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Wastewater Treatment and Water Resources Engineering

JYOTI CHOUDHARY

Lecturer, Dept. of Civil Engineering, Govt. Polytechnic College, Alwar, Rajasthan, India

ABSTRACT: Water resources engineering is the study and management of equipment, facilities and techniques that are used to manage and preserve life's most plentiful resource. In addition to assessing how and the best ways in which to control water as it pertains to water-related activities – such as irrigation, waste disposal and canal development – water resource engineers are also frequently involved in water management to ensure that it's safe to drink both for humans, plants and animal usage. As previously referenced, surface water makes up about 71% of the planet, which is the equivalent of roughly 326 million cubic miles. At the same time, though, just 3% of the Earth's water is fresh, according to the Bureau of Reclamation. And of this total, 2.5% of it is out of reach, contained in the soil, polar ice caps, the atmosphere and glaciers or too polluted to use safely.

Water resource engineers may be tasked with the awesome responsibility of ensuring that the planning and management of available water supply are adequately leveraged and remain safe to use for as long as possible. They may also be involved in water treatment so that the quality of water is improved upon for various end uses, whether that's recreationally, commercially or industrially.

Why is water resources engineering important?

Resources, by their very nature, are finite. There are only a small handful that are naturally renewable – such as wind, solar, hydro and biomass. While water may be renewable in terms of the many different ways it can be used and reused, it's not as abundant as it once was, which many earth scientists and climatologists point to as a function of climate change.

The Bureau of Reclamation provides some perspective as to just how limited this resource is in terms of usability, despite its vastness. If the world's water supply were roughly 26 gallons, the amount of freshwater available for safe usage would be the equivalent to 0.003 liters. That's equal to roughly a half-teaspoon.

Water resource engineers may be charged with developing new systems or processes for private or government entities that can preserve freshwater sources and find new ones. This may require the assistance of civil engineers involved as well, designing water purification methods through desalination or creating new equipment for contaminant transport when water is used for irrigation purposes. Understanding what works and what doesn't when it comes to water resource management is often a combined effort and may involve a number of different analyses, including hydrologic, which is the study of the water cycle and directions in which it flows, which may be influenced by weather and other environmental forces.

How much does a water engineer earn?

Like most other professions, the average water engineer salary is largely a function of how much experience they have and their level of education. At a bare minimum, most water resource engineering jobs require a bachelor's degree. The more experience you have, such as a master's degree in environmental engineering, the more you stand to earn. According to the most recent figures available from the Bureau of Labor Statistics, professionals in environmental engineering typically make approximately $87,600, which was the median in 2018. However, the top 10% earned nearly $137,100 and were generally employed by the federal government.

Are there disciplines within water engineering?

Just as there are many branches of environmental engineering, the same is true for water engineering. One of which is wastewater engineering. As its title implies, engineers in this role are responsible for performing activities that can more effectively manage or safely transport water that is no longer usable. This may involve wastewater treatment and detecting the degree to which water is polluted via remote sensing. Wastewater engineers may also provide insight to

businesses or government entities on how to better clean or channel wastewater away from sources like rivers and estuaries so they don't become contaminated.

KEYWORDS- Wastewater treatment, water resources, engineering, government, business

I. INTRODUCTION

The Importance of Water Engineering: Ensuring Sustainable Access to Clean Water

Water is a precious resource that is essential for life, and its availability and quality are crucial for human well-being and economic development. However, with increasing population growth, urbanization, and climate change, the demand for water has been rising rapidly, leading to challenges in ensuring sustainable access to clean water for all. This is where water engineering plays a pivotal role.

Water engineering is a multidisciplinary field that involves the planning, design, construction, and management of water-related infrastructure and systems. It encompasses a wide range of activities, including the development of water supply systems, wastewater treatment plants, irrigation systems, flood control measures, and hydroelectric power generation facilities, among others. The importance of water engineering cannot be overstated, as it plays a critical role in addressing various water-related challenges and achieving sustainable development goals.[1,2,3]

One of the primary roles of water engineering is to ensure access to clean drinking water for communities. According to the World Health Organization (WHO), around 2.2 billion people worldwide lack access to safely managed drinking water services, and approximately 4.2 billion people do not have access to basic sanitation services. Lack of clean water can lead to waterborne diseases such as cholera, diarrhea, and typhoid, causing severe health risks, especially for vulnerable populations such as children and the elderly. Water engineers work towards developing efficient water supply systems that can provide safe drinking water to communities, including source water protection, water treatment, and distribution systems. They also develop strategies for managing water resources sustainably to ensure long-term availability of water for human consumption.

Another critical aspect of water engineering is wastewater treatment. As urbanization and industrialization increase, the amount of wastewater generated also grows exponentially. Wastewater contains pollutants such as chemicals, nutrients, and pathogens that can harm the environment and human health if not treated properly. Water engineers design and implement wastewater treatment plants that can efficiently treat and discharge wastewater safely into the environment, or reuse it for various purposes such as irrigation or industrial processes. Effective wastewater treatment not only protects the environment but also helps in conserving water resources by recycling and reusing treated wastewater.

