos, Calif. (1982).

SUMMARY

A number of occupational hazards confront treatment plant and wastewater collection systems workers. The danger of infection to these workers through contact with wastewater is real if proper safety precautions are not observed. Although the possibility of infection is greatest for workers in high-exposure areas, such as collection systems and raw sludge processing, all workers who handle or come in contact with wastewater are susceptible to infection.

The incidence of occupational illness or disease among experienced wastewater workers is comparable to other non-wastewater-related professions. Wastewater workers, however, must be alert to the potential for illness and should use common sense and follow safe work procedures. The implementation of strong safety programs, good personal hygiene practices, and protective equipment and clothing will minimize the risk of exposure to infectious agents commonly found in wastewater and sludge.

Extensive studies pertaining to health effects associated with long-term exposure to sludge compost have not been conducted. Studies of these workers that have been conducted show a susceptibility to fungal infection from microorganisms grown in the composting process. However, these studies are of groups of compost workers in only four areas and may not be universally representative of the composting process. Further studies will be needed (for example, some varieties of *Nocardia* are pathogenic to man) to determine if there are any significant biological hazards associated with the long-term use of the sludge-composting process.

Table 14 Safe laboratory practices.

• Do not eat, drink, or smoke while handling wastewater or sludge samples.
• Wash hands before and often while working in the laboratory.
• Wear protective clothing, lab coats, eye protection, and latex gloves as required.
• Do not place hands on face, eyes, nose, or mouth while working in the laboratory—always keep your hands below the collar.
• Use bulb to pipette samples; do not pipette by mouth.
• Wipe up spills immediately.
• Discard all unused samples immediately.
• Store noncompatible or highly reactive chemicals separately. Acids, alkalies, and chlorine should not be stored next to each other.
• Take extra precautions when handling glassware to prevent breakage injury.

Sludge Composting Personnel

Specific studies have been conducted on those workers who deal with wastewater sludge composting. The heat generated in a properly managed composting operation is sufficient to significantly reduce levels of all pathogens of concern in the wastewater industry. The conditions created in composting, however, allow for the proliferation of many thermophilic microorganisms such as *Aspergillus fumagatus*. *A. fumagatus* grows well at 45°C (140°F) and higher, which makes it prevalent at composting sites. The mode of infection is by way of inhalation of *A. fumagatus* spores in the dust at the site. Symptoms that have been reported by workers include abnormal skin, ear, and nose infections. Higher rates of eye and skin irritations have also been noted.[17] Although it is unknown whether these symptoms were attributable to the composting operation, appropriate eye and respiratory protective measures should be used.

Figure 7 Laboratory personnel should take proper precautions to prevent infection.

environment, therefore, should be properly ventilated by a plenum and exhaust air system to minimize exposure to chemical or biological risks. Exhaust air should be routed from the laboratory to the outside of the building and discharged to the atmosphere.

Laboratory workers must be provided with adequate training in proper microbiological techniques and safety (Figure 7). Workers should be familiar with aseptic handling techniques and the biology of the organisms under evaluation to fully appreciate the potential hazard. An emergency procedure should also be developed to deal with accidental contamination of personnel and work area and appropriate vaccinations should be administered if known pathogens are being evaluated. All laboratory apparatus and waste should also be decontaminated by disinfection or sterilization to keep the environment free from microorganisms. Table 14 lists recommended safe laboratory practices.

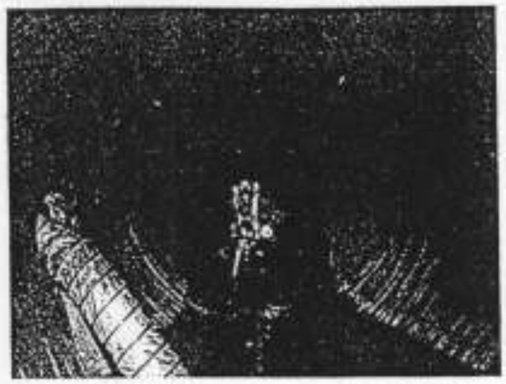

Figure 6 Collection system workers should wear protective clothing and facial and respiratory protection.

Treatment Plant And Laboratory Personnel

All operators at wastewater treatment facilities do not necessarily fall into the high-exposure group. Studies have shown increased risk for those operators involved with raw sludge handling or in enclosed areas where wastes are aerated or agitated. While all operators have the opportunity to come in contact with the various infectious agents, those handling digested sludge or outdoor wet processes appear to have lower risk of infection.

Laboratory personnel are required to perform analyses on a variety of wastewater and sludge samples. Although the risk of infection from wastewater samples is not as high in the laboratory environment as in the sewers or outside facilities, infectious agents that are commonly found in such samples are nevertheless a biological hazard.

The risk of laboratory-acquired infection results from any procedure that releases infective organisms to the environment or affords access for such organisms to the human body. The most widespread mechanism for laboratory-acquired infection is usually by airborne contamination of the infective agent. The laboratory

Most studies have indicated that areas with the greatest risk for infection involve routine and direct contact with untreated wastewater or sludge. Included in this category are workers involved with sewer maintenance and raw sludge handling. Various treatment processes designed for solids or BOD removal will provide varying degrees of disinfection as shown in Table 13.[15] Risk of infection will rapidly decline as wastewater undergoes various treatment steps.

Table 13 Percent removal of bacterial pathogens by different treatment processes.

Process	Percent removal
Course screens	0-5
Fine screens	10-20
Grit chambers	10-25
Plain sedimentation	25-75
Chemical precipitation	40-80
Trickling filters	90-95
Activated sludge	90-98

Collection Systems Personnel

Because of their direct high exposure to raw wastewater, collection systems workers have greater risks of infection than do treatment plant employees (Figure 6). Various studies have indicated evidence of increased risk of viral infections (including hepatitis A), parasite infection, and gastrointestinal illness in these workers but improved and modern work practices can reduce these risks. Leptospirosis, transmitted through the urine of infected rats, was once considered to be the British sewer worker's disease before the 1950s. Recent investigations have revealed that the risk of this particular bacterial infection is minimal. Present day wastewater characteristics and probable lower infection rates in rats may have contributed to the reduced prevalence of this disease.

WORKERS WHO ARE AT RISK

Several studies have been conducted on the actual infection rate of wastewater workers. During the early years of employment, wastewater workers may be more prone to illness than more experienced workers. Newer employees may experience increased rates of gastrointestinal and upper respiratory illnesses, which are thought to be related to biological exposures.[2]

Table 12 shows the results of various studies of health effects of biological hazards to wastewater workers.[2] Although areas of higher risk exist, the risk of contamination is not overwhelming. Simple procedures involving personal hygiene and work methods, however, can reduce these risks to far below other common occupational hazards.

Table 12 Summary of biological health risks to wastewater workers.

Type of hazard	Effects observed
Hepatitis A	Evidence of increased risk when working with raw wastewater and primary sludge.
Other viral infections	May indicate infection in the most exposed workers. Other factors contributing to infection should not be overlooked.
Leptospirosis	Formerly considered a problem; risks now appear minimal.
Gastrointestinal illness	Increased rates especially among new workers. Other factors contributing to infection should not be overlooked.
Compost-related factors	Excess nasal, ear, and skin abnormalities and eye irritation.

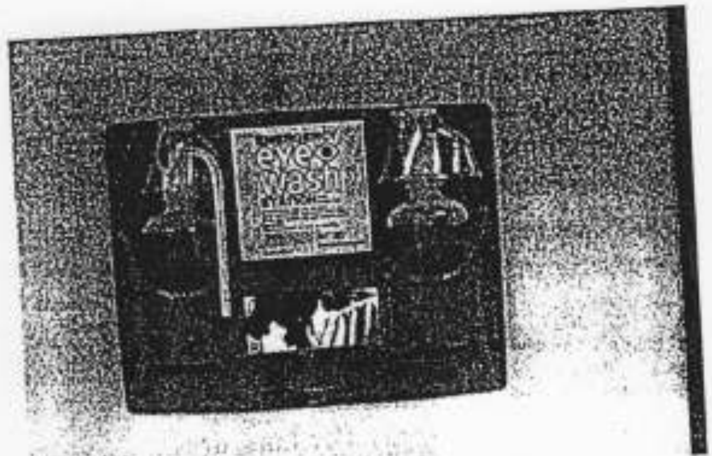

Figure 5 Eye wash stations should be within easy access to all operators.

Because wastewater workers frequently expose their hands to water and wastewater, occasional skin problems such as fungal infections, rashes, chapping, and cracking may occur. Protective hand creams or lotions can generally be used to minimize such problems. If these medications are ineffective or if contact dermatitis becomes a problem, an occupational physician should be consulted. If wastewater gets splashed into the eyes, ears, or nose, the area should be immediately flushed with fresh potable water or the eye wash solution from the first aid kit (Figure 5).

HOW TO TREAT INFECTIONS

First Aid

All injuries should be treated promptly to prevent infection or illness. Potential entry points will exist for microorganisms to cause infection if minor breaks in the skin or mucous membranes resulting from burns, rashes, cuts, and insect bites are left untreated. Soap and water are the best initial first aid measures that can be used for minor cuts. Table 11 lists recommended contents of a standard first aid kit. The first aid kit should include a variety of antibacterial ointments or disinfectants, dressings, waterless soap, antiseptic wipes, and sterile eyewash solution. An antibiotic ointment or disinfectant should be applied to the wound after thorough washing. Adhesive bandages, tape, and sterile gauze should also be used to further protect the treated area and keep the wound clean and dry. Generally, prompt medical attention is required if the skin or mucous membrane is severely injured and in contact with contaminated wastewater or sludge or if severe wounds or punctures do not respond to methods for control of bleeding.

Table 11 Suggested contents of first aid kit.

- Variety of bacterial ointments/disinfectants,
- Dressings,
- Waterless soap,
- Antiseptic wipes,
- Sterile eyewash solution,
- Adhesive bandages,
- Tape,
- Scissors,
- Sterile gauze,
- Splint, and
- Aspirin.

Table 10 Immunizations recommended by the U.S. Public Health Service.[14]

Disease	Who needs immunization	Immunization
Hepatitis A	Individuals with close personal contact with hepatitis A	Hepatitis A immune globulin treatment
Hepatitis B	Homosexual males, household and sexual contacts with carriers, and those who have had direct exposure to blood of a person known or suspected to be a carrier	Hepatitis A immune globulin treatment and hepatitis B vaccine
Influenza	Adults 65 years or older	Annual influenza vaccine
Measles	Adults born in 1957 or later, unless they have evidence of vaccination on or after their first birthday, documentation of physician diagnosed disease, or laboratory evidence of disease	Combined measles, mumps, and rubella (MMR)
Mumps	Adults, especially males, who have not been previously infected	Mumps vaccine
Pneumococcal disease	Adults 65 years or older	Pneumococcal polysaccharide vaccine
Rubella	Women of childbearing age, unless proof of vaccination or laboratory evidence of immunity is available	Rubella vaccine
Tetanus and diphtheria	Adults every 10 years after initial doses and after wounds, unless it has been fewer than 5 years since last dose	TD vaccine

Immunizations

The Centers for Disease Control recommends that immunizations for diphtheria and tetanus be current for the general public, including all wastewater workers. Boosters are recommended every 10 years after the initial immunizations (usually during childhood years) are administered. The tetanus booster needs to be repeated if a wound or puncture becomes dirty and if boosters have not been given within 5 years.

Primary vaccination for polio and typhoid are presently considered to be sufficient unless there is a regional outbreak. The preventive effect of the vaccine immune serum globulin for hepatitis A is short lived (about 3 weeks), and is not routinely recommended for wastewater workers unless there has been direct exposure to wastewater splashed into an open wound or the mouth or a severe outbreak has occurred in the community. The vaccine for hepatitis B is also not routinely recommended for wastewater workers because the risk of transmission by wastewater is extremely remote. Vaccinations are available from physicians, health clinics, and county health departments.

At the present time, no additional immunizations above those recommended by the U.S. Public Health Service for adults in the general population are advised for workers in contact with wastewater. Wastewater workers and all other adults should be adequately vaccinated against diphtheria and tetanus. Poliovirus and typhoid vaccines and immune globulin are not routinely recommended for wastewater workers. Table 10 summarizes the immunizations recommended by the U.S. Public Health Service.[11]

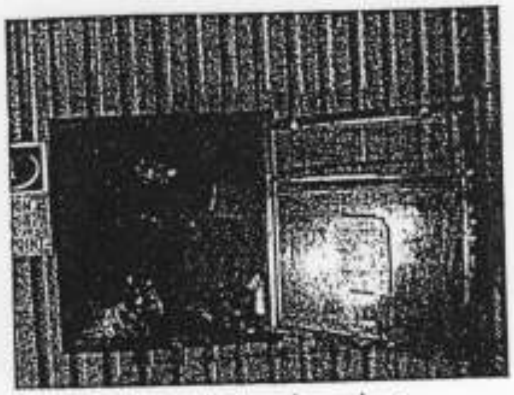

Figure 3 Gloves, dust masks, and eye protection should be made available to workers in high-risk areas.

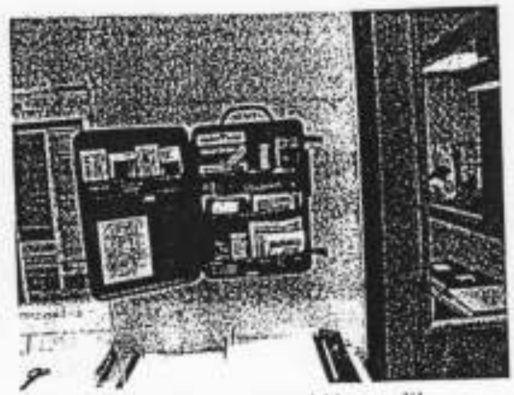

Figure 4 First aid kits should be readily available at the job site.

Although there has been no evidence that wastewater workers have transmitted infection to their families, good personal hygiene is still important. Workers should thoroughly clean up at the end of the work day before going home. Ideally, soiled clothing should be laundered before they are taken home or should be handled separately from domestic laundry and washed with hot water and disinfected. Dual locker systems are desirable for all wastewater workers, allowing one locker for work clothes and one for street clothes.

Another important key to preventing exposure is the proper use of personal protective devices. Waterproof and puncture-resistant gloves should be worn whenever working with wastewater or sludge. If prolonged exposure to aerosols or dusts is anticipated, respiratory and eye protection should be worn (Figure 3). First aid kits should be readily available at the job site to allow for the immediate treatment of minor cuts (Figure 4). All tools contaminated with wastewater should be cleaned with a common cleaner or a mild solution of sodium hypochlorite.[11]

HOW TO PREVENT INFECTIONS

Personal Protection Measures

The safety precautions required to significantly reduce the possibility of biological contamination by wastewater are outlined in Table 9.[13] The most important consideration is the use of good common sense. If collection systems and treatment plant workers are aware of the hazards, they can protect themselves simply by following correct personal hygiene habits. Laboratory workers also must be aware of the potential for infection because of the nature of the samples being handled.

Table 9 Workplace precautions and personal hygiene guidelines.[12]

- Wash hands frequently with soap and water after contacting wastewater; visiting restrooms; before eating, drinking, or smoking; and at end of work shift.
- Promptly treat cuts and abrasions using appropriate first aid measures.
- Wear heavy duty gloves (or double gloving) and boots that are waterproof and puncture resistant.
- Wear surgical-type masks and goggles or face shields for prolonged exposure to wastewater aerosols.
- Change soiled uniforms or protective clothing as soon as the job is completed.
- Shower before changing into clean work clothes and shoes.
- Launder work clothes at work not at home.
- Handle sharp items with extra care to prevent accidental injuries.
- Clean contaminated tools after use.
- Follow good common sense and exercise extra caution whenever there is contact with contaminated water or sludge.
- Wherever possible, use dual lockers to separate work and street clothes.
- Promptly clean body parts that contact wastewater or sludges.

Table 8 Methods to prevent direct contact entry of pathogenic organisms.

Body
- Wear protective clothing and equipment;
- Shower and change clothes before going home;
- Leave work clothes, gloves, and boots on site to prevent possible disease transmission to family or friends;
- Use separate lockers for street and work clothes to minimize contamination; and
- If work clothes are washed at home, separate from the family wash and use chlorine bleach.

Hands
- Wear gloves whenever there is contact with wastewater or sludge;
- Use thin disposable latex gloves for light work, use reinforced rubber gloves for heavy activities, and discard gloves that become torn; and
- Do not submerge hand below top of glove.

Face
- Never touch face, mouth, eyes, ears, or nose while working with wastewater or sludge;
- Wear goggles in the presence of heavy aerosols; and
- Wear surgical-type masks or respirators in the presence of heavy aerosols.

Table 7 Methods to prevent ingestion of pathogenic organisms.

Wash hands — Never eat, drink, or use tobacco products before washing hands; — Avoid touching face, mouth, eyes, or nose before washing hands; and — Wash hands immediately after any contact with wastewater or sludge.
Control activities — Eat only in designated areas of the plant and away from treatment facilities, and — Do not smoke or use chewing tobacco while working in direct contact with wastewater or sludge.

At locations where wastewater or sludge is sprayed, the possibility of inhaling infectious agents will increase. Workers should avoid prolonged exposures at those areas where contact with such aerosols are likely. In instances where prolonged exposure to aerosols is anticipated, the use of surgical masks and goggles may help to minimize contact. Methods to prevent direct entry of pathogenic organisms by contact are included in Table 8.

HOW INFECTIONS CAN SPREAD

There are three basic routes that may lead to infection: ingestion through splashes, contaminated food, or cigarettes; inhalation of infectious agents or aerosols; and infection due to an unprotected cut or abrasion. Wastewater workers often come in physical contact with raw wastewater and sludge through the course of their daily activities. Even when direct physical contact is avoided, the worker may handle objects that are contaminated. Cuts and abrasions, including those that are minor, should be cared for properly. Open wounds invite infection from many of the viruses and bacteria present in wastewater. Table 6 summarizes the major routes of infection.

Table 6 Routes of infection.

• Ingestion	— eating, drinking, or accidentally swallowing a pathogenic organism (for example, hepatitis A).
• Inhalation	— breathing spray or mist containing pathogenic organisms (for example, common cold).
• Direct contact	— entry of pathogenic organism to body via cut or break in the skin (for example, tetanus).

Ingestion is generally the major route of wastewater worker infection. The common practice of touching the mouth with the hand will contribute to the possibility of infection. Workers who eat or smoke without washing their hands have a much higher risk of infection. Most surfaces near wastewater equipment are likely to be covered with bacteria or viruses. These potentially infectious agents may be deposited on surfaces in the form of an aerosol or may come from direct contact with the wastewater or sludge. A good rule of thumb to follow is to never touch yourself above the neck whenever there is contact with wastewater.[13] Table 7 lists methods to prevent ingestion of pathogenic organisms.

The eggs of many varieties of roundworms, hookworms, and tapeworms have also been found in wastewater. Infestation of roundworms and tapeworms is usually transmitted orally and typically results in abdominal pain and weight loss.

Hookworms are generally transmitted through cracks in bare skin (such as between the toes), although oral infestation is also possible. Hookworms cause a general loss of energy and anemia.[4]

Parasites' survival rates are affected by the wastewater or sludge treatment processes to which they are subjected. In general, each process that exposes a parasite to a different or hostile environment may shorten its survival time.

In cases of parasitic infestation, it is possible that the host's symptoms may be nonexistent. Because hand-to-mouth contact is the principal cause of infection, it is important that hands are washed frequently.

cysts and eggs, in which the protozoa and worms reproduce, are often resistant to adverse conditions. These resistant cysts and eggs, therefore, may show up in wastewater or sludge samples.

The number and variety of parasitic forms present in wastewaters or sludges depend heavily on the origin of wastes entering the treatment plant. The most commonly studied protozoa are *Entamoeba histolytica* and *Giardia lamblia*. *E. histolytica* is the agent that causes amoebic dysentery, a disease with symptoms that include varying degrees of abdominal cramps and diarrhea, alternating with constipation. *G. lamblia* is also contracted orally and can lead to a variety of intestinal symptoms. *Giardia* is a hardy protozoa that exists in a cyst stage and can be resistant to chlorination. The most common parasites found in wastewater are listed in Table 5.[2, 4]

Table 5 Parasites found in wastewater.

Organism	Disease
Protozoa	
Entamoeba histolytica	Amoebic dysentery
Giardia lamblia	Giardiasis
Roundworms (nematodes)	Abdominal pain and weight loss
Hookworms (ancylostomatodes)	Anemia
Tapeworms (cestodes)	Abdominal pain and weight loss

The Centers for Disease Control (CDC) has stated that there is no scientific evidence that HIV is spread in wastewater or its aerosols. The virus has never been recovered from wastewater and it is believed that the pH, temperature, and other conditions of the collection system are not suitable to its survival. There have been no known cases of wastewater workers or plumbers who have contracted AIDS where the mode of transmission was judged to be from occupational exposure.

The scientific evidence to date indicates that AIDS cannot be contracted through occupational exposure associated with wastewater treatment. Generally, infected body fluids that are discharged to sewers are immediately diluted to the point where they do not represent a significant risk to wastewater workers. The AIDS virus, in particular, is not well suited to the collection system environment and is likely to become deactivated upon contact with wastewater. Wastewater workers should, however, pay close attention to personal hygiene and exercise caution and common sense whenever they are working in and around contaminated wastewater to minimize exposure to bacteria and viruses.

Parasites

A parasite lives on or in another organism of a different species, from which it derives its nourishment. The organism is called the parasite's host. Parasites normally do not kill their hosts, because the life of the parasite would also be terminated.

In many cases, however, parasites will weaken the host or cause symptoms similar to disease caused by bacteria or viruses. Waterborne parasites found in wastewater consist of various types of protozoa and worms. These organisms often do not survive the journey through the wastewater collection system and treatment facilities. The

Adenovirus

Adenoviruses have been associated with respiratory tract infections and conjunctivitis (eye infection). The virus has been isolated from wastewater and sludges and can cause acute diarrheal disease and viral gastroenteritis.

Rotavirus

Rotaviruses are a common cause of acute viral gastroenteritis. Outbreaks of this common illness have been associated with wastewater-contaminated water resources. Raw wastewater and chlorinated wastewater effluents from activated sludge plants treating domestic wastes have been shown to discharge high densities of these viruses each day.[10]

Coxsackieviruses A and B

Coxsackievirus A causes aseptic meningitis and conjunctivitis and is one of the causes of the common cold.[11] Coxsackievirus B causes several types of disease, including heart disease.[11] The primary modes of transmission for the coxsackieviruses are through inhalation and ingestion of contaminated materials.

Poliovirus

The poliovirus is associated with poliomyelitis, which affects the central nervous system. The primary mode of transmission is ingestion of fecal-contaminated water containing the virus. The poliovirus is a more stable virus than most other viruses and can remain infectious for relatively long periods in contaminated food and water.[5]

Poliovirus vaccines have reduced the incidence of poliomyelitis and have contributed to the decline in reported cases of the disease. Outbreaks usually occur only in segments of the population lacking proper immunization.

poliomyelitis, respiratory diseases, gastroenteritis, and the common cold. Along with these various diseases almost all of the viruses produce latent infections, which can go undetected because no symptoms may be present.

Hepatitis A

The major waterborne disease resulting from viral infection is hepatitis A. The hepatitis A virus is the causative agent of infectious hepatitis, a systemic disease primarily involving the liver. The virus is commonly associated with fecal-oral transmission through wastewater contamination and contaminated food. An infected person generally exhibits flu-like symptoms, cramps, vomiting, high fever, and jaundice.

The hepatitis A infectious agent is resistant to heat, acid, and chemical treatment, including low levels of chlorine.[9] Thus, wastewater personnel have a higher potential incidence of exposure to the hepatitis A virus because of their daily contact with wastewater.

Norwalk Virus

Another common type of virus that has been associated with inadequately treated wastewater is the Norwalk agent. The Norwalk agent produces an acute gastrointestinal disease consisting of vomiting, diarrhea, low-grade fever, and body aches. Symptoms generally last for a short period of time, usually 24-48 hours. During this time, the virus can be passed through the stool and has the potential to affect other members of the family if appropriate hygiene is not practiced in the home. Outbreaks of the illness have been associated with septage disposal, municipal water supplies, and recreational water contact.

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Jack E. Campbell

Roger J. Dolan

Arnold E. Greenberg

Franklin D. Munsey

Theodore Popowchak

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PREFACE

This special publication discusses the variety of biological hazards that may exist at municipal wastewater treatment and collection facilities. Although most health effects studies indicate that infections from specific biological agents are not common, operations and maintenance personnel must presume that biological hazards will exist at any location within the facility where contaminated wastewater and treated sludge solids are present. The many potential biological hazards that may confront wastewater workers are compounded by daily contact and possible exposure to infectious wastes that are routinely discharged into the community sewer system.

The manual is designed to assist wastewater workers in obtaining a basic understanding of types of bacteria, viruses, and parasites that are commonly found in wastewater and the potential health effects of exposure to these agents. The main routes of infection and the types of workers who have a high risk potential for infection are also covered. The types of immunizations and first aid procedures described will provide guidance to both management and employees and emphasize the importance of treating all cuts and wounds. The manual also contains a number of tables that describe the variety of personal protective measures to help minimize risk of infection and disease.

