COAST VIEW PLUMBING & RESTORATION

Science of Sewage Remediation

(949) 806-3300

https://www.coastviewrestoration.com

coastviewrestoration@gmail.com

2840 E White Star Ave, Suite 117, Anaheim, CA 92806, USA

The Science of Sewage

AND

Implications for Remediation

Gene Cole, DrPH

Sewage

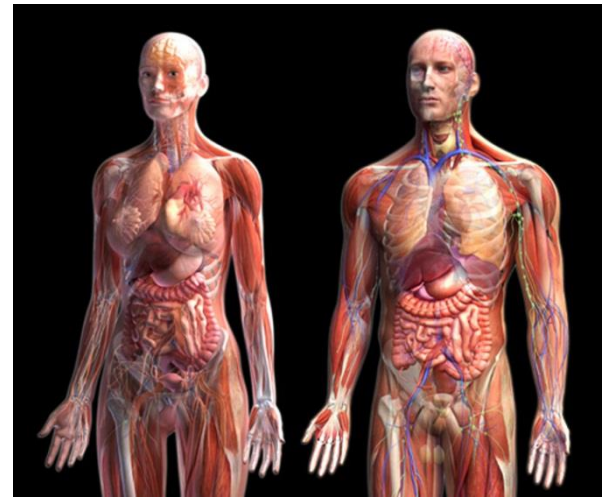
- **Untreated residential and commercial wastewater, typically referred to as sewage, presents a significant risk to the public's health through**:
  - Contamination of drinking & recreational waters
  - Food products grown with untreated animal and/or human waste
  - Occupational interaction with raw sewage in a variety of job categories: **wastewater treatment facility workers, sewer & septic tank workers, sewage sludge processors, and water damage restoration specialists** dealing with sewage backflows and contaminated flood waters.

Sewage Risks

- **Disease risk from sewage exposure has become more complex and threatening than in the past due to:**
  - **Increased antibiotic resistance in microbes.**
  - **Increased virulence in newly emerged or re-emerging agents.**
  - **Sensitivity to microbial products and components characterized as allergens and toxins.**
  - **A more susceptible human population relative to altered immune function due to heredity, drug treatment, or multiple co-morbidities.**
    - **At any given time, approximately 25% of the US population is immunosuppressed to some degree**

Sewage Risks

- The changing makeup of chemical pollutants in sewage becoming more complex, with hazardous mixtures of organic pesticides, disinfectant byproducts, heavy metals, and radionuclides, in addition to residues from cleaning, hygiene, and pharmaceutical products, as well as hormones and metabolites from human body excretions.



Sewage Hazards

- Microbes
- Chemical agents
  - Vapors, fumes, & gases
- Pharmaceutical agents
- Organic dusts
- Radioactive materials

Microbial Sewage Hazards

- Viruses
- Bacteria
- Bacterial Toxins
  - Exotoxins
  - Enterotoxins
  - Endotoxins
- Fungi
  - Fungal Mycotoxins
- Parasites

EMERGING INFECTIOUS DISEASES

“Pathogenic microbes can be resilient, dangerous foes. Although it is impossible to predict their individual emergence in time and place, we can be confident that new microbial diseases will emerge”

Institute of Medicine, 1992

Microbial Sewage Hazards

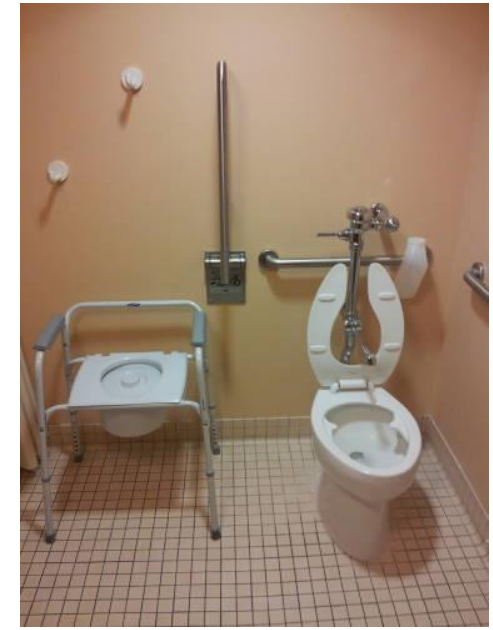
- **Viruses**
  - **Globally, at least 234 viruses are excreted in human feces and urine and find their way into sewage, to include:**
    - **Aichi virus 1**
    - **Astrovirus**
    - **Adenovirus**
    - **Enterovirus**
    - **Hepatitis A, E**
    - **Human papilloma virus**
    - **Norovirus**
    - **Rotavirus**

Microbial Sewage Hazards

- **Bacteria**
  - **Hundreds of various bacteria exist in raw sewage, many of which are recognized human pathogens, are antibiotic resistant, and include:**
    - ***Escherichia coli***
    - ***Shigella sp.***
    - ***Campylobacter sp.***
    - ***Pseudomonas sp.***
    - ***Salmonella sp.***
    - ***Legionella sp.***
    - ***Mycobacteria***
    - ***Aeromonas sp.***
    - ***Klebsiella sp.***