Water engineering also plays a crucial role in managing floods and mitigating their impacts. Floods can cause significant damage to infrastructure, disrupt economic activities, and threaten human lives. Water engineers develop flood control measures such as dams, levees, and stormwater management systems that can reduce the risk of floods and protect communities and their assets. They also develop flood forecasting and warning systems to provide timely information to communities at risk, enabling them to evacuate or take preventive measures.

Furthermore, water engineering plays a critical role in irrigation systems for agriculture, which is the largest consumer of water globally. Water engineers design and implement irrigation systems that are efficient in water use and can optimize crop production while minimizing water waste. They also develop strategies for managing water resources sustainably in agriculture, such as rainwater harvesting, groundwater recharge, and water use monitoring, to ensure the long-term sustainability of agricultural water supply.

In addition to these vital roles, water engineering also plays a significant role in hydroelectric power generation, aquatic habitat restoration, water quality monitoring, and environmental impact assessments of water-related projects, among others. Water engineers also contribute to the development of policies and regulations related to water resources management and collaborate with other professionals such as hydrologists, geologists, ecologists, and social scientists to ensure holistic and sustainable solutions.

In conclusion, water engineering is a critical field that plays a pivotal role in ensuring sustainable access to clean water, protecting the environment, and promoting economic development. With the growing global challenges of water scarcity, water pollution, and climate change, the role of water engineering becomes even more crucial. Investments in water engineering infrastructure, technologies, and management practices are essential[4,5,6]

II. DISCUSSION

Through the Environmental and Water Resources Engineering Program (EWRE), prepare to expand understanding and skills in science and engineering for the protection of human health and the environment. Under the mentorship of award-winning faculty, students take a core of fundamental courses that relate theory to design practices; additional elective coursework and research opportunities are plentiful in areas such as drinking water quality and treatment, groundwater hydraulics, hazardous waste, municipal and industrial wastewater treatment, solid waste, water quality and pollution, water resources and supply.

The EWRE program is committed to solving the environmental problems of today and educating the engineers and researchers of tomorrow. By combining a tradition of excellence with a passion for innovation, our program provides students with a highly competitive education. Most graduate students are supported through research assistantships, fellowships, and teaching assistantships.

Effective management across stakeholders, fabrication, construction, and engineering, is critical for building the transparency required to deliver your project.

Our fully integrated equipment supply chain provides you with the required engineering design, procurement, expediting, fabrication, inspection, testing, and preparation needed for any package.

Managing Risk and Accountability

We take ownership of our water treatment approach throughout the entire project and can help share risk so that we partner in our client’s success.

Many of our projects are delivered under a fixed cost structure and include design, build, and operate options. Additionally, you can benefit from our ability and willingness to provide financial and partnership opportunities that could help see your project to completion.

Wastewater treatment, the removal of impurities from wastewater, or sewage, before it reaches aquifers or natural bodies of water such as rivers, lakes, estuaries, and oceans. Since pure water is not found in nature (i.e., outside chemical laboratories), any distinction between clean water and polluted water depends on the type and concentration of impurities found in the water as well as on its intended use. In broad terms, water is said to be polluted when it contains enough impurities to make it unfit for a particular use, such as drinking, swimming, or fishing. Although water quality is affected by natural conditions, the word pollution usually implies human activity as the source of contamination. Water pollution, therefore, is caused primarily by the drainage of contaminated wastewater into surface water or groundwater, and wastewater treatment is a major element of water pollution control.[7,8,9]
Historical background

Direct discharge of sewage

Many ancient cities had drainage systems, but they were primarily intended to carry rainwater away from roofs and pavements. A notable example is the drainage system of ancient Rome. It included many surface conduits that were connected to a large vaulted channel called the Cloaca Maxima (“Great Sewer”), which carried drainage water to the Tiber River. Built of stone and on a grand scale, the Cloaca Maxima is one of the oldest existing monuments of Roman engineering.

There was little progress in urban drainage or sewerage during the Middle Ages. Privy vaults and cesspools were used, but most wastes were simply dumped into gutters to be flushed through the drains by floods. Toilets (water closets) were installed in houses in the early 19th century, but they were usually connected to cesspools, not to sewers. In densely populated areas, local conditions soon became intolerable because the cesspools were seldom emptied and frequently overflowed. The threat to public health became apparent. In England in the middle of the 19th century, outbreaks of cholera were traced directly to well-water supplies contaminated with human waste from privy vaults and cesspools. It soon became necessary for all water closets in the larger towns to be connected directly to the storm sewers. This transferred sewage from the ground near houses to nearby bodies of water. Thus, a new problem emerged: surface water pollution.

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Developments in sewage treatment

It used to be said that "the solution to pollution is dilution." When small amounts of sewage are discharged into a flowing body of water, a natural process of stream self-purification occurs. Densely populated communities generate such large quantities of sewage, however, that dilution alone does not prevent pollution. This makes it necessary to treat or purify wastewater to some degree before disposal.