This manual is also the first in a series of planned special publications being sponsored by the WPCF Safety & Occupational Health Committee to assist operators, collection system workers, and others in gaining a basic understanding of safety and health issues of concern within the wastewater industry. The Committee hopes that users of this manual will provide constructive comments and propose topics for further development.

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Water Pollution Control Federation
Technical Practice Committee Control Group

P. T. Karney, *Chairman*

F. D. Munsey, *Vice-Chairman*

A. J. Callier

L. J. Glueckstein

C. N. Lowery

T. Popowchak

Authorized for Publication by the Board of Control
Water Pollution Control Federation

Quincalee Brown, *Executive Director*

The Water Pollution Control Federation is a nonprofit, educational organization comprising 38 000 members from Member Associations and affiliated associations throughout the world. Since 1928, WPCF has provided educational and technical services to water quality specialists, including civil, design, and environmental engineers; biologists; bacteriologists; local, state, and federal government officials; treatment plant operators and collection systems personnel; laboratory personnel; technicians; chemists; industrial technologists; students; academics; and equipment manufacturers and distributors.

For information on membership, publications, and conferences, contact

Water Pollution Control Federation
601 Wythe Street
Alexandria, VA 22314-1994
(703)684-2400

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Binder V4

Biological Hazards At Wastewater Treatment Facilities

A Special Publication

Prepared by
Task Force on Biological Hazards
Jeffrey Theerman, *Chairman*

Deanna L. Anderson
Arul Ayyaswami
Lawrence Bannister
Alan J. Callier
Donald G. Campbell, II
Robert J. Campbell
C. Scott Clark
Andrew P. Fisichelli
Samuel J. Hadeed
Stephen M. Hoffman
Gary M. Hutter
Robert B. Klausegger
Marvin E. Lambert
Catherine N. Lowery
Jan C. Manwaring
Sandra J. Middleton
William Moore
Michael W. Myers
W. Joseph Myers, Jr.
M. Daniel Rockwell
Andrew H. Sims, Jr.
Edith Snethen
Thomas J. Whiteman

1991

Water Pollution Control Federation
601 Wythe Street
Alexandria, Virginia 22314-1994

Bacteria

Pathogenic bacteria thrive in wastewater and can be found in large quantities in sewage.

Bacterial Pathogens found in Wastewater

Microorganism	Disease or sickness caused
Salmonella	Diarrhea & vomiting, Typhoid fever
Shigella	Bacterial dysentery (severe diarrhea with blood and high fever)
Leptospira	Weil's Disease
Clostridium	Tetanus & Gas gangrene (from infected puncture wounds), diarrhea & vomiting
Vibrio	Asiatic Cholera
Campylobacter	Diarrhea & vomiting
Yersinia	Bacterial dysentery

Infectious agents potentially present in wastewater containing fecal matter:

Infectious Agent	Presenting Symptoms
Bacillary Dysentery: *Shigella* species, Ingestion	**Incubation period of 0-3 days:** Fever, chills, muscle aches, nausea, vomiting, diarrhea, abdominal cramps **1-8 days:** Frequent passage of blood and mucous, cramping abdominal pain **3-10 days:** Dehydration, peritonitis (bacteria in the abdominal cavity), septicemia (blood stream infection) **chronic complications:** arthritis
Asiatic Cholera: *Vibrio cholerae* Ingestion	**Incubation period of 1-7 days:** prodrome of fever, headache, muscle aches **shortly thereafter, lasting 7+days:** fever, diarrhea, bloody bowel movements **chronic complications:** arthritis, Guillain-Barre syndrome
Typhoid Fever: *Salmonella typhi* Ingestion	**incubation period of 8-28 days:** prodrome: fever, chills, headache, prostration **Subsequently:** abdominal pain, diarrhea in 1/3 of patients; rose spots on skin; delerium, intestinal bleeding rarely; **Rare complications:** pneumonia, heart infection, gall bladder infection, meningitis (brain infection).
Other enteric pathogens: *Yersinia entercolitica, Campylobacter fetus, Campylobactter jejuni, Norwalk viruses, rotaviruses*	Acute gastroenteritis: fever, diarrhea, moderate dehydration.
Infectious Hepatitis: Viral Hepatitis A: Ingestion	Incubation period: 2-6 weeks **Prodrome:** fatigue, loss of appetite, nausea, vomiting, joint aches, loss of taste for coffee, cigarettes. **Icteric phase:** lightening of stool, darkening of urine, jaundice (yellow skin) and icterus (yellow eyes), fever, liver enlargement, spleen enlargement, skin itching. **Convalescent phase:** fatigue may persist.
Tetanus: *Clostridium tetani:* wound infection	contraction of muscles controlling the jaw, body muscle spasms, paralysis of throat muscle, leading to death from respiratory failure
Polio: Poliovirus, ingestion	Only if lacking proper immunization: Incubation period 4-10 days. Followed by non-specific systemic illness or is assymptomatic; in a small percentage, major illness begins with fever, malaise, generalized headache, vomiting, neck and back stiffness. May stabilize or progress to paralysis on 2nd to 5th day following headache. Involvement of various nerves. May lead to death due to respiratory and heart impairements.
Parasites: •*Amoeba histolytica*: ingestion	Amoebic dysentery: Abdominal cramps and diarrhea, alternating with constipation.
•Giardiasis: *Giardia lamblia* ingestion	Diarrhea, other intestinal symptoms.

PARASITES

A Parasite lives within or on another organism (host) from which it takes its nourishment. Parasites consist of various types of worms and protozoa (microscopic animals that are made up of one cell).

Parasite eggs and cysts are commonly present in wastewater. They are transmitted primarily by accidental ingestion.

Parasites Found in Wastewater

Organism	Disease or sickness caused
PROTOZOA	
Amoebas (entamoeba histolytica)	Dysentery (diarrhea with blood), stomach cramps, liver abcessess
Giardia (Giardia Lamlia)	Diarrhea, indigestion
WORMS	
Roundworms (Ascaris)	abdominal pain, weight loss coughing (with blood), pneumonia
Hookworms (can enter body through skin)	anemia, loss of energy, diarrhea, cough
Tapeworms (undercooked meat)	weight loss, stomach pain, brain cysts

VIRUSES

More than **<u>100</u>** types of viruses are found in human waste

Transmitted by breathing in viruses which become aerosolized or accidentally ingesting them (inadvertent hand to mouth contact).

Intestinal viruses are typically found in sewage water. Blood-borne viruses (HIV, Hepatitis B) are less likely to be transmitted through sewage.

Common Human Viruses Found in Wastewater

Virus Group	Disease or Sickness Caused
Hepatitis A	Acute Infectious Hepatitis
Poliovirus	Polio
Norwalk, Rotavirus	Diarrhea, Vomiting
Coxsackieviruses A	Common Cold, eye infection
Coxsackieviruses B (less common)	Heart Disease, Respiratory tract infection, Meningitis, Bornholm's Disease
Echovirus	Common Cold, eye infection

AIDS: caused by HIV (human immunodeficiency virus). The Centers for Disease Control has stated that scientific evidence indicates that HIV is **NOT** transmitted through wastewater.

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INTRODUCTION

Thousands of wastewater collection system and treatment plant personnel are exposed daily to a variety of work-related hazards. These hazards range from common industrial work exposures to dangers that are specific to the wastewater field. Surveys conducted by the Water Pollution Control Federation (WPCF) have consistently found that the wastewater industry has one of the highest frequency and severity of accident occurrences of all industries reporting to the National Safety Council.[1] One common hazard that has been studied extensively but is often misunderstood by the wastewater industry is exposure to biological contamination.

A common characteristic of wastewater is its high concentration of microorganisms. Wastewater facilities that were constructed before the passage of the Clean Water Act of 1972 were built primarily to prevent the spread of waterborne diseases within the community by collecting and treating wastewater at one location. Biological secondary treatment is a popular means of treating wastewater because wastewater is a favorable environment for reproduction for many microorganisms. The environment that contributes to the biological breakdown of wastes, however, also may allow for the growth of many pathogenic organisms. In many instances, the need for disinfection is determined by the quality and use of the body of water into which the treated effluent is discharged. The disinfection process kills many pathogens before the effluent is discharged to the receiving stream.

Because of the nature of the waste and the processes that collect and treat it, the potential for daily exposure to infectious wastes exists for most wastewater workers. Collection system maintenance crews often come in contact with raw wastewater when conducting inspections and performing routine repairs and maintenance. The collection system is also a favorable environment for many pathogens because of its moderate temperature, high concentration of nutrients, and abundant moisture.

Table 1 is a summary of the various diseases associated with wastewater-contaminated environments.

Treatment plant workers' exposure to biological hazards differs from that of collection system crews. Although wastewater treatment plant personnel may not be in physical contact with wastewater as often as collection system workers, they do handle equipment that comes in direct contact with wastewater or sludge. In addition, bacteria, viruses, and other microorganisms may be found in aerosols or mists in and around the various unit processes (Figure 1) and can be concentrated in sludges.

Table 1 Diseases associated with wastewater-contaminated environments.

Disease	Organism	Mode of transmission
Bacillary dysentery	*Shigella* spp.	Ingestion[b]
Asiatic cholera	*Vibrio cholerae*	Ingestion
Typhoid fever	*Salmonella typhi*	Ingestion
Tuberculosis	*Mycobacterium tuberculosis*	Inhalation[c]
Tetanus	*Clostridium tetani*	Wound contact
Infectious hepatitis	Hepatitis A virus	Ingestion
Poliomyelitis	Poliovirus	Ingestion
Common cold[a]	Echovirus	Inhalation
Hookworm disease	*Necator americanus* *Ancylostoma duodenale*	Skin contact
Histoplasmosis	*Histoplasma capsulatum*	Inhalation

[a]The common cold is usually associated with various rhinovirus types, several coronaviruses, and some unknown viruses.

[b]Inhalation is by way of mouth and nose and taken through the lungs and into the bloodstream.

[c]Ingestion is by way of mouth or nose and taken in through the stomach and intestine and into the bloodstream.

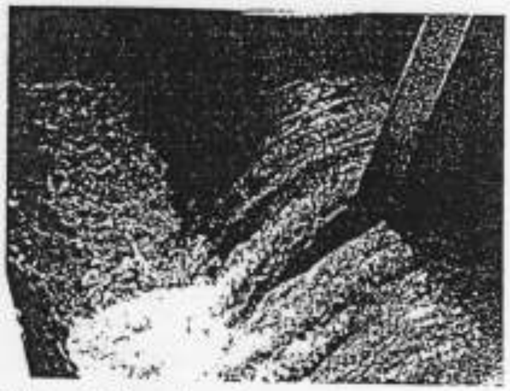


Figure 1 Bacteria, viruses, and other disease-causing microorganisms are often present in wastewater aerosols and mists around turbulent areas.

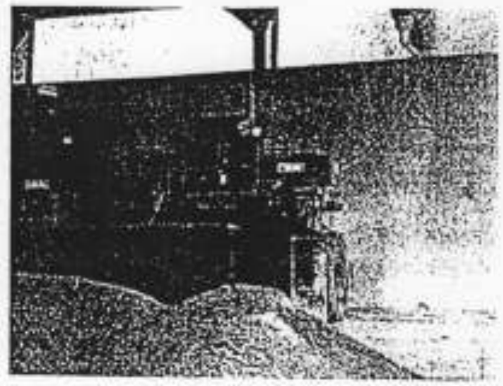


Figure 2 Inhalation of infected dust poses a health risk for sludge composting operators.

Laboratory personnel at wastewater facilities also may come in contact with potentially infectious wastes. In smaller facilities, plant operators may also assist in performing laboratory tests. In larger facilities, full-time staff are generally assigned to work in the laboratory. Because wastewater and sludges are routinely brought into the laboratory for analysis, the potential exists for bacterial contamination if technicians use sloppy laboratory techniques or if accidental spills occur.

Workers involved in the disposal of wastewater sludges are also in contact with potentially infectious wastes. Frequent and direct operator contact often occurs in this operation. Workers handling compost or applying dried sludge to land may risk infection through inhaled dusts and personal contact if proper safety precautions are not followed (Figure 2).

For all wastewater facility employees, the possibility of exposure and the hazards of contamination may be increased if adequate personal hygiene procedures are not followed. The main sources of biological waste materials within a community wastewater system originate from homes, hospitals, institutions, commercial establishments, laboratories, industries, and stormwater. After these community wastes reach the wastewater facility, many potential sites for the transmission of water-borne viruses and bacteria exist. These include exposure to mists throughout the facility; exposure at or near processes involving mixing or aeration, pump stations, and sludge processing and handling operations; and exposure at effluent discharge areas.

Although most studies indicate that infections from specific agents are not common, workers in contact with wastewater, especially during their first few years of employment, have been known to experience increased rates of gastrointestinal or upper respiratory illnesses.[2] Operations and maintenance personnel, therefore, must presume that biological hazards will exist at any location within the facility where contaminated wastewater and treated sludge solids are present.

TYPES OF HAZARDS

Bacteria

Unlike viruses, bacteria do no require a living host cell to reproduce. Pathogenic bacteria are microscopic in size and are extremely common in wastewater. Because bacterica can reproduce outside the body, microorganisms can be present in large quantities in the collection system. Bacterial infections, therefore, will result from their proliferation in an aqueous environment.

Because of their daily exposure to wastewater-contaminated environments, wastewater personnel have a higher incidence of potential exposure to pathogens than the general public. For most workers, however, the risk of developing a disease is relatively low. Proper personal hygiene is critical, however, because infections may occur without symptoms, and antibodies to bacteria and viruses may develop without illness symptoms (latent infection) being readily apparent.

The most common bacterial pathogens found in wastewater are *Salmonella* and *Shigella*. Other bacterial microorganisms include *Vibrio*, *Clostridium*, *Yersinia*, *Campylobacter*, and *Leptospira*. *Escherichia coli (E. coli)*, which can cause gastroenteritis, is generally not considered a pathogen because it is a microorganism that naturally inhabits the gastrointestinal tract of man. The most common bacterial pathogens found in wastewater are listed in Table 2.

Salmonella

Salmonella is a major cause of food poisoning from improperly prepared products. *Salmonella* can cause infections of the stomach and intestinal tract (acute gastroenteritis), typhoid fever, and paratyphoid fever. *Salmonella* infection results from oral ingestion, although large numbers of these microorganisms are required to cause illness.

Table 2 Bacterial pathogens found in wastewater.

Microorganism	Disease
Salmonella	Salmonellosis (gastroenteritis) Typhoid fever
Shigella	Shigellosis (gastroenteritis) Bacillary dysentery
Clostridium	Tetanus Gas gangrene Gastroenteritis
Vibrio	Asiatic cholera
Leptospira	Weil's disease
Campylobacter	Acute bacterial enteritis
Yersinia	Acute gastroenteritis

Salmonella are routinely isolated from wastewater treatment processes, compost operations, sludge-handling facilities, and associated landfills. Isolation of *Salmonella* from treatment plant effluent and sludge varies from plant to plant and season to season.[3] Infection is unlikely in the wastewater field without direct ingestion of waste.[4] The risk of infection from *Salmonella* and all other pathogens will be significantly reduced with proper hygienic practices.

Shigella

Shigella infection (shigellosis) is responsible for bacillary dysentery and is the primary cause of infectious diarrhea in the U.S.[4] Like *Salmonella*, *Shigella* is usually transmitted through oral ingestion of contaminated food and water or through hand-to-mouth contact. Few organisms are required to cause infection, which makes this bacteria a common biological hazard to wastewater workers.[4] *Shigella* survives for only a short time in the sewer system, however, and generally represents a greater potential hazard for collection system workers than treatment plant operators.

Vibrio

Asiatic cholera is caused by *Vibrio cholerae*, which produce a poison or endotoxin that results in vomiting, diarrhea, and loss of body fluids. Cholera can be spread by the ingestion of fecal-contaminated water and is normally present in many developing countries and communities with inadequate sanitation practices. Control of this disease is achieved through proper measures such as water disinfection and wastewater treatment.

Clostridium

Tetanus results from a localized infection of a deep or puncture wound by *Clostridium tetani*. Symptoms of infection include contraction of the muscles controlling the jaw, body muscle spasms, and paralysis of the throat muscle, which can lead to death from respiratory failure. The organism is commonly found in fecal-contaminated environments and in soils. Infection may occur whenever a deep wound is contaminated with wastewater-contaminated material. The general public, including wastewater system personnel, should make sure that tetanus vaccines are taken every 10 years after initial doses and after wounds, unless it has been fewer than 5 years since the last dose. A booster tetanus toxoid given at the time of injury will also provide immunity to the disease.

Yersinia

Yersinia entercolitica is an enteric pathogen that causes acute gastroenteritis. The most common symptoms are fever and diarrhea, with moderate dehydration. The fecal-oral route is the most common mode of transmission.

Campylobacter

Campylobacter fetus and *C. jejuni* cause acute bacterial enteritis.[5] These organisms are transmitted by the fecal-oral route through contaminated water sources and other modes. Most outbreaks of enteritis caused by *Campylobacter* have been associated with surface and drinking water supplies.[6]

Leptospira

Leptospira bacteria are responsible for leptospirosis, or Weil's disease, which infects the liver, kidneys, and central nervous system. This disease was known as the illness of the wastewater worker in England before the 1950s. Recent studies, however, have not verified this bacteria as a current problem for wastewater workers. Infection usually occurs by way of contact with mucous membranes or skin abrasions.[7] Although *Leptospira* are killed rapidly in wastewater carrying detergent byproducts, this may represent an infection risk to collection system workers in some cases.

Viruses

A virus is any of a group of ultramicroscopic agents that reproduce only in living cells. This characteristic of viruses is important because they cannot reproduce without a host cell and, therefore, will not reproduce in wastewater. The major source of viruses that are infectious to man is from human waste that has been discharged to the sewer.[7]

More than 100 different types of viruses are found in human waste. Human viruses commonly found in wastewater are listed in Table 3.[8] These viruses multiply in the living cells of the intestinal tract and end up in human feces. Because millions of viruses can be produced by an infected cell, they are found in large quantities in wastewater.[4] Characteristics of various wastewater viruses and their mode of transmission and communicability are found in Table 4.[8]

Table 3 Human viruses found in wastewater.

Virus group	Disease
Norwalk	Acute gastroenteritis
Rotavirus	Acute gastroenteritis
Adenovirus	Acute respiratory disease, conjunctivitis, pharynoconjunctival fever
Coxsackie A	Upper respiratory tract infection
Coxsackie B	Upper respiratory tract infection, myocarditis, aspectic menin-gitis, Bornholm's disease
Echovirus	Common cold, aseptic meningitis, conjunctivitis, gastroenteritis
Hepatitis A	Infectious hepatitis
Poliovirus	Poliomyelitis
Reovirus	Upper respiratory tract infection

Table 4 Characteristics of various wastewater viruses.

Virus group	Mode of transmission	Incubation period	Period of communicability
Adenovirus	Inhalation	5-7 days	Short
Echovirus	Inhalation	1-2 days	Short
Hepatitis A	Ingestion	15-40 days	Long
Poliovirus	Ingestion	5-20 days	Long
Norwalk	Ingestion		
Rotavirus	Ingestion		
Coxsackie A	Ingestion or Inhalation		
Coxsackie B	Ingestion or Inhalation		

While there are many types of viruses present in wastewater, the general category that has received the most study is the enteric, or intestinal, virus. This group includes the varieties that are responsible for diseases such as infectious hepatitis, meningitis, cases was being performed in accordance with the strict guidelines of the Department of Health Services.

MANAGEMENT ALTERNATIVES

Crop water and nutrient requirements are primarily related to the type of crop and its growth stage; climatic conditions of temperature, humidity, wind, and solar radiation; and modifications brought on by water and chemical deficiencies or imbalances. Little can be done about the weather, but water and chemical problems can be alleviated through a proper irrigation and fertility management program. This may involve dilution and/or the use of amendments, or the water source may be adapted by modifications in the cultural practices or crop selection. Following are more specific management alternatives dealing with specific problems as recommended by Ayers and Westcott (1976).

Salinity

The major objective in choosing a management alternative to overcome a salinity problem is to improve soil water availability to the crop. Some of the management alternatives include:

tailwater, thus minimizing the possibility of polluting other surface waters.

Crop contamination can result from irrigating with water which has received inadequate treatment or by applying the water improperly (sprinkler irrigation of food crops). Some trace organics which could be present in reclaimed water are known to be carcinogenic. It is generally believed, however, that these substances are adsorbed by the soil matrix and are not absorbed into the plant tissue (Uiga and Crites, 1980). Additional dangers result from the creation of aerosols by sprinkler irrigation systems which contain virus and bacteria. If ingested, these aerosols have some potential for infection by the organisms which they contain.

Uiga and Crites (1980) found that there is a greater risk to public health using reclaimed water on food crops than on nonfood crops. They noted, however, that the present use of reclaimed water for crop irrigation provides a safety factor of 10^8 to 10^{13} over the last reported incidence of disease transmittal (early 1900's) through the use of "night soil" on food crops. Of the 21 sites reviewed, there were no indications that health problems were of any concern. The farmer is probably more concerned with the quality of his crops or the effect reclaimed water might have on crop marketability. Crop irrigation in all deficiencies are sometimes corrected by the use of reclaimed water.

HEALTH CONCERNS

Public health concerns related to crop irrigation with reclaimed water include:

- Bacterial and viral agents associated with the possible transmission of disease.
- Hazardous chemicals that may reach ground or surface waters.
- Contamination of crops by chemical or biological pollutants.

The Department of Health Services regulates the use of reclaimed water for crop irrigation and has very specific treatment requirements. The treatment requirements, type of crops, and method of irrigation were shown in Figure 3-1. Disinfection is generally required to reduce bacterial or viral contamination of the water. The Health Department is also concerned with protecting the quality of other water sources that can be used as potable water. Leaching of nitrates in the soil is a primary concern in this respect.

Pollution control agencies usually require that all reclaimed water used for irrigation be totally contained on the user's property. This requires the user to recover inhalation. Direct ingestion would occur if the farm workers drank the reclaimed water. This form of exposure has the greatest potential for infection or illness. The concern for safety, in part, stems from the questions of liability in the case of a worker who may become ill while on the job. While the potential for illness must be considered, Uiga and Crites found that the overall health risk for site workers was small.

The farmer also looks at the question of safety from the point of the ability of the treatment plant to produce reclaimed water at consistently high quality. Conventional wastewater treatment systems can be upset which results in poor quality effluent. These occurrences also increase health risks. There have been isolated instances of crop damage by treatment plant upset; however, the overall safety record of these facilities has been good.

Consumer-Related Effects

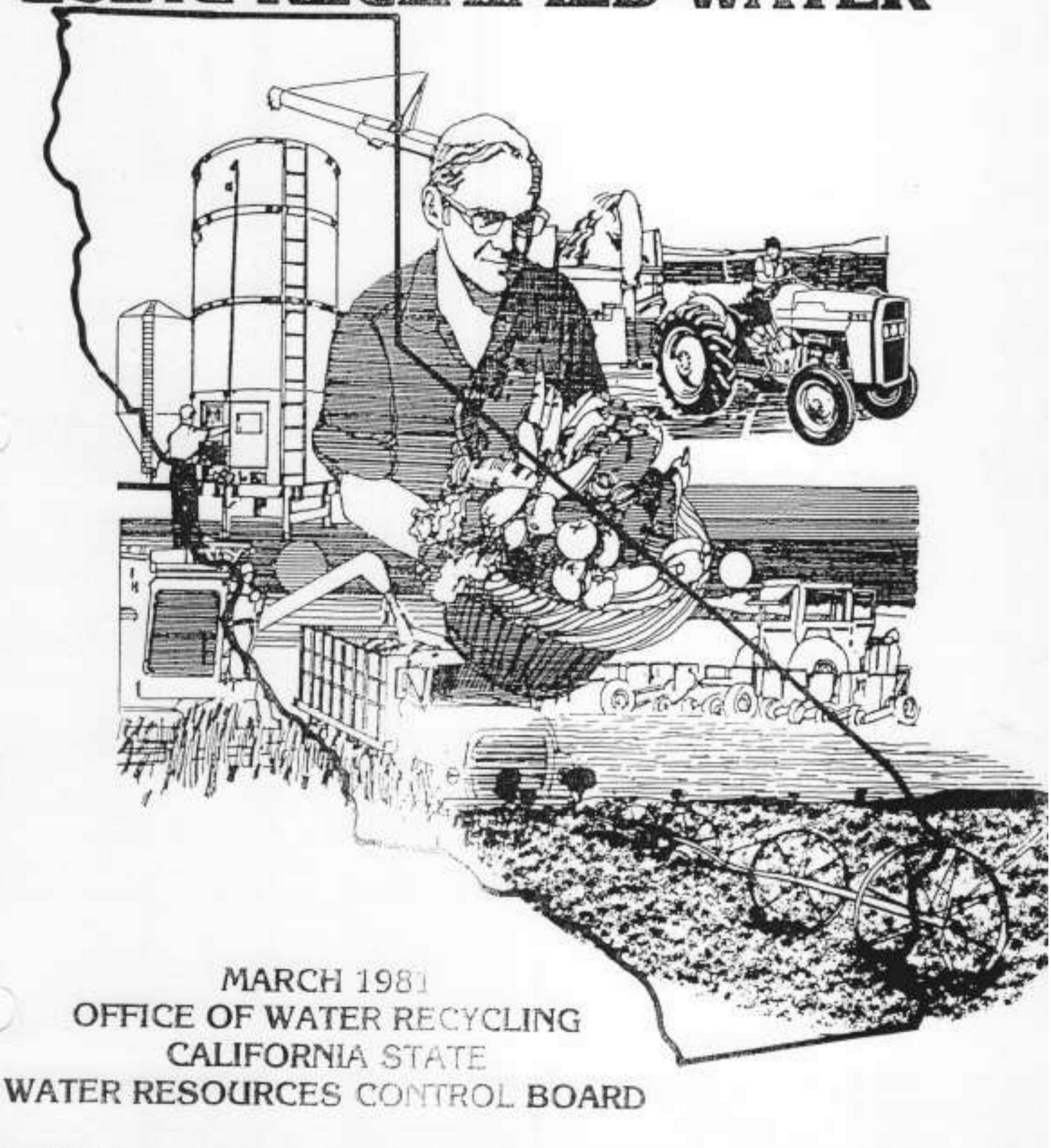
Farmers are concerned with consumer acceptance of crops grown with reclaimed water. The degree of concern is, of course, highest with edible crops and particularly with fresh produce. Adverse consumer reaction to crops grown with reclaimed water could lead to economic disaster in the highly competitive specialty crop markets. On the other hand, crops which come into contact with the public indirectly (such as cotton) may be much less subject to agricultural irrigation. However, in areas where the agricultural community is unfamiliar with reclamation, it is viewed with some skepticism. This section will identify some of the attitudes and concerns of the agricultural community.