Microbial Sewage Hazards

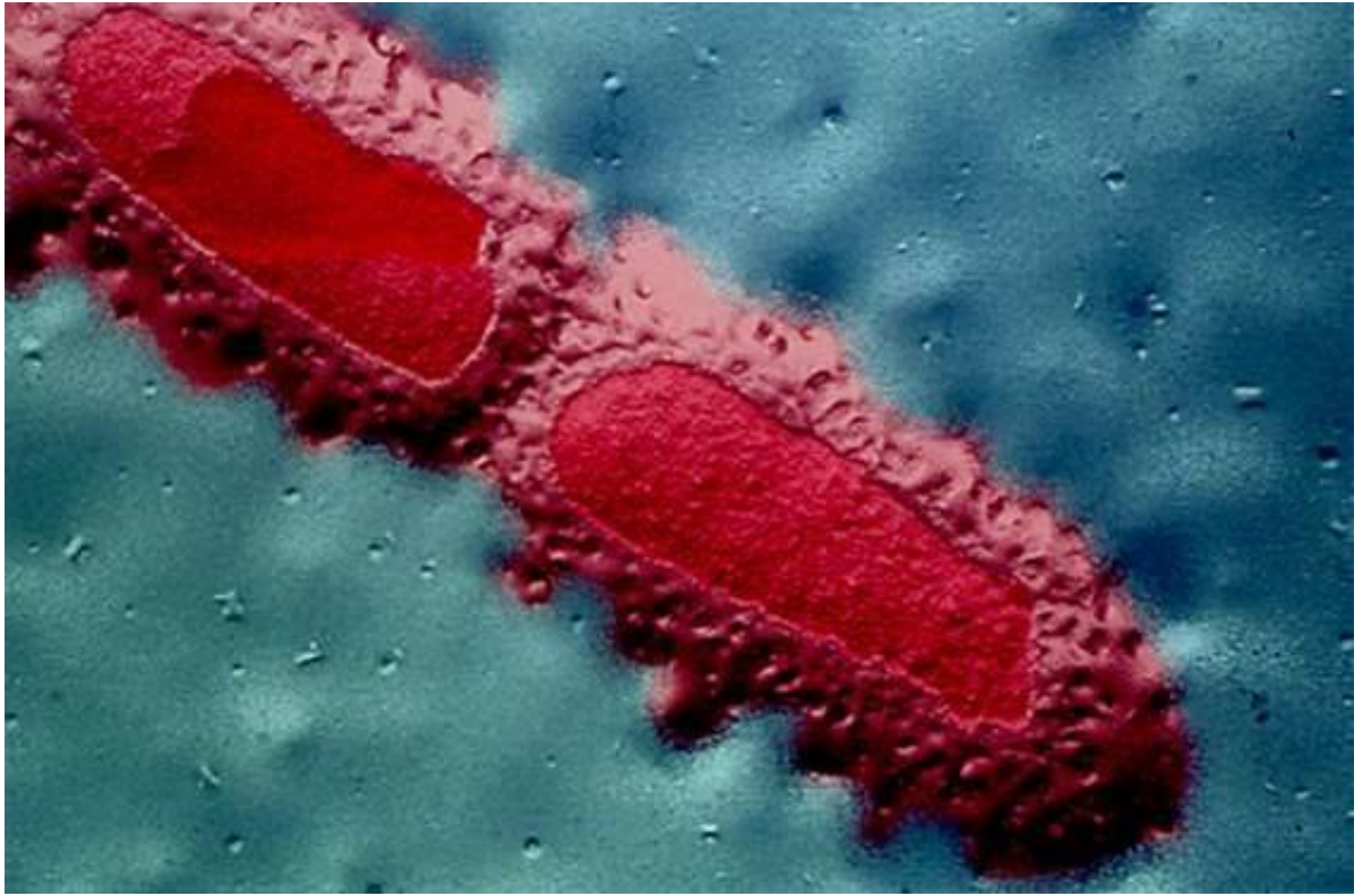
- **Antibiotic Resistance**
  - The testing of bacteria from **raw sewage** across the US and the world, has shown extensive antibiotic resistance.
  - Bacteria from 5 **sewage treatment plants** in Kansas were found resistant to one or more of 3 broad-spectrum anitibiotics.
  - Antibiotic-resistant *E. coli* and *Enterococcus*, along with other human disease-causing bacteria have been isolated from **hospital sewage** from around the globe.



Microbial Sewage Hazards

Bacterial Toxins

- **Potent chemical secretions or cellular components that can exhibit a toxic effect on human tissues and organs.**
  - **Exotoxins** are secreted by certain bacterial strains (e.g. ***Staphylococcus aureus, Clostridium botulinum,*** **Enterohemorrhagic** ***Escherichia coli O157:H7***).
  - **Enterotoxins** are exotoxins that target the intestines (e.g. ***Clostridium perfringens, Vibrio cholerae*** enterotoxins).
  - **Endotoxins** are components of the cell wall material of gram-negative bacteria (e.g. ***Pseudomonas, E. coli***).



Microbial Sewage Hazards

Endotoxins

- Cell wall fragments of gram-negative bacteria containing a lipopolysaccharide (or very reactive Lipid A molecule).
- Exposure typically occurs via the respiratory route by inhalation of endotoxin-containing dusts during dry down and cleanup of indoor environments contaminated by sewage or flood waters.
- Recognized to result in lung inflammation and reduced pulmonary function, especially in situations where exposures are chronic and illness is manifested as **asthma** or **byssinosis** (Brown Lung).

Microbial Sewage Hazards

Fungal Mycotoxins

- **Chemical secretions produced by fungal species (primarily molds) that can exhibit a toxic effect on human tissues and organs via ingestion or inhalation.**
  - **Aflatoxins** are potent carcinogenic compounds produced by ***Aspergillus*** species of molds, (e.g. ***A. fumigatus***)
  - **Fumonisins** are highly toxic chemicals produced by species of ***Fusarium*** molds.
  - **Trichothecenes** inhibit protein synthesis; produced by ***Stachybotrys, Trichoderma*** and other **water damage molds**.

