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Toxicity of Water in Sewage and its Treatment

Dr. Ashutosh Tripathi[1], Prabhat Pandey[2]

[1]Associate Professor, KS Saket PG College, Ayodhya, Uttar Pradesh, India
[2]Dr. Rammanohar Lohia Avadh University, Ayodhya, Uttar Pradesh, India

ABSTRACT

Sewage (or domestic sewage, domestic wastewater, municipal wastewater) is a type of wastewater that is produced by a community of people. It is typically transported through a sewer system. Sewage consists of wastewater discharged from residences and from commercial, institutional and public facilities that exist in the locality. Sub-types of sewage are greywater (from sinks, bathtubs, showers, dishwashers, and clothes washers) and blackwater (the water used to flush toilets, combined with the human waste that it flushes away). Sewage also contains soaps and detergents. Food waste may be present from dishwashing, and food quantities may be increased where garbage disposal units are used. In regions where toilet paper is used rather than bidets, that paper is also added to the sewage. Sewage contains macro-pollutants and micro-pollutants, and may also incorporate some municipal solid waste and pollutants from industrial wastewater.

Sewage usually travels from a building's plumbing either into a sewer, which will carry it elsewhere, or into an onsite sewage facility. Collection of sewage of several households together usually takes places in either sanitary sewers or combined sewers. The former is designed to exclude stormwater flows whereas the latter is designed to also take stormwater. The production of sewage generally corresponds to the water consumption. A range of factors influence water consumption and hence the sewage flowrates per person. These include: Water availability (the opposite of water scarcity), water supply options, climate (warmer climates may lead to greater water consumption), community size, economic level of the community, level of industrialization, metering of household consumption, water cost and water pressure.

The main parameters in sewage that are measured to assess the sewage strength or quality as well as treatment options include: solids, indicators of organic matter, nitrogen, phosphorus, and indicators of fecal contamination. These can be considered to be the main macro-pollutants in sewage. Sewage contains pathogens which stem from fecal matter. The following four types of pathogens are found in sewage: pathogenic bacteria, viruses, protozoa (in the form of cysts or oocysts) and helminths (in the form of eggs). In order to quantify the organic matter, indirect methods are commonly used: mainly the Biochemical Oxygen Demand (BOD) and the Chemical Oxygen Demand (COD).

Management of sewage includes collection and transport for release into the environment, after a treatment level that is compatible with the local requirements for discharge into water bodies, onto soil or for reuse applications. Disposal options include dilution (self-purification of water bodies, making use of their assimilative capacity if possible), marine outfalls, land disposal and sewage farms. All disposal options may run risks of causing water pollution.

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INTRODUCTION

Sewage (or domestic wastewater) consists of wastewater discharged from residences and from commercial, institutional and public facilities that exist in the locality. Sewage is a mixture of water (from the community's water supply), human excreta (feces and urine), used water from bathrooms, food preparation wastes, laundry wastewater, and other waste products of normal living.

Sewage from municipalities contains wastewater from commercial activities and institutions, e.g. wastewater discharged from restaurants, laundries, hospitals, schools, prison, offices, stores and establishments serving the local area of larger communities.

Sewage can be distinguished into "untreated sewage" (also called "raw sewage") and "treated sewage" (also called "effluent" from a sewage treatment plant).[1,2]

The term "sewage" is nowadays often used interchangeably with "wastewater" – implying "municipal wastewater" – in many textbooks, policy documents and the literature. To be precise, wastewater is a broader term, because it refers to any water after it has been used in a variety of applications. Thus it may also refer to "industrial wastewater", agricultural wastewater and other flows that are not related to household activities. Blackwater in a sanitation context denotes wastewater from toilets, which likely contains pathogens which may spread by the fecal–oral route. Blackwater can contain feces, urine, water and toilet paper from flush toilets.