Agriculturists have occasionally publicized their concerns relating to the use of reclaimed water, a notable example being the Symposium held in Salinas, California, which grew into the current Monterey Wastewater Reclamation Study for Agriculture. Agriculturists are concerned with the complete range of effects that are tied to reclaimed water use for agriculture including safety and liability concerns, consumer related effects, ecological effects, economic impacts, and regulatory or operational limitations.

Safety and Liability

An important concern of farmers is the exposure of workers to effluent, either by incidental physical contact, inhalation of aerosols, or direct or potable ingestion. Virus, bacteria, and parasites are all transmittable via these routes. Uiga and Crites (1980) indicate that incidental physical contact is the least likely to cause infection or illness. Infection through the inhalation of aerosols requires the transport of viable infectious organisms in droplets of proper size for potential

EVALUATION OF AGRICULTURAL IRRIGATION PROJECTS USING RECLAIMED WATER



MARCH 1981

OFFICE OF WATER RECYCLING

CALIFORNIA STATE

WATER RESOURCES CONTROL BOARD

AIDS

Acquired immune deficiency syndrome (AIDS) is caused by the human immunodeficiency virus (HIV) that attacks the body's immune system, leaving the body susceptible to numerous diseases. The AIDS virus is a delicate virus that cannot survive for long periods of time outside of the human body. The virus exists in low concentrations in the blood of infected persons, and after entering the wastewater sewer system, it is subjected to enormous dilution factors and harsh environments (low levels of heat, pH extremes, surfactants, and chemical agents) that are not conducive to AIDS virus survival.[12]

Operators have expressed considerable interest in the possible transmission of AIDS from human wastes such as urine, excrement, and blood that are discharged to sewer lines serviced by municipal wastewater treatment facilities.[2] Fears have been raised over the handling of raw wastewater during routine contact and during repairs and maintenance to lift station pumps, bar screens, broken sewer lines, and clogged laterals. Further contact with contaminated wastewater, originating from prisons, hospitals, and institutions, and uneasiness over the removal of hypodermic needles, condoms, feminine napkins, and aborted fetuses have added to the growing apprehension about disease transmission.[2]

AIDS and hepatitis B are both blood-borne viruses and cannot reproduce outside the human body. To be transmitted, AIDS and hepatitus B must enter the bloodstream directly. A blood-borne virus from contaminated wastewater can gain direct access through an open wound or abrasion on the skin. Merely coming in contact with contaminated wastewater does not imply exposure to AIDS or hepatitis B.

ASSESSMENT REPORT

- WATER REUSE
- WASTEWATER
- RECLAMATION
- POTABLE
- NONPOTABLE

INTEGRATED RESOURCES MANAGEMENT

Water Reuse

PROJECT 92-WRE-1

Water Environment Research Foundation

1994

CHAPTER 4.0

HEALTH ASSESSMENT

The public health is protected by:

- reducing concentrations of pathogenic bacteria, parasites, and enteric viruses in the reclaimed water;
- controlling specified chemical constituents in the reclaimed water; and/or
- limiting public exposure (contact, inhalation, ingestion) to the reclaimed water.

If human exposure is likely in a reuse application, a higher quality of reclaimed water is required. Conversely, if public access to a reuse site can be restricted so that exposure is unlikely, a lower level of treatment may be satisfactory, provided that worker safety is not compromised.

Providing the necessary treatment for the intended reuse application requires an understanding of the constituents of concern in wastewater and the levels of treatment and processes necessary to remove such constituents to achieve the desired reclaimed water quality.

4.1 Constituents of Concern

4.1.1 Pathogenic Microorganisms

The principal infectious agents in wastewater can be classified into three broad groups: bacteria, parasites (protozoa and helminths), and viruses. Table 4-1 lists many of the infectious agents potentially present in raw domestic wastewater. No cases of intestinal diseases have been associated with reuse projects in the U.S. In developing countries, on the other hand, the irrigation of market crops is a major source of enteric disease.

Table 4–1. Infectious Agents Potentially Present in Untreated Domestic Wastewater

Pathogen	Disease
Bacteria	
Shigella (4 spp.)	Shigellosis (dysentery)
Salmonella typhi	Typhoid fever
Salmonella (1700 serotypes)	Salmonellosis
Vibro cholerae	Cholera
Escherichia coli (enteropathogenic)	Gastroenteritis
Yersinia enterocolitica	Yersiniosis
Leptospira (spp.)	Leptospirosis
Legionella	Legionnaire's disease
Campylobacter jejuni	Gastroenteritis
Protozoa	
Entamoeba histolytica	Amebiasis (amebic dysentery)
Giardia lamblia	Giardiasis
Balantidium coli	Balantisiasis (dysentery)
Cryptosporidium	Cryptosporidiosis, diarrhea, fever
Helminths	
Ascaris lumbricoides (roundworm)	Ascariasis
Ancylostoma duodenale (hookworm)	Ancylostomiasis
Necator americanus (roundworm)	Necatoriasis
Ancylostoma (spp.) (hookworm)	Cutaneous larva migrans
Strongloides stercoralis (threadworm)	Strongyloidiasis
Trichuris trichiura (whipworm)	Trichuriasis
Taenia (spp.) (tapeworm)	Taeniasis
Enterobius vermicularis (pinworm)	Enterobiasis
Echinococcus granulosus (spp.) (tapeworm)	Hydatidosis

Table 4-1, cont.

Infectious Agents Potentially Present in Untreated Domestic Wastewater

Viruses	
Enteroviruses (72 types) (polio, echo, coxsackie, new enteroviruses)	Gastroenteritis, heart anomolies, meningitis, others
Hepatitis A virus	Infectious hepatitis
Adenovirus (47 types)	Respiratory disease, eye infections
Rotavirus (4 types)	Gastroenteritis
Parvovirus (3 types)	Gastroenteritis
Norwalk agent	Diarrhea, vomiting, fever
Reovirus (3 types)	Not clearly established
Astrovirus (5 types)	Gastroenteritis
Calicivirus (2 types)	Gastroenteritis
Coronavirus	Gastroenteritis

Source: Adapted from Sagik et al., 1978; Hurst et al., 1989.

4.1.1.1 Bacteria

One of the most common pathogens found in municipal wastewater is the genus *Salmonella*. The *Salmonella* group contains a wide variety of species that can cause disease in humans and animals. The three distinct forms of salmonellosis in humans are enteric fevers, septicemias, and acute gastroenteritis. The most severe form of salmonellosis is typhoid fever, caused by *Salmonella typhi*. The *Salmonella* septicemias (blood poisoning) are not particularly common inhuman populations. The third form of salmonellosis, acute gastroenteritis, is the disease form with which Salmonella are most often associated. Some 1,700 different serotypes have been identified.

A less common genus of bacteria in wastewater is *Shigella*, which produces an intestinal disease known as bacillary dysentery or shigellosis. Waterborne outbreaks of shigellosis have been reported where wastewater has contaminated wells used for drinking water (National Communicable Disease Center, 1969 and 1973). The survival time of *Shigella* in wastewater is relatively short, and shigellosis appears to be spread primarily by person–to–person contact. However, *Shigella* is the leading cause of recreational waterborne outbreaks in lakes and rivers.

Other bacteria have also been isolated from raw wastewater. These include *Vibrio, Mycobacterium, Clostridium, Leptospira*, and *Yersinia* species. While these pathogens may be present in wastewater, their concentrations are usually too low to initiate disease outbreaks. *Vibrio cholerae* is the disease agent for cholera, uncommon in the United States but still prevalent in other parts of the world. Humans are the only known hosts, and the most frequent mode of transmission is through water. *Mycobacterium tuberculosis* has been found in wastewater (Greenberg and Kupka, 1957), particularly where an institution treating tuberculosis patients is involved or where industries, such as dairies and slaughterhouses handling tubercular animals, discharge to a municipal sewerage system. Outbreaks have been reported among persons swimming in water contaminated with wastewater (California Department of Health and Cooper, 1975).

Waterborne gastroenteritis of unknown cause is frequently reported, with the suspected agent being bacterial. One potential source of this disease is certain gram–negative bacteria normally considered to be nonpathogenic. These include enteropathogenic *Escherichia coli* and certain strains of *Pseudomonas*, which may affect the newborn. Waterborne enterotoxigenic *E. coli* have been implicated in gastrointestinal disease outbreaks (National Communicable Disease Center, 1975).

Campylobacter coli has been identified as the cause of a form of bacterial diarrhea in humans. While it has been well established that this organism causes disease in animals, it has also been implicated as the etiological agent in human waterborne disease outbreaks (Craun, 1988).

In recognition of the many constraints associated with analyzing wastewater for all of the potential pathogens that may be present, it has been common practice to use a microbial indicator or surrogate to indicate fecal contamination of water. Bacteria of the coliform group have long been considered the prime indicators of fecal contamination and are the most frequently applied indicators of water quality by state regulatory agencies. The coliform group is made up of a number of bacteria, including the genera *Klebsiella, Citrobacter, Escherichia, Serratia,* and *Enterobacteria*. The total coliform group are all gram-negative asporogenous rods and are found in feces of warm-blooded animals and in soil. Fecal coliform bacteria are restricted to the intestinal tract of warm-blooded animals and comprise a portion of the total coliform group. *Escherichia coli* and enterococci (U.S. Environmental Protection Agency, 1986a) are sometimes used as indicators of bacteriological contamination in recreational waters. Coliform organisms are used as indicators because they occur naturally in the feces of warm-blooded animals in higher concentrations than pathogens and are easily and unambiguously detectable, exhibit a positive correlation with fecal contamination, and generally respond similarly to environmental conditions and treatment processes as many bacterial pathogens. However, coliform bacteria determinations, by themselves, do not adequately predict the presence or concentration of pathogenic viruses or protozoa.

There are deficiencies in the use of coliforms or enterococci as water quality indicators. The data base for their use relies on epidemiological investigations that have not always been replicated (Haas, 1993). Concerns for newly-emerging pathogenic organisms which may arise from nonhuman reservoirs, e.g., *Giardia* and *Cryptosporidium*, have led to questioning the use of indicators that arise primarily from human fecal inputs. The cysts and oocysts responsible for the spread of these organisms are not easily monitored and not as readily inactivated by chlorine as bacterial surrogates now in use. *Research is needed to determine the most appropriate indicator organism(s) to use for assessment for treatment efficiency in reclaimed water systems.*

4.1.1.2 Protozoa

Several pathogenic protozoan parasites have been found in municipal wastewater. Probably the most important of the parasites is the protozoan, *Entamoeba histolytica,* which is responsible for amoebic dysentery and amoebic hepatitis. The amoeba is found in sewage in the form of cysts, which are excreted by infected humans. The diseases are found worldwide, but in the U.S., *Entamoeba histolytica* has not been an important disease agent since the 1950s.

Waterborne disease outbreaks around the world have been linked to the protozoans *Giardia lamblia* and *Cryptosporidium*, although no giardiasis or cryptosporidiosis cases related to water reuse projects have been reported. They originate in water from the feces of wild and domestic animals. Giardiasis is responsible for gastrointestinal disturbances, diarrhea, and general discomfort and is emerging as a major waterborne disease. Infection is caused by ingestion of *Giardia* cysts. *Cryptosporidium* also causes diarrheal disease, with oocysts being the infectious stage. *Cryptosporidium* oocysts are not readily inactivated by chlorination. Cysts and oocysts are present in most wastewaters. Analysis for cysts and oocysts is difficult; hundreds of liters need to be used per sample and recovery is poor. Cryptosporidiosis is fatal to immuno–compromised individuals and is associated with acquired immunodeficiency syndrome patients. In Milwaukee, in April 1993, water drawn from Lake Michigan, after treatment met microbiological drinking water standards, caused more than 400,000 cases of cryptosporidiosis and some 50 deaths. Waterborne cases of these diseases may well go unrecognized, because the diarrheal symptoms are not specific to these diseases and analysis of feces for cysts and oocysts often is not done.

4.1.1.3 Helminths

The most important helminthic parasites that may be found in wastewater are intestinal worms, including the stomach worm *Ascaris lumbricoides,* the tapeworms *Taenia saginata* and *Taenia solium,* the whipworm *Trichuris trichiura,* the hookworms *Ancylostoma duodenale* and *Necator americanus,* and the threadworm *Strongyloides stercoralis.* Many of the helminths have complex life cycles, including a required stage in intermediate hosts. The infective stage of some helminths is either the adult organism or larvae, while the eggs or ova of other helminths constitute the infective stage of the organisms. The free–living nematode larvae stages are not pathogenic to human beings. The eggs and larvae are resistant to environmental stresses and may survive usual wastewater disinfection procedures, although eggs are readily removed by commonly used wastewater treatment processes, such as sedimentation, filtration, or stabilization ponds.

4.1.1.4 Viruses

Over 100 different types of enteric viruses capable of producing infection or disease are excreted by humans. Enteric viruses multiply in the intestinal tract and are released in the fecal matter of infected persons. Not all types of enteric viruses cause waterborne disease.

The most important human enteric viruses are the enteroviruses (polio, echo, and coxsackie), Norwalk virus, rotaviruses, reoviruses, parvoviruses, adenoviruses, and hepatitis A virus (Hurst et al., 1989; Water Pollution Control Federation, 1989). The reoviruses and adenoviruses, which are known to cause respiratory illness, gastroenteritis, and eye infections, have been isolated from wastewater. Of the viruses that cause diarrheal disease, only the Norwalk virus and rotavirus have been shown to be major waterborne pathogens (Rose, 1986). Hepatitis A, the virus that causes infectious hepatitis, is a virus frequently reported to be transmitted by water. Sewage-contaminated water has been implicated in waterborne outbreaks of infections hepatitis (American Society of Civil Engineers, 1970; Mosley, 1967).

There is no evidence that the human immunodeficiency virus (HIV), the pathogen that causes the acquired immunodeficiency syndrome (AIDS), can be transmitted via a waterborne route (Riggs, 1989; Gover, 1993). The results of one laboratory study (Casson et al., 1992), where primary and undisinfected secondary effluent samples were inoculated with HIV (Strain IIIB) and held for up to 48 hours at 25°C, indicated that HIV survival was significantly less than poliovirus survival under similar conditions. Ansari, Farrah, and Chaudry (1992) reported that HIV-1 nucleic acids were detected in three of seven raw wastewater samples by using in vitro amplification of the target sequences by the polymerase chain reaction (PCR) method. In the same study, HIV-1 nucleic acids were not detected in 13 samples of sludge, final effluent (treatment level not given), pond water, and soil. The PCR method determines the presence of viral nucleic acids but does not indicate the presence of infectious viral particles.

It has been reported that viruses and other pathogens in wastewater used for crop irrigation do not readily penetrate fruits or vegetables unless the skin is broken (Bryan, 1974). In one study in which soil was inoculated with poliovirus, viruses were detected in the leaves of plants only when the plant roots were damaged or cut (Shuval, 1978). Although absorption of viruses by plant roots and subsequent acropetal translocation has been reported (Murphy and Syverton, 1958), it probably does not occur with sufficient regularity to be a mechanism for the transmission of viruses. Therefore, the likelihood that pathogens would be translocated through trees or vines to the edible part of crops is extremely low.

The study of low–level or endemic occurrence of waterborne virus diseases has been virtually ignored for several reasons:

- Current viral detection methods are not sufficiently sensitive to reliably detect viruses at low concentrations;
- Enteric viral infections are often subclinical, thus making it difficult to establish the endemicity of such infections;
- Most enteric viral infections go unreported by the patient and physicial because of the often mild nature of the illnesses;
- Current epidemiological techniques are not sufficiently sensitive to detect low level transmission of viral diseases through waterborne routes;
- Illness resulting from enteroviral infections may not become obvious for several months or years; and
- Once introduced into a population, person–to–person contact becomes a major mode of transmission of an enteric virus, thereby obscuring the role of water in its transmission.

In view of increasing concern for the health of people with compromised immune systems, the need for virus standards merits reexamination.

4.1.1.5 Mechanism of Disease Transmission

Diseases can be transmitted to humans either directly by skin contact, ingestion, or inhalation of infectious agents in water, or indirectly by contact with objects previously contaminated. The following circumstances must occur for an individual to become infected from exposure to reclaimed water:

- the infectious agent must be present in the community and, hence, in the wastewater from that community;

- the agents must survive the wastewater treatment processes to which they are exposed;

- the individual must either directly or indirectly come in contact with the reclaimed water; and

- the agents must be present in sufficient numbers to cause infection at the time of contact.

Whether illness occurs depends on a series of complex interrelationships between the host and the infectious agent. Specific variables include: the numbers of the invading microorganism (dose); the numbers of organisms necessary to initiate infection (infective dose); the organism's ability to cause disease (pathogenicity); and the relative susceptibility of the host. The infectious dose of some organisms may be lower than the dose required to cause overt symptoms of the disease. Infection may be defined as an immunological response to pathogenic agents by a host without necessarily showing signs of a disease.

Susceptibility is highly variable and depends on both the general health of the subject and the specific pathogen in question. Infants, elderly persons, malnourished persons, and persons with concomitant illness or compromised immune systems are more susceptible than healthy adults. Table 4–2 presents the infective doses of selected pathogens.

Pathogenic microorganisms in wastewater are derived principally from the feces of infected human and animal hosts. There are occasions when host infections cause passage of pathogens in urine. The three principal infections leading to significant appearance of pathogens in urine are: urinary schistosomiasis, typhoid, and leptospirosis. Coliform and other bacteria may be numerous in urine during urinary tract infections, but they constitute little public health risk in wastewater. Microbial agents resulting from venereal infections can also be present in urine, but they are so vulnerable to conditions outside the body that wastewater is not an important vehicle of transmission (Feachem et al., 1983).

Table 4-2. Infective Doses of Selected Pathogens

Organisms	Infective Dose
Escherichia coli (enteropathogenic)	$10^6 - 10^{10}$
Clostridium perfringens	$1 - 10^{10}$
Salmonella typhi	$10^4 - 10^7$
Vibrio cholerae	$10^3 - 10^7$
Shigella flexneri 2A	180
Entamoeba histolytica	20
Shigella dysenteriae	10
Giardia lamblia	<10
Cryptosporidium	1–10
Viruses	1–10
Ascaris lumbricoides	1–10

Source: Adapted from Feachem et al., 1981 and Feachem et al., 1983.

4.1.1.6 Presence and Survival of Pathogens

The occurrence and concentration of pathogenic microorganisms in raw wastewater depend on a number of factors, and it is not possible to predict with any degree of assurance what the general characteristics of a particular wastewater will be with respect to infectious agents. Important variables include the sources contributing to the wastewater, the general health of the contributing population, the existence of "disease carriers" in the population, and the ability of infectious agents to survive outside their hosts under a variety of environmental conditions.

Table 4-3 illustrates the variation and order of magnitude of the concentration of organisms in raw wastewater. As an example of the large quantities of pathogens that may be introduced into a sewer system, it has been reported that the excretion of *Salmonella typhi* by asymptomatic carriers may be as high as 45×10^6 organisms per gram of feces (Drexel University, 1978).

Table 4-3. Microorganism Concentration in Raw Wastewater

Organisms	Concentration (number/100 mL)
Fecal Coliforms	10^4 - 10^9
Fecal streptococci	10^4 - 10^6
Shigella	1- 1,000
Salmonella	400 - 8,000
Helminth ova	1 - 180
Enteric virus	100 - 50,000
Giardia lambia cysts	50 - 10^4
Entamoeba histolytica cysts	1 - 10

Viruses are not normally excreted for prolonged periods by healthy individuals, and the occurrence of virus in municipal wastewater is sporadic. Virus concentrations are generally highest during the summer and early autumn months. Viruses shed by an infected individual commonly range from 1,000 to 100,000 infective units per gram of feces, but may be as high as 1,000,000 per gram of feces (Feachem et al., 1983). Viruses are generally more resistant to environmental stresses than many of the bacteria, although some viruses persist for only a short time in municipal wastewater. In water-short areas, where per capita water use is relatively low, virus concentrations have been reported to range from 600 to approximately 50,000 plaque-forming units (pfu) per 100 milliliters (Buras, 1976). This is in contrast to virus levels in the U.S., which have been reported to be as high as 700 virus units/100 mL but are typically less than 100 pfu/100 mL (Melnick et al., 1978; American Society of Civil Engineers, 1970).

Under favorable conditions, pathogens can survive for long periods of time on crops or in water or soil. Factors that affect survival include the number and type of organism, soil organic matter content (presence of organic matter aids survival), temperature (longer survival at low temperatures), humidity (longer survival at high humidity), pH, amount of rainfall, amount of sunlight (solar radiation is detrimental to survival), protection provided by foliage, and competitive microbial fauna and flora. Survival times for any particular microorganism exhibit wide fluctuations under differing conditions. Typical ranges of survival times for some common pathogens on crops and in water and soil are presented in Table 4-4.

Table 4-4. Typical Pathogen Survival Times at 20-30 °C

Pathogen	Survival Time (days)		
	Fresh Water & Sewage	Crops	Soil
Viruses[a]			
Enteroviruses[b]	<120 but usually <50	<60 but usually <15	<100 but usually <20
Bacteria			
Fecal coliforms[a]	<60 but usually <30	<30 but usually <15	<70 but usually <20
Salmonella spp.[a]	<60 but usually <30	<30 but usually <15	<70 but usually <20
Shigella spp.[a]	<30 but usually <10	<10 but usually <5	
Vibrio cholerae[c]	<30 but usually <10	<5 but usually <2	<20 but usually <10
Protozoa			
Entamoeba histolytica cysts	<30 but usually <15	<10 but usually <2	<20 but usually <10
Helminths			
Ascaris lumbricoides eggs	Many months	<60 but usually <30	Many months

[a] In seawater, viral survival is less, and bacterial survival is very much less, than in fresh water.

[b] Includes polio, echo, and coxsackie viruses.

[c] *V. cholerae* survival in aqueous environments is a subject of current uncertainty.

Source: Adapted from Feachem et al., 1983.

4.11.7 Aerosols

The concentration of pathogens in aerosols is a function of their concentration in the applied wastewater and the aerosolization efficiency of the spray process. During spray irrigation, the amount of water that is aerosolized can vary from less than 0.1% to almost 2%, with a mean aerosolization efficiency of 1% or less (Johnson et al., 1980a, 1980b; Bausum et al., 1983; Canann et al., 1988). Infection or disease may be contracted directly by aerosols deposited on surfaces such as food, vegetation, and clothes. The infective dose of some pathogens is lower for respiratory tract infections than for infections via the gastrointestinal tract; thus, for some pathogens, inhalation may be a more likely route for disease transmission than either contact or ingestion (Hoadley and Goyal, 1976). A comprehensive review of viruses indicated that a number of waterborne viruses are capable, if aerosolized, of producing respiratory tract infections and disease (Sobsey, 1978).

The infectivity of an inhaled aerosol depends on the depth of the respiratory penetration and the presence of pathogenic organisms capable of infecting the respiratory system. Aerosols in the 2 to 5 μm size range are primarily removed in the respiratory tract, some to be subsequently swallowed. Therefore, if gastrointestinal pathogens are present, infection could result. A considerably greater potential for infection occurs when respiratory pathogens are inhaled in aerosols smaller than 2 μm in size, which pass directly to the alveoli of the lungs (Sorber and Guter, 1975).

