The Science of Sewage: Risks for Public and Worker Health in the New Millennium

Community wastewater in the United States has never been more hazardous to the health of humans and the environment than it is now. Thus, those impacted by sewage backflows or sewage-contaminated flood waters in residential or commercial buildings, as well as those who work directly with sewage processing or are engaged in the remediation of sewage contamination in indoor environments, require the latest science-based information necessary to implement appropriate approaches to health protection.

Introduction

Untreated residential and commercial wastewater, typically referred to as sewage, presents a significant risk to the public's health, typically through contamination of drinking and recreational waters, as well as a variety of agricultural products produced both domestically and internationally. Foodborne outbreaks in the U.S. linked to sewage-contaminated agricultural products grown with the use of untreated animal and/or human waste are not uncommon and pose a risk for illness and sometimes death to members of the general public.[32] Prevention of such incidents is a continual concern and effort on the part of federal, state and local health agencies, as well as food producers, processors and service vendors.

A still greater health risk exists within the occupational health area, as individuals are potentially chronically exposed via direct interaction with raw sewage within a variety of job categories. Wastewater treatment facility workers, sewer and septic tank workers, sewage sludge processors and water damage restoration specialists dealing with cleanup from storm flood waters and remediation of residential and commercial pressurized sewage backflows incur a greater exposure risk for sewage-associated morbidity and mortality.[2, 3, 25, 42] Educational training

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SYNOPSIS

Community wastewater has never been more hazardous. Thus, those impacted by sewage backflows or sewage-contaminated flood waters, as well as those who are engaged in the remediation of sewage contamination, require the latest science-based information necessary to implement appropriate approaches to health protection.

Sewage presents a significant risk to public health. Foodborne outbreaks linked to sewage-contaminated agricultural products are not uncommon. A still greater health risk exists within the occupational health area, as individuals are potentially chronically exposed via direct interaction with raw sewage within a variety of job categories, including water damage restoration specialists.

The infectious disease risk from sewage exposure has recently become more complicated and threatening due to increased antibiotic-resistant microbes as well as increased virulence in newly emerged and re-emerging pathogens. Additionally, the makeup of chemical pollutants in wastewater has become more complex and hazardous.

Microbial Hazards. As the world's population and economic growth have expanded, we have experienced a wave of emerging and re-emerging infectious disease agents. Many of these microbial agents and toxins can be detected in raw sewage and sewage-contaminated floodwaters.

Infectivity. Many human disease bacteria are associated with wastewater and contaminated water sources. Similarly, protozoan parasites and some of the parasitic worms or helminths typically found in wastewater may also have low infective doses for man, as can viruses in sewage.

Antibiotic Resistance. When individuals experience disease initiated by exposure to contaminated wastewater, quick diagnosis and treatment will usually resolve the situation, but sometimes drug treatment is required. If the causative agent is bacterial, treatment may be compromised by antibiotic resistance. It's not only direct sewage exposures — as might occur in the remediation of homes and buildings experiencing storm backflows — that are a health concern in regard to antibiotic-resistant human bacteria, but contact with any flood waters.

Allergens and Microbial Toxins. Fungi are found in indoor and outdoor environments, including sewage and flood waters. Many fungi produce mycotoxins that may result in a variety of adverse human health effects. Bacteria found in sewage are also a source of toxic compounds known as endotoxins.

Chemical and Radiological Hazards. Recent research has revealed the presence of hundreds of organic contaminants in wastewater and impacted surface waters. While human health effects from exposure to these compounds and substances have not been demonstrated, a precautionary approach to exposures is recommended.

Considerations for Remediation, Verification and Worker Protection. Of primary concern to professionals responding to a sewage-contaminated indoor environment is the health and safety of the occupants. If evacuation of occupants from the affected structure has not been accomplished, it must be immediately instituted.

- Procedures to be followed for the effective remediation of sewage and other "grossly contaminated" water losses are described in the ANSI/IICRC S500-2015. It includes a thorough inspection in order to define a thorough and appropriate remediation plan. Such a plan will involve extraction of wastewater, removal of contaminated materials, antimicrobial application, and detergent cleaning that may involve the use of pressure washing.
- Verification, or "clearance testing," of the remediation phase of the job is required upon completion to confirm the effectiveness of meeting a predetermined criterion and permit restoration to commence.
- Those who professionally remediate and restore residential sewage backflows are at significant risk for adverse health effects. Training, immunization and the use of personal protective equipment (PPE) is required.

on reducing exposures and associated health risks from sewage contact must be continually made available to at-risk workers and this training must also be updated as the science of sewage continues to emerge.