Microbial Sewage Hazards

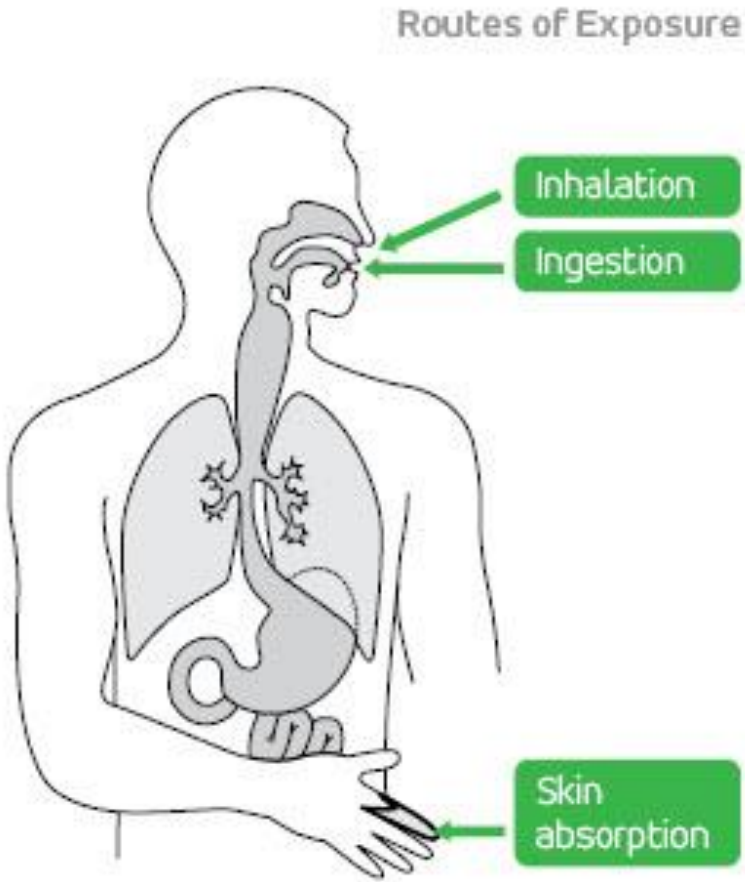
- **Parasites**
  - **Multicellular organisms that cause invasive disease in humans, resulting in significant morbidity and mortality.**
  - **Exposure is by ingestion, dermal, or vector-borne transmisisson.**

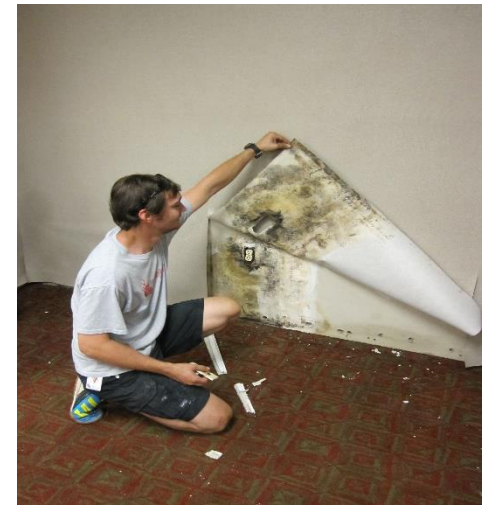
- ***Ascaris sp.***
- ***Giardia sp.***
- ***Cryptosporidium***
- ***Strongyloides***

- **West Nile virus**
- **St. Louis Encephalitis virus**
- **Zika virus**

Exposure

Air, Water, Materials

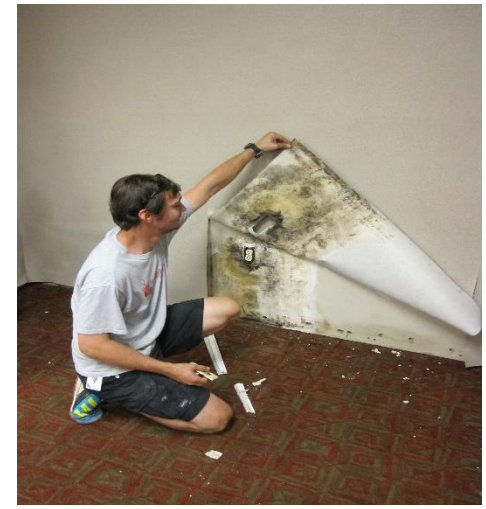




Exposure

Air, Water, Materials

- **The most significant exposures are typically those that are encountered as aerosols:**
  - **Biological**
  - **Non-biological**

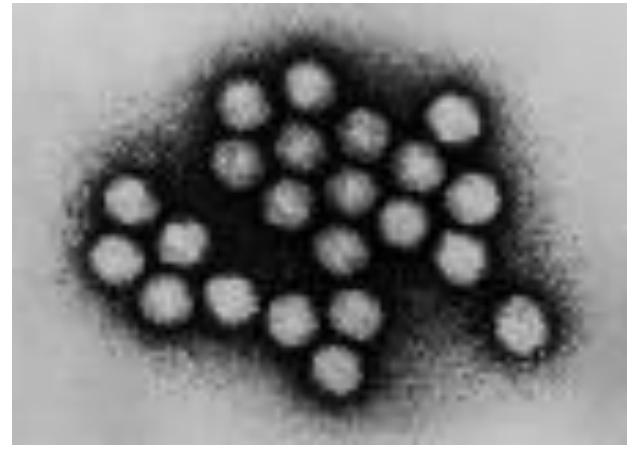


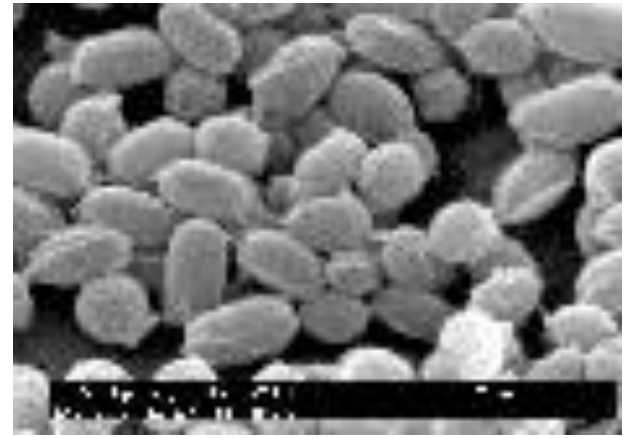
Bioaerosols

- A bioaerosol is an assembly of particles of variable biological origin suspended in a gaseous medium (e.g. air).
- It is suspended long enough to cause exposure and enable observation and measurement.
- Chronic or acute exposures may result in allergic or infectious disease.