In general, bacteria and viruses in aerosols remain viable and travel farther with increased wind velocity, increased relative humidity, lower temperature, and lower solar radiation. Other important factors are the initial concentration of pathogens in the wastewater and droplet size. Aerosols can be transmitted for several hundred meters under optimal conditions. Some types of pathogenic organisms, e.g., enteroviruses and *Salmonella*, appear to survive the wastewater aerosolization process much better than the indicator organisms (Teltsch et al., 1980). Bacteria and viruses have been found in aerosols emitted by spray irrigation systems using untreated and poorly treated wastewater (Camann and Guentzel, 1985; Camann and Moore, 1988; Teltsch et al., 1980).

One study found that coliforms were carried 90 to 130 m (300 to 430 ft) with a wind velocity of 1.5 m/s (3.4 mi/hr), and it was estimated that fine mist could be carried 300 to 400 m with a 5 m/s (11 mi/hr) wind (Sepp, 1971). Other researchers reported that the mean net bacterial aerosol levels, i.e., the observed minus the simultaneous mean upwind value, were 485 colonyforming units (CFU)/m^3 at a distance of 21 to 30 m (69 to 98 ft) from the most downwind row of sprinkler heads in a spray field and 37 CFU/m^3 at 200 m (660 ft) downwind (Bausum et al., 1983). The sprayed wastewater had been treated in stabilization lagoons before disinfection with chlorine.

During a study in Israel, echovirus 7 was detected in air samples collected 40 m (130 ft) downwind from sprinklers spraying undisinfected secondary effluent (Teltsch and Katzenelson, 1978). Aerosol measurements at Pleasanton, California, where undisinfected secondary effluent was sprayed, indicated that the geometric mean aerosol concentration of enteroviruses obtained 50 m (165 ft) downwind of the wetted spray area was 0.014 pfu/m^3 (Johnson et al., 1980b).

One of the most comprehensive aerosol studies, the Lubbock Infection Surveillance Study (Camann et al., 1986), monitored viral and bacterial infections in a mostly rural community surrounding a spray irrigation site near Wilson, Texas. The source of the irrigation water was undisinfected trickling filter effluent from the Lubbock Southeast water reclamation plant. Spray irrigation of the wastewater significantly elevated air densities of fecal coliforms, fecal streptococci, mycobacteria, and coliphage above the ambient background levels for at least 200 m (650 ft) downwind. The geometric mean concentration of enteroviruses recovered 44 to 60 m (150 to 200 ft) downwind was 0.05 pfu/m^3, a level higher than that observed at other wastewater aerosol sites in the U.S. and in Israel (Camann et al., 1988). While disease surveillance found no obvious connection between the self–reporting of acute illness and the degree of aerosol exposure, serological testing of blood samples indicated that the rate of viral infections was slightly higher among members of the study population who had a high degree of aerosol exposure (Camann et al., 1986).

For intermittent spraying of properly disinfected reclaimed water, occasional inadvertent contact should pose little health hazard from inhalation. Aerosols that continuously issue from cooling towers may present a greater concern if the water is not properly disinfected. For example, *Legionella pneumophila*, the bacterium that causes Legionnaire's Disease, is present in many types of water and proliferates in some cooling water systems, thus presenting a potential health hazard regardless of the source of the water. The concentration of pathogens in the recirculated waters of cooling towers using reclaimed water is reduced somewhat by the treatment to prevent biofouling, which is generally by the addition of chlorine. On the other hand, the evaporation in cooling towers concentrates contaminants in the water, and the water in the tower and in aerosols or windblown spray may contain pathogen concentrations little different from the reclaimed water. Although much effort has been expended to quantitate fecal coliforms and enteric pathogens in cooling tower waters, there is no evidence that they occur in large numbers, although the numbers of other bacteria may be quite large (Adams and Lewis, n.d.).

Because only limited information is available regarding the health risks associated with wastewater aerosols, health implications are difficult to assess. Several studies in the U.S. have been directed at residents in communities subjected to aerosols from sewage treatment plants (Camann et al., 1979; Camann et al., 1980; Fannin et al., 1980; Johnson et al., 1980a). These investigations have not detected any definitive correlation between exposure to aerosols and disease. Although some studies have indicated higher incidences of respiratory and gastrointestinal illnesses in areas receiving aerosols from sewage treatment plants than in control areas, the elevated illness rates were either suspected to be the result of other factors, such as economic disparities, or were not verified by antibody tests for human viruses and isolations of pathogenic bacteria, parasites, or viruses (Fannin et al., 1980; Johnson et al., 1980a).

No documented disease outbreaks have resulted from spray irrigation with disinfected reclaimed water, and studies indicate that the health risk associated with aerosols from spray irrigation sites using reclaimed water is low (U.S. Environmental Protection Agency, 1980b). However, until more sensitive and definitive studies are conducted to fully evaluate the ability of pathogens contained in aerosols to cause disease, the general practice is to limit exposure to aerosols produced from reclaimed water that is not highly disinfected through design or operational controls. *Emission of aerosols or windblown spray from spray irrigation (and also from cooling towers) receiving reclaimed water warrant attention. The risk can come from exposure to the spray itself or from contact with wet grass or the ground itself after spraying.*

4.1.1.8 Disease Incidence Related to Water Reuse

In one survey of 63 disease outbreaks (some dating back to the late 1800s) associated with foods contaminated by sewage sludge or wastewater, vegetables contaminated by raw or partially treated sewage were implicated as the vehicle in 12 outbreaks, watercress in 10 outbreaks. Some were because of contamination by animal feces, and fruit was the vehicle in four of the reported outbreaks (Bryan, 1974).

Epidemiological investigations directed at wastewater-contaminated drinking water supplies, use of raw or minimally treated wastewater for food crop irrigation, health effects on farmworkers who routinely come in contact with poorly treated wastewater used for irrigation, and the health effects of aerosols or windblown spray emanating from spray irrigation sites using undisinfected wastewater have all provided evidence of infectious disease transmission from such practices (Sepp, 1971; Lund, 1980; Feachem et al., 1983; Shuval et al., 1986).

The majority of documented disease outbreaks have been the result of contamination by bacteria or parasites. Several incidences of typhoid fever were reported in the early 1900s (Melick, 1917), and a major outbreak of cholera in Jerusalem in 1970 was reportedly caused by food crop irrigation with undisinfected wastewater (Shuval et al., 1986). In Germany, ascaris worm infections have been attributed to the irrigation of vegetables and salad crops with untreated wastewater (Shuval et al., 1986).

Sepp (1971) reported that irrigation with sewage caused hookworm infections in India. Hookworms were found in contaminated soil and on sewage-irrigated vegetables and were transferred to humans both by direct contact and by eating the vegetables.

Human infection with the adult stage of the beef tapeworm *Taenia saginata* through ingestion of meat containing the cyst form, i.e., *Cysticercus bovis*, is another problem that has resulted from sewage irrigation of grazing land. Evidence of tapeworm transmission via infected cattle and sheep in Europe, Australia, and elsewhere has been well documented by Sepp (1971), who also reported that a survey of animals pasturing on municipal sewer farms in Poland revealed that 21% of the cattle and all of the sheep were infected with animal parasites.

Epidemiological studies of the exposed population at water reuse sites receiving disinfected reclaimed water treated to relatively high levels are of limited value because of the mobility of the population, 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 from the reuse practice, insufficient sensitivity of current epidemiological techniques to detect low-level disease transmission, and other confounding factors. It is particularly difficult to detect the low-level transmission of viral disease because many 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.

The limitations of epidemiological investigations notwithstanding, planned water reuse in the U.S. has not been documented as the cause of any infectious disease outbreaks (Water Pollution Control Federation, 1989).

Reasonable standards of personal hygiene, e.g., use of protective clothing, change of clothing at the end of the work period, avoiding exposure to reclaimed water where possible, and care in hand washing and bathing following exposure and prior to eating, appear to be effective in protecting the health of workers at water reuse sites, regardless of the level of treatment provided. *Despite the apparent lack of disease among farm workers, research directed at the microbiological health risks to farm workers from various types of agricultural irrigation with reclaimed water is lacking.*

Using pathogen risk assessment models to assess health risks associated with the use of reclaimed water is a relatively new concept. Risk analysis has been used as a tool in assessing relative health risks from microorganisms in drinking water (Cooper et al., 1986; Gerba and Haas, 1989; Olivieri et al. 1986; Regli et al., 1991; Rose et al., 1991), seawater (Olivieri, Cooper, and Danielson, 1989), and reclaimed water (Asano and Sakaji, 1990; Rose and Gerba, 1991; Rose and Carnahan, 1992; Tanaka et al., 1993). Risk analyses require several assumptions to be made, e.g., minimum infective dose of selected pathogens, concentration of pathogens in reclaimed water, quantity of reclaimed water (or pathogens) ingested, inhaled, or otherwise contacted by humans, and probability of infection based on infectivity models. Mathematical models used to represent dose-response data include the log-normal, exponential, beta, and logistic models. Operation and management practices, such as treatment reliability features and use area controls, play an important role in reducing estimated health risks. At the present time, no reclaimed water standards or guidelines in the U.S. are based on risk assessment using microorganism infectivity models. *Research into the applicability of microbial infectivity models for nonpotable reuse applications, such as exposure to reclaimed water in swimming, is needed.*

4.1.2 Chemical Constituents

The chemical constituents potentially present in municipal wastewater are a major concern for potable reuse and may also affect the acceptability of reclaimed water for other uses, such as food crop irrigation. The mechanisms of food crop contamination include: physical contamination, in which evaporation and repeated application may result in a buildup of contaminants on crops; uptake through the roots from the applied water or the soil; and foliar intake. *Some chemicals in reclaimed water could also enter the human food chain from animals fed crops irrigated with reclaimed water. This concern requires further study.* Chemical constituents must be considered when reclaimed water percolates into groundwater as a result of irrigation, groundwater recharge, or other uses. Some of the inorganic and organic constituents that may be of importance in water reclamation and reuse are listed in Table 4-5.

Table 5-1. Typical Composition of Untreated Municipal Wastewater[a]

Constituent	Concentration Range[b]			U.S. Average[c]
	Strong	Medium	Weak	
Solids (total)	1,200	720	350	--
Dissolved, total[d]	850	500	250	--
Fixed	525	300	145	--
Volatile	325	200	105	--
Suspended	350	220	100	192
Fixed	75	55	20	--
Volatile	275	165	80	--
Settleable solids, ml/L	20	10	5	--
Biochemical oxygen demand, 5-day 20°C	400	220	110	181
Total organic carbon	290	160	80	102
Chemical oxygen demand	1,100	500	250	417
Nitrogen (total)	85	40	20	34
Organic	35	15	8	13
Ammonia	50	25	12	20
Nitrite	0	0	0	--
Nitrate	0	0	0	0.6
Phosphorus (total)	15	8	4	9.4
Organic	5	3	1	2.6
Inorganic	10	5	3	6.8
Chlorides[d]	100	50	30	--
Alkalinity (as $CaCO_3$)[d]	200	100	50	211
Grease	150	100	50	--
Total coliform bacteria (no./100 mL)	10^7–10^9	10^7–10^8	10^6–10^7	22×10^6 [e]
Fecal coliform bacteria (no./100 mL)	--	--	--	8×10^6
Viruses, pfu/100 mL[f]	--	--	--	500

a Values are expressed in mg/L, except as noted.
b After Metcalf & Eddy, Inc., 1991.
c Culp et al., 1979.
d Values should be increased by amount in domestic water supply.
e Geldreich, 1978.
f Plaque-forming units/100mL

5.2 Primary Treatment

Primary treatment does little to remove colloidal and dissolved constituents. Additional phosphorus and heavy metal removal can be achieved through the addition of chemical coagulants and polymers. Primary sedimentation typically removes 50% to 60% of the suspended solids and 30% to 40% of the organic matter; it does not remove the soluble constituents of the wastewater. Primary sedimentation also is effective for the removal of some organic nitrogen, organic phosphorus, and heavy metals. Average constituent removal efficiencies for primary treatment processes are shown in Table 5-2.

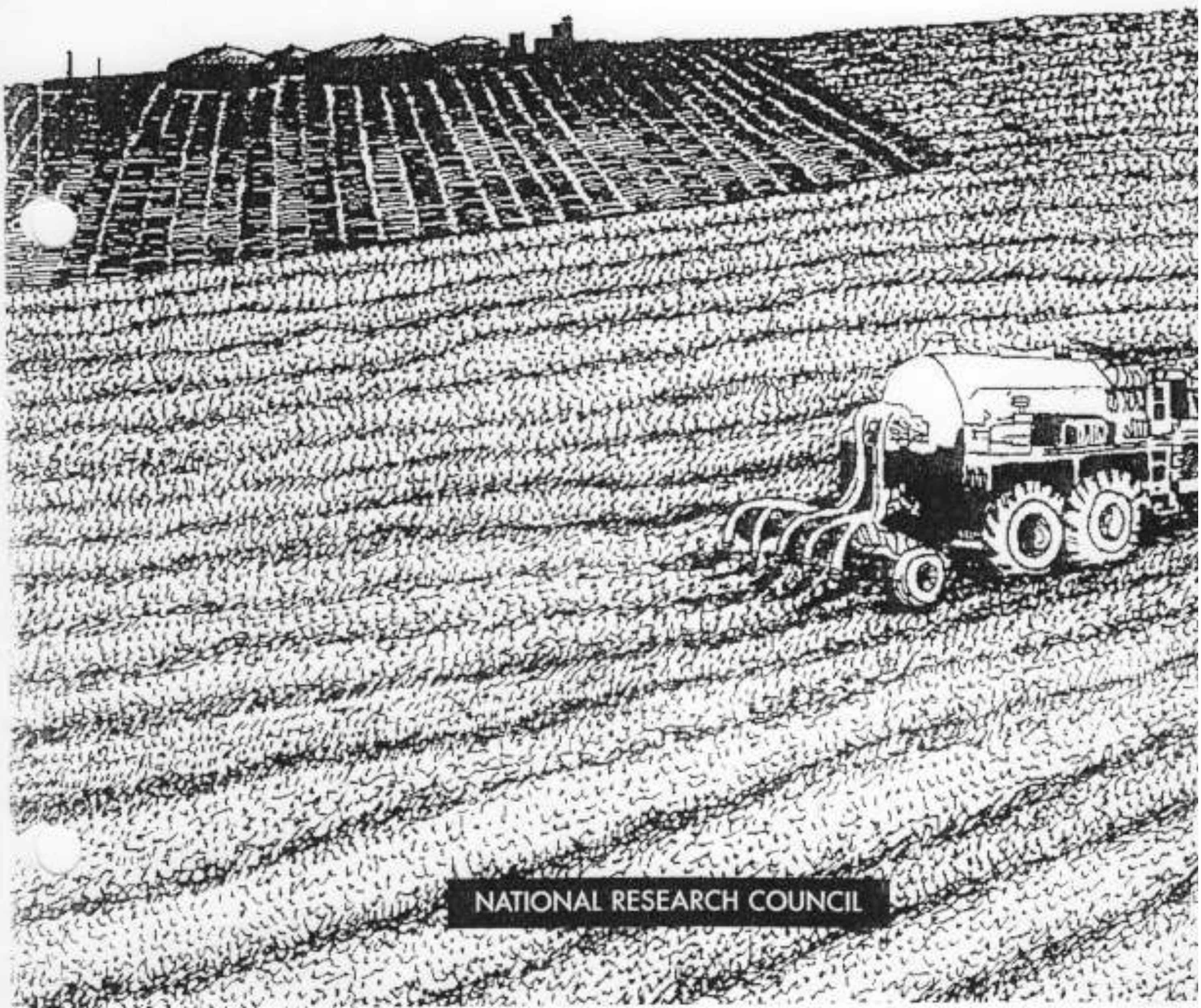
Primary treatment has little effect on the removal of most biological species present in wastewater. However, some protozoa and parasite ova and cysts will settle out during primary treatment, and some particulate-associated microorganisms may be removed with settleable matter. Primary treatment does not effectively reduce the level of viruses in sewage. The typical microorganism removal efficiencies of primary treatment are shown in Table 5-3. Generally, primary treatment by itself is not considered adequate for reuse applications.

5.3 Secondary Treatment

Typical microorganism and other constituent removal efficiencies for selected secondary treatment processes are presented in Tables 5-2 and 5-3.

The activated sludge, and trickling filter and other attached growth processes are capable of removing up to 95% of BOD, COD, and SS originally present in wastewater, as well as significant amounts of many (but not all) heavy metals and specific toxic organic compounds. Biological treatment, including secondary sedimentation, typically reduces the total BOD to 15 to 30 mg/L, COD to 40 to 70 mg/L, and TOC to 15 to 25 mg/L. Very little dissolved minerals are removed during conventional secondary treatment. Typical concentrations for some inorganic and organic constituents in secondary effluent are shown in Table 5-4.

Use of Reclaimed Water and Sludge in Food Crop Production



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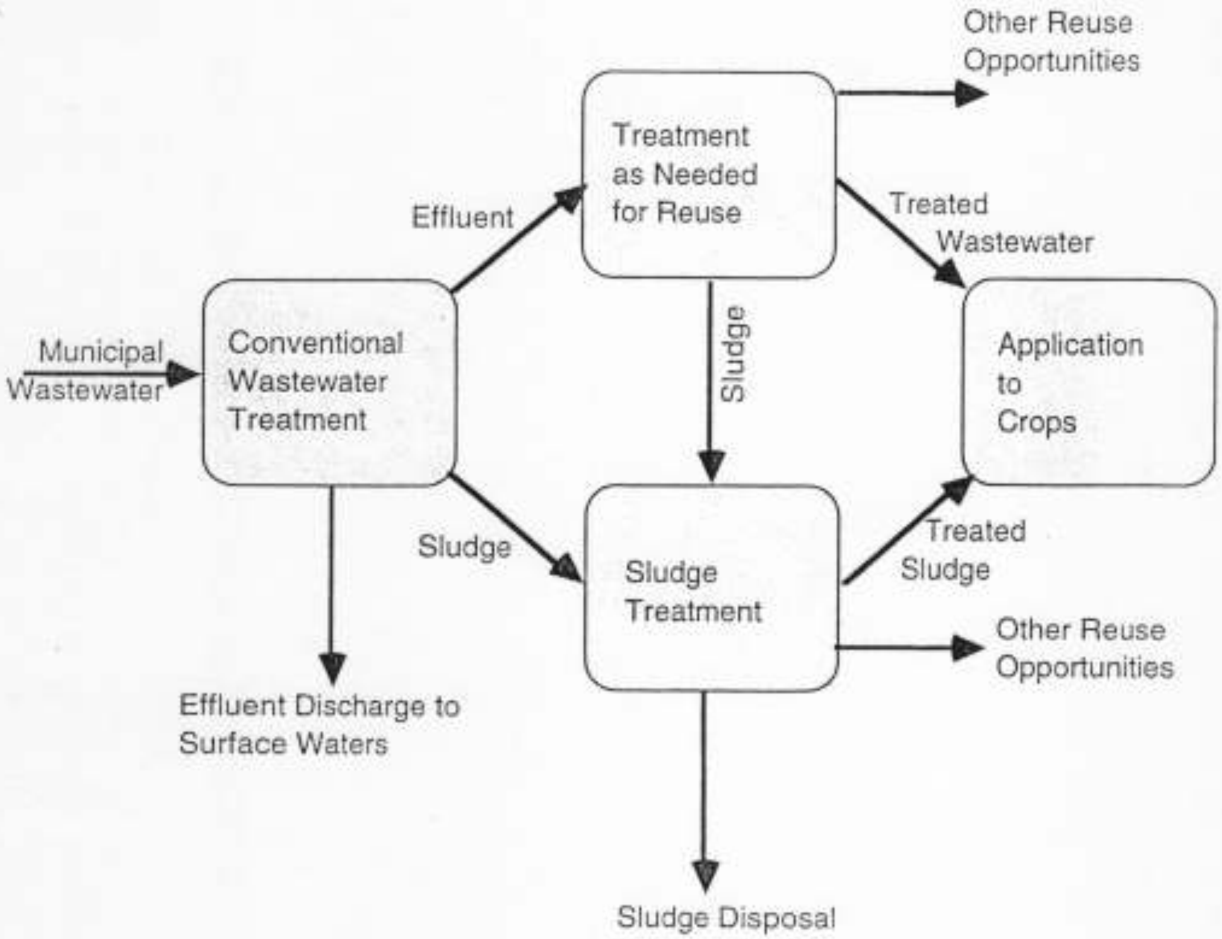

FIGURE 3.1 Following conventional wastewater treatment (preliminary, primary, and secondary), municipal wastewater is discharged to surface waters or reused, or before discharge to surface waters (not illustrated). Additional treatment may be needed before reuse. Sludge from wastewater treatment processes are treated and then disposed or reused in crop production or other applications.

age per capita usage from public water supply systems in the United States was 184 gallons (700 liters) per day (Solley et al., 1993). In arid areas, municipal wastewater production is typically less than the amount withdrawn for water supply, but in some areas, wastewater flow exceeds the water supply because of infiltration and inflow (e.g. stormwater) into wastewater collection systems. Using 85 percent of water use as an estimate of typical wastewater production (Henry and Heinke, 1989), a city of 200,000 people would produce an average of about 31,000,000 gal/day (about 117,000 m^3/day) of raw wastewater. The amount of treated wastewater effluent extracted is not appreciably diminished from the original quantity of raw wastewater particularly if sludge is dewatered, as is common.

The quality of treated effluent from secondary wastewater treatment plants in the United

States must comply with the federal regulation of a monthly average of 30 milligrams per liter of biochemical oxygen demand or BOD (a measure of the amount of biodegradable organic material remaining in the treated wastewater) and 30 mg/liter of suspended solids (particles removable by filtration). Typical concentrations of other constituents in wastewater treatment plant effluent are summarized in Chapter 2. More detailed information on typical effluent quality is presented in sections of this report where potential effects of individual constituents are considered. For example, Chapter 5 includes information on the types and quantities of pathogens typically found in various wastewater treatment plant effluents.

The volume of municipal wastewater sludge produced by wastewater treatment facilities is an elusive quantity because it varies as a result of typical sludge treatment (see "Volume Reduction Processes" later in this chapter). Since the mass of dry solids is conserved during most treatment processes, dry weight is a more useful basis for expressing the amount of sludge from municipal wastewater treatment. Typical primary and secondary wastewater treatment produces a total of about 1.95 lbs (0.94 kg) of dry solids per 1,000 gal (3.78 m^3) of wastewater treated (Metcalf and Eddy, 1991). Chemical addition to sludges during conditioning and stabilization processes (see later sections of this chapter) can appreciably increase the mass of solids in sludges. Biological stabilization acts to reduce the mass of suspended solids through oxidation of some of the volatile organic solids in sludges. For example, if sludge contains 80 percent volatile suspended solids and 50 percent of them are destroyed through oxidation, the stabilized mass of sludge solids would be reduced to 60 percent of the initial mass.

Typical solids contents of sludges at various stages of treatment are summarized in this chapter. Typical ranges of other common constituents in sludges are summarized in Chapter 2. As with wastewater effluents, more detailed information about specific sludge constituents is found in sections of the report where the potential effects of those constituents are discussed.

CONVENTIONAL WASTEWATER TREATMENT PROCESSES

Municipal wastewater treatment typically comprises preliminary treatment, primary treatment, and secondary treatment. Secondary treatment is the United States national standard for effluent discharged to surface waters. A higher degree of treatment, termed here "advanced" or "tertiary" treatment, may be required at specific locations to protect health or environmental quality. In this report, conventional municipal wastewater treatment is considered to include screening, grit removal, primary sedimentation, and biological treatment because it is the most common method (Figure 3.2). Elaboration on these terse descriptions may be found in sources such as Henry and Heinke (1989) and Metcalf and Eddy (1991).

Preliminary Wastewater Treatment

Preliminary wastewater treatment ordinarily includes screening and grit removal. Wastewater screening removes coarse solids such as rags that would interfere with mechanical equipment. Grit removal separates heavy, inorganic, sandlike solids that would settle in channels and interfere with treatment processes.

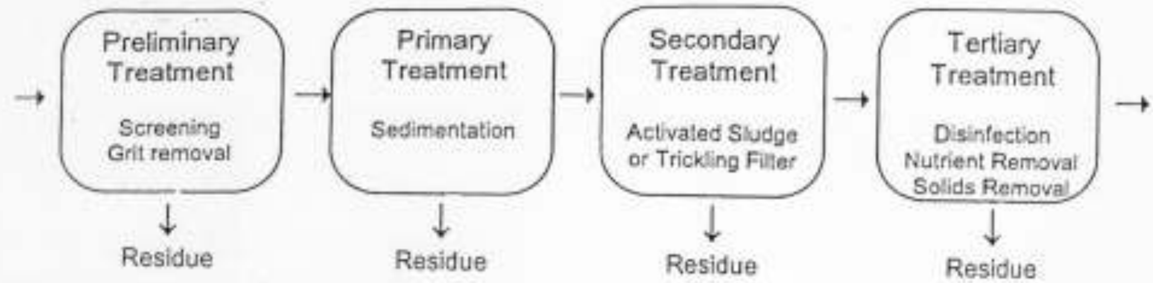

FIGURE 3.2 Municipal wastewater is conventionally subjected to preliminary, primary, and secondary treatment in the United States. Additional tertiary or advanced treatment may be justified by local conditions. Processes typically involved in each stage of treatment are shown. Preliminary treatment effects minimal change in wastewater quality. Primary treatment typically removes about one-third of the BOD and one-half of the suspended solids in domestic wastewaters. Combined primary and secondary treatment is required to achieve 85 percent reduction in both BOD and suspended solids concentration to meet the regulatory definition of secondary treatment.