The long-recognized infectious disease risk from sewage exposure has recently become more complicated and threatening. This is due to increased antibiotic-resistant microbes, as well as increased virulence in newly emerged and re-emerging pathogens. Sensitivity reactions to microbial products and components characterized as allergens and toxins continue to be a health-risk concern, especially as the human population appears more susceptible to those effects, perhaps through altered immune function due to heredity, drug treatment or multiple illnesses.

Additionally, the makeup of chemical pollutants in wastewater has become potentially more complex and hazardous with mixtures of organic pesticides, disinfection byproducts, heavy metals and radionuclides, in addition to residues from emerging contaminants from modern cleaning and hygiene products, as well as thousands of residual pharmaceutical products, and hormones and metabolites from human body excretions. Thus, chronic or even occasional inadvertent exposures to raw wastewater via inhalation, ingestion, or the dermal route, in combination with individuals' predisposition to its effects, presents a variety of worker health risks from a wide spectrum of infectious, allergic and toxic exposures.

Bacterium	Human Health Effects
Escherichia coli	Diarrhea, vomiting, cramps; some strains are toxigenic, resulting in severe and bloody diarrhea; others are toxigenic and hemorrhagic (*E.coli* O157:H7), resulting in multiple organ failure and death.
Salmonella spp.	Diarrhea, nausea, fever, sepsis, death
Shigella spp.	Diarrhea, bloody diarrhea, fever, stomach cramps, death
Campylobacter spp.	Diarrhea, bloody diarrhea, nausea, vomiting, arthritis
Yersinia enterocolitica	Diarrhea, bloody diarrhea, fever, abdominal pain, vomiting
Legionella pneumophila	Pneumonia, nausea, diarrhea, death
Vibrio spp.	Profuse diarrhea, nausea, vomiting, fever, chills, death
Helicobacter pylori	Chronic gastritis, peptic ulcers, stomach cancer, lymphoma
Bacteroides spp.	Intraabdominal abscesses, bacteremia

Adapted from Bitton, 2011 (7)

Table 1: Water And Wastewater Bacteria And Human Health Effects

Microbial Hazards

Over the past several decades, as the world's population and economic growth have continued to expand, we have experienced a wave of emerging and re-emerging infectious disease agents.[23] Some have just recently been recognized, such as H5N1 Avian Influenza Virus, enterohemorrhagic *E. coli* O157:H7, and *Borrelia burgdorferi,* the agent of Lyme disease. Other bacterial agents have recently increased in incidence, have been associated with chronic illness, and/or have exhibited increased virulence or antibiotic resistance (e.g., *Helicobacter pylori, Mycobacterium tuberculosis, Staphylococcus aureus, Enterococcus spp.,* and *Streptococcus pneumoniae*). In addition, a variety of human and environmental bacteria produce potentially harmful endotoxins. Similarly many varieties of fungi, particularly molds, act as allergens with some producing potent metabolites known as mycotoxins. Both endotoxins and mycotoxins can result in human health effects. Many of these microbial agents and toxins can be detected and expected to be found in raw sewage and sewage-contaminated floodwaters, therein initiating a human health risk upon exposure.

Infectivity. Many human disease bacteria are associated with wastewater and contaminated water sources (Table 1). Some, such as *E. coli* O157:H7, *Shigella* spp., *Campylobacter* spp., and *Vibrio* spp., are recognized as having low infective doses necessary to initiate infection, thus presenting a higher risk for disease. Similarly, of the protozoan parasites often present in wastewater (Table 2), some such as *Giardia, Cryptosporidium,* and *Entamoeba,* have an infective dose of only about 10 cysts[7], making them extremely infectious. Likewise, some of the parasitic worms or helminths typically found in wastewater (Table 3), may also have low infective

Parasite	Human Health Effects
Giardia lamblia	Diarrhea, nausea, vomiting, malabsorption
Entamoeba histolytica	Stomach pain, bloody stools, liver abscess
Acanthamoeba spp.	Eye pain/blurred vision, encephalitis
Naegleria fowleri	Amebic meningoencephalitis
Cryptosporidium spp.	Watery diarrhea, nausea, vomiting, weight loss
Cyclospora cayetanensis	Watery diarrhea, nausea, cramping, fatigue
Toxoplasma gondii	Flu-like symptoms, fetal infection

Adapted from Bitton, 2011 (7)

Table 2: Water And Wastewater Protozoan Parasites And Human Health Effects

doses for man, as can viruses in sewage, including Hepatitis A virus (Table 4).