The construction of centralized sewage treatment plants began in the late 19th and early 20th centuries, principally in the United Kingdom and the United States. Instead of discharging sewage directly into a nearby body of water, it was first passed through a combination of physical, biological, and chemical processes that removed some or most of the pollutants. Also beginning in the 1900s, new sewage-collection systems were designed to separate storm water from domestic wastewater, so that treatment plants did not become overloaded during periods of wet weather.[10,11,12]

After the middle of the 20th century, increasing public concern for environmental quality led to broader and more stringent regulation of wastewater disposal practices. Higher levels of treatment were required. For example, pretreatment of industrial wastewater, with the aim of preventing toxic chemicals from interfering with the biological processes used at sewage treatment plants, often became a necessity. In fact, wastewater treatment technology advanced to the point where it became possible to remove virtually all pollutants from sewage. This was so expensive, however, that such high levels of treatment were not usually justified.

Wastewater treatment plants became large, complex facilities that required considerable amounts of energy for their operation. After the rise of oil prices in the 1970s, concern for energy conservation became a more important factor in the design of new pollution control systems. Consequently, land disposal and subsurface disposal of sewage began to receive increased attention where feasible. Such "low-tech" pollution control methods not only might help to conserve energy but also might serve to recycle nutrients and replenish groundwater supplies.

Sources of water pollution

Water pollutants may originate from point sources or from dispersed sources. A point-source pollutant is one that reaches water from a single pipeline or channel, such as a sewage discharge or outfall pipe. Dispersed sources are broad, unconfined areas from which pollutants enter a body of water. Surface runoff from farms, for example, is a dispersed source of pollution, carrying animal wastes, fertilizers, pesticides, and silt into nearby streams. Urban storm water drainage, which may carry sand and other gritty materials, petroleum residues from automobiles, and road deicing chemicals, is also considered a dispersed source because of the many locations at which it enters local streams or lakes. Point-source pollutants are easier to control than dispersed-source pollutants, since they flow to a single location where treatment processes can remove them from the water. Such control is not usually possible over pollutants from dispersed sources, which cause a large part of the overall water pollution problem. Dispersed-source water pollution is best reduced by enforcing proper land-use plans and development standards.

General types of water pollutants include pathogenic organisms, oxygen-demanding wastes, plant nutrients, synthetic organic chemicals, inorganic chemicals, microplastics, sediments, radioactive substances, oil, and heat. Sewage is the primary source of the first three types. Farms and industrial facilities are also sources of some of them. Sediment from eroded topsoil is considered a pollutant because it can damage aquatic ecosystems, and heat (particularly from power-plant cooling water) is considered a pollutant because of the adverse effect it has on dissolved oxygen levels and aquatic life in rivers and lakes.[13,14,15]

Sewage characteristics

Types of sewage

There are three types of wastewater, or sewage: domestic sewage, industrial sewage, and storm sewage. Domestic sewage carries used water from houses and apartments; it is also called sanitary sewage. Industrial sewage is used water from manufacturing or chemical processes. Storm sewage, or storm water, is runoff from precipitation that is collected in a system of pipes or open channels.

Domestic sewage is slightly more than 99.9 percent water by weight. The rest, less than 0.1 percent, contains a wide variety of dissolved and suspended impurities. Although amounting to a very small fraction of the sewage by weight, the nature of these impurities and the large volumes of sewage in which they are carried make disposal of domestic wastewater a significant technical problem. The principal impurities are putrescible organic materials and plant nutrients, but domestic sewage is also very likely to contain disease-causing microbes. Industrial wastewater usually contains specific and readily identifiable chemical compounds, depending on the nature of the industrial process. Storm sewage carries organic materials, suspended and dissolved solids, and other substances picked up as it travels over the ground.

Principal pollutants

Organic material

The amount of putrescible organic material in sewage is indicated by the biochemical oxygen demand, or BOD; the more organic material there is in the sewage, the higher the BOD, which is the amount of oxygen required by microorganisms to decompose the organic substances in sewage. It is among the most important parameters for the design and operation of sewage treatment plants. Industrial sewage may have BOD levels many times that of domestic sewage. The BOD of storm sewage is of particular concern when it is mixed with domestic sewage in combined sewerage systems [16,17,18]

Dissolved oxygen is an important water quality factor for lakes and rivers. The higher the concentration of dissolved oxygen, the better the water quality. When sewage enters a lake or stream, decomposition of the organic materials begins. Oxygen is consumed as microorganisms use it in their metabolism. This can quickly deplete the available oxygen in the water. When the dissolved oxygen levels drop too low, trout and other aquatic species soon perish. In fact, if the oxygen level drops to zero, the water will become septic. Decomposition of organic compounds without oxygen causes the undesirable odours usually associated with septic or putrid conditions.

Suspended solids

Another important characteristic of sewage is suspended solids. The volume of sludge produced in a treatment plant is directly related to the total suspended solids present in the sewage. Industrial and storm sewage may contain higher concentrations of suspended solids than domestic sewage. The extent to which a treatment plant removes suspended solids, as well as BOD, determines the efficiency of the treatment process.