Preliminary treatment serves to prepare wastewater for subsequent treatment, but it effects little change in wastewater quality. The residues from preliminary wastewater treatment, screenings and grit, are not ordinarily incorporated with sludges, and they are not considered further in this report.

Primary Wastewater Treatment

Primary wastewater treatment usually involves gravity sedimentation of screened, degritted wastewater to remove settleable solids; slightly more than one-half of the suspended solids ordinarily are removed. BOD in the form of solids removable by sedimentation (typically about one-third of total BOD) is also removed. At one time during the evolution of domestic wastewater treatment in the United States, facilities only practiced primary wastewater treatment and the primary effluent was commonly discharged to surface waters offering appreciable dilution. Now, primary treatment is used as an economical means for removing some contaminants prior to secondary treatment. The residue from primary treatment is a concentrated suspension of particles in water called "primary sludge."

Although the goal of primary wastewater treatment is to separate readily-removable suspended solids and BOD, wastewater constituents that exist as settleable solids or are sorbed to settleable wastewater solids may also be removed. Thus, primary treatment effects some reduction in the effluent concentration of nutrients, pathogenic organisms, trace elements, and potentially toxic organic compounds. The constituents that are removed are contained in primary sludge.

Secondary Wastewater Treatment

Secondary municipal wastewater treatment is almost always accomplished by biological treatment process. Microorganisms in suspension (in the "activated sludge" process), attached to media (in a "trickling filter" or one of its variations), or in ponds or other processes are used to remove biodegradable organic material. Part of the organic material is oxidized by the microorganisms to produce carbon dioxide and other end products, and the remainder provides the energy and materials needed to support the microorganism community. The microorganisms biologically flocculate to form settleable particles, and, following biological treatment, this excess biomass is separated in sedimentation tanks as a concentrated suspension called "secondary sludge" (also known as "biological sludge," "waste activated sludge," or "trickling filter humus").

Wastewater constituents can become associated with secondary sludge as a result of microbial assimilation, by sorption onto settleable solids, or by incorporation into agglomerate particles formed as a result of bioflocculation. Some of the wastewater constituents that are incidentally associated with the biomass from secondary treatment processes include pathogens, trace elements, and organic compounds.

Tertiary or Advanced Wastewater Treatment

Tertiary treatment is used at municipal wastewater treatment plants when receiving water conditions or other uses require higher quality effluent than that produced by secondary wastewater treatment. Disinfection for control of pathogenic microorganisms and viruses is the most common type of tertiary treatment. The concentrations of suspended solids and associated BOD in treated effluent can be reduced by filtration, sometimes with the aid of a coagulant. Adsorption, ordinarily on activated carbon, can be used to remove some persistent organic compounds and trace elements. The concentration of ammonia in secondary effluent can be reduced by nitrification. Tertiary treatment to remove nitrogen and phosphorus, so as to minimize nutrient enrichment of surface waters, is common; nitrogen is usually removed by nitrification followed by denitrification, and phosphorus is removed by microbial uptake or chemical precipitation. Not all tertiary treatment processes follow secondary treatment, as was shown schematically in Figure 3.1; nutrient removal, for example, can be achieved by design and operational variations to primary and secondary treatment processes. The residues from tertiary treatment typically become incorporated with sludges from primary and secondary treatment.

There are many variations to these treatment practices. For instance, secondary treatment is rarely achieved using physical and chemical processes rather than biological treatment. Primary treatment is sometimes eliminated. Long-term retention in lagoons is sometimes substituted for both primary and secondary treatment.

Figures 3.3a, b, and c illustrate sludge management schemes for agricultural application of liquid, dewatered, and dried municipal sludges, respectively. Liquid sludge discharge to agricultural land, as illustrated in Figure 3.3a, is the simplest scheme, but substantial liquid storage capacity might be needed if land application sites are unavailable for extended periods. Agricultural application of dewatered sludge, as illustrated in Figure 3.3b, requires more expensive and extensive processing, but could be compatible with other disposal and use options that may be used in addition to agricultural use. Inclusion of drying in the sludge process-flow as diagramed in Figure 3.3c is ordinarily the most costly of the three options. Storage to accommodate agricultural demand is easiest when sludge is dried, and dried sludge can also be adapted to other disposal and use options.

Integration of sludge treatment processes for use on agricultural land also requires consideration of the effects of the treatment processes on sludge quality. For example, dewatering, composting, or alkaline treatment can be expected to reduce the amount of nitrogen in sludge that is available to plants. This would require on increase in the areal rate of sludge solids applied to satisfy the plant nitrogen demand, and would, in turn, increase the rate at which trace metals and toxic organic chemicals associated with the sludge solids were applied to soil.

INDUSTRIAL WASTEWATER PRETREATMENT

Pretreatment of industrial wastewaters is a means to manage toxic contaminants in treated wastewater effluents and sludge residuals. It is defined as "the removal of toxic materials at the industrial plant before the wastewater is released to the municipal sewer" (National Research Council, 1977). Because industrial activity is a substantial source of toxic chemicals in sludge and reclaimed wastewater in populated metropolitan areas, pretreatment programs have been effective in reducing the concentrations of most heavy metals in wastewater (refer back to Tables 2.3, 2.4, 2.5, and 2.6). They are grouped in four Priority Pollutant categories: Section 307 of the Clean Water Act regulates 127 hazardous compounds, (1) 14 heavy metals and cyanide, (2) 28 volatile organic compounds, (3) 58 semi-volatile organic compounds and (4) 25 pesticides and polychlorinated biphenyls (PCBs) (40 CFR 123.21 (1986)).

Fate of Toxic Chemicals During Secondary Wastewater Treatment

As will be discussed below, most of the priority pollutants in wastewater accumulate in sludge during the wastewater treatment process (Lue-Hing et al., 1992).

Heavy Metals

Investigations of heavy metal partitioning in secondary wastewater treatment plants include both surveys of operating POTWs (Mytelka et al., 1973; Oliver and Cosgrove, 1974; EPA, 1982) and more controlled pilot-plant studies (Petrasek and Kugelman, 1983; Patterson and Kodukula, 1984; Hannah et al., 1986). Researchers have focused on seven heavy metals:

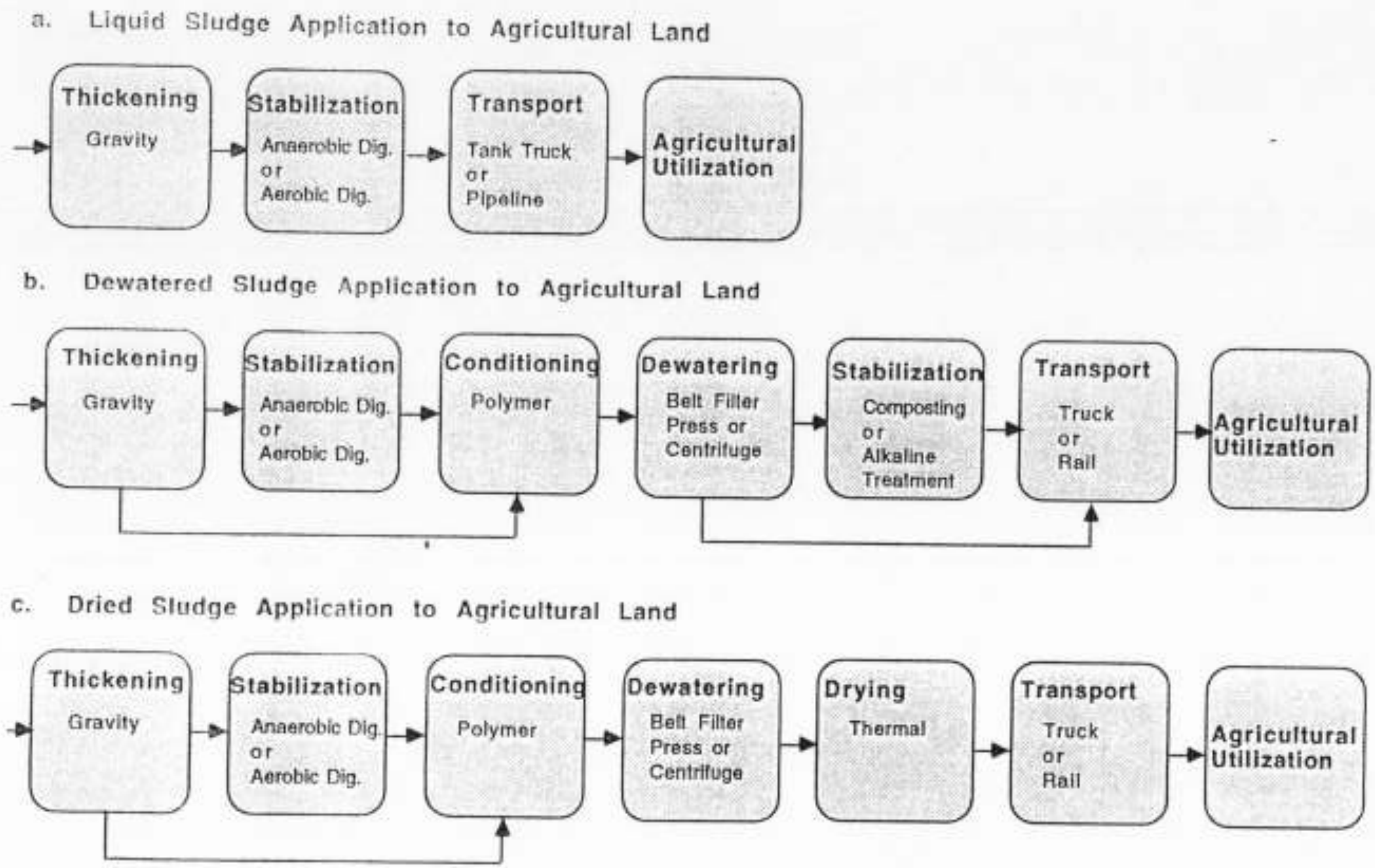

FIGURE 3.3 Sludge Management Schemes

5

Public Health Concerns About Infectious Disease Agents

The infectious disease agents associated with municipal wastewater and sludge are those found in the domestic sanitary waste of the population and from industries that process meats, fish, and other food products. These microbial pathogens include a large number of bacteria, viruses, and parasites. Important examples are members of the bacterial genera *Salmonella* and *Shigella*; the infectious hepatitis, Rota and Norwalk viruses; and the parasites associated with giardiasis, cryptosporidiosis, taeniasis, and ascariasis (See Table 5.1 for a more complete list). It is reasonable to assume that any or all of these infectious agents might be present in the water and solids fractions of raw sewage.

INFECTIOUS DISEASE TRANSMISSION

Three conditions are necessary to produce infectious disease in a population: (1) the disease agent must be present, (2) it must be present in sufficient concentration to be infectious, and (3) susceptible individuals must come into contact with the agent in a manner that causes infection and disease. From a public health perspective, it is prudent to presume that raw sewage and sludge contain pathogenic organisms; thus, the first of the above criteria is always met. The concentration of these agents in sewage will be a function of the disease morbidity in the contributing population. An example of the number of pathogenic microorganisms found in raw sewage, treated effluent, and in raw and treated sludge is shown in Table 5.2.

The second of the above criteria—that the infectious agent be present in sufficient concentration—is fraught with uncertainty because available data on human dose response are very limited, particularly at the population level. Usually it takes more than a single organism to produce a detectable disease response in an individual in the exposed population. In many instances a lower dose of pathogens will produce infection but not disease. The limited human dose-response data that have been reported indicate much variation in the severity of sickness among those exposed to known dosages of pathogens (Bryan, 1974). Table 5.3 contains some examples of bacterial pathogen dose response.

TABLE 5.1 Examples of Pathogens Associated With Raw Domestic Sewage and Sewage Solids

Pathogen Class	Examples	Disease
Bacteria	*Shigella sp.*	Bacillary dysentery
	Salmonella sp.	Salmonellosis (gastroenteritis)
	Salmonella typhi	Typhoid fever
	Vibrio cholerae	Cholera
	Enteropathogenic-*Escherichia coli*	A variety of gastroenteric diseases
	Yersinia sp.	Yersiniosis (gastroenteritis)
	Campylobacter jejuni	Campylobacteriosis (gastroenteritis)
Viruses	Hepatitis A virus	Infectious hepatitis
	Norwalk viruses	Acute gastroenteritis
	Rotaviruses	Acute gastroenteritis
	Polioviruses	Poliomyelitis
	Coxsackie viruses	"flu-like" symptoms
	Echoviruses	"flu-like" symptoms
Protozoa	*Entamoeba histolytica*	Amebiasis (amoebic dysentery)
	Giardia lamblia	Giardiasis (gastroenteritis)
	Cryptosporidium sp.	Cryptosporidiosis (gastroenteritis)
	Balantidium coli	Balantidiasis (gastroenteritis)
Helminths	*Ascaris sp.*	Ascariasis (roundworm infection)
	Taenia sp.	Taeniasis (tapeworm infection)
	Necator americanus	Ancylostomiasis (hookworm infection)
	Trichuris trichuria	Trichuriasis (whipworm infection)

The final link in the infectious disease transmission chain is the exposure of the susceptible human population to infectious agents. The primary route of exposure to wastewater-associated pathogens is by ingestion, although other routes, such as respiratory and ocular, can be involved. If reclaimed water and sludges are to be used in the production of human food crops, particularly those that are eaten raw, then there is a chance of exposure through ingestion. Consequently, there is a greater need to reduce pathogen numbers to low levels prior to soil application, or at least prior to crop harvesting or livestock exposure.

Available engineering knowledge and technology can produce reclaimed water of the desired quality for use in such activities as agriculture, landscape irrigation, and ground water recharge. Data in Table 5.2 are illustrative of the effect of tertiary (advanced) treatment of wastewater in the removal of pathogens. The technology has advanced such that, in a number of instances, the use of reclaimed water to augment of water sources for drinking water supplies is either being seriously proposed or is a reality (City of San Diego, 1992; Gunn and Reberger, 1980; James M. Montgomery, Inc., 1983; Lauer and Johns, 1990). Treatment processes are also available to effectively reduce the concentration of pathogens in sewage sludge to levels safe for direct contact. Some examples include lime treatment, heat treatment, drying and composting (EPA, 1992b).

TABLE 5.2 Typical Numbers of Microorganisms Found in Various Stages of Wastewater and Sludge Treatment

Microbe	Number Per 100 ml Of Effluent				Numbers Per Gram of Sludge	
	Raw Sewage	Primary Treatment	Secondary Treatment	Tertiary[a] Treatment	Raw	Digested[b]
Fecal coliform MPN[c]	1,000,000,000	10,000,000	1,000,000	<2	10,000,000	1,000,000
Salmonella MPN	8,000	800	8	<2	1,800	18
Shigella MPN	1,000	100	1	<2	220	3
Enteric virus PFU[d]	50,000	15,000	1,500	0.002	1,400	210
Helminth ova	800	80	0.08	<0.08	30	10
Giardia lamblia cysts	10,000	5,000	2,500	3	140	43

[a] Includes coagulation, sedimentation, filtration and disinfection
[b] Mesophilic anaerobic digestion.
[c] MPN = Most Probable Number
[d] PFU = Plaque-forming units

SOURCES: EPA, 1991 and 1992a; Dean and Smith, 1973; Feachem et al., 1980; Engineering Science, 1987; Gerba, 1983 and Logsdon et al., 1985.

Thus, the technical knowledge is available for the design of processes that can adequately reduce the number of infectious agents present in raw wastewater and solids to safe levels. The important public health concern lies in the ability of these processes to reliably produce an acceptable product. Such reliability must be a critical element in the design and operation of wastewater treatment plants or other facilities producing these materials.

In California, treatment processes specified by the Water Reclamation Criteria (California Water Code, 1994) can achieve a 5 orders of magnitude reduction *in situ* of viruses. This level of reduction produces effluent that is accepted as being "free" of viruses. In the Monterey Wastewater Reclamation Study for Agriculture (Sheikh et al., 1990), tests conducted over a 5-year period of over 80,000 gal of reclaimed water that met Title 22 requirements found no viruses (Engineering Science, 1987). Virus seeding studies were conducted that verified the 5-log reduction in viruses from the treatment process. Additionally, a 99 percent natural die-off rate over 5 days was demonstrated under both field and laboratory conditions for the virus T99.

A rough calculation illustrates the very low level of viruses to be expected after irrigation with reclaimed water of this quality on food crops. In the Monterey study, the median number of viruses detected in the raw wastewater influent was 8 plaque-forming units (pfu) in 67 samples, so that even without treatment, the number of viruses that might remain following irrigation is very small. To illustrate, reclaimed water is typically applied to the crop in an

TABLE 5.3 Dose Required for a 25 to 75 Percent Disease Response in Humans

Number of Bacteria	Bacterial Species
100 - 1,000	*Shigella* sp.
1,000 - 10,000,000	*Salmonella typhi* (Typhoid fever)
100,000 - 1,000,000,000	*Salmonella* sp. (Gastroenteritis)
1,000 - 100,000,000	*Vibrio cholerae* (Cholera)

SOURCE: Bryan, 1974.

"irrigation set" of 2 in. of water. In California, crops cannot be harvested for two weeks following a reclaimed water irrigation set. If a plant occupies 2 square feet, it would receive about 2.4 gal of water. Even if the treatment plant failed completely, and assuming all the viruses in that volume of untreated wastewater stuck to the edible part of the plant, one would expect approximately 10^{-3} pfu per plant. With treatment, the number of viruses remaining on the plant is essentially zero. The study also found that a five-log reduction in viruses occurred in soil after ten days.

While the use of essentially pathogen-free sewage sludge or effluent would be ideal, materials of lesser sanitary quality (less treatment) can be applied in cases where direct human exposure to applied sludge or effluent is minimal. In these instances natural decay processes in the soil would be relied on to reduce the number of pathogenic agents to safe levels. Site restrictions would be required to limit public access and to allow adequate time for pathogen reduction prior to crop planting, harvesting, or domestic animal grazing.

INFECTIOUS DISEASE RISK

Where wastewater or sludge treatment is the primary mechanism to protect the public from infectious disease, acceptable microbiological quality standards must be developed. In the case of treated effluents used for crop irrigation, these values have developed over time and are based upon the use of standard water quality bacterial indicator microorganisms (e.g., coliform group or fecal coliform bacteria). More recently, specific treatment processes have been relied on to effect a significant reduction in the numbers of viruses and parasites (i.e. a process standard rather than a strict microbiological standard). For example, the Water Reclamation Criteria of California, which has been a model of reclaimed water regulations for many states (see Chapter 7), has established process standards for crop irrigation to ensure that the reclaimed water has a concentration of total coliform (or fecal coliform) less than or equal to 2.2 per 100 ml. This criteria is considered safe for human contact, and is based on past experience of health professionals and on a lack of detectable health problems associated with agricultural irrigation with treated effluent that meet this microbiological quality criteria. Thus, the microbiological quality values are not based on a formal risk assessment but rather on experience and the knowledge that accepted treatment processes can effectively reduce pathogen numbers.

There is, in the United States, less public health experience with sludge application than there is with wastewater reuse. EPA has established microbial quality criteria for sewage sludge that is to be applied to land in the Part 503 Sludge Rule (EPA, 1993). As with reclaimed water, the microbiological standards for sludge in the Part 503 Sludge Rule (discussed in more detail in Chapter 7) are also set primarily on the basis of experience, and expected efficiency of treatment processes to reduce pathogens.

There is a desire among regulators, producers, and users to develop and evaluate standards based on a more defined framework for risk assessment. This desire is generating interest in the use of mathematical models to predict the risk of infectious disease among those exposed to domestic waste-associated materials. Mathematical modeling makes assumptions explicit and is useful in organizing data and assumptions into a framework that leads to quantitative predictions. Models should, however, be used with caution. The model itself brings no new data or information to the process, and careful interpretation of modeling results is required; a numerical result of a model has human health significance only in the context of the model's assumptions. The mathematical format and numerical output of these models can lead to overconfidence in their results. There is the danger that inaccurate parameter estimates can lead to unrealistic risk forecasts.

Attempts to provide a quantitative model for the assessment of human health risks associated with the ingestion of waterborne pathogens have generally focused on estimating the probability of an individual infection resulting from a single exposure event. Most models described in the literature are of the same generic form (Fuhs, 1975; Dudley et al., 1976; Hass, 1983; Payment, 1984; Asano and Sakaji, 1990 and Rose and Gerba, 1991). They give a single value estimate of the probability of a particular exposure leading to infection or disease in a single individual and, except for Dudley's work, provide little or no information on the uncertainty or variability in this estimate.

A different approach to infectious disease risk assessment modeling starts from a population perspective and carries the analysis beyond the simple individual risk of infection or disease by estimating the probability distribution of the number of infected or diseased people in the exposed population (Cooper et al., 1986; Olivieri et al., 1986, 1989). This type of dynamic model allows for the evaluation of the sensitivity of the risk distribution to varying the dose and to varying the dose-response assumptions. Ideally the dynamic risk model should include the size of the exposed population, the immune status of the population, and other relevant demographic factors. The strength of this modeling approach is that it overtly acknowledges both uncertainty and variability in parameter values in a structured fashion that helps avoid unrealistic worst-case analysis results. Presently, it would be premature to give too much weight to the results of any of the existing models. It is anticipated that the development of the more sophisticated dynamic models will eventually enable risk managers to better understand the uncertainties involved and more realistically evaluate risk estimates.

MONITORING INFECTIOUS DISEASE POTENTIAL

Many of the variables associated with the transmission of infectious disease from wastewater and sludge are either not well understood or are unpredictable. Thus, it is essential that the dose of infectious agents in these materials be reduced to numbers that minimize the risk of disease transmission. This implies that a treatment process, including site restrictions, be applied that will *reliably* reduce the concentration of pathogens to an acceptable level prior to human or animal contact.

There is a great diversity of pathogenic agents involved in the fecal-oral exposure route, and an equal diversity of dose-response relationships. Monitoring for all of these agents is impractical; therefore, the use of indicator organisms has been the traditional approach to estimating sanitary quality. Coliform bacteria have been the most used in this regard. Their presence in the environment, particularly the fecal coliforms, is an indication of the presence of animal and human fecal matter, and thus the possible presence of many associated pathogens. Intestinal bacterial pathogens will react to environmental phenomena in much the same manner as coliforms, so the rates of removal of coliforms during water reclamation or sludge processing should reflect a similar reduction in pathogenic bacteria. Coliform bacteria determinations, in themselves, may not adequately predict the presence of viruses, protozoa or helminths. Many enteric viruses, for example, have a greater resistance to chemical disinfection and irradiation than do most bacterial indicators.

There are instances in sludge processing, such as composting, in which the coliform levels cannot be satisfactorily reduced even though there is reason to believe that the sanitary quality of the material is otherwise acceptable (EPA, 1992b; Skanavis and Yanko, 1994). In this situation, when the coliform numbers remain high, one should directly monitor for species of *Salmonella* to demonstrate the absence of this common bacterial pathogen.

Many of the parasites of concern exist in the encysted stage outside of the human or animal intestinal track, and are quite resistant to chemical and physical disinfection in this form. Wastewater reclamation practice relies on the treatment process to control these parasites. Parasite ova and cysts concentrate in sewage sludge and thus are of most concern for land application of sludge. Helminth ova are very resistant to those environmental factors that reduce the numbers of bacterial indicators or animal viruses in sludge. Because of its particular resistance, the presence or absence of viable helminth ova is being used as a criterion for monitoring for the presence of helminths in sludge to be applied to land (EPA, 1993).

As previously explained, there in no general agreement on the numerical values used in setting microbiological standards. They vary from region to region, both domestically and internationally. The standards are based on expected performance of wastewater treatment processes and on past experience with land application rather than on predictive science.

Because coliform bacteria are not always reliable indicators of the sanitary quality of reclaimed water or of sludge, there is a continuing search for substitute indicator organisms or for methods for directly measuring pathogens. The bacterium *Clostridium perfringens* is an example. Because of its presence in large numbers in wastewater, ease and speed of detection and the resistance of its spores to disinfection, this bacterium is considered by some to be a good indicator of how effective a treatment process has been. The evaluation of such potential process monitoring indicators should be encouraged.

Applications of immunological and molecular biological methods to environmental microbiology are evolving and offer the possibility for low levels of pathogenic microbes to be detected directly from environmental materials such as water and soil. Fluorescent antibody

(FA) methods are available that are both qualitative and quantitative for specific microbial pathogens such as *Giardia* and *Cryptosporidium*. Gene probes have equal or greater specificity for species of microorganisms as FA, but at the present time are less suitable for rapid quantification. The application of polymerase chain reaction (PCR) methodology has the potential to detect very low levels of specific pathogen nucleic acid and, by inference, the presence of pathogenic microbes. While the application of these sensitive detection methods could result in more definitive monitoring, questions remain about the viability of the microbes detected and about the public health significance detecting very low numbers of these agents in water and sludge that are applied to land.