It is recognized that contaminated water and wastewater may contain some 140 different types of enteric viruses which multiply readily in the gastrointestinal tract and can be excreted in large numbers in the feces of infected individuals[7]. We thus recognize the significant risk of infection and disease associated with human exposures to raw sewage or sewage-contaminated flood waters, especially as regards those individuals who are particularly susceptible due to compromised immune function.

Antibiotic Resistance. When individuals experience disease initiated by exposure to contaminated water or wastewater, quick diagnosis and treatment will usually resolve the situation. In fact, for most enteric illness, hydration and related supportive therapy is often all that is necessary for an uneventful recovery. But sometimes the disease is so severe as a result of the pathogen's virulence, that drug treatment is required. And if the causative agent is bacterial, then treatment may be compromised due to extensive antibiotic resistance carried by the organism.

In fact, increased antibiotic resistance on the part of many bacterial disease pathogens is now considered a major public health concern.[39] The problem has arisen due to multiple factors, such as poor patient treatment compliance or self-treatment with antibiotics that patients may initiate on their own. It is also a result of physician overprescribing or mis-prescribing anitibiotics to patients over the years, as well as the extensive use of antibiotics in the livestock industry. While poultry, cattle and swine antibiotics aren't the exact same drugs used to treat humans, they are molecularly similar enough to potentially contribute to the problem of resistance in antibiotics used to treat humans.

Helminth	Human health effects
Ascaris lumbricoides	Roundworm disease, abdominal discomfort, intestinal blockage, cough
Trichuris trichiura	Whipworm disease, abdominal pain, anemia
Taenia spp.	Tapeworm disease, abdominal pain, weight loss, stomach discomfort
Necator americanus	Hookworm disease, anemia
Ancylostoma duodenale	Hookworm disease, anemia
Toxocara spp.	Intestinal disturbance, organ damage, eye disease

Adapted from Bitton, 2011 (7)

Table 3: Water And Wastewater Parasitic Worms And Human Health Effects

While clinicians regularly confirm treatment challenges due to antibiotic-resistant bacteria (ARB), the scope of the resistance problem is further illustrated by the testing of bacteria isolated from raw sewage across the U.S., as well as other parts of the world. Gram-negative bacteria isolated from five sewage treatment plants in Kansas were found resistant to one or more of three broad-spectrum antibiotics tested: ciprofloxacin, tetracycline, and chloramphenicol.[41] Similarly, multiple drug-resistant bacteria were isolated from liquid pig manure and sewage sludge used as fertilizer in Germany.[16] And, as expected, antibiotic-resistant *E. coli* and *Enterococcus*, along with other human disease-causing bacteria have been isolated from hospital sewage from around the globe.[43]

Of similar concern is increased resistance that likely develops in bacteria within wastewater treatment facilities, either by new mutations or the exchange of genetic information between organisms.[8, 19, 34] Additionally, there is concern that such organisms may survive wastewater treatment and be discharged to surface waters, as was recently shown with ampicillin-resistant *E. faecium* in the Netherlands.[34] This latter environmental concern that natural waters may harbor reservoirs

Virus	Human health effects
Adenovirus	Gastroenteritis, respiratory infections, eye infections, asthma, meningoencephalitis, intussusception, hemorrhagic cystitis
Aichi virus	Gastroenteritis
Astrovirus	Gastroenteritis
BK polyomavirus	Hemorrhagic cystitis, kidney disease
Enteroviruses:	
Coxsackievirus	Gastroenteritis, respiratory infections, aseptic meningitis, myocarditis, encephalitis, insulin-dependent diabetes mellitus
Echovirus	Gastroenteritis, respiratory infections, aseptic meningitis, myocarditis
Poliovirus	Aseptic meningitis, paralysis
Hepatitis A virus	Infectious hepatitis
Hepatitis E virus	Infectious hepatitis
JC polymavirus	Kidney disease
Norovirus	Gastroenteritis, diarrhea, vomiting, stomach pain
Sapovirus	Gastroenteritis, diarrhea, vomiting, stomach pain
Reovirus	Respiratory infections, gastroenteritis
Rotavirus	Gastroenteritis