Plant nutrients

Domestic sewage contains compounds of nitrogen and phosphorus, two elements that are basic nutrients essential for the growth of plants. In lakes, excessive amounts of nitrates and phosphates can cause the rapid growth of algae. Algal blooms, often caused by sewage discharges, accelerate the natural aging of lakes in a process called eutrophication.

Microbes

Domestic sewage contains many millions of microorganisms per gallon. Most are coliform bacteria from the human intestinal tract, and domestic sewage is also likely to carry other microbes. Coliforms are used as indicators of sewage pollution. A high coliform count usually indicates recent sewage pollution.

Sewerage systems

A sewerage system, or wastewater collection system, is a network of pipes, pumping stations, and appurtenances that convey sewage from its points of origin to a point of treatment and disposal.

Combined systems

Systems that carry a mixture of both domestic sewage and storm sewage are called combined sewers. Combined sewers typically consist of large-diameter pipes or tunnels, because of the large volumes of storm water that must be carried during wet-weather periods. They are very common in older cities but are no longer designed and built as part of new sewerage facilities. Because wastewater treatment plants cannot handle large volumes of storm water, sewage must bypass the treatment plants during wet weather and be discharged directly into the receiving water. These combined sewer overflows, containing untreated domestic sewage, cause recurring water pollution problems and are very troublesome sources of pollution.

In some large cities the combined sewer overflow problem has been reduced by diverting the first flush of combined sewage into a large basin or underground tunnel. After temporary storage, it can be treated by settling and disinfection before being discharged into a receiving body of water, or it can be treated in a nearby wastewater treatment plant at a rate that will not overload the facility. Another method for controlling combined sewage involves the use of swirl

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concentrators. These direct sewage through cylindrically shaped devices that create a vortex, or whirlpool, effect. The vortex helps concentrate impurities in a much smaller volume of water for treatment.

Separate systems

New wastewater collection facilities are designed as separate systems, carrying either domestic sewage or storm sewage but not both. Storm sewers usually carry surface runoff to a point of disposal in a stream or river. Small detention basins may be built as part of the system, storing storm water temporarily and reducing the magnitude of the peak flow rate. Sanitary sewers, on the other hand, carry domestic wastewater to a sewage treatment plant. Pretreated industrial wastewater may be allowed into municipal sanitary sewerage systems, but storm water is excluded.

Storm sewers are usually built with sections of reinforced concrete pipe. Corrugated metal pipes may be used in some cases. Storm water inlets or catch basins are located at suitable intervals in a street right-of-way or in easements across private property. The pipelines are usually located to allow downhill gravity flow to a nearby stream or to a detention basin. Storm water pumping stations are avoided, if possible, because of the very large pump capacities that would be needed to handle the intermittent flows.

A sanitary sewerage system includes laterals, submains, and interceptors. Except for individual house connections, laterals are the smallest sewers in the network. They usually are not less than 200 mm (8 inches) in diameter and carry sewage by gravity into larger submains, or collector sewers. The collector sewers tie in to a main interceptor, or trunk line, which carries the sewage to a treatment plant. Interceptors are usually built with precast sections of reinforced concrete pipe, up to 5 metres (15 feet) in diameter. Other materials used for sanitary sewers include vitrified clay, asbestos cement, plastic, steel, or ductile iron. The use of plastic for laterals is increasing because of its lightness and ease of installation. Iron and steel pipes are used for force mains or in pumping stations. Force mains are pipelines that carry sewage under pressure when it must be pumped.[19,20]

Alternative systems

Sometimes the cost of conventional gravity sewers can be prohibitively high because of low population densities or site conditions such as a high water table or bedrock. Three alternative wastewater collection systems that may be used under these circumstances include small-diameter gravity sewers, pressure sewers, and vacuum sewers.

In small-diameter gravity systems, septic tanks are first used to remove settleable and floating solids from the wastewater from each house before it flows into a network of collector mains (typically 100 mm, or 4 inches, in diameter); these systems are most suitable for small rural communities. Because they do not carry grease, grit and sewage solids, the pipes can be of smaller diameter and placed at reduced slopes or gradients to minimize trench excavation costs. Pressure sewers are best used in flat areas or where expensive rock excavation would be required. Grinder pumps discharge wastewater from each home into the main pressure sewer, which can follow the slope of the ground. In a vacuum sewerage system, sewage from one or more buildings flows by gravity into a sump or tank from which it is pulled out by vacuum pumps located at a central vacuum station and then flows into a collection tank. From the vacuum collection tank the sewage is pumped to a treatment plant.