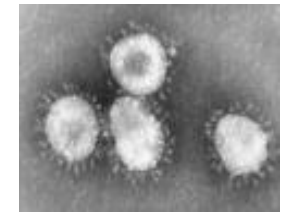
Infectious Bioaerosols

- **Aerosols of bacterial, viral, or fungal origin are capable of initiating an infectious process in a susceptible host.**
- **Such aerosols usually consist of a mixture of mono-dispersed and aggregate cells, spores, or viruses, carried by other materials, such as respiratory-size droplets and/or inert particles.**





Infectious Bioaerosols



- **While infectious agents have discrete size ranges:**
  - **~ 0.3–10 µm for most bacterial cells/spores**
  - **~ 2.0-5.0 µm for fungal spores**
  - **~0.02-0.30 µm for viruses,**
    - **Their size, in conjunction with the carrier matrix upon generation from a source, changes as they are aerosolized and exposed to environmental factors (RH, temperature) that favor desiccation or hygroscopicity.**
    - **With rapid desiccation, the resultant smaller aerosols can remain airborne longer, while larger aerosols may initially fall out and then become re-suspended after desiccation.**

Infectious Bioaerosols

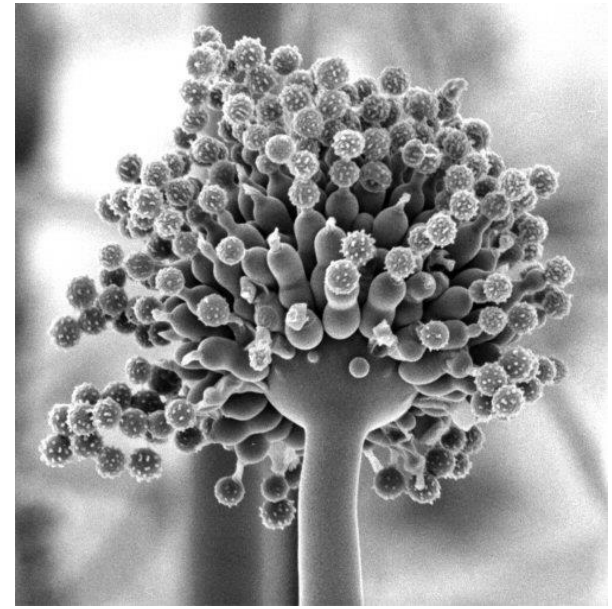
- Generally, it is considered that **particles up to 100 µm** in diameter are capable of remaining airborne long enough to be observed or measured as aerosols (or **droplets**) and hence able to transmit infectious agents.

Infectious Bioaerosols

- Respiratory disease agents are expelled from the respiratory tract within a matrix of mucus and other secretions that typically begin to desiccate upon expulsion by coughing, sneezing, talking, or singing.
- The dried residuals of these large aerosols are termed **droplet nuclei (0.5-12 μm)**

Infectious Bioaerosols

- Infectious agents generated from **wet environmental sources** (such as HVAC and cooling tower water with ***Legionella*****,** or flood/sewage water with ***E. coli*** or ***Salmonella***) can also result in droplet nuclei.
- Infectious aerosol carriers generated from **dry sources** (such as remediation dusts with ***Aspergillus fumigatus*** spores, or indoor dusts with **Hantavirus**) may absorb water in the airborne state, yet still measure in the droplet nuclei size range.



Infectious Bioaerosols

EVAPORATION

- **Studies of aerosolized pure water droplets have shown very brief drying times:**
  - **Water droplets with diameters of 100 µm and 50 µm falling in 50% RH air, had drying times of 1.3 and 0.3 seconds, respectively.**
  - **Water droplets with diameters of 20 µm and smaller evaporated in less than 1.0 second.**
- **It is recognized however that respiratory droplets contain dissolved substances and microorganisms and therefore would dry less quickly.**

Infectious Bioaerosols

GRAVITATION & AIR FLOW

- **A droplet in air settles due to the gravitational field at a velocity dependent upon its mass. As the rate of fall increases, so does the drag or viscous frictional force acting on the particle. When the two forces are equal the droplet attains its final terminal velocity.**
- **Droplet aerosols <100 µm can remain suspended for prolonged periods of time because typical room air velocities exceed the terminal settling velocities of the particles.**
- **Aerosols >100 µm are typically very large, fall out of the air rapidly, and are usually described as splash or splatter.**

Infectious Bioaerosols

INFECTIVITY

- For man, the initiation of some diseases requires only **small infective doses (<10 cells or viruses)** because the agents have an affinity for specific tissue and possess one or more potent virulence factors that render them resistant to inactivation.
  - **Infection with *Francisella tularensis* and *M. tuberculosis* bacteria is reported to result from a single organism.**
  - **Many other diseases require a dose in the thousands or millions, yet such numbers can easily be found in just one or more drops of sewage or other contaminated waters.**

Infective Dose Factors

- **Infective Dose**
  - **Sufficient numbers must survive effects of RH, temperature, UV, and other pollutants to constitute an appropriate infective dose.**
- **Microbe virulence**
  - **Genetically based, disease-promoting factors that enable an agent to overcome normal physical and immunologic defenses (e.g. *Salmonella*, *Staphylococcus*, Noroviruses, influenza viruses, Giardia, *Cryptosporidium*).**
- **Host susceptibility**
  - **Slow, weak, or non-existent immune function (due to immunodeficiency disease, or immunosuppression as a result of chemotherapy, transplantation, pregnancy, or lack of appropriate and available vaccination).**

Bloodborne Pathogens

"The single biggest threat to man's continued dominance on the planet is a virus"

-Joshua Lederberg

Molecular Biologist & Nobel Laureate

Bloodborne Pathogens

- **Transmitted by exposure to blood & body fluids, and present in sewage.**
- **Viruses present the greatest risk for being bloodborne.**
- **Viruses are a concern due to their presence in circulating blood and for their potential to cause severe acute disease, or chronic illness, and death such as:**
  - **HIV, HBV, HCV**, and **Ebola**

Bloodborne Pathogens

Ebola Virus Disease

- A severe, often-fatal hemorrhagic disease in humans and nonhuman primates (monkeys, gorillas, and chimpanzees) that has appeared sporadically since 1976.
- Transmission – contact with blood, body fluids, tissues of infected humans and primates.
  - No airborne transmission demonstrated in nature.
  - Recovered patients remain infectious for months.