Adapted from Bitton, 2011 (7)

Table 4: Water And Wastewater Viruses And Human Health Effects

of ARB has been confirmed, as isolates of *E. coli* from urban waterways in Milwaukee, WI were found to exhibit greater antibiotic resistance than *E. coli* from Milwaukee sewage.[18] And in Japan, vancomycin-resistant *Enterococcus faecium* and *Enterococcus faecalis* have been isolated not only from sewage, but from urban river waters as well.[26] Thus, it's not only direct sewage exposures — as might occur in the remediation of homes and buildings experiencing storm backflows — that are a health concern in regard to antibiotic-resistant human bacteria, but contact with *any* flood waters.

Allergens and Microbial Toxins. Fungi (molds and yeasts) are ubiquitous organisms in nature found in indoor and outdoor environments, including sewage and flood waters. Based upon heredity, immune function, and frequency and degree of exposures, many people develop a sensitization to mold allergens (fragments of vegetative growth and/or mold spores) in particular, and the resultant health effects may be manifested as upper and/or lower respiratory conditions, including asthma, rhinitis, allergic fungal sinusitis, and hypersensitivity pneumonitis.[4]

Many fungi also produce one or more mycotoxins — chemical compounds produced by actively growing molds on wet or damp substrates (nutrient sources) that may result in a variety of adverse human health effects that can be characterized as neurologic[28], teratogenic, mutagenic, carcinogenic, immunotoxic, and hepatotoxic.[20] Many mycotoxins contaminate human and animal food crops, some of which can be found in surface waters and flood waters, and wastewater from sewage treatment facilities.[38, 15]

Bacteria found in sewage are also a source of toxic compounds know as endotoxins. They are components of the cell walls of gram-negative bacteria, and are released when the bacterial cells break apart and are aerosolized, thus resulting in an inhalation risk to those exposed. Endotoxin has been shown to result in decreased pulmonary function in sewage treatment plant workers[12], and identified as a risk factor for asthma.[35]

Chemical and Radiological Hazards

Recent research has revealed the presence of hundreds of organic contaminants in wastewater and impacted surface waters. As shown in Table 5, some common categories of these include estrogenic hormones, antibiotics, surfactants, endocrine disruptors, human and veterinary pharmaceuticals, x-ray contrast media, pesticides and disinfection byproducts.[27, 13] Drugs detected in wastewater most often include painkillers, antihistamines, beta-blockers, lipid regulators, antidepressants, antiepileptics, antidiabetics, analgesics and anti-inflammatories, birth control hormones, blood-thinning agents and antifungal agents.[27] And while human health effects from exposure to these compounds and substances in micro-concentrations in wastewater, either individually or in combination, have not been demonstrated, a precautionary approach to exposures is recommended.

In addition to containing a myriad of human pathogens, sewage from hospitals, cancer treatment centers, and other healthcare facilities, is well burdened with an enormous spectrum of chemical and radiological agents used for therapeutic purposes, diagnostics, research and disinfection. This can include cancer chemotherapeutic agents, heavy metals and radioactive elements. The radioisotope Iodine-131 is the most widely used radionuclide in medicine, and is excreted by patients and discharged directly to sewer systems where it can be detected in wastewater and sewage sludge.[30, 22]

Considerations for Remediation, Verification and Worker Protection

Remediation. Of primary concern to those professionals responding to a sewage-contaminated indoor environment is the health and safety of the occupants. If complete evacuation of occupants from the affected structure has not been accomplished, it must be immediately instituted. And the occupants must understand that for their own protection, they will have very limited or no access to the premises until the remediation and restoration is complete and the site is safe for reoccupancy.