Pumps

Pumping stations are built when sewage must be raised from a low point to a point of higher elevation or where the topography prevents downhill gravity flow. Special nonclogging pumps are available to handle raw sewage. They are installed in structures called lift stations. There are two basic types of lift stations: dry well and wet well. A wet-well installation has only one chamber or tank to receive and hold the sewage until it is pumped out. Specially designed submersible pumps and motors can be located at the bottom of the chamber, completely below the water level. Dry-well installations have two separate chambers, one to receive the wastewater and one to enclose and protect the pumps and controls. The protective dry chamber allows easy access for inspection and maintenance. All sewage lift stations, whether of the wet-well or dry-well type, should include at least two pumps. One pump can operate while the other is removed for repair.[18,19,20]

Flow rates

There is a wide variation in sewage flow rates over the course of a day. A sewerage system must accommodate this variation. In most cities domestic sewage flow rates are highest in the morning and evening hours. They are lowest during the middle of the night. Flow quantities depend upon population density, water consumption, and the extent of commercial or industrial activity in the community. The average sewage flow rate is usually about the same as the average water use in the community. In a lateral sewer, short-term peak flow rates can be roughly four times the average flow rate. In a trunk sewer, peak flow rates may be two-and-a-half times the average.

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Although sewage flows depend upon residential, commercial, and industrial connections, sewage flow rates potentially can become higher as a result of inflows and infiltration (I&I) into the sanitary sewer system. Inflows correspond to storm water entering sewers from inappropriate connections, such as roof drains, storm drains, downspouts and sump pumps. High amounts of rainwater runoff can reach the sewer system during precipitation and stormflow events or during seasonal spring flooding of rivers inundated with melting ice. Infiltration refers to the groundwater entering sewers via defective or broken pipes. In both these cases, downstream utilities and treatment plants may experience flows higher than anticipated and can become hydraulically overloaded. During such overloads, utilities may ask residents connected to the system to refrain from using dishwashers and washing machines and may even limit toilet flushing and the use of showers in an attempt to lessen the strain. Such I&I issues can be especially severe in old and aging water infrastructures.

Wastewater treatment and disposal

The size and capacity of wastewater treatment systems are determined by the estimated volume of sewage generated from residences, businesses, and industries connected to sewer systems as well as the anticipated inflows and infiltration (I&I). The selection of specific on-lot, clustered, or centralized treatment plant configurations depends upon factors such as the number of customers being served, the geographical scenario, site constraints, sewer connections, average and peak flows, influent wastewater characteristics, regulatory effluent limits, technological feasibility, energy consumption, and the operations and maintenance costs involved.

The predominant method of wastewater disposal in large cities and towns is discharge into a body of surface water. Suburban and rural areas rely more on subsurface disposal. In either case, wastewater must be purified or treated to some degree in order to protect both public health and water quality. Suspended particulates and biodegradable organics must be removed to varying extents. Pathogenic bacteria must be destroyed. It may also be necessary to remove nitrates and phosphates (plant nutrients) and to neutralize or remove industrial wastes and toxic chemicals.[17,18,19]

The degree to which wastewater must be treated varies, depending on local environmental conditions and governmental standards. Two pertinent types of standards are stream standards and effluent standards. Stream standards, designed to prevent the deterioration of existing water quality, set limits on the amounts of specific pollutants allowed in streams, rivers, and lakes. The limits depend on a classification of the “maximum beneficial use” of the water. Water quality parameters that are regulated by stream standards include dissolved oxygen, coliforms, turbidity, acidity, and toxic substances. Effluent standards, on the other hand, pertain directly to the quality of the treated wastewater discharged from a sewage treatment plant. The factors controlled under these standards usually include biochemical oxygen demand (BOD), suspended solids, acidity, and coliforms.

There are three levels of wastewater treatment: primary, secondary, and tertiary (or advanced). Primary treatment removes about 60 percent of total suspended solids and about 35 percent of BOD; dissolved impurities are not removed. It is usually used as a first step before secondary treatment. Secondary treatment removes more than 85 percent of both suspended solids and BOD. A minimum level of secondary treatment is usually required in the United States and other developed countries. When more than 85 percent of total solids and BOD must be removed, or when dissolved nitrate and phosphate levels must be reduced, tertiary treatment methods are used. Tertiary processes can remove more than 99 percent of all the impurities from sewage, producing an effluent of almost drinking-water quality. Tertiary treatment can be very expensive, often doubling the cost of secondary treatment. It is used only under special circumstances.

For all levels of wastewater treatment, the last step prior to discharge of the sewage effluent into a body of surface water is disinfection, which destroys any remaining pathogens in the effluent and protects public health. Disinfection is usually accomplished by mixing the effluent with chlorine gas or with liquid solutions of hypochlorite chemicals in a contact tank for at least 15 minutes. Because chlorine residuals in the effluent may have adverse effects on aquatic life, an additional chemical may be added to dechlorinate the effluent. Ultraviolet radiation, which can disinfect without leaving any residual in the effluent, is becoming more competitive with chlorine as a wastewater disinfectant.