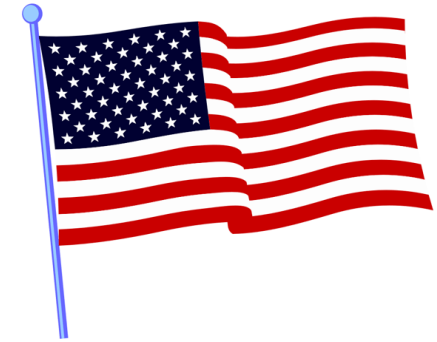
Bloodborne Pathogens

Ebola Virus Disease

- **Incubation period – usually 5-12 days, with range of 2-21 days.**
- **Symptoms – sudden onset with fever, chills, anorexia, headache, and myalgia; followed by nausea, vomiting, sore throat, abdominal pain and diarrhea.**
- **Pathology – hemorrhage from multiple sites, liver damage, renal failure, CNS involvement with shock, multi-organ dysfunction and death.**

Bloodborne Pathogens

Ebola Virus Disease in U.S. 2014



- 11 total cases
- 7 cases evacuated to US
- 4 cases first diagnosed in US
- 2 cases contracted in US
- 2 deaths
- 9 patients recovered

Bloodborne Pathogens

Prevention & Control

- **Education**
  - Infectivity, transmission, symptoms, pathology
- **Training**
  - Protection (PPE) and protocols
- **Immunization**
  - HBV, HAV, Tdap, others.
- **Medical Surveillance**
  - Assessment of symptoms

Bloodborne Pathogens

Cleaning & Decontamination

- Disinfection application
- Physical removal
- Detergent cleaning
- Disinfection application
- Personal protection
  - Current on immunizations
  - Respiratory, eye, body
  - Use of more puncture-resistant PPE

Vector-borne Disease




“Death is the cure for all diseases”

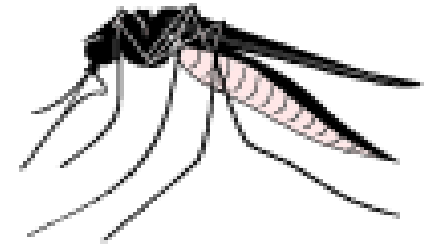
- Thomas Browne

17th century physician, scientist, writer

Mosquito Vectors

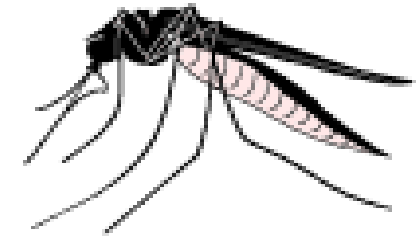
- After heavy rains and flooding, there are always pools of stagnant water lasting long enough to breed mosquitos that serve as disease vectors.

West Nile Virus (WNV)



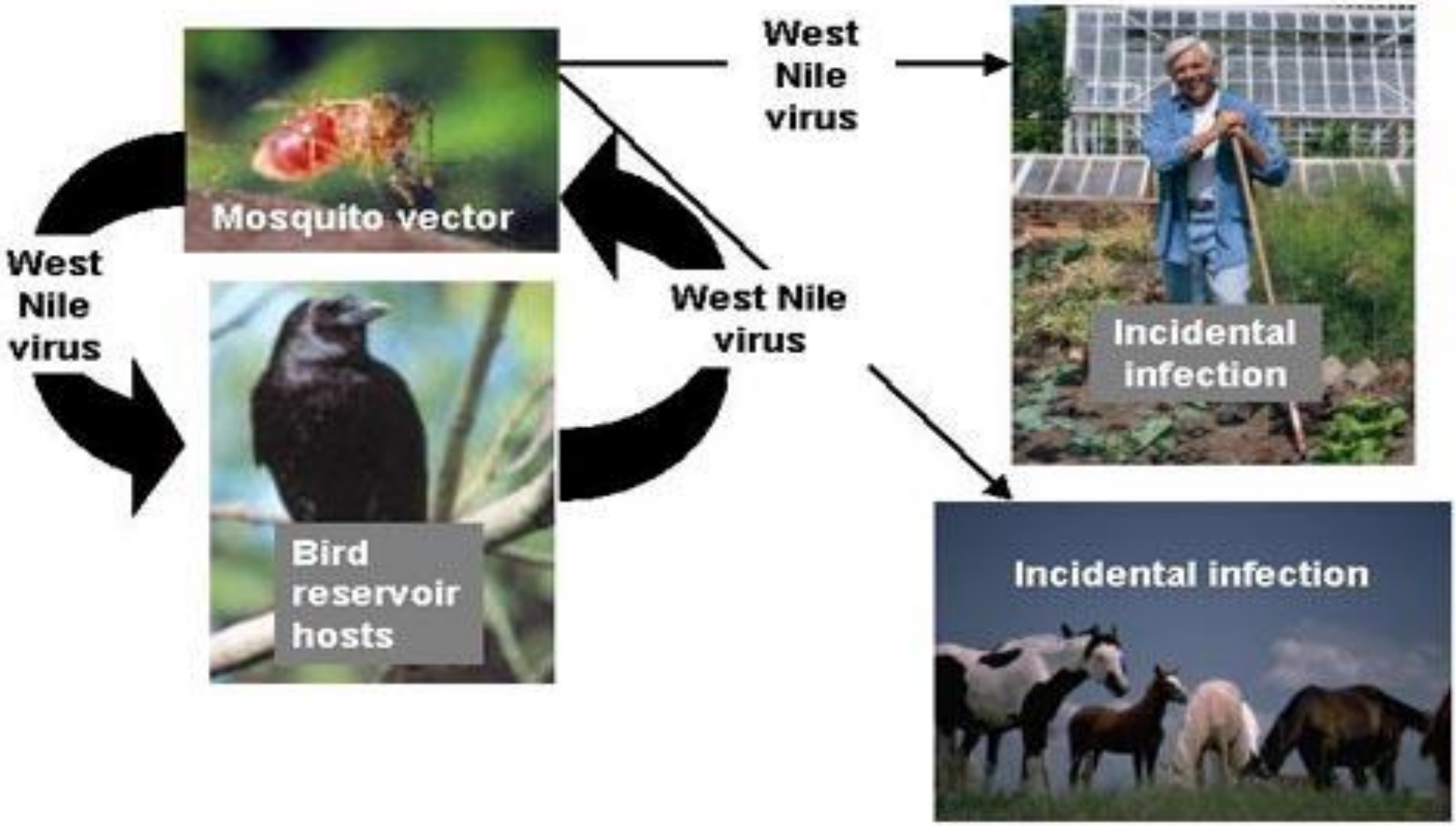
- **Disease** – A mosquito-borne febrile disease that is often serious and potentially fatal. It appears to be established as a seasonal epidemic in North America that flares up in the summer and continues into the fall.
- **Classification** – Single-stranded RNA virus; Family: *Flaviviridae*; Genus: Flavivirus.
- **Transmission** – From the bite of an infected mosquito, predominantly *Culex* species; no person-to-person transmission.
  - **Reservoirs include birds, livestock, small wild animals, cats and dogs.**