PUBLIC HEALTH EXPERIENCE WITH THE USE OF RECLAIMED WATER AND SLUDGE

There is an extensive literature on the public health (infectious disease) experience with wastewater reclamation and reuse (EPA, 1992a). This is not the case for the application of treated sludge onto land. There have been no reported outbreaks of infectious disease associated with a population's exposure—either directly or through food consumption pathways—to adequately treated and properly distributed reclaimed water or sludge applied to agricultural land.

Reports of the occurrence of infectious disease transmission linked to the irrigation of food crops with wastewater are associated with *untreated* sewage or treated wastewater of questionable quality. A recent epidemiological review of disease transmission from irrigation with reclaimed water (Shuval, 1990) also concludes that only untreated wastewater has been implicated in the transmission of infectious disease. Except for the use of raw sewage or primary effluent on sewage farms in the late 19th century, there have not been any documented cases of infectious disease resulting from reclaimed water use in the United States (EPA, 1992a, Water Pollution Control Federation, 1989).

In California, as a result of the Monterey study and others (Sheikh et al., 1990), a treatment process for reclaimed water has been approved by the state for any nonpotable purpose, including application to crops eaten raw. State health officials are convinced that specific treatment processes can be used to reduce the levels of pathogens such that treated wastewater is "safe to use." California standards for reclaimed water tend to lead the way in the United States, and are compatible with those developed by EPA in their *Guidelines for Water Reuse* (EPA, 1992a). See Chapter 7 for a discussion of the regulations governing pathogen control in reclaimed water and sludge.

The most extensive literature on human exposure to wastewater is concerned with the infectious disease risk to wastewater treatment plant operators and maintenance personnel. A review of the literature indicates that the occurrence of clinical disease associated with occupational exposure among these workers is rarely reported (Cooper, 1991a,b). From these observations it is not unreasonable to assume that exposure of agricultural workers to reclaimed water used in irrigation would result in an even lower risk of infectious disease than that to sewage plant operators.

Because of the intense public concern over AIDS, sewage treatment plant operators and others who come in close contact with wastewater and sludges have questioned their risk of infection with the HIV virus. All evidence indicates that there is no cause for alarm since the HIV virus does not survive in water; its transmission requires intimate contact with infected blood or body fluids (Moore, 1993; Riggs, 1989).

There have been a limited number of reports concerning an allergic response in sewage treatment plant workers exposed to species of *Aspergillus* fungi in the dust associated with the composting of sewage sludge (Clark et al., 1984; Epstein, 1994). In this instance the fungi source is not wastewater but growth of this common fungi as part of the composting process.

The potential effects of aerosols generated by wastewater treatment plants on the surrounding community have been the subject of much speculation. To date, the information collected by multiple investigators indicates that no health problems have been demonstrated to be associated with these aerosols. This issue was thoroughly documented in the proceedings of an EPA symposium on wastewater aerosols and disease (Pharen, 1979). From these observations, one could assume that the risk of contracting infectious disease from exposure to aerosols of reclaimed irrigation water is also negligible. No adverse health effects have ever been reported from the irrigation of median strips, parks, or private residences irrigated with properly treated reclaimed wastewater.

The limited number of epidemiological studies that have been conducted in the United States on treatment plant workers exposed to municipal wastewater or sludge or populations exposed to reclaimed water or treated sludge land application projects indicate that exposure to these materials was not a significant risk factor. However, the value of prospective epidemiological studies on reclaimed water or sludge use is limited because of a number of factors, including a low illness rate—if any—documented as resulting from these reuse practices, insufficient sensitivity of current epidemiological techniques to detect low-level disease transmission, population mobility, and difficulty in assessing actual levels of exposure.

Infectious diseases of the types that could be associated with municipal wastewater are under-reported and exposures are scattered, so that effects may well go unrecorded. From a public health point of view, the major microbiological considerations for evaluating any reuse management scheme are the ability to effectively monitor for treatment efficacy and the reliability of the process used to effect pathogen reduction.

One must keep in mind that there are a great many sources of these infectious disease agents other than reuse of wastewater or sludge, such as prepared food and person-to-person contact. Therefore, the potential added increment of pathogen exposure from the proper reuse of reclaimed water or sludge is minuscule compared to our everyday exposure to pathogens from other sources.

SUMMARY

Pathogenic microbes are inherent to domestic sewage and sewage solids. Because of the potential for the transmission of these infectious disease agents to humans and animals, use of these effluents on crops and grazing land must employ management strategies that protect the public's health. The main thrust of any management strategy is reduction of concentrations of pathogens to acceptable levels. This reduction can be achieved by treatment prior to land application or, as an alternative scheme in the case of sludge and reclaimed water of lower sanitary quality, crop restrictions and management of the application site to restrict human and grazing animal contact during the time required for pathogens to decay to acceptable levels. Two prime considerations in evaluating any management scheme are the ability to effectively monitor for treatment efficacy and the reliability of the process used to effect pathogen reduction.

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6

Public Health Concerns About Chemical Constituents in Treated Wastewater and Sludge

There are many chemical constituents that enter the municipal waste stream that are of potential concern for human health. These substances include organic chemicals, inorganic trace elements (such as cadmium and lead), and nitrogen. Conventional agricultural practices, such as the use of commercial fertilizers, also have the potential to introduce additional chemical constituents to soil. However, this report is not attempting a comparison between public health effects of conventional agricultural inputs and those derived from municipal wastewater or sludge. The degree to which constituents from municipal wastewater present a risk to human health depend on their concentration in reclaimed water and treated sludge and the fate and transfer of these chemicals from the wastewater/sludge sources to human receptors via various exposure pathways. The chemical composition of sewage and the degree to which chemical concentrations are reduced in effluent and sludge by secondary and advanced treatment were discussed in Chapters 2 and 3. The degree to which chemical concentrations of these contaminants in reclaimed wastewater and sludge are further reduced through natural processes in the environment and their availability to food plants were the subjects of Chapter 4. Transmission of toxic contaminants to humans from agricultural use of reclaimed wastewater and sludge is covered in this chapter.

The U.S. Environmental Protection Agency (EPA) identified Priority Pollutants in regulations that deal with municipal and industrial wastewater (EPA, 1984) due to their toxicity to humans and the aquatic environment. These Priority Pollutants are divided into four classes: (1) heavy metals (oftentimes referred to as trace elements or trace metals) and cyanide, (2) volatile organic compounds, (3) semivolatile organic compounds, and (4) pesticides and polychlorinated biphenyls (PCBs). In addition, nontoxic organic compounds in wastewater can be transformed into potentially toxic chlorinated organic compounds, such as trihalomethanes, when chlorine is used for disinfection purposes (National Research Council, 1980).

For the purpose of this review, non-metallic trace elements, such as selenium, are grouped together with the heavy metals under the more general designation of "trace elements." The following discussion first considers the fate of organic compounds from sludge and wastewater applications to soil. The uptake of these chemicals into plants and animals that go into the human food chain is then examined. Finally, the potential for adverse health effects from trace elements in sludge and wastewater via these same pathways is evaluated.

FATE OF AND EXPOSURE TO ORGANIC CHEMICALS

Principal pathways of human exposure to sludge- and effluent-borne toxic organic compounds from land application to cropland include (Dean and Suess, 1985):

- Uptake by plant roots, transfer to edible portions of plants, and consumption by humans.
- Direct contact of edible plant parts with sludge or reclaimed water applied by spraying, and consequent consumption by humans.
- Direct contact by children who play on sludge/wastewater-treated soil and inadvertently ingest small amounts of soil.
- Uptake by plants used as animal feed, animal ingestion causing transfer to animal food products, and consumption of the animal food products by humans.
- Direct ingestion of soil and/or sludge by grazing animals, transfer to animal food products, and consumption of animal food products by humans.

Human exposure to toxic organic chemicals through incidental ingestion of sludge, effluents, or treated soil (pathways 2 and 3 above) is not considered in detail in this report. Chapter 7 discusses EPA's risk analysis, which evaluated all exposure pathways.

Behavior of Toxic Organics in the Soil

It has been suggested that most toxic organic compounds are present in sludge at concentrations less than 10.0 mg/kg (Jacobs et al., 1987). Therefore, when sludges are applied to soil at agronomic rates and mixed with the surface, concentrations of toxic organics within the top 15 cm of soil normally will not exceed 0.10 mg/kg. In one survey, the level of toxic organics in sludge-amended soils was considered to be similar to or lower than background pesticide soil concentrations of 0.01 to 1.0 mg/kg (Naylor and Loehr 1982). They are further reduced by microbial decomposition.

In theory, there are a number of environmental processes that, when added to the soil, can interrupt the entry of toxic organic chemicals into the food chain. Organic chemicals from wastewater or sewage sludge may be destroyed directly after land application by biodegradation and chemical- and photo-oxidation. Organic compounds may also be volatilized, immobilized onto solid particles by sorption processes, or transported (leached) unaltered through the soil column to reach the ground water. In more complex mechanisms, sorbed organics may subsequently be chemically or photochemically degraded, microbially decomposed, or desorbed.

A considerable body of research has been performed on the behavior of organic pesticides in soil. Both laboratory and field experiments suggest that during land treatment, most pesticide residues are adsorbed by soil particles and remain sorbed on surface soils until degraded by microorganisms or volatized (Cork and Krueger, 1991). The relative degree of intrinsic biodegradability of toxic organics on the EPA Priority Pollutants list was illustrated by Tabak et al. (1981) in laboratory studies. They collected data on biodegradability and microbial acclimation of 96 compounds using bacterial inoculum from domestic wastewater and synthetic

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Regulations Governing Agricultural Use of Municipal Wastewater and Sludge

Government regulations at both the federal and state levels develop within a complex set of circumstances. To fully understand them, regulations must be examined in terms of the regulatory approach taken, the underlying scientific principles that are applied, the objectives of the regulation, and the effectiveness of implementation. The following section begins with a discussion of the regulatory background for agricultural use of municipal wastewater and sludge. Current federal standards for control of pathogens and toxic chemicals in sludge use are then described and evaluated. Finally, state regulations and United States Environmental Protection Agency (EPA) guidelines for agricultural irrigation with treated effluents are discussed.

The implementation of wastewater and sludge reuse programs also involves other regulatory components, including program management, surveillance, and enforcement. Economic considerations, liability issues, and public concerns will likewise play a role. These implementation issues are considered in Chapter 8.

REGULATORY BACKGROUND

Agricultural Irrigation With Wastewater

Irrigation of crops with treated effluent and farmland application of sewage sludge have been conducted without federal regulations for decades in the United States. Early regulations by states addressed infectious disease transmission and the reduction of odor. Wastewater irrigation continues to be regulated at the state level, and those states (such as Arizona, California, Florida, Hawaii, and Texas) that have active water reuse programs have developed comprehensive, numerical water quality criteria for different water uses, including crop irrigation. Pathogen reduction continues to be the major concern, and microbiological limits for treated effluents are based largely on practical experience within the public health community, and on the expected performance of wastewater treatment processes. There have been no reports of infectious disease associated with agricultural reuse projects, and existing criteria are considered to be adequate (see Chapter 5). Most states distinguish between produce (or crops that can be eaten raw) from crops that are commercially processed or cooked prior to consumption, and require more stringent water quality levels for produce crops.

Nevertheless, states differ in the manner in which wastewater irrigation can be implemented. For example, California, with the longest history of regulating reclaimed wastewater for agricultural use, permits high-quality effluents to be used on produce crops. Florida normally restricts the agricultural use of reclaimed water to those food crops that are skinned, cooked, or thermally processed before consumption (EPA, 1992).

Chemical pollutants in treated municipal wastewater have not been targeted by state regulations for reclaimed water. This is because the concentrations of these pollutants in effluents that receive a minimum of secondary treatment are comparable to those in conventional sources of irrigation water, and the reclaimed water generally meets current irrigation water quality criteria (e.g., Wescot and Ayers, 1985) for chemicals that are potentially harmful to crop production or to ground water contamination (see Chapters 2 and 4 for further discussion). Source control of industrial inputs, conventional secondary treatment, and advanced treatment are relied upon to reduce effluent concentrations of chemical pollutants to levels that do not impact the particular end use.

Agricultural Use of Sewage Sludge

Sewage sludges are recognized as potentially harmful because of the chemical pollutants and the disease-causing agents they may contain. Prior to the early 1970s, there was no direct legislative authority for any federal agency to regulate sludge disposal. In 1972, Congress directed EPA to regulate the disposal of sludge entering navigable waters through Section 405(a) of the Federal Water Pollution Control Act. The Resource Conservation and Recovery Act (RCRA) of 1976 (P.L. 95-512) exempts sewage sludge from hazardous waste management regulation in cases where industrial discharges to the publicly owned treatment plant (POTW) are already regulated under EPA-approved pretreatment programs. In 1977, Congress amended section 405 of the Federal Water Pollution Control Act to add a new section, 405(d), that required EPA to develop regulations containing guidelines for the use and disposal of sewage sludge on land as well as in water. These guidelines were to (1) identify alternatives for sludge use and disposal; (2) specify what factors must be accounted for in determining the methods and practices applicable to each of the identified uses; and (3) identify concentrations of pollutants that would interfere with each use. Federal criteria (40 CFR Part 257) identifying "acceptable solid waste disposal practices—including landfill and land application—were issued in 1979 under the joint authority of RCRA (Subtitle D) and the Clean Water Act (Section 405). These criteria specified limits on cadmium in sludge and soil pH levels, limited the soil incorporation of sludges with greater than 10 mg/PCB/kg, and contained criteria for pathogen reduction. However, these criteria for sludge use and disposal were not widely used.

In 1987, Congress once again amended Section 405 to establish a timetable for developing technical standards for sewage sludge use and disposal (Water Quality Act of 1987, P.L. 100-4). Congress directed EPA to identify toxic pollutants that may be present in sewage sludge in concentrations that may affect public health and the environment, and to specify acceptable management practices and numerical limits for sludge that contain these pollutants.

General Approach to Risk Assessment

The method for performing a risk assessment, as outlined by the NRC (1983), consist of four steps: (1) hazard identification, (2) dose-response evaluation, (3) exposure evaluation and (4) characterization of risks.

Hazard Identification

The first step in the risk assessment process—hazard identification—is to determine th nature of the effects that may be experienced by a human exposed to an identified pollutant an whether evidence of toxicity exists sufficient to warrant a quantitative risk assessment. Data ar gathered on a specific pollutant and qualitatively evaluated based on the type of health effec produced, the conditions of exposure, and the metabolic processes that govern pollutant behavio within the human body or other organism studied. It may also be necessary to characterize th behavior of the pollutant in the environment. Thus, hazard identification helps to determin whether it is scientifically appropriate to infer that effects observed under one set of condition (e.g., in experimental animals) are likely to occur in other settings (e.g., in human beings), an whether data are adequate to support a quantitative risk assessment. The following two section discuss how such quantitative assessments are conducted.

Dose-Response Assessment

The second step in the risk assessment process is estimating or evaluating the dose-response relationships—what "dose" of a chemical produces a given "response"—for the pollutant under review. Evaluating dose-response data involves quantitatively characterizing the connection between exposure to a pollutant (measured in terms of quantity and duration) and the extent of toxic injury or disease. Most dose-response relationships estimates are based on animal studies, because even good epidemiological studies rarely have reliable information on human exposure. In this context, two general approaches to dose-response evaluation are used, depending on whether the health effects are based on threshold or nonthreshold characteristics of the pollutant. "Threshold" refers to exposure levels below which no adverse health effects are assumed to occur. Effects that involve altering genetic material (including carcinogenicity and mutagenicity) may take place at very low doses; therefore, they are modeled with no thresholds. For most other biological effects, it is usually, but not always, assumed that threshold levels exist.

Exposure Evaluation

Exposure evaluation estimates environmental concentrations of pollutants. The severity of the exposure is then assessed by evaluating the nature and size of the population exposed to the pollutant, the route of exposure (i.e., oral, inhalation, or dermal), the extent of exposure (concentration times duration), and the circumstances of exposure.

Risk Characterization

In the final phase of a risk assessment, the risk characterization, information on the range of exposures and risks and on all major uncertainties, along with their influence on the assessment, are presented.

EPA's Risk Assessment Approach

Hazard Identification

EPA initially developed environmental profiles and hazard indices on 50 pollutants that were selected by a group of experts convened by EPA in 1984 (EPA, 1993). Of those 50 pollutants, 22 (10 metals and 12 organics) were selected, through a screening process, for regulation in the 1989 proposed rule for land application (Federal Register, 1989). These 22 pollutants are listed in Table 7.3.

After the proposed rule was issued, EPA completed a National Sewage Sludge Survey (NSSS) (EPA, 1990). The NSSS sampled sludge from 209 sewage treatment plants throughout the country to produce national estimates of concentrations of toxic pollutants in sewage sludge.

Using the NSSS data and information from the risk assessment, EPA conducted a further screening analysis to eliminate from regulation any pollutant that was not present in concentrations that posed a significant public health or environmental risk. Based on this screening analysis, 12 organic chemicals were deleted, leaving 10 inorganic chemicals for regulation by the Part 503 Sludge Rule. The criteria used to remove organic pollutants from the rule is discussed below.

Three screening criteria were used to assess the need for regulating the 12 organic pollutants that were part of the original 22 pollutants identified in the proposed rule. If a pollutant satisfied any one of the criteria below, it was exempted from regulation in Part 503. The three criteria were described as follows:

- The pollutant has been banned for use, has restricted use, or is no longer manufactured for use in the United States.
- The pollutant has a low frequency of detection in the sewage sludge (less than 5 percent), based on data from the NSSS.
- The concentration of the pollutant in sewage sludge is already low enough that the estimated annual loading to cropland soil would result in an annual pollutant loading rate within allowable risk-based levels.

Based on these criteria, EPA exempted all of the organic pollutants under consideration. The pollutant loading used for the third criterion is based on the quantity of sewage sludge that would be applied at agronomic rates and using the sludge pollutant concentration equal to the

TABLE 7.11 Maximum Permissible Organic Pollutant Loading Rates Calculated from F Chain Exposure Pathways

Pollutant	Most Limiting Pollutant Rate (kg/ha/yr)	Maximum Permissible Pollutant Loading (kg/ha/yr)		
		Pathway 1	Pathway 4	Pathway
Aldrin/Dieldrin	0.03 (5)	2.8[a]	0.2[a]	(
Benzo(a)Pyrene	0.15 (3)	23	NA[c]	NA
Chlorodane	0.9 (3)	34	360[a]	2:
DDT/DDD/DDE	1.2 (12)	560	48	1
Dimethylnitrosoamine	0.02 (3)	87	NA	NA
Heptachlor	0.7 (5)	990	110	(
Hexachlorobenzene	0.3 (5)	320	48	(
Hexachlorobutadiene	6 (3)	43,300	NA	6
Lindane	0.8 (3)	2,300	1,500	1
PCBs	0.05 (5)	37	4.3	(
Toxaphene	0.10 (5)	2,800	120	(
Trichloroethylene	100 (3)	220,000	NA	NA

[a]Values shown for the Most Limiting Pollutant Rate are obtained from EPA, 1993b in Table 5.4-5.6, pp. 5 of the Technical Support Document of the Part 503 Regulation. These values represent the smallest of the ref annual pollutant application rates (or "RPa" measured in kg/ha/yr) for the organic pollutant. Where an RP not directly available, it was derived from the reference cumulative application rates (or "RPc" measured in k which are used in Table 7-10) by assuming a life span of the application site of 100 years. Therefore, th would be 1/100th of RPc. Alternately, an RPa was derived from the reference concentration of a pollut sewage sludge (or "RSC" measured in μg/g) by assuming an annual sewage sludge application rate of 10 tons/ha. The number in parenthesis indicates the pathway from which the most limiting pollutant rate is de

[b]All values converted from concentration of pollutant in sewage sludge (mg/kg) with the assumption of s sludge application rate at 10 metric tons/ha/yr.

[c]NA: not applicable because (1) plant uptake is inconsequential, or (2) food exposure route to humans is extr small compared to exposure from other sources.

SOURCE: EPA, 1993b

rigation. Although the practice has not been extensive, reclaiming municipal wastewate crop irrigation is well-established in some parts of the country. Over the years, federal age have not exercised direct regulatory authority over either wastewater irrigation or other ty effluent reuse, except through provisions in the National Pollutant Discharge Elimination Sy permit system which regulates the discharge of treated wastewater effluents. In practice, w water irrigation is normally treated as a community-wide environmental sanitation and p work improvement project that should undergo rigorous facility planning and engine evaluation (EPA, 1981). The technical merit, market feasibility, and public health risks of potential project should be carefully reviewed by many agencies before it is implemented.

TABLE 7.12 Limiting Pathways for Organic Chemical Pollutants Evaluated in the Development of The Part 503 Sludge Rule

Pollutant	Highly Exposed Individual (HEI)	Limiting Pathway Number
Aldrin	Eating animal fat/milk	5
Dieldrin	Eating animal fat/milk	5
Benzo(a)Pyrene	Sludge eaten by child	3
Chlordane	Sludge eaten by child	3
DDT/DDD/DDE	Eating fish	12
Dimethylnitrosamine	Sludge eaten by child	3
Heptachlor	Eating animal fat/milk	5
Hexachlorobenzene	Eating animal fat/milk	5
Hexachlorobutadiene	Eating animal fat/milk	5
Lindane	Sludge eaten by child	3
PCBs	Eating animal fat/milk	5
Toxaphene	Eating animal fat/milk	5
Trichlororethylene	Sludge eaten by child	3

is usually done and there have been no reported incidents in the United States of food contamination and/or water pollution caused by applying treated wastewater effluents to cropland.

The public health is protected by adequate and reliable treatment of the reclaimed water as well as site restrictions associated with the degree of treatment. In the United States, both the level of wastewater treatment and the microbiological requirements for agricultural reuse vary from state to state. By 1992, at least 19 States had set regulations or guidelines for the use of reclaimed water on food crops.

Recently the EPA published guidelines for the reuse of wastewater in a number of applications, including use in agriculture (EPA, 1992a). Those recommended criteria that are pertinent to infectious disease transmission through agricultural application are summarized in Table 7.13. Reclaimed water applied to most food crops, particularly those that can be eaten uncooked, should be processed at least through secondary treatment followed by filtration and adequate disinfection.

Evolution of Regulations Governing Irrigation with Treated Municipal Wastewater

In many respects, California has been a pioneer in reclaiming and reuse of municipal wastewater. The wastewater irrigation-related regulations in California can therefore be used as a model for examining regulatory development. The California Water Code (State of California, 1987) declares that "the people of the state have a primary interest in the development of facilities to reclaim water containing waste to supplement existing surface and underground water supplies and to assist in meeting the future water requirement of the state" (Cal. Water Code, Section 13510). The statute further declares that "the use of potable domestic water for nonpotable uses, including, but not limited to, cemeteries, golf courses, parks, highway land-

TABLE 7.13 Summary of EPA Guidelines for Reclaimed Water Reuse in Agriculture

Type of reuse	Treatment Required	Water quality
Food crops not commercially processed	Secondary Filtration Disinfection	<2.2 fecal Coliform/100mL 1mg/L Cl_2 residual after 30 min. contact tim (minimum) Turbidity ≤ 2NTU ≤ 10mg/L BOD
Food crops commercially processed including orchards and vineyards	Secondary Disinfection	≤200 fecal coliform/100mL 1mg/L Cl_2 residual after 30 min. contact time (minimum) ≤ 30mg/L BOD ≤ 30mg/L SS
Nonfood crops pasture, fodder, fiber and seed	Secondary Disinfection	≤ 200 fecal coliform/100mL 1mg/L Cl_2 residual after 30 min. contact tim (minimum) ≤ 30mg/L BOD ≤ 30mg/L SS

scaped areas, and industrial and irrigation uses, is a waste or an unreasonable use of the wat within the meaning of .... the California Constitution if reclaimed water is available....." (Ca Water Code, Section 13550). These policy declarations culminated in a mandate that "the Sta Department of Health Services shall establish statewide reclamation criteria for each type of u of reclaimed water where such use involves the protection of public health" (Cal. Water Cod Section 13521). In California, wastewater reclamation and reuse is an integral part of the wat resource management plan. The provisions of Reclamation Criteria of California (Departme of Health Services, 1993) reflect the legislative intent. They are conducive to water reuse ar are enacted to protect public health when reclaimed water is used.

Long before the statutes were official, domestic wastewater was used in crop irrigati (Ward and Ongerth, 1970). In 1910, at least 35 communities in California operated sewa farms to dispose of raw sewage or septic tank effluents. In 1918, the California Board of Heal adopted regulations governing the use of sewage for irrigation purposes. It prohibited the u of raw sewage, septic tank effluents, and other similar wastewater for irrigation of vegetabl that would be consumed uncooked by people. The regulation permitted the use of untreat wastewater for irrigating crops that would be cooked before consumption, provided that a 30-d or longer waiting period was observed prior to harvest. It also permitted the use of reclaim water for fruit and nut trees and melon crops if the products did not come into direct conta with the wastewater. For the next 75 years, the regulations continued to evolve in re-sponse new experience in wastewater use, new wastewater treatment technology, and as the demand f reclaimed wastewater rose.