The remediation of sewage-contaminated building structures includes recognition of physical and electrical hazards, ventilation and confined space concerns, assessment of the degree of damage, HVAC contamination, extent of contaminated porous materials, the use of detergents and EPA-registered disinfectants, drying challenges due to temperature and relative humidity,

Diuretics	Cosmetics	Phthalates	Algal toxins
Analgesics	Hormones	Heavy metals	Endotoxins
Antibiotics	Surfactants	Disinfectants/ byproducts	Mycotoxins
Betablockers	Pesticides	Perfluorinated compounds	Plasticizers
Lipid regulators	Contrast media	Cytostatics (chemotherapy)	Radionuclides
Anti-depressants	Hygiene products	Fluorescent whitening agents	Flame retardants

Adapted from Deblonde, 2011 (13)

Table 5: Categories Of Common Chemical Pollutants And Biological Toxins Identified In Sewage

and the need for post-remediation verification to confirm achievement of the primary goal of restoring the environment to an acceptable preloss condition.

At a minimum, procedures to be followed for the effective remediation of sewage and other "grossly contaminated" (Category 3) water losses are those contained in the ANSI/IICRC S500-2015 *Standard and Reference Guide for Professional Water Damage Restoration* (4th edition) published by the Institute of Inspection, Cleaning and Restoration Certification (IICRC). This requires a thorough inspection to identify sewage penetration of subflooring and wall systems, in order to define a thorough and appropriate remediation plan. Such a plan will involve extraction of wastewater, removal of contaminated materials, antimicrobial application and detergent cleaning that may involve the use of pressure washing.

Sewage contaminated porous materials must be confined in plastic bags and transported to appropriate disposal facilities, in accord with all local, state and federal regulations. Also, a one-step detergent-disinfectant may be used to jointly facilitate the physical removal of contamination, as well as the inactivation of remaining residuals and the prevention of secondary microbial colonization by allergenic and toxigenic molds. Following the initial disinfectant application and detergent cleaning and extraction, a second application of disinfectant may be required. The use of a low-pressure sprayer is especially recommended for the application of any antimicrobial in order to minimize aerosolization.[17] The major classes of disinfectants, along with their microbial efficacy and advantages and disadvantages, have previously been described.[6, 17]

Consideration might also be given to an alternative technology that may reduce the use of chemical disinfectants, or serve as an adjunct to them: steam cleaning. Steam is receiving attention in the healthcare environment as a way to maximize the reduction of human pathogens and curb disease transmission, as well as reduce costs associated with disinfectants. A study of the capability of steam to inactivate a broad spectrum of human pathogenic bacterial challenges dried on a hard surface showed complete kill by exposure to steam vapor within 5.0 seconds.[33]

High concentrations (4 $\log_{10}$-8 $\log_{10}$) of methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant *Enterococcus faecalis, Salmonella enterica, Pseudomonas aeruginosa, Escherichia coli,* and *Shigella flexneri* exposed to a steam device with its head covered with a cotton-terry material, showed initial kill beginning at 0.5 seconds and continuing through 1.0 and 2.0 seconds, with complete kill of all challenges by 5.0 seconds. Such results confirmed the fact that steam begins to kill vegetative bacteria on contact, and that inactivation continues rapidly and logarithmically. And in-use effectiveness of microfiber and steam technology was confirmed to be significantly more effective in controlling a norovirus gastroenteritis outbreak than a two-step process involving detergent cleaning followed by hypochlorite solution (1,000 ppm) with a 10-minute contact time.[1] At the very least, in clinical sewage-contamination situations, the use of steam to reduce or eliminate any remaining residual microbes following wet washing, extraction, disinfectant application, drying and HEPA vacuuming, should be considered.

Bacterial endotoxins can be aerosolized during improper remediation, such as attempts to clean and dry sewage-contaminated carpets in-place. Drying of such carpets will liberate airborne endotoxins that may induce respiratory inflammation and airway restriction, and have the ability to potentiate allergic and infectious-disease responses in those exposed. Additionally, the inactivation and reduction of microbial contamination necessary to confirm a return of the carpet to a sanitary condition cannot be assured.

Recent research, however, on the off-site cleaning and disinfection of oriental rugs contaminated with Category 3 flood water has shed light on a potential approach to salvaging high-value materials contaminated with sewage or sewage-related microorganisms.[5] Two used Oriental rugs, knotted with 100% wool face yarns were utilized in the study — one with symmetrical knots and the other with asymmetrical knots. Potential human pathogenic bacteria were used in conjunction with Category 3 flood water to saturate rug samples for one hour, followed by immersion for 20 minutes in either a thyme oil, phenol-based, or quaternary ammonium disinfectant, compared to tap water control. Replicate samples were exposed to disinfectant two times versus the original one time, followed by cleaning with a neutral detergent. Drying time was also investigated. Results showed that the greatest microbial reduction, consistent with a sanitization condition, was achieved when two disinfectant treatments were utilized and drying was done in less than 24 hours. However, microscopic examination of post-exposure rug fibers showed degradation after exposure to the phenol-based and quaternary ammonium disinfectants. Such research has implications for sewage-contaminated high-value rugs, yet a specific science-based study in that regard remains to be done.