West Nile Virus (WNV)



- **Epidemiology – First reported in the West Nile district of Uganda in 1937. Outbreaks in Israel in 1998 and New York City in 1999.**
  - **Outbreaks peak in August**
  - **Greatest risks: > 50, male; those > 60 for encephalitis.**
  - **Horse outbreaks continue worldwide.**
  - **From 1999-2014 for USA**
    - **41,762 reported cases/1,765 deaths (4%)**
    - **18,810 Neuroinvasive disease (45%) and 1,641 deaths (9%)**
    - **22,952 Non-neuroinvasive disease (55%) and 124 deaths (1%)**

West Nile Virus Transmission Cycle

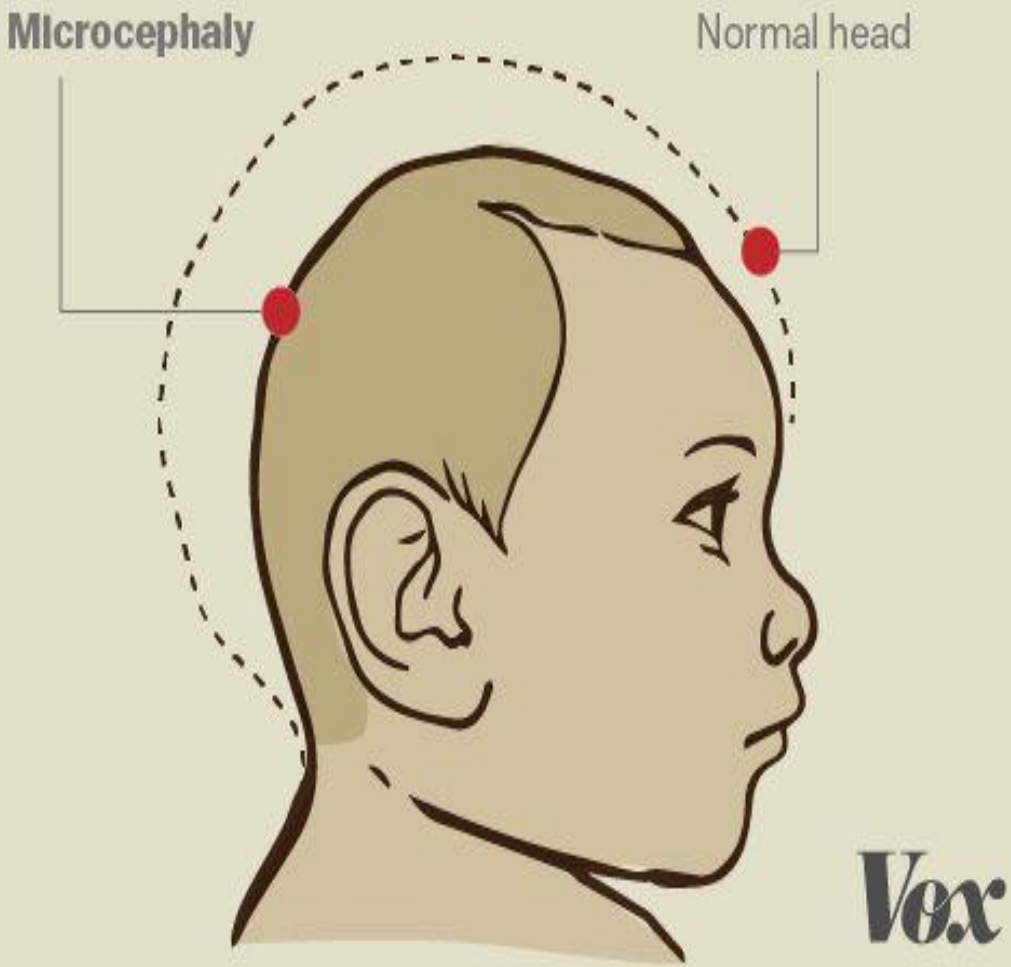


Zika Virus Disease

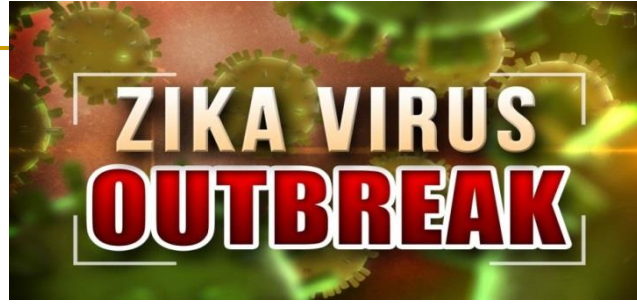
- **Transmitted by *Aedes* species of mosquito.**
- **Mild illness with symptoms lasting for several days to a week.**
  - **Most common symptoms are fever, rash, joint pain, and conjunctivitis. Similar to dengue fever.**
- **Many persons infected with Zika show no symptoms, and may transmit it sexually.**
- **The fetuses of infected pregnant women are at greatest risk of neurological birth defects, such as microcephaly (small head, poorly developed brain).**