Primary treatment

Primary treatment removes material that will either float or readily settle out by gravity. It includes the physical processes of screening, comminution, grit removal, and sedimentation. Screens are made of long, closely spaced, narrow metal bars. They block floating debris such as wood, rags, and other bulky objects that could clog pipes or pumps. In modern plants the screens are cleaned mechanically, and the material is promptly disposed of by burial on

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the plant grounds. A comminutor may be used to grind and shred debris that passes through the screens. The shredded material is removed later by sedimentation or flotation processes.[16,17,18]

Grit chambers are long narrow tanks that are designed to slow down the flow so that solids such as sand, coffee grounds, and eggshells will settle out of the water. Grit causes excessive wear and tear on pumps and other plant equipment. Its removal is particularly important in cities with combined sewer systems, which carry a good deal of silt, sand, and gravel that wash off streets or land during a storm.

Suspended solids that pass through screens and grit chambers are removed from the sewage in sedimentation tanks. These tanks, also called primary clarifiers, provide about two hours of detention time for gravity settling to take place. As the sewage flows through them slowly, the solids gradually sink to the bottom. The settled solids—known as raw or primary sludge—are moved along the tank bottom by mechanical scrapers. Sludge is collected in a hopper, where it is pumped out for removal. Mechanical surface-skimming devices remove grease and other floating materials.

Secondary treatment

Secondary treatment removes the soluble organic matter that escapes primary treatment. It also removes more of the suspended solids. Removal is usually accomplished by biological processes in which microbes consume the organic impurities as food, converting them into carbon dioxide, water, and energy for their own growth and reproduction. The sewage treatment plant provides a suitable environment, albeit of steel and concrete, for this natural biological process. Removal of soluble organic matter at the treatment plant helps to protect the dissolved oxygen balance of a receiving stream, river, or lake.

There are three basic biological treatment methods: the trickling filter, the activated sludge process, and the oxidation pond. A fourth, less common method is the rotating biological contacter.

Trickling filter

A trickling filter is simply a tank filled with a deep bed of stones. Settled sewage is sprayed continuously over the top of the stones and trickles to the bottom, where it is collected for further treatment. As the wastewater trickles down, bacteria gather and multiply on the stones. The steady flow of sewage over these growths allows the microbes to absorb the dissolved organics, thus lowering the biochemical oxygen demand (BOD) of the sewage. Air circulating upward through the spaces among the stones provides sufficient oxygen for the metabolic processes.

Settling tanks, called secondary clarifiers, follow the trickling filters. These clarifiers remove microbes that are washed off the rocks by the flow of wastewater. Two or more trickling filters may be connected in series, and sewage can be recirculated in order to increase treatment efficiencies.

Activated sludge

The activated sludge treatment system consists of an aeration tank followed by a secondary clarifier. Settled sewage, mixed with fresh sludge that is recirculated from the secondary clarifier, is introduced into the aeration tank. Compressed air is then injected into the mixture through porous diffusers located at the bottom of the tank. As it bubbles to the surface, the diffused air provides oxygen and a rapid mixing action. Air can also be added by the churning action of mechanical propeller-like mixers located at the tank surface.

Under such oxygenated conditions, microorganisms thrive, forming an active, healthy suspension of biological solids—mostly bacteria—called activated sludge. About six hours of detention is provided in the aeration tank. This gives the microbes enough time to absorb dissolved organics from the sewage, reducing the BOD. The mixture then flows from the aeration tank into the secondary clarifier, where activated sludge settles out by gravity. Clear water is skimmed from the surface of the clarifier, disinfected, and discharged as secondary effluent. The sludge is pumped out from a hopper at the bottom of the tank. About 30 percent of the sludge is recirculated back into the aeration tank, where it is mixed with the primary effluent. This recirculation is a key feature of the activated sludge process. The recycled microbes are well acclimated to the sewage environment and readily metabolize the organic materials in the primary effluent. The remaining 70 percent of the secondary sludge must be treated and disposed of in an acceptable manner (see Sludge treatment and disposal).

Variations of the activated sludge process include extended aeration, contact stabilization, and high-purity oxygen aeration. Extended aeration and contact stabilization systems omit the primary settling step. They are efficient for treating small sewage flows from motels, schools, and other relatively isolated wastewater sources. Both of these treatments are usually provided in prefabricated steel tanks called package plants. Oxygen aeration systems mix pure oxygen with activated sludge. A richer concentration of oxygen allows the aeration time to be shortened from six to two hours, reducing the required tank volume.

Oxidation pond

Oxidation ponds, also called lagoons or stabilization ponds, are large, shallow ponds designed to treat wastewater through the interaction of sunlight, bacteria, and algae. Algae grow using energy from the sun and carbon dioxide and inorganic compounds released by bacteria in water. During the process of photosynthesis, the algae release oxygen needed by aerobic bacteria. Mechanical aerators are sometimes installed to supply yet more oxygen, thereby reducing the required size of the pond. Sludge deposits in the pond must eventually be removed by dredging. Algae remaining in the pond effluent can be removed by filtration or by a combination of chemical treatment and settling.[15,16,17]

Rotating biological contacter

In this treatment system a series of large plastic disks mounted on a horizontal shaft are partially submerged in primary effluent. As the shaft rotates, the disks are exposed alternately to air and wastewater, allowing a layer of bacteria to grow on the disks and to metabolize the organics in the wastewater.