In 1933, the regulation was revised to allow the use of well-oxidized, nonputrescible, a reliably disinfected or filtered effluents for irrigation of vegetable crops for raw consumptio

Requirements were established for the finished water's coliform counts and the treatment plant operations. Subsequently, a more comprehensive regulation for the use of reclaimed water for irrigation and recreational impoundments was adopted in 1968 to accommodate the increasing population and volume of reclaimed water available for reuse. The new standards specified levels of wastewater treatment required and coliform density of finished water for various type of uses. The need to insure wastewater treatment reliability and to limit public access to the application site was documented based on the data of several field investigations. In 1975, regulatory provisions were added to guarantee wastewater treatment reliability and to limit public access to the application site. Since it inception, the Reclamation Criteria (California Department of Health Services, 1993) has been revised several times. However, the technical requirements for crop irrigation remained the same as written in 1975.

General Description of the State Regulations

As the demand for reclaimed wastewater for crop irrigation spread across the nation, many states enacted regulations or developed guidelines to govern its use. Recently, EPA (1992a) published guidelines for water reuse including the use of reclaimed water in agriculture in the United States. The conditions for use of reclaimed water for irrigating food and nonfood crops in 18 and 35 states, respectively were summarized.

The Reclamation Criteria of California (California Department of Public Health Services, 1993) have been a model for reclaimed water regulations for many states. The primary health concerns targeted have been the risk of pathogen and chemical pollutant exposure to workers involved in irrigation projects, to residents near a wastewater irrigation site, and to consumers of food produced from wastewater-irrigated fields. Regulations have focused on infectious disease risks by establishing the following:

- the level of wastewater treatment required (primary treatment, secondary treatment, oxidized, filtered, coagulated, disinfected, etc.);
- the upper limits for selected water quality parameters to insure wastewater treat-ment reliability (maximum BOD, total suspended solids, chlorine residual, turbidity, indicator organisms concentrations permitted, and pH range, etc.), and on-line chlorine residual and turbidity;
- treatment reliability provisions;
- site management practices that prevent workers and residents from being exposed to applied water and contaminated soils at the application site (providing setback distance, limiting public and worker access, posting warning signs, cross-connection prevention, hydraulic loading rate, etc.); and
- water management practices that minimize contamination of crops (specifying method of irrigation and/or types of crops permitted, requiring waiting period for crop harvesting or animal grazing, maximum water application rate, etc.)

Regulations define the conditions necessary to minimize human exposure to pathogens. This is accomplished by specifying the degree of treatment the wastewater receives, by specifying time and environmental conditions to reduce pathogen survival prior to human contact, a by restricting certain food crops depending on the level of reclaimed water quality. There usually backup technical requirements in these state regulations such as simultane specification of wastewater treatment levels to minimize presence of pathogens, provision setback distance to prevent direct contact with pathogens, and waiting period requirement af irrigation to reduce pathogen survival.

Five of the 18 states that permit reclaimed water for irrigation of produce crops requ advanced wastewater treatment (e.g., oxidation, clarification, coagulation, filtration, and c infection). To ensure the consistency of treatment performance, the total coliform (or fe coliform) density of finished water is required to be less than or equal to 2.2 per 100 millilit Under such a circumstance, the reclaimed water is considered to be essentially free of pathog for nonpotable reuse purposes. Other requirements such as setback distance, waiting period, a restricted site access are, in this case, not necessary.

At the other end of the spectrum, primary effluents may be permitted to irrigate fo crops for processing if requirements are met to protect workers and nearby residents and prevent water pollution. Human exposure to pathogens is controlled by factors other th pathogen density in the wastewater effluents. The deficiency in one factor may be mitigated more stringent requirements of other factors. For example, in Utah, food crops may be irriga by secondary effluents with total coliform density up to 2000/100 ml (30-day average), provi spray irrigation is not used. In this case, the risk of exposure to pathogens is reduced preventing the water from coming into direct contact with the food crop.

If reclaimed water is used to irrigate nonfood crops or animal food crops, the risk exposure to pathogens is considerably smaller than with vegetables produced for raw c sumption by humans. Therefore, restrictions on wastewater treatment levels and operatio reliability usually are more relaxed for nonfood crops than are those required for irrigat human-consumed food crops. Effluents from oxidation ponds, primary treatment, and second treatment are all acceptable under various circumstances. But the other requirements such setback distance and site access usually remained the same or become more stringent for protection of workers and nearby residents. Many states (15 of the 35 states that permit reclaimed wastewater for nonfood crop irrigation in 1992) either: (1) ban the used of low quality treated wastewater on pasture, (2) require disinfection when irrigating pastures milking animals, or (3) require an extended waiting period before animals are allowed on fie irrigated with lower-quality wastewater effluents.

So far, trace chemical contaminants in treated municipal wastewater have not b targeted by State regulations or EPA guidelines for reclaimed water because their concentrati in wastewater receiving a minimum of secondary treatment are comparable to conventio sources of irrigation water (see Chapter 4). Source control of industrial inputs, conventio secondary treatment, and advanced treatment are relied on to reduce effluent concentrations chemical pollutants to levels that meet current irrigation water quality criteria (e.g., Wescot a Ayers, 1985) for chemicals that are potentially harmful to crop production or to ground wa contamination. This assumption appears justified if industrial pretreatment programs are rig ously enforced by municipalities and wastewater is properly treated. In such case, it is possi to produce reclaimed wastewater that meets the highest required water quality standard irrigation of food crops and with trace element and organic chemical concentrations that lower than the maximum contamination levels of the National Primary Drinking Water Standard (Crook et al., 1990). If the concentrations of chemical pollutants tabulated in Table 7.14 are typical for reclaimed water, the annual pollutant inputs to the soil through reclaimed water irrigation will be small and will be balanced or out-balanced by the output through crop absorption (see Chapter 4 for details). In this manner, toxic chemicals and trace elements are not expected to accumulate in soils irrigated with reclaimed water to levels that are harmful to humans.

Adequacy of Current Regulations for Reclaimed Water

California's Water Code defines the Reclamation Criteria as "levels of constituents of reclaimed water, which will result in reclaimed water safe from the standpoint of public health, for the uses to be made" (Cal. Water Code, Section 13520). Early on, state regulatory agencies recognized that numerous pollutants are present in reclaimed water, and it is impractical, if not impossible, to track all of them. Besides, there is little epidemiological data to define the dose-response relationships. Defining "levels of constituents of reclaimed wastewater" suitable for various uses is difficult if the epidemiological data for quantitative dose-response evaluation are not available. As a result, regulations for reclaimed wastewater irrigation always rely on the capability of wastewater treatment and site management to accomplish the goal of public health protection.

While the public health safety record for reclaimed water irrigation has been excellent, there are little epidemiological data to support or refute the currently regulated levels (Crook, 1978; 1982). For developing countries, recent research in epidemiology indicates that the public health risks resulting from crop irrigation with treated municipal wastewater are overestimated, and that the United States guideline may be "unjustifiably restrictive, particularly with respect of bacterial pathogens" (World Health Organization, 1989).

Are current regulations for reclaimed water adequate to protect human health? The answer to this question does not lie in the regulations alone. Over the past century, the environmental sanitation practice of collecting, treating, and disposing municipal wastewater has been instrumental in improving the public health. Over time, an integrated infrastructure has evolved to regulate, plan, and implement the monumental task of handling municipal wastewater day-in and day-out. This system is vertically integrated with the environmental protection and pollution control authorities at the federal level, water quality and public health authorities at the state level, and the environmental sanitation authorities at the local level. The nation is also horizontally connected across political boundaries by special service agencies that have responsibilities for collecting, treating and disposing wastewater. Within the framework of this infrastructure, policies are made; funds are generated and appropriated, regulations are enacted; and physical plants are planned, built, and maintained. The common objective cutting across the entire infrastructure are to safeguard public health and to prevent environmental pollution.

TABLE 7.14 Concentration of Trace Elements and Toxic Organic Chemicals in Selected Treated Effluents in California

Pollutant	Unit	San Jose Creek	Whittier Narrow	Pomona	NPDWS[a]
Arsenic	mg/l	0.005	0.004	<0.004	0.05
Aluminum	mg/l	<0.06	<00	<0.08	1.0
Barium	mg/l	0.06	0.04	0.04	1.0
Cadmium	mg/l	ND[b]	ND	ND	0.01
Chromium	mg/l	<0.02	<0.03	<0.03	0.05
Lead	mg/l	ND	ND	<0.05	0.05
Manganese	mg/l	<0.02	<0.01	<0.01	0.05
Mercury	mg/l	<0.0003	ND	<0.0001	0.002
Selenium	mg/l	<0.001	0.007	<0.004	0.01
Silver	mg/l	<0.005	ND	<0.005	0.05
Lindane	μg/l	ND	ND	ND	4
Endrin	μg/l	ND	ND	ND	0.2
Toxaphene	μg/l	ND	ND	ND	5
Methoxychlor	μg/l	ND	ND	ND	100
2,4-D	μg/l	ND	ND	ND	100
2,4,5-D	μg/l	<01	ND	ND	10
Turbidity	NTU[b] (silica scale)	1.6	1.6	1.0	2
Total Coliform	No./100 ml	<1	<1	<1	2.2

[a]National Primary drinking water standards

[b]ND denotes the constituent was not detected in the specimen.

SOURCE: Crook et al., 1990.

The interdependency and interlinking of the components provide check-and-balance and technical redundancy to ensure that integrity will not be breached and that the well-being of the public is not threatened by pollutants and pathogens in the wastewater (see additional discussion in Chapter 8 on Other Government Regulations).

When viewed in this manner, the practice of irrigation with reclaimed water is not a monolithic event. Instead, it is merely one component of this integrated wastewater handling, treatment, and disposal infrastructure erected to protect public health and prevent environmental pollution. Whether crop irrigation can be safely administered is therefore interdependent on whether other components of the system are performing up to expectation. The current reclaimed wastewater irrigation regulations take full advantage of the advances in wastewater treatment technology to deliver water of appropriate quality. Again, the record has been a successful one.

If the integrity of the infrastructure is maintained, it is reasonable to assume that reclamation of wastewater for food crop irrigation will continue to be practiced safely. Because of the checks and balances and technical redundancy offered by the system, the likelihood of failure is small and, if failure occurs, it is likely to be promptly detected and corrected. Although the risk from trace chemical contaminants in reclaimed water applied to food crops has not been quantified, it is likely that such use presents little additional risk since the levels of trace chemical contaminants in reclaimed water are normally within accepted guidelines that have been developed for irrigation with conventional sources of irrigation water.

SUMMARY

Pathogen Regulations for Sludge

In the United States, the Part 503 Sludge Rule is the current management strategy for the application of sludge to land. At the present state of our knowledge, this rule appears to be, with one possible exception, adequate for the protection of the public from the transmission of waste associated pathogens. The possible exception is the potential that the prescribed waiting period between the application of Class B sludge and animal grazing may not be adequate to prevent the transmission of tapeworm to grazing cattle.

Toxic Chemicals Regulations for Sludge

The Part 503 Sludge Rule was developed with the intent to encourage beneficial use of sewage sludge. Using risk-assessment-based calculations, the regulation specifies numerical limits for chemical pollutant loading rates within which the sewage sludge may be safely applied on cropland. The regulation has a sound conceptual basis for protecting public health and encouraging beneficial use of sewage sludge.

In terms of trace elements, sewage sludge that is applied according to the pollutant loading rates specified in Part 503 should not affect the safety of the nation's food supply. The pollutant loading rates are set by the maximum permissible loading rates of nonfood-chain

Good management in field distribution of animal waste water is as necessary as good management of holding ponds. Regulations of county health departments and the Central Valley Regional Water Quality Control Board require that (a) animal waste be kept on the property of the operator, (b) not pollute groundwater, and (c) not contribute to a nuisance problem. Well managed field distribution will keep manure-carrying water—whether irrigation tailwater in summer or rainfall in winter—out of drains, ditches and creeks that carry surface drainage off the operator's property. (California guidelines covering regulations for handling animal wastes are available at regional Water Quality Control Board offices, from the state milk inspection service [dairy inspectors], and other sources.)

Reduce Holding Time and Save Nitrogen

In 4 to 6 years, the value of nitrogen saved in an efficiently operated liquid manure system can more than offset the cost of constructing a holding pond. But to make the maximum amount of nitrogen from manure available to crops, irrigation from holding ponds must be frequent. This is because bacterial action in manure causes nitrogen loss to the atmosphere in the form of ammonia. The longer wastes are held in the pond, the more nitrogen will be lost, with warm weather speeding up the process. Therefore, only about one-third of a pond's capacity should be used for storage in the irrigation season, and the pond should be pumped dry at least once a month. Less holding time not only makes maximum use of nitrogen in the manure, but also reduces flies, gnats, mosquitoes, weeds and noxious odors. (See "Pond Operation."

Fertilizer Value of Dairy Manure

As it decomposes, manure releases nutrients for plant growth, and its organic matter improves soil tilth and water-holding capacity. A 1,400 pound cow produces nearly 2 cubic feet of urine and feces per day, containing about 87 percent moisture and weighing about 120 pounds. In a year, the cow will produce about 22 tons of manure which, when fresh, contains about 220 pounds of nitrogen, 110 pounds of phosphate and 220 pounds of potash.

TABLE 1. Plant Nutrients in Fresh Dairy Manure*

Nutrient	Feces lb/ton	+	Urine lb/ton	=	Total lb/ton
Nitrogen, N	5		5		10
Phosphate, P_2O_5	4.75		0.25		5
Potash, K_2O	1.5		8.5		10

*Manure also contains many trace elements used by crops.

Assuming that nitrogen, phosphorous and potash sell for 19, 16 and 6 cents per pound, respectively, the nutrients in the cow's manure would be worth $77 per year. That would be a value of $3.50 per ton of fresh manure, not counting added bedding materials. However, these amounts of nutrients in fresh manure may not all reach the crop. The amount of manure required to equal a given amount of commercial fertilizer depends on:

- the chemical form of the nutrients in manure and their changes during storage;
- physical losses from runoff, leaching or volatization;
- the amount of bedding or water added.

Furthermore, even after they are applied to the soil, the nutrients are not all immediately available for plant growth. A good part of the nitrogen, especially, is tied up in humus and will become available only in future years. When planning how much commercial fertilizer to apply in addition to manure, assume that only about 50 percent of the nitrogen (N), 60 percent of the phosphorous (P), and 70 percent of the potash (K) in manure will be available the first year. In other words, the crop will receive only about $2 worth of NPK (at the above prices) per ton of fresh manure during the first year. The balance of about $1.50 worth of NPK will remain in the soil and be released more slowly for future use.

Rate of Manure Application

The amount of manure applied should not exceed the ability of the soil-crop combination to use the nutrients. The greater the crop requirement for plant nutrients, the greater the amount of manure that can be applied. It is particularly important not to put on more nitrogen than is required, because excess nitrogen (that not used by the crop) can pollute surface waters or groundwater.

Under single cropping systems, the upper limit for manure application should be a ratio of no more than three cows per acre of cropland. In other circumstances—depending largely on soil conditions, but also on crops and other factors—higher application rates may be used without causing groundwater pollution problems. Assistance in determining maximum rates with no groundwater problem can be obtained from county UC Cooperative Extension offices.

Double cropping of corn and cereal crops, is an effective way to utilize larger amounts of manure.

(4) No refuse material to inhibit spraying access.
(5) Owners are responsible for weed and floatage control.
(6) Separators bypass drains must be equipped to prevent pond floatage.
(7) Pond-to-field discharges should not stand more than four days.

A recent study of dairy lagoons shows most are well managed and larvae were scarce, but it only takes one outbreak to affect the whole industry. Lagoons that are suspect generally are those with less than two feet of free bank space from wastewater surface level to top of levee, "dead" corners where little wind action can occur, or floatage is not"chained" to one end and removed.

5. IRRIGATING ALFALFA WITH DAIRY WASTEWATER

Written by Dr. Stuart Pettygrove, Extension Specialist, UC Davis

Dairy lagoon effluent is a potential source of water and nutrients for crops. Attention must be given to the management of salt in the wastewater, which is often at a high enough level to require dilution with fresh water. Also, livestock wastewater is regulated by the Regional Water Quality Control Boards under Title 23, Chapter 15 of the California Code of Regulations.

Chapter 15 states that no surface runoff is allowed from fields being irrigated with wastewater, and percolation to groundwater must be minimized. Alfalfa, because of its deep root system and its high yield, is a good crop on which to use wastewater from dairy lagoons.

DAIRY WASTEWATER - SALINITY ASPECTS

First, some basics: Salinity is measured with a conductivity meter, and the resulting electrical conductivity (EC) is expressed in units of deciSiemens/meter (dS/m) or millimhos/cm (mmho/cm). The two are numerically identical. Water with an Ec value of 1.3 used in a normal irrigation of alfalfa will result in an EC_e (saturated soil paste extract) of 2.0 dS/m, which is officially the highest salt level that alfalfa can tolerate without a decrease in yield.

This salt tolerance value is on the conservative side in the sense that yield will not be reduced if the threshold value is exceeded for only a short time or only in a small part of the root zone. Also, this published value does not reflect such variables as cultivar differences, weather effects, or irrigation water constituents such as chloride to which alfalfa is sensitive.

Examples of dairy wastewater EC, range from 0.9 to 4.8 dS/m (See Table).

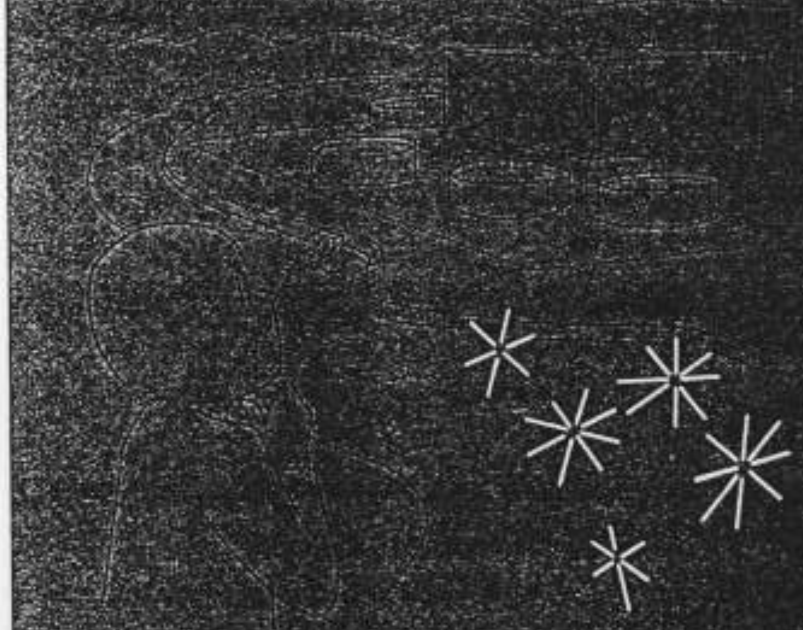
Examples of Dairy Lagoon Water Composition from Unpublished Cooperative Extension and Regional Water Quality Control Board Files

Description	EC (dS/m)	Nutrients in Lb/Acre-inch: Total N	Ammon. N	Total P (as P_2O_5)	Total K (as K_2O)
1 Wash water + manure	3.00	72	28	16	—
2 Wash water + manure + corral drainage, no alley scrapings	2.30	26	14	23	68
3 Wash water + freestall flush after passing through solids separation pond	3.30	51	35	27	73
4 Same as 3, but with mechanical separators	4.20	53	44	30	72
5 Same as 4, but with field tailwater returned to pond	4.80	106	53	61	114

Conversion factors for dairy lagoon nutrients

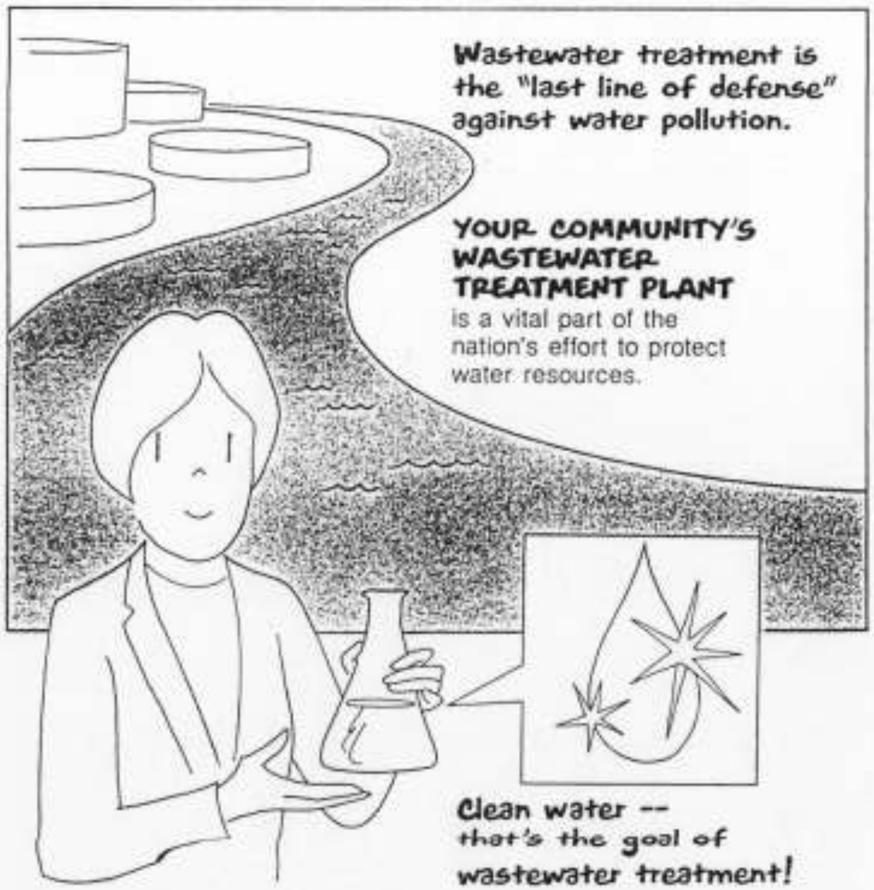
N (ppm) x 0.226 = lb N/acre-inch
P (ppm) x 0.518 = lb P_2O_5/acre-inch
K (ppm) x 0.271 = lb K_2O/acre-inch

ABOUT WASTEWATER TREATMENT



WHAT IS WASTEWATER TREATMENT?

It's cleaning used water and sewage so it can be returned safely to our environment.



Wastewater treatment is the "last line of defense" against water pollution.

YOUR COMMUNITY'S WASTEWATER TREATMENT PLANT is a vital part of the nation's effort to protect water resources.

Clean water -- that's the goal of wastewater treatment!

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WHY ARE WASTEWATER TREATMENT PLANTS IMPORTANT?

For 2 reasons:

THEY PROTECT PUBLIC HEALTH from disease-causing bacteria and viruses. Today's treatment plants actually disinfect wastewater, eliminating many of these harmful organisms.

THEY PROTECT WATER QUALITY so we can enjoy clean oceans, lakes, streams and rivers. In this way, wastewater treatment helps us enjoy life to the fullest.

Learn more . . .

WHERE DOES WASTEWATER COME FROM?

It can come from:

HOMES
– human and household wastes from toilets, sinks, baths and drains.

INDUSTRY, SCHOOLS, AND BUSINESSES
– chemicals and other wastes from factories, food-service operations, airports, shopping centers, etc.

STORM RUNOFF AND GROUNDWATER
– water that collects in street drains during a storm, as well as groundwater that enters through cracks in sewers.

On the average, each person in the U.S. contributes 50-100 gallons of wastewater every day.

HOW DO TREATMENT PLANTS PROTECT OUR WATER?

A wastewater treatment plant:

REMOVES SOLIDS
This includes everything from rags and sticks to sand and smaller particles found in wastewater.

REDUCES ORGANIC MATTER AND POLLUTANTS
Helpful bacteria and other microorganisms are used to consume organic matter in wastewater. The bacteria and microorganisms are then separated from the water.

RESTORES OXYGEN
Treatment facilities help ensure that the water put back into our lakes or rivers has enough oxygen to support life.

NOTE: While our lakes and streams clean water in much the same way, wastewater treatment plants are faster and can handle more water. This makes treatment plants essential in areas where there's too much wastewater for nature to handle alone.

HOW DOES A WASTEWATER TREATMENT PLANT WORK?

Wastewater treatment usually takes place in 2 steps:

PRIMARY TREATMENT

removes 40-60% of the solids.

"SANITARY" (OR "SEPARATE") SEWERS

carry wastewater from homes and businesses to the treatment plant. In some areas, "combined" sewers carry storm runoff, as well.

BAR SCREENS

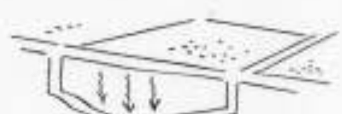
let water pass, but not trash (such as rags or sticks). The trash is collected and properly disposed of.

A GRIT CHAMBER

(large tank) slows down the flow of water. This allows sand, grit and other heavy solids to settle at the bottom. Later, they're removed.