Researchers think Zika might be behind the rise of "microcephaly"

A birth defect that is associated with a small head and incomplete brain development in newborns



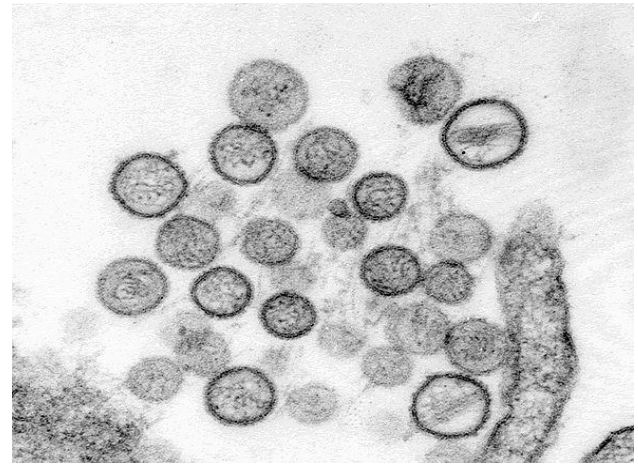
Zika Virus Disease



- As of 26 July 2017, 5,399 cases have been reported in US, including 2,047 in pregnant women.
- There is no vaccine for Zika virus at this time.
- Prevention is the same as for prevention of Dengue Fever:
  - Avoiding mosquito bites through repellent use; abating mosquito breeding sites; spraying pesticides; and education of the population.

Hantavirus Pulmonary Syndrome

- **Transmission** – a zoonotic disease caused by the inhalation of virus from dried rodent urine, feces, or saliva.
  - **Common exposure results from cleaning out barns, sheds, or homes infested with the primary rodent host, the Deer Mouse.**
  - **May be present in sewage**.
- **Incubation period** – about 2-4 weeks, usually 14-17 days, but may occur from a few days to 2 months.



Hantavirus Pulmonary Syndrome

- **Symptoms** - The typical prodrome lasts 3-5 days and consists of **fever, chills, myalgia, headache, non-productive cough, nausea, vomiting**, and other and gastrointestinal symptoms.

  Malaise, diarrhea, and lightheadedness are reported by approximately half of all patients, with less frequent reports of arthralgias, back pain, and abdominal pain.

  Patients may report **shortness of breath**.

Hantavirus Pulmonary Syndrome

- **Pathology** – Symptoms may be followed by **abrupt onset of respiratory distress and hypotension, progressing to severe respiratory failure and shock**. **Survivors may require weeks to months to convalesce**.
  - **Case-fatality rate can be 40-50%.**
- **Treatment** – Treatment is only **supportive in nature**; those with pulmonary complications often require supplemental oxygen.

Chemical Sewage Hazards

- **Industrial Wastewater** results from various processes such as steel or chemical manufacturing and often includes a variety of heavy metals and synthetic organic compounds, dyes, nitrosamines, and PCBs.

- Extremely low levels of a variety of chemicals in sewage may combine to become extremely toxic, in a process known as **“Toxic Synergy”**.
- Gases, such as **hydrogen sulfide** in confined spaces, can be deadly.

Chemical Sewage Hazards

- **Consumer Wastewater** from homes, offices, businesses, medical centers, and schools, contains a wide variety of chemical pollutants.
  - **Residues of cleaning chemicals, hygiene products, and pesticides.**
- Pharmaceuticals are regularly flushed, and along with human wastes include:
  - **Antibiotics, antacids, steroids, analgesics, anti-depressants, anti-inflammatories, hormones, antipyretics, beta-blockers, lipid-lowering drugs, tranquilizers, stimulants, etc.**

Chemical Sewage Hazards

- **Healthcare Wastewater** from hospitals, medical centers, clinics, and outpatient surgical centers, typically contain a variety of hazardous chemicals recognized as potentially **toxic, carcinogenic, mutagenic, and teratogenic**.
- Waters tested from drains and sewage outflow lines have detected platinum-based and other **cytostatic (anticancer) drugs, neuropsychiatric drugs, antibiotics, diagnostic dyes and heavy metals, as well as disinfectants and sanitizers**.

Chemical Sewage Hazards

- Many of these wastewater chemicals are known as persistent organic pollutants and endocrine disrupting chemicals (EDCs), which may affect the immune system, result in thyroid deficiency, and increase the risk for breast, ovarian, and testicular cancers.

Chemical Sewage Hazards

- EDCs are known to result in the feminization of male fish, cause testicular dysgenesis in frogs, and hermaphroditism in polar bears and other mammals.

- EDCs are suspected to play a role in human infertility, as well as neurologic disease which may be severe, as shown in these case studies:

Neurologic Impairment from Chronic Sewage Exposure

- **Case Study #1**
  - Tilda Gray
  - 32 year old white female
  - Sewage backflow remediator for 8 years
  - San Diego, CA
  - Symptoms prior to acute phase included mood swings, mild depression, occasional vocal outbursts.
  - Acute phase manifested as violent physical attacks on co-workers, family, and friends

Neurologic Impairment from Chronic Sewage Exposure

- **Case Study #2**
  - Edgar Turner
  - 41 year old white male
  - Sewage sludge processor at WWTP for 13 years
  - Lansing, MI
  - No chronic symptoms were observed. He suddenly went missing for 9 days before being found in a wooded rural area where he survived by killing small animals, eating the raw meat, and sucking out their brains.