Blackwater is distinguished from greywater, which comes from sinks, baths, washing machines, and other kitchen appliances apart from toilets. Greywater results from washing food, clothing, dishes, as well as from showering or bathing. As greywater contains fewer pathogens than domestic wastewater, it is generally safer to handle and easier to treat and reuse onsite for toilet flushing, landscape or crop irrigation, and other non-potable uses. Greywater may still have some pathogen content from laundering soiled clothing or cleaning the anal area in the shower or bath. he temperature tends to be slightly higher than in drinking water but is more stable than the ambient temperature. The color of fresh sewage is slightly grey, whereas older sewage (also called "septic sewage") is dark grey or black. The odor of fresh sewage is "oily" and relatively unpleasant, whereas older sewage has an unpleasant foul odor due to hydrogen sulfide gas and other decomposition by-products[3,4]

Sewage consists primarily of water and usually contains less than one part of solid matter per thousand parts of water. In other words, one can say that sewage is composed of around 99.9% pure water, and the remaining 0.1% are solids, which can be in the form of either dissolved solids or suspended solids. The thousand-to-one ratio is an order of magnitude estimate rather than an exact percentage because, aside from variation caused by dilution, solids may be defined differently depending upon the mechanism used to separate those solids from the liquid fraction. Sludges of settleable solids removed by settling or suspended solids removed by filtration may contain significant amounts of entrained water, while dried solid material remaining after evaporation eliminates most of that water but includes dissolved minerals not captured by filtration or gravitational separation. The organic matter in sewage consists of protein compounds (about 40%), carbohydratres (about 25–50%), oils and grease (about 10%) and urea, surfactants, phenols, pesticides and others (lower quantity). Apart from organic matter, sewage also contains nutrients. The major nutrients of interest are nitrogen and phosphorus. If sewage is discharged untreated, its nitrogen and phosphorus content can lead to pollution of lakes and reservoirs via a process called eutrophication.

Human feces in sewage may contain pathogens capable of transmitting diseases. The following four types of pathogens are found in sewage:

- Bacteria like *Salmonella*, *Shigella*, *Campylobacter*, or *Vibrio cholerae*;
- Viruses like hepatitis A, rotavirus, coronavirus, enteroviruses;
- Protozoa like *Entamoeba histolytica*, *Giardia lamblia*, *Cryptosporidium parvum*; and
- Helminths and their eggs including *Ascaris* (roundworm), *Ancylostoma* (hookworm), and *Trichuris* (whipworm)

In most practical cases, pathogenic organisms are not directly investigated in laboratory analyses. An easier way to assess the presence of fecal contamination is by assessing the most probable numbers of fecal coliforms (called thermotolerant coliforms), especially *Escherichia coli*. *Escherichia coli* are intestinal bacteria excreted by all warm blooded animals, including human beings, and thus tracking their presence in sewage is easy, because of their substantially high concentrations (around 10 to 100 million per 100 mL).

Sewage contains environmental persistent pharmaceutical pollutants. Trihalomethanes can also be present as a result of past disinfection. Sewage may contain microplastics such as polyethylene and polypropylene beads, or polyester and polyamide fragments from synthetic clothing and bedding fabrics abraded by wear and laundering, or from plastic packaging and plastic-coated paper products disintegrated by lift station pumps. Pharmaceuticals, endocrine disrupting compounds, and hormones may be excreted in urine or feces if not catabolized within the human body.[5,6]

Discussion

Sewage treatment (or domestic wastewater treatment, municipal wastewater treatment) is a type of wastewater treatment which aims to remove contaminants from sewage to produce an effluent that is suitable for discharge to the surrounding environment or an intended reuse application, thereby preventing water pollution from raw sewage discharges. Sewage contains wastewater from households and businesses and possibly pre-treated industrial wastewater. There are a high number of sewage treatment processes to choose from. These can range from decentralized systems (including on-site treatment systems) to large centralized systems involving a network of pipes and pump stations (called sewerage) which convey the sewage to a treatment plant. For cities that have a combined sewer, the sewers will also carry urban runoff (stormwater) to the sewage treatment plant. Sewage treatment often involves two main stages, called primary and secondary treatment, while advanced treatment also incorporates a tertiary treatment stage with polishing processes and nutrient removal. Secondary treatment can reduce organic matter (measured as biological oxygen demand) from sewage, using aerobic or anaerobic biological processes.

A large number of sewage treatment technologies have been developed, mostly using biological treatment processes. Engineers and decision makers need to take into account technical and economical criteria, as well as quantitative and qualitative aspects of each alternative when choosing a suitable technology. Often, the main criteria for selection are: desired effluent quality, expected construction and operating costs, availability of land, energy requirements and sustainability aspects. In developing countries and in rural areas with low population densities, sewage is often treated by various on-site sanitation systems and not conveyed in sewers. These systems include septic tanks connected to drain fields, on-site sewage systems (OSS), vermifilter systems and many more. On the other hand, advanced and relatively expensive sewage treatment plants in cities that can afford them may include tertiary treatment with disinfection and possibly even a fourth treatment stage to remove micropollutants.