Verification. Verification of the remediation phase of the job, also referred to as "clearance testing," is required

upon completion to confirm the effectiveness of meeting a predetermined criterion and permit the restoration phase to commence. In this regard, the utilization of a trained indoor environmental professional (IEP) to identify the verification criterion, develop the testing protocol and conduct the verification is essential.[17] And while the testing protocol may include some area air samples, the bulk of the sampling will focus on the now cleaned/decontaminated surfaces for assurance that residual contamination is absent or remains at an extremely low level of probability for disease transmission. Failure to meet the criterion in any area of the structure requires repeat cleaning/decontamination of that area until the criterion is met. And clearance criteria can vary depending upon the population that will eventually reoccupy the structure, as well as the work operations that will be conducted there. Thus, for example, a healthcare facility will require a very stringent verification criterion due to the susceptibility of the patient population that will reoccupy the area.

Worker Protection. Those who professionally remediate and restore residential sewage backflows are at significant risk for adverse health effects from infectious agents, potent allergens, noxious gases, vapors and fumes, endotoxins and mycotoxins. Studies have shown that workers with routine sewage exposures exhibit respiratory dysfunction,[40, 29] fatigue and headache,[24] infection[31] and increased incidence of cancers.[21, 14] Thus, adequate training, immunization and the use of personal protective equipment that provides dermal, mucus membrane and respiratory protection is needed.

According to the Centers for Disease Control and Prevention (CDC), all workers who handle human waste or sewage should receive training on disease prevention.[11] The training should include information on basic hygiene practices, use and disposal of personal protective equipment, and proper handling of human waste or sewage. Workers should be medically screened by a physician prior to beginning sewage-related work and also urged to promptly seek medical attention if displaying any signs of illness; especially if experiencing nausea, vomiting or diarrhea. Workers should also be encouraged to seek the recommendations of their primary healthcare physician or an occupational medicine physician concerning conditions that might put them at higher risk for working in a sewage-contaminated environment; such as chronic skin problems, other medical conditions or the use of immunosuppressive medications. It is also recommended that those working with sewage be current on immunizations and discuss this with a physician, especially in regard to the Tetanus, Hepatitis A and Hepatitis B vaccines.

Appropriate Personal Protective Equipment (PPE) should be provided to all workers likely to have exposures to sewage and sewage-contaminated flood waters. Choices of PPE include goggles, face-shields, respirators, liquid-repellent coveralls, gloves, boots and head protection. Utilization of respirators requires a comprehensive program of fit-testing and training or retraining. Likewise, workers must be trained on and work to prevent heat-induced stress, when environmental conditions of high temperature and high humidity exist at the worksite.

Confined spaces containing sewage can sometimes be deficient in oxygen from organic oxidation and displacement by carbon dioxide. They may also contain flammable gases such as methane and toxic gases such as carbon monoxide and hydrogen sulfide. Confined space training is recommended for all those who remediate sewage and flood-water damage. The U.S. Occupational Health and Safety Administration (OSHA) regulations on confined spaces can be found in the U.S. Code of Federal Regulations, 29 CFR 1910.146 and 29 CFR 1926.21.

Summary

With its mix of virulent and drug-resistant disease-causing microbes, hazardous chemical agents, residuals of thousands of pharmaceuticals, heavy metals, radionuclides, human excretions and industrial pollutants, sewage today is one of the greatest threats to human health and that of the global ecosystem. Scientific investigations have illuminated the increased risks from sewage components. They have also helped define the practices, precautions and protections that must be adopted to reduce human exposures and resultant adverse health effects, especially in regard to those who have direct contact with sewage and sewage-contaminated flood waters in the process of providing effective remediation services. We look forward to forthcoming scientific studies on sewage that will provide additional knowledge to allow us to better prepare for, prevent and protect ourselves from the ravages of human wastewater.

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