Tertiary treatment

When the intended receiving water is very vulnerable to the effects of pollution, secondary effluent may be treated further by several tertiary processes.

(Left) During the filtering step, wastewater from secondary treatment, still containing suspended solids, pours from a trough and percolates through a filter bed made of porous media such as sand, gravel, and anthracite. The filtered water is then piped away for disposal. (Right) In the backwashing step, entrained solids are periodically flushed from the filter media by pumping filtered water back through the assembly. The backwash water, carrying suspended solids, is returned to the beginning of the wastewater treatment process.(more)

For the removal of additional suspended solids and BOD from secondary effluent, effluent polishing is an effective treatment. It is most often accomplished using granular media filters, much like the filters used to purify drinking water. Polishing filters are usually built as prefabricated units, with tanks placed directly above the filters for storing backwash water. Effluent polishing of wastewater may also be achieved using microstrainers of the type used in treating municipal water supplies.

Removal of plant nutrients

When treatment standards require the removal of plant nutrients from the sewage, it is often done as a tertiary step. Phosphorus in wastewater is usually present in the form of organic compounds and phosphates that can easily be removed by chemical precipitation. This process, however, increases the volume and weight of sludge. Nitrogen, another important plant nutrient, is present in sewage in the form of ammonia and nitrates. Ammonia is toxic to fish, and it also exerts an oxygen demand in receiving waters as it is converted to nitrates. Nitrates, like phosphates, promote the growth of algae and the eutrophication of lakes. A method called nitrification-denitrification can be used to remove the nitrates. It is a two-step biological process in which ammonia nitrogen is first converted into nitrates by microorganisms. The nitrates are further metabolized by another species of bacteria, forming nitrogen gas that escapes into the air. This process requires the construction of more aeration and settling tanks and significantly increases the cost of treatment.

A physicochemical process called ammonia stripping may be used to remove ammonia from sewage. Chemicals are added to convert ammonium ions into ammonia gas. The sewage is then cascaded down through a tower, allowing the gas to come out of solution and escape into the air. Stripping is less expensive than nitrification-denitrification, but it does not work very efficiently in cold weather.

Land treatment

In some locations, secondary effluent can be applied directly to the ground and a polished effluent obtained by natural processes as the wastewater flows over vegetation and percolates through the soil. There are three types of land treatment: slow-rate, rapid infiltration, and overland flow.[14,15,16]

In the slow-rate, or irrigation, method, effluent is applied onto the land by ridge-and-furrow spreading (in ditches) or by sprinkler systems. Most of the water and nutrients are absorbed by the roots of growing vegetation. In the rapid infiltration method, the wastewater is stored in large ponds called recharge basins. Most of it percolates to the groundwater, and very little is absorbed by vegetation. For this method to work, soils must be highly permeable. In overland flow, wastewater is sprayed onto an inclined vegetated terrace and slowly flows to a collection ditch. Purification is achieved by physical, chemical, and biological processes, and the collected water is usually discharged into a nearby stream.

Land treatment of sewage can provide moisture and nutrients for the growth of vegetation, such as corn or grain for animal feed. It also can recharge, or replenish, groundwater aquifers. Land treatment, in effect, allows sewage to be recycled for beneficial use. Large land areas are required, however, and the feasibility of this kind of treatment may be limited further by soil texture and climate.

Clustered wastewater treatment systems

In certain instances when it is not feasible to connect residences or units to public sewer systems, communities may opt for a clustered wastewater treatment system. Such facilities are smaller versions of centralized treatment plants and serve only a limited number of connections. The technologies used for clustered wastewater treatment may be the same as those used for centralized systems or for individual on-site systems, depending upon the specific applications and degree of treatment required. Upon treatment, effluent from clustered wastewater systems can be discharged via surface or subsurface disposal methods.

On-site septic tanks and leaching fields

In sparsely populated suburban or rural areas, it is usually not economical to build sewage collection systems and a centrally located treatment plant. Instead, a separate treatment and disposal system is provided for each home. On-site systems provide effective, low-cost, long-term solutions for wastewater disposal as long as they are properly designed, installed, and maintained. In the United States, about one-third of private homes make use of an on-site subsurface disposal system.

The most common type of on-site system includes a buried, watertight septic tank and a subsurface absorption field (also called a drain field or leaching field). The septic tank serves as a primary sedimentation and sludge storage chamber, removing most of the settleable and floating material from the influent wastewater. Although the sludge decomposes anaerobically, it eventually accumulates at the tank bottom and must be pumped out periodically (every two to four years). Floating solids and grease are trapped by a baffle at the tank outlet, and settled sewage flows out into the absorption field, through which it percolates downward into the ground. As it flows slowly through layers of soil, the settled wastewater is further treated and purified by both physical and biological processes before it reaches the water table.

An absorption field includes several perforated pipelines placed in long, shallow trenches filled with gravel. The pipes distribute the effluent over a sizable area as it seeps through the gravel and into the underlying layers of soil. If the disposal site is too small for a conventional leaching field, deeper seepage pits may be used instead of shallow trenches; seepage pits require less land area than leaching fields. Both leaching field trenches and seepage pits must be placed above seasonally high groundwater levels.