At the global level, an estimated 52% of sewage is treated. However, sewage treatment rates are highly unequal for different countries around the world. For example, while high-income countries treat approximately 74% of their sewage, developing countries treat an average of just 4.2%.

The treatment of sewage is part of the field of sanitation. Sanitation also includes the management of human waste and solid waste as well as stormwater (drainage) management. The term "sewage treatment plant" is often used interchangeably with the term "wastewater treatment plant". With regards to biological treatment of sewage, the treatment objectives can include various degrees of the following: transform dissolved and particulate biodegradable components (especially organic matter) into acceptable end products, transform and remove nutrients (nitrogen and phosphorus), remove or inactivate pathogenic organisms, and remove specific trace organic constituents (micropollutants)[7,8]

Typical values for physical–chemical characteristics of raw sewage in developing countries have been published as follows: 180 g/person/d for total solids (or 1100 mg/L when expressed as a concentration), 50 g/person/d for BOD (300 mg/L), 100 g/person/d for COD (600 mg/L), 8 g/person/d for total nitrogen (45 mg/L), 4.5 g/person/d for ammonia-N (25 mg/L) and 1.0 g/person/d for total phosphorus (7 mg/L). The typical ranges for these values are: 120–220 g/person/d for total solids (or 700–1350 mg/L when expressed as a concentration), 40–60 g/person/d for BOD (250–400 mg/L), 80–120 g/person/d for COD (450–800 mg/L), 6–10 g/person/d for total nitrogen (35–60 mg/L), 3.5–6 g/person/d for ammonia-N (20–35 mg/L) and 0.7–2.5 g/person/d for total phosphorus (4–15 mg/L).

Sewerage (or sewage system) is the infrastructure that conveys sewage or surface runoff (stormwater, meltwater, rainwater) using sewers. It encompasses components such as receiving drains, manholes, pumping stations, storm overflows, and screening chambers of the combined sewer or sanitary sewer. Sewerage ends at the entry to a sewage treatment plant or at the point of discharge into the environment. It is the system of pipes, chambers, manholes, etc. that conveys the sewage or storm water.

In many cities, sewage (or municipal wastewater) is carried together with stormwater, in a combined sewer system, to a sewage treatment plant. In some urban areas, sewage is carried separately in sanitary sewers and runoff from streets is carried in storm drains. Access to these systems, for maintenance purposes, is typically through a manhole. During high precipitation periods a sewer system may experience a combined sewer overflow event or a sanitary sewer overflow event, which forces untreated sewage to flow directly to receiving waters. This can pose a serious threat to public health and the surrounding environment.

Sewage can be treated close to where the sewage is created, which may be called a "decentralized" system or even an "on-site" system (on-site sewage facility, septic tanks, etc.). Alternatively, sewage can be collected and transported by a network of pipes and pump stations to a municipal treatment plant. This is called a "centralized" system (see also sewerage and pipes and infrastructure).[9,10]

A large number of sewage treatment technologies have been developed, mostly using biological treatment processes (see list of wastewater treatment technologies). Very broadly, they can be grouped into high tech (high cost) versus low tech (low cost) options, although some technologies might fall into either category. Other grouping classifications are "intensive" or "mechanized" systems (more compact, and frequently employing high tech options) versus "extensive" or "natural" or "nature-based" systems (usually using natural treatment processes and occupying larger areas) systems. This classification may be sometimes oversimplified, because a treatment plant may involve a combination of processes, and the interpretation of the concepts of high tech and low tech, intensive and extensive, mechanized and natural processes may vary from place to place.