Neurologic Impairment from Chronic Sewage Exposure

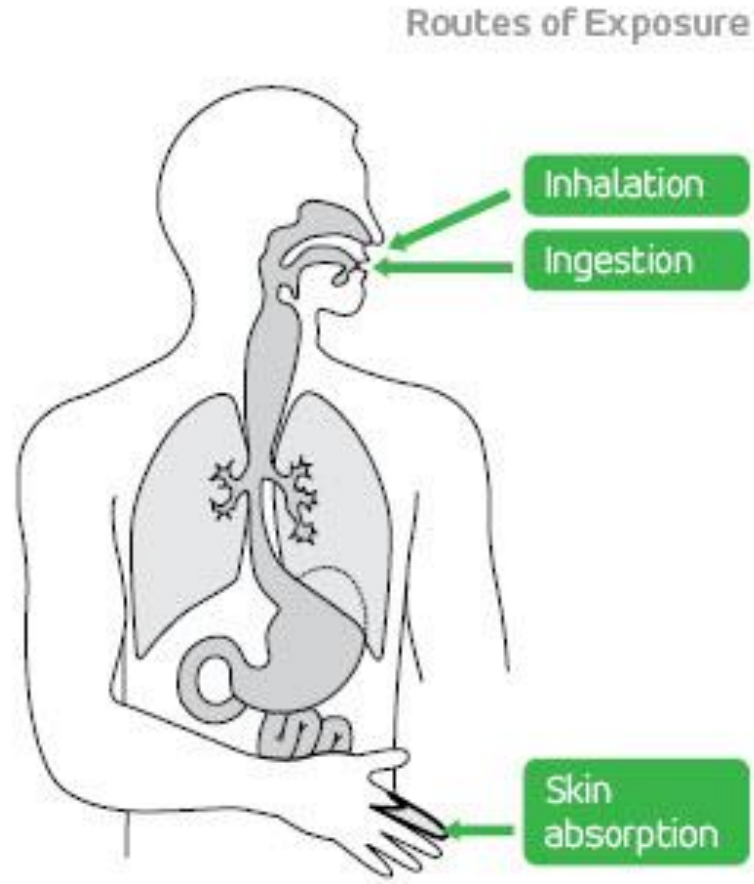
- **Case Study #3**
  - Ellen Wilkinson
  - 39 year old white female
  - Stay-at-home Mom was exposed to 5 major sewage backflows into her home in less than 3 years.
  - Denver, CO
  - Exhibited severe cognitive and motor defects, would wander off, and became increasingly agitated and then violent. She was incarcerated after she killed the neighbor's dog with her bare hands, and decapitated it with her teeth.

Radiation Sewage Hazards

- Radionuclides are used in medicine for diagnostic imaging, and therapeutic or research purposes, and are excreted by patients and discharged directly to sewer systems.
- Common radioisotopes include Iodine-131, Phosphorous-32, Strontium-89, and Yttrium-90
- Chronic exposures increase risks for a variety of malignancies.

Worker Health & Safety

- **Raw sewage is considered Category 3 water – grossly contaminated and can contain pathogenic, toxigenic, or other harmful agents, and can cause significant adverse reactions to humans if inhaled, contacted, or consumed (IICRC, 2015).**



Sewage Health & Safety

- **Respiratory Protection**
  - **Selection varies dependent on situation (P-100, N-95, half or full face w/HEPA + organic vapor cartridges). Prolonged use in high humidity areas may compromise efficiency. Or a PAPR may be needed, especially in confined spaces.**
- **External Body Protection**
  - **Disposable/durable coveralls, chemical/water-resistant, with hood and booties.**
  - **Eye protection against splash, dust, and debris.**
  - **Chemical resistant gloves and boots**
  - **Ear protection**


CAUTION

Sewage Health & Safety

- **Worker Screening**
  - **Initial medical evaluation by a physician**
    - **Includes assessment of chronic conditions and medications**
  - **Continued medical surveillance**
    - **Assessment of occurring illnesses and injuries**
    - **Periodic pulmonary function testing, ECG, and sulf-hemoglobin test**
  - **Immunizations**
    - **Tetanus/diphtheria/pertussis (Tdap), HAV, HBV, Typhoid**

Sewage Remediation

- Initial extraction of water and residues (muck out).
- Before physical removal of contaminated materials, spray with EPA-registered disinfectant for initial knockdown of microbes.
- Removal and bagging of contaminated materials.
- Pressure washing with industrial detergent or detergent-disinfectant, followed by extraction.
- Repeat pressure washing/cleaning/disinfection, extraction.
- Application of appropriate antimicrobial product.
- Structural drying, dehumidification, and air scrubbing with HEPA filtration units.
- Evaluation, cleaning, decontamination of HVAC system.

Post-Sewage Remediation

- **Proper disposal of contaminated materials.**
- **Critical cleaning/decontamination of all remediation equipment/tools.**
- **Clearance testing conducted throughout affected areas, preferably by an independent third party, using a scientifically sound and defensible clearance criterion – such as zero positives for *E. coli*, with positive areas re-cleaned and re-tested until passed.**

Legal Concerns

- **Sewage remediation, as well as flood remediation (which often involves sewage-contaminated flood waters), carries a significant measure of legal liability, both relative to ensuring that remediation and restoration have been done following the industry standard of practice, along with professional experience that conveys the utmost in ethics and integrity.**
- **Litigation cases involving sewage have been brought against restoration professionals, not only on charges of insufficient remediation, but also on charges of excess remediation activities as well.**
- **The key is to use the science of sewage remediation to inform best practices, and to document the rationale for every aspect of the remediation and restoration process that's done.**

Conclusions

- **Science has continued to identify increasingly hazardous components of untreated wastewater that have:**

- significantly elevated the risk for human morbidity and mortality, not only in regard to the general public, but in particular to those who professionally remediate sewage losses.

Conclusions

- **Only by continually disseminating such information in the context of updated training and appropriate modification to current practices, can we hope to advance the professionalism of sewage remediators, who risk so much to protect the public.**

Thank You!