A PRIMARY SEDIMENTATION TANK

lets smaller particles settle. Scrapers or other devices collect the solid matter that remains (called "primary sludge") plus scum or grease floating on top of the tank.

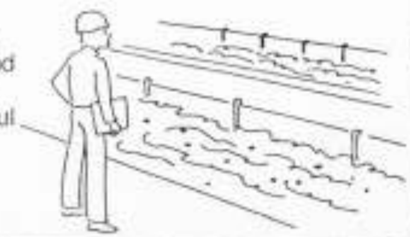


SECONDARY TREATMENT

completes the process, so that about 90% of the pollutants are removed.

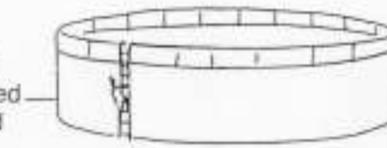
AN AERATION TANK

supplies large amounts of air to a mixture of wastewater, bacteria and other microorganisms. Oxygen in the air speeds the growth of helpful microorganisms, which consume harmful organic matter in the wastewater.



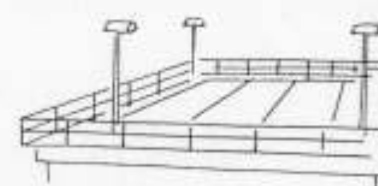
A SECONDARY SEDIMENTATION TANK

allows the microorganisms and solid wastes to form clumps and settle. Some of this mixture, called "activated sludge," can be mixed with air again and reused in the aeration tank.



A DISINFECTANT,

such as chlorine, is usually added to the wastewater before it leaves the treatment plant. The disinfectant kills disease-causing organisms in the water.



After treatment, the water can be returned to nearby waterways. It can also be used on land for agriculture and other purposes.

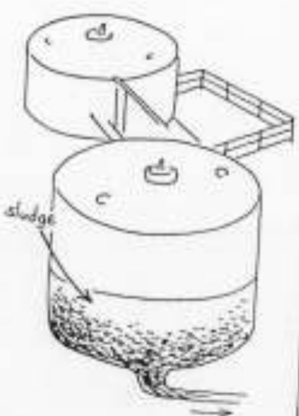
SLUDGE CAN BE A USEFUL BYPRODUCT OF TREATED WASTEWATER

Sludge may be treated (thickened) to remove some of its water, then further processed by:

STABILIZATION

Raw sludge is allowed to decompose in digester tanks. In some cases, special chemicals are used for stabilization.

Stabilized sludge has no odor and is free of disease-causing organisms.



DEWATERING

This process removes most of the water from the sludge mixture. Filters, drying beds, and various kinds of presses are used.

DISPOSAL

The dried sludge, called "cake," is ready to be used or disposed of.

Some nontoxic sludge can be safely used as:

SOIL CONDITIONER

Sludge can be used to improve the soil for crops in some areas of the nation.

Sludge can also improve the soil for lawns, fields and parks.

FUEL

Using certain processes, sludge can also be used to produce methane gas. The methane can then be burned to supply energy for a small power plant or for other purposes.

IF IT CAN'T BE SAFELY USED,

sludge must be carefully disposed of. For example, it may be:

- BURIED in approved landfills
- BURNED using special technology to prevent air pollution.

SOME SPECIAL CHALLENGES OF TREATING WASTEWATER

NUTRIENTS

Phosphorus, nitrogen and other chemical nutrients found in wastewater can damage lakes and rivers. These nutrients need to be changed into less harmful substances or removed before being released into the environment.

TOXIC CHEMICALS

Sometimes wastewater contains poisonous chemicals (from industry, pesticides, etc.). Controlling these chemicals requires advanced treatment methods and careful planning.

WATER INFILTRATION

Water entering the treatment system through cracks or joints in sewer lines or storm drains places an extra burden on a facility

CHANGES IN WATER FLOW

The amount – and kind – of wastewater entering a treatment plant can change quickly. Plant operators must be ready to respond to these changing conditions.

WHO OPERATES TREATMENT PLANTS?

The daily operation of a treatment plant is the work of some highly skilled people. It requires:

A PLANT MANAGER

to ensure that the plant has enough money, trained personnel and equipment to carry out its job.

LABORATORY PERSONNEL

to monitor the contents of wastewater and to make sure that treatment methods are working correctly.

MAINTENANCE PERSONNEL

to prevent mechanical failures and solve problems with equipment.

PLANT OPERATORS

who know how to treat wastewater properly before discharging it into the environment. Most operators must have a license after being trained and passing an exam.

DISPOSING OF HOUSEHOLD PRODUCTS SAFELY

- Don't pour solvents, pesticides, paint thinners, engine oil, or household cleaning products with hazardous chemicals down the drain or into storm sewers. (Take them to a recycling center or hazardous waste collection site.)
- Use fertilizers and pesticides carefully – and only as directed.
- Try to find safe alternatives to products that can harm water supplies.

SUPPORTING YOUR LOCAL TREATMENT PLANT

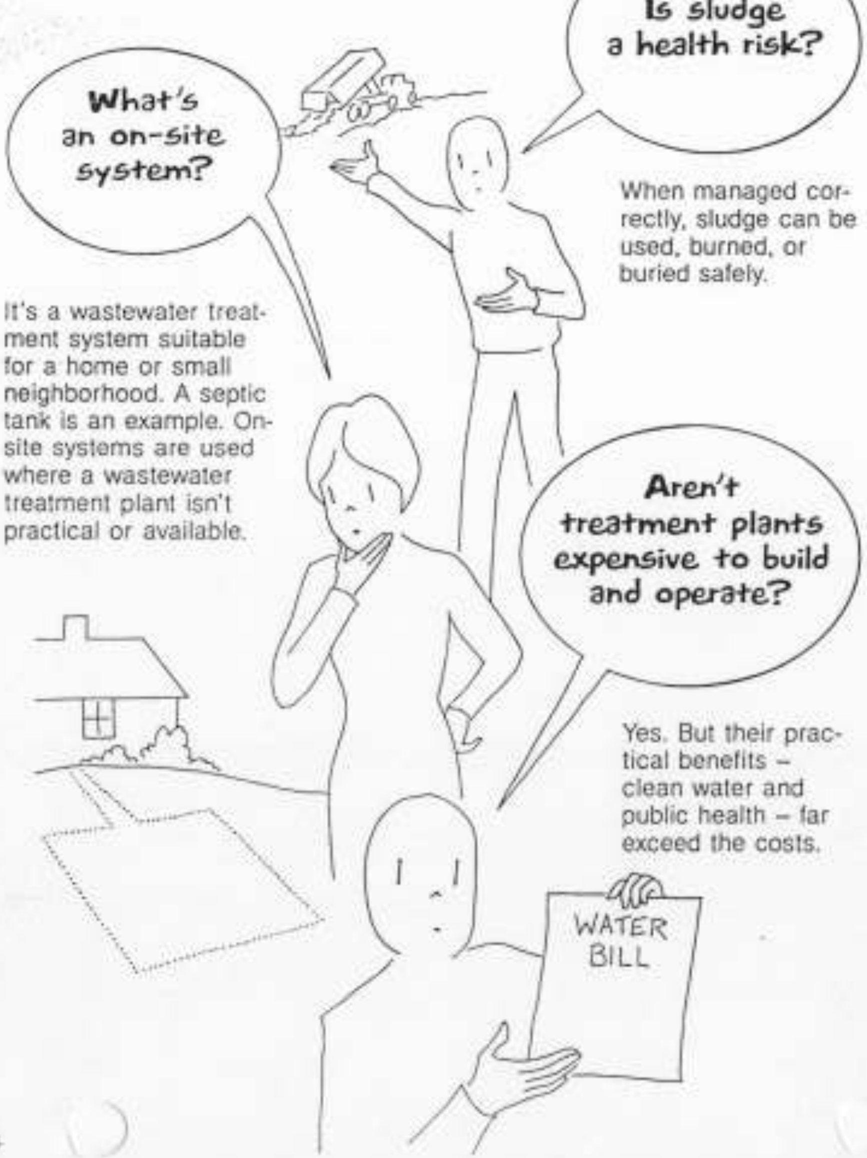
- Be aware of your treatment plant's efforts to provide clean water.
- Help make sure that it has the money, equipment and personnel to get the job done.
- Visit your local treatment plant. Learn what special problems it must solve and what you can do to help.

BEING INFORMED

- Learn about your local water supplies, and any possible threats they face.
- Know what your community is doing to protect your water supplies.
- Help other citizens be aware of the importance of clean water in your community.

USING WATER WISELY

- Practice water conservation at home and at work.
- Fix leaks, and install water-saving devices and appliances.
- Be aware of how much water you use in your household. Don't take this valuable resource for granted!



It's a wastewater treatment system suitable for a home or small neighborhood. A septic tank is an example. On-site systems are used where a wastewater treatment plant isn't practical or available.

When managed correctly, sludge can be used, burned, or buried safely.

Yes. But their practical benefits – clean water and public health – far exceed the costs.

Soo--

WASTEWATER TREATMENT GIVES US CLEAN, SAFE WATER!

✓ **KNOW THE FACTS** about wastewater treatment.

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✓ **UNDERSTAND THE VALUE** of wastewater treatment.

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NOTE: Authority cited: Section 142.3, Labor Code. And Chapter 6.1 of Division 20 of the Health and Safety Code

History:
1. New Section filed 12-9-92; operative 1-11-93 (Register 92, No. 50).

SECTION 2
MOST FREQUENTLY ASKED QUESTIONS ABOUT THE BLOODBORNE PATHOGENS STANDARD

TITLE 8
CALIFORNIA CODE OF REGULATIONS
SECTION 5193

(a)Scope & Application

Question. Which industries are exempt from the regulation?

Answer. The standard applies to all employees who may reasonably be anticipated to have occupational exposure to blood or other potentially infectious materials (OPIM). However, Construction is exempt by regulation, as cited in subsection (a). Maritime is currently exempt by policy. Agriculture is currently exempt by policy.

Question. How is coverage determined?

Answer. It is the responsibility of the employer to conduct an exposure determination, which is part of the written exposure control plan required by subsection (c)(l), to determine which employees and which tasks present a risk of potential occupational exposure to bloodborne pathogens.

Question. Who is an employee within the context of an employer employee relationship?

Answer. For Cal/OSHA purposes, an employee is a person who is directed or controlled by the employer.

Question. Are volunteers covered by the standard?

Answer. Occupational Safety and Health Act of 1973 does not apply to non-employees, such as volunteers, medical or nursing students, student laboratorians, student physical, occupational or

respiratory therapists, or other types of non-employees who work in a health care environment. Having presented the general rule, questions can arise, however, in any specific health care setting about the "volunteer" status of any particular worker. The indicia of an "employment" relationship, e.g., receipt by the worker of consideration for tasks performed, coverage of the worker by workers' compensation insurance, and coverage for unemployment insurance benefits. should not be present in order for the employer to argue that the worker is a true "volunteer."

Question. What type of facilities or operations are presumed to have occupational exposure?

Answer. The following types of operations have employees, whose job duties place them in the class of employees who are reasonably anticipated to have eye, skin, mucous membranes and potential contact with blood or OPIM. These employees are covered by the standard unless contraindicated by substantial evidence:

Blood Intensive Operations;

Hemodialysis;

Blood Banks [See glove exception for volunteer donations centers, (d)(3)(G)4.];

Plasma Centers;

Commercial Laundries that service Healthcare or Public Safety Operations

Correctional facilities;

Prisons Juvenile

Detention facilities;

Emergency or Public Safety Operations, such as:

Ambulance services;

Emergency First Aid Operations [See Collateral Duty Exception, (f)(1)(A)];

Emergency Medical Operations;

Fire services;

Lifeguard Services;

Paramedical;

Police services;

Facilities for the developmentally disabled;

Funeral service operations;

Healthcare Facilities;

Dental facilities;

General dentistry;

Orthodontia Oral Surgeries;

Support Operations such as those employing dental hygienists, dental laboratory technicians and dental assistants;

Hospice Facilities;

Hospitals;

Emergency rooms;

Housekeeping Operations;

Laundry;

Nursing Operations;

Operating rooms;

Regulated Waste Operations;

Industrial Clinics;

Home Healthcare Facilities;

Long Term Nursing and Long Term Care Facilities;

Medical Laboratories;

Nurse Practitioner's Offices;

Physician's Offices;

Outpatient Medical Clinics;

Medical Equipment Service and Repair Operations;

Regulated Waste Operations;

School-based Health Clinics; and

Tissue Bank Operations.

Question. Does the regulation apply to clinical or diagnostic laboratories?

Answer. Yes. However, clinical or diagnostic laboratories refers to those facilities that are engaged solely in the analysis of blood, tissues, or organs. They do not fall within subsection (e) of the regulation which pertains to HIV and HBV Research Laboratories and Production Facilities. Subsection (e) applies to facilities engaged in the culture, production, concentration, experimentation and manipulation of HIV and HBV.

Question. Are academic research laboratories included in the definition of a research laboratory under the standard?

Answer. Academic research laboratories are included in the definition of a research laboratory in subsection (e) of the standard. A research laboratory is one that produces or uses research laboratory scale amounts of HIV and HBV. Although research laboratories may not have the volume found in production facilities, they deal with solutions containing higher viral titers than those normally found in patients' blood.

Question. Are volunteers and students covered by the standard?

Answer. No, volunteers and students are not covered by the standard.

Question. Are physicians who are not employees of the hospital in which they work covered by the standard?

Answer. Physicians, who are "incorporated," are considered employees of their corporation. The corporation which employs these physicians may be cited for violations affecting those physicians. The hospital where the physician practices may also be held responsible as the employer who created or controlled the hazard or who had employees exposed to the hazard.

Question. Are "independent contractors" who are healthcare practitioners covered?

Answer. Healthcare practitioners, who are independent contractor healthcare providers, are not considered employees under the Labor Code, and therefore, are not covered by the protections of the standard. However, if an independent contractor physician or dentist were to create a hazard

to which employees were exposed, it would be consistent with current Cal/OSHA policy to cite the employer of the exposed employees for failure to provide the protections of the Bloodborne Pathogens Standard.

Question. Can a hospital be cited by Cal/OSHA if an independent contractor healthcare provider refuses to comply with the requirements of the Bloodborne Pathogen Standard?

Answer. The hospital has a responsibility to protect its employees from workplace hazards. In so far as the hospital is a controlling employer of a contract employee, the hospital may be cited for violations of standards.

Question. Can a healthcare provider be cited if the provider is an employee of a professional corporation?

Answer. If the employee of the corporation is in violation of a standard, the corporation, as the employer, can be cited.

Question. Is the standard applicable to lifeguards?

Answer. The standard will be strictly applied to lifeguards, as they are regarded as emergency response personnel.

Question. Who is the responsible employer at a multi-employer worksite?

Answer. The key element is who directs and controls an individual employee's conduct in a the multi-employer worksite. The employer who "directs and controls" the work activity of the employee is responsible. Multi-employer worksites are very common in some industries, such as the construction industry. A significant body of occupational safety and health law has developed on the issue of which employer, in a multi-employer worksite, has the duty to comply with occupational safety and health standards and regulations. Decisions of the Occupational Safety and Health Appeals Board, relying in part on decisions of the California Supreme Court and appellate courts, have imposed the responsibility for worker safety and health on the employer who "directs and controls" the work activity of the employee. In most settings, including the health care industry, there can be two potential persons or entities which could be "the" employer of the employee. Occupational safety and health law has explicitly recognized the "duality of employers" in these workplaces.

Question. How does Cal/OSHA determine liability?

Answer. Cal/OSHA does not determine "liability" in the legal sense but rather makes determinations relative to compliance with the regulations in Title 8 of the California Code of Regulations (T8 CCR).

Question. My company supplies contract employees to health care facilities. What are my responsibilities under the Bloodborne Pathogens Standard?

Answer. Cal/OSHA considers personnel providers, who send their own employees to work at other facilities, to be employers whose employees may be exposed to hazards. Since your

company maintains a continuing relationship with its employees, but another employer (your client) creates and controls the hazard, there is a shared responsibility for assuring that your employees are protected from workplace hazards. The client employer has the primary responsibility for such protection, but you also have a responsibility. Under the Bloodborne Pathogens Standard your company would be required, for example, to provide the general training outlined in the standard; ensure that employees are provided with the required vaccinations; and provide proper follow-up evaluations following an exposure incident. Your clients would be responsible, for example, for providing site specific training and would have the primary responsibility regarding the control of potential exposure conditions. The client, of course, may specify what qualifications are required for supplied personnel, including vaccination status. It is certainly in your interest to ensure that all steps required under the standard have been taken by the client employer to ensure a safe and healthful workplace for the leased employees. Toward that end, your contacts with your clients should clearly describe the responsibilities of both parties in order to ensure that all requirements of the regulation are met and.reference to such contacts should be cited in each employers' Exposure Control Plan.

Question We have employees who are designated to render first aid. Are they covered by the standard?

Answer. Yes, employees who are designated as responsible for rendering first aid or medical assistance as part of their job duties, are covered by the protections of the standard. However, employees, who administer first aid only as a collateral duty to their routine work assignments, are not required to be offered the pre-exposure hepatitis B vaccination. Such employees fall within the scope of the exemption provided in subsection (fl(l)(A); see also subsection (f) for further discussion of the Exception.

Question. Are plumbers covered by the standard?

Answer. In the analysis required by the Injury and Illness Prevention Program, the employer should have identified any potential occupational exposure to bloodborne pathogens by plumbers who are employees at health care facilities. In addition plumbers, when working intermittently or on a one time basis in health care facilities, are covered by the regulation because of their potential occupational exposure.

Question. Are members of emergency response teams covered by the standard?

Answer. Emergency response teams, where it has been indicated that first aid is not a part of their job description, are not covered by the regulation. For example, the emergency response team may be responsible for security spill control. However, where providing first aid is a collateral duty, such employees are covered by the proposed standard with the option for providing post exposure hepatitis B vaccination. The election of post or exposure prophylaxis will require identification of such election in the exposure control plan. Therefore, employers should make certain that as the proposed regulation is implemented that both the job description and the tasks performed are evaluated. Note: first aid training does not make, and does not require that an individual so trained must respond. However, again, if the employer determines that an employee may be exposed in the course of assigned duties, the employee falls within the scope of the standard.

Question. Are housekeepers and laundry attendants in a hotel environment covered by the standard?

Answer. The Division is concerned with employee protection. Regardless of how the hazard is addressed, either by the Bloodborne Pathogens Standard, 8 CCR 5193, or the Illness and Injury Prevention Program, 8 CCR 3203, the potential for bloodborne infections can be encountered in the hotel environment. Potential exposure incidents include encountering insulin syringes, cleaning blood stained laundry, as well as disposing of sanitary napkins, or blood arising from accidents in the hotel. Cal/OSHA feels that training is a key element for the protection of housekeepers and laundry attendants in the hotel environment. The employer must make a determination whether there is potential exposure which may arise in the workplace and if so, address the potential in the workplace safety and health plan required by the regulations.

Question. Are employees such as housekeepers, maintenance workers, or janitors covered by the standard?

Answer. While Cal/OSHA does not generally consider housekeepers, maintenance personnel and janitorial staff employed in non-health care facilities to have occupational exposure, it is the employer's responsibility to determine which job classifications or specific tasks and procedures involve occupational exposure. For example, Cal/OSHA expects products such as used sanitary napkins to be discarded into waste containers which are lined in such a way as to prevent employee contact with the contents. But at the same time, the employer must determine if employees can come into contact with blood during the normal handling of such products from initial pick-up through disposal in the outgoing trash. Further, housekeeping workers in health care facilities may have occupational exposure to bloodborne pathogens, as defined by the regulation. Individuals who perform housekeeping duties, particularly in patient care and laboratory areas, may perform tasks, such as cleaning blood spills and handling regulated wastes, which also constitute occupational exposure.

If Cal/OSHA determines, on a case-by-case basis, that sufficient evidence of reasonably anticipated exposure exists, the employer will be held responsible for providing the protections of the regulation to the employees with occupational exposure.

Question. Are sewage plant, waste water workers or non-healthcare facility plumbers covered?

Answer. These workers are not ordinarily covered, since material they contact is not visibly contaminated with blood. However, if their duties include working on plumbing or sewage systems in or directly from health care facilities, they may reasonably anticipated to be occupationally exposed, and therefore, covered. There is no evidence to suggest that sewage plant or waste water workers are at increased risk for hepatitis B infection. HBV and HIV may be present in waste water, but in very dilute concentrations which would not pose a risk to waste water workers or sewage plant workers.

(b) Definitions.

Collateral duty first-aid provider, which is not defined within this subsection, but is used in subsection (f), is defined as follows: A collateral duty first aid provider is an employee, who is designated by the employer to have first aid response job duties. This additional job duty is in the employees job description, is identified in the exposure control plan and the employee must receive the training required by the standard in addition to first aid training.

Construction as an exempt industry (Provided for clarification but not defined in this subsection) The construction industry is composed of the following activities: construction, excavation, alterations, painting, repairing, construction maintenance, renovation, removal, or wrecking of any fixed structure or its parts, as described in the Construction Safety Orders commencing with T8CCR 1500.

First aid incident, which is not defined within this subsection, but is used in subsection (fig is defined as follows: A first aid incident has occurred if there is any blood or other potentially infectious material resulting from an accident or injury. The first aid provider need not have been exposed to the blood in order for the required hepatitis B prophylaxis to be offered. A first aid incident may be an employee exposure incident. The employer's evaluation of the report of the incident is the determining factor; i.e. did the employee get blood, as defined in the standard, or other potentially infectious materials on broken skin or mucous membranes.

Maritime, which is not defined within this subsection, but is an exempt industry

The maritime industry consists of shipyards, marine terminals, and long shoring. Marine terminals are wharves, bulkheads, quays, piers, docks and other berthing locations adjacent storage or contiguous areas and structures associated with the primary movements of cargo or materials from vessels to shore and shore to vessel, including structures which are devoted to receiving, handling, holding, consolidation, loading or delivery of waterborne shipments and passengers and areas devoted to terminal or equipment maintenance.

Question. What constitutes "reasonably anticipated" within the definition of occupational exposure?

Answer. The term is "reasonably anticipated" is not defined in the regulation. It includes the potential for exposure as well as actual exposure. A lack of history of exposure among first aid personnel at a particular manufacturing site, for instance, does not preclude coverage. If an employee in a position is likely to be exposed at least once during a working lifetime, that position should be considered for coverage by the standard, since even a single exposure can result in transmission of a life threatening infection.

Question. What does Cal/OSHA mean by the term "regulated waste"?

Answer. The Bloodborne Pathogens Standard uses the term, Regulated waste," to refer to the following categories of waste which require special handling at a minimum; (1) liquid or semi-liquid blood or other potentially infectious material (OPIM); (2) items contaminated with blood or OPIM and which would release these substances in a liquid or semi-liquid state if compressed; (3) items that are caked with dried blood or OPIM and are capable of releasing these materials during handling; (4) contaminated sharps; and (5) pathological and microbiological wastes containing blood or OPIM.

See also (d)(4)(C).

A distinction should be made between contaminated waste and regulated waste. Regulated waste is red bagged and its storage and disposal is further governed by the Medical Waste Act.

Contaminated waste includes materials that may be soiled with blood during the course of their use but are not within the scope of regulated waste, as described above. Such items such as dental drapes, band aids, sanitary napkins and the like need not be disposed of as hazardous waste or medical waste and can be discarded as solid waste. It is recommended that contaminated waste be placed in containers which do not contain labeled red bags but rather other bags placed within the fixed container. This procedure allows employees to distinguish between this waste and regulated waste. A biohazard label on the fixed container warns individuals of the contaminated nature of the contents of these receptacles. Such containers could be utilized in general dentistry offices for discarding dental drapes and other disposable items that are outside the scope of the definition of regulated waste because they are not capable of releasing blood or OPIM during handling.

(c) Exposure Control

(c)(1)(A)

Question. What is an exposure control plan?

Answer. The exposure control plan is the employer's written program that outlines the protective measures an employer will take to eliminate or minimize employee exposure to blood and OPIM.

Question. Why must the exposure control plan be consistent with T8CCR 3203?

Answer. The Injury and Illness Prevention Program specifies that an effective program shall include procedures for evaluating workplace hazards. It should be noted also that these plans can be combined into a single document.

Question. Does the exposure control plan need to be a separate document?

Answer. No. The exposure control plan may be part of another document, such as the facility's Injury and Illness Prevention Program (T8CCR 3203) or health and safety manual, as long as all components are included. However, the plan must be accessible to employees. There must be a guiding document which states the overall policy and goals and references the elements of existing separate policies that comprise the plan. For small facilities, the plan's schedule and method of implementation of the standard may be an annotated copy of the final standard that states in one document when and how the provisions of the standard will be implemented. Larger facilities could develop a broad facility program, incorporating provisions from the standard that apply to their establishments.

Question What language must the Exposure Control Plan be in?

Answer. The exposure control plan need only be in English. However, the communication of the plan, as required by subsection (g)(2), requires training regarding the plan to be in the language of and at a educational and literacy level commensurate with that of the employees.