Results

Examples for more low-tech, "natural", often less expensive sewage treatment systems are shown below. They often use little or no energy. Some of these systems do not provide a high level of treatment, or only treat part of the sewage (for example only the toilet wastewater), or they only provide pre-treatment, like septic tanks. On the other hand, some systems are capable of providing a good performance, satisfactory for several applications. Many of these systems are based on natural treatment processes, requiring large areas, while others are more compact. In most cases, they are used in rural areas or in small to medium-sized communities. For example, waste stabilization ponds are a low cost treatment option with practically no energy requirements but they require a lot of land. [11,12] The processes are:-

- Anaerobic digester types and anaerobic digestion, for example:
  - Upflow anaerobic sludge blanket reactor
  - Septic tank
  - Imhoff tank
- Constructed wetland (see also biofilters)
- Decentralized wastewater system
- Nature-based solutions
- On-site sewage facility
- Sand filter
- Vermifilter
- Waste stabilization pond with sub-types:
  - Facultative ponds
  - Anaerobic pond – facultative ponds systems
  - Facultative aerated lagoons
  - Complete-mix aerated lagoon sedimentation pond systems
  - High rate ponds
  - Maturation ponds

Trickling filter sewage treatment plant

Examples for systems that can provide full or partial treatment for toilet wastewater only:

- Composting toilet (see also dry toilets in general)
- Urine-diverting dry toilet
- Vermifilter toilet

Examples for more high-tech, intensive or “mechanized”, often relatively expensive sewage treatment systems are listed below. Some of them are energy intensive as well. Many of them provide a very high level of treatment.

Aeration tank of activated sludge sewage treatment plant

For example, broadly speaking, the activated sludge process achieves a high effluent quality but is relatively expensive and energy intensive.[13,14]

- Activated sludge systems
- Aerobic granulation
- Aerobic treatment system
- Enhanced biological phosphorus removal
- Expanded granular sludge bed digestion
- Extended aeration
- Filtration
- Membrane bioreactor
- Moving bed biofilm reactor
- Reverse osmosis
- Rotating biological contactor
- Sequencing batch reactor
- Trickling filter
- Ultrafiltration
- Ultraviolet disinfection

There are other process options which may be classified as disposal options, although they can also be understood as basic treatment options. These include: Application of sludge, irrigation, soak pit, leach field, fish pond, floating plant pond, water disposal/groundwater recharge, surface disposal and storage. Application of sewage to land can be considered as a form of final disposal or of treatment, or both. It leads to groundwater recharge and/or to evapotranspiration. Land application include slow-rate systems, rapid infiltration, subsurface infiltration, overland flow. It is done by flooding, furrows, sprinkler and dripping. It is a treatment/disposal system that requires a large amount of land per person.[15]

Upflow anaerobic sludge blanket (UASB) reactor

Implications

Choosing the most suitable treatment process is complicated and requires expert inputs, often in the form of feasibility studies. This is because the main important factors to be considered when evaluating and selecting sewage treatment processes are numerous: process applicability, applicable flow, acceptable flow variation, influent characteristics, inhibiting or refractory compounds, climatic aspects, process kinetics and reactor hydraulics, performance, treatment residuals, sludge processing, environmental constraints, chemical product requirements, energy requirements, requirements of other resources, personnel requirements, operating and maintenance requirements, ancillary processes, reliability, complexity, compatibility, area availability

Available process steps

1 Preliminary treatment (sometimes called pretreatment) removes coarse materials that can be easily collected from the raw sewage before they damage or clog the pumps and sewage lines of primary treatment clarifiers.

2 The influent in sewage water passes through a bar screen to remove all large objects like cans, rags, sticks, plastic packets, etc. carried in the sewage stream

3 Grit consists of sand, gravel, rocks, and other heavy materials. Preliminary treatment may include a sand or grit removal channel or chamber, where the velocity of the incoming sewage is reduced to allow the settlement of grit. Grit removal is necessary to (1) reduce formation of deposits in primary sedimentation tanks, aeration tanks, anaerobic digesters, pipes, channels, etc. (2) reduce the frequency of tank

cleaning caused by excessive accumulation of grit; and (3) protect moving mechanical equipment from abrasion and accompanying abnormal wear. The removal of grit is essential for equipment with closely machined metal surfaces such as comminutors, fine screens, centrifuges, heat exchangers, and high pressure diaphragm pumps.

4 Equalization basins can be used to achieve flow equalization, with the aim to reduce peak dry-weather flows or peak wet-weather flows in the case of combined sewer systems

5 In some larger plants, fat and grease are removed by passing the sewage through a small tank where skimmers collect the fat floating on the surface. Air blowers in the base of the tank may also be used to help recover the fat as a froth. Many plants, however, use primary clarifiers with mechanical surface skimmers for fat and grease removal.

6 Primary treatment is the "removal of a portion of the suspended solids and organic matter from the sewage"

7 The main processes involved in secondary sewage treatment are designed to remove as much of the solid material as possible. Secondary treatment can reduce organic matter (measured as biological oxygen demand) from sewage, using aerobic or anaerobic processes. The organisms involved in these processes are sensitive to the presence of toxic materials, although these are not expected to be present at high concentrations in typical municipal sewage.

8 Advanced sewage treatment generally involves three main stages, called primary, secondary and tertiary treatment but may also include intermediate stages and final polishing processes. The purpose of tertiary treatment (also called "advanced treatment") is to provide a final treatment stage to further improve the effluent quality before it is discharged to the receiving water body or reused. More than one tertiary treatment process may be used at any treatment plant. If disinfection is practiced, it is always the final process. It is also called "effluent polishing". Tertiary treatment may include biological nutrient removal (alternatively, this can be classified as secondary treatment), disinfection and removal of micropollutants, such as environmental persistent pharmaceutical pollutants.[16]

9 Disinfection of treated sewage may be attempted to kill pathogens (disease-causing microorganisms) prior to disposal, and is increasingly effective after more elements of the foregoing treatment sequence have been completed. The purpose of disinfection in the treatment of sewage is to substantially reduce the number of pathogens in the water to be discharged back into the environment or to be reused. The effectiveness of disinfection depends on the quality of the water being treated (e.g. turbidity, pH, etc.), the type of disinfection being used, the disinfectant dosage (concentration and time), and other environmental variables. Water with high turbidity will be treated less successfully, since solid matter can shield organisms, especially from ultraviolet light or if contact times are low. Generally, short contact times, low doses and high flows all militate against effective disinfection. Common methods of disinfection include ozone, chlorine, ultraviolet light, or sodium hypochlorite.

10 Biological nutrient removal Excessive release to the environment can lead to nutrient pollution, which can manifest itself in eutrophication. This process can lead to algal blooms, a rapid growth, and later decay, in the population of algae. In addition to causing deoxygenation, some algal species produce toxins that contaminate drinking water supplies.

11 Ammonia nitrogen, in the form of free ammonia (NH_3) is toxic to fish. Ammonia nitrogen, when converted to nitrite and further to nitrate in a water body, in the process of nitrification, is associated with the consumption of dissolved oxygen. Nitrite and nitrate may also have public health significance if concentrations are high in drinking water, because of a disease called metahemoglobinemia. Phosphorus removal is important as phosphorus is a limiting nutrient for algae growth in many fresh water systems. Therefore, an excess of phosphorus can lead to eutrophication. It is also particularly important for water reuse systems where high phosphorus concentrations may lead to fouling of downstream equipment such as reverse osmosis. A range of treatment processes are available to remove nitrogen and phosphorus. Nitrogen is removed through the biological oxidation of nitrogen from ammonia to nitrate (nitrification), followed by denitrification, the reduction of nitrate to nitrogen gas. Nitrogen gas is released to the atmosphere and thus removed from the water.[17]

12 Micropollutants are treated by activated carbon filtering.

13 Sludge is mostly water with some amounts of solid material removed from liquid sewage.

Primary sludge includes settleable solids removed during primary treatment in primary clarifiers. Secondary sludge is sludge separated in secondary clarifiers that are used in secondary treatment bioreactors or processes using inorganic oxidizing agents. In intensive sewage treatment processes, the sludge produced needs to be removed from the liquid line on a continuous basis because the volumes of the tanks in the liquid line have insufficient volume to store sludge.[18]

Conclusions

Water reclamation (also called wastewater reuse, water reuse or water recycling) is the process of converting municipal wastewater (sewage) or industrial wastewater into water that can be reused for a variety of purposes. Types of reuse include: urban reuse, agricultural reuse (irrigation), environmental reuse, industrial reuse, planned potable reuse, de facto wastewater reuse (unplanned potable reuse). For example, reuse may include irrigation of gardens and agricultural fields or replenishing surface water and groundwater (i.e., groundwater recharge). Reused water may also be directed toward fulfilling certain needs in residences (e.g. toilet flushing), businesses, and industry, and could even be treated to reach drinking water standards. Treated municipal wastewater reuse for irrigation is a long-established practice, especially in arid countries. Reusing wastewater as part of sustainable water management allows water to remain as an alternative water source for human activities. This can reduce scarcity and alleviate pressures on groundwater and other natural water bodies[19]

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