For subsurface on-site wastewater disposal to succeed, the permeability, or hydraulic conductivity, of the soil must be within an acceptable range. If it is too low, the effluent will not be able to flow effectively through the soil, and it may seep out onto the surface of the absorption field, thereby endangering public health. If permeability is too high, there may not be sufficient purification before the effluent reaches the water table, thereby contaminating the groundwater. The capacity of the ground to absorb settled wastewater depends largely on the texture of the soil (i.e., relative amounts of gravel, sand, silt, and clay). Permeability can be evaluated by direct observation of the soil in excavated test pits and also by conducting a percolation test, or "per test." The perc test measures the rate at which water seeps into the soil in small test holes dug on the disposal site. The measured perc rate can be used to determine the total required area of the absorption field or the number of seepage pits.

Where unfavourable site or soil conditions prohibit the use of both absorption fields and seepage pits, mound systems may be utilized for on-site sewage disposal. A mound is an absorption field built above the natural ground surface in order to provide suitable material for percolation and to separate the drain field from the water table. Septic tank effluent is intermittently pumped from a chamber and applied to the mound. Other alternative on-site disposal methods include use of intermittent sand filters or of small, prefabricated aerobic treatment units. Disinfection (usually by

chlorination) of the effluent from these systems is required when the effluent is discharged into a nearby stream.[13,14,15]
Wastewater reuse

Wastewater can be a valuable resource in cities or towns where population is growing and water supplies are limited. In addition to easing the strain on limited freshwater supplies, the reuse of wastewater can improve the quality of streams and lakes by reducing the effluent discharges that they receive. Wastewater may be reclaimed and reused for crop and landscape irrigation, groundwater recharge, or recreational purposes. Reclamation for drinking is technically possible, but this reuse faces significant public resistance.

There are two types of wastewater reuse: direct and indirect. In direct reuse, treated wastewater is piped into some type of water system without first being diluted in a natural stream or lake or in groundwater. One example is the irrigation of a golf course with effluent from a municipal wastewater treatment plant. Indirect reuse involves the mixing of reclaimed wastewater with another body of water before reuse. In effect, any community that uses a surface water supply downstream from the treatment plant discharge pipe of another community is indirectly reusing wastewater. Indirect reuse is also accomplished by discharging reclaimed wastewater into a groundwater aquifer and later withdrawing the water for use. Discharge into an aquifer (called artificial recharge) is done by either deep-well injection or shallow surface spreading.

Quality and treatment requirements for reclaimed wastewater become more stringent as the chances for direct human contact and ingestion increase. The impurities that must be removed depend on the intended use of the water. For example, removal of phosphates or nitrates is not necessary if the intended use is landscape irrigation. If direct reuse as a potable supply is intended, tertiary treatment with multiple barriers against contaminants is required. This may include secondary treatment followed by granular media filtration, ultraviolet radiation, granular activated carbon adsorption, reverse osmosis, air stripping, ozonation, and chlorination.

The use of gray-water recycling systems in new commercial buildings offers a method of saving water and reducing total sewage volumes. These systems filter and chlorinate drainage from tubs and sinks and reuse the water for nonpotable purposes (e.g., flushing toilets and urinals). Recycled water can be marked with a blue dye to ensure that it is not used for potable purposes.

Sludge treatment and disposal
Mixed sludge received from secondary wastewater treatment is passed through a dissolved-air flotation tank, where solids rise to the surface and are skimmed off. The thickened sludge is pulped with steam, then passed to thermal hydrolysis, where large molecules such as proteins and lipids are broken down under heat and pressure. The hydrolyzed sludge is passed through a flash tank, where a sudden drop in pressure causes cells to burst, and then to anaerobic digestion, where bacteria convert dissolved organic matter to biogas (which can be used to fuel the treatment process). Digested sludge is passed through a dewatering step; the dried solids are disposed of, and the water is sent back to secondary treatment.[12,13,14]

III. RESULTS

The residue that accumulates in sewage treatment plants is called sludge (or biosolids). Sewage sludge is the solid, semisolid, or slurry residual material that is produced as a by-product of wastewater treatment processes. This residue is commonly classified as primary and secondary sludge. Primary sludge is generated from chemical precipitation, sedimentation, and other primary processes, whereas secondary sludge is the activated waste biomass resulting from biological treatments. Some sewage plants also receive septage or septic tank solids from household on-site wastewater treatment systems. Quite often the sludges are combined together for further treatment and disposal.

Treatment and disposal of sewage sludge are major factors in the design and operation of all wastewater treatment plants. Two basic goals of treating sludge before final disposal are to reduce its volume and to stabilize the organic materials. Stabilized sludge does not have an offensive odour and can be handled without causing a nuisance or health hazard. Smaller sludge volume reduces the costs of pumping and storage.

Treatment methods

Treatment of sewage sludge may include a combination of thickening, digestion, and dewatering processes.
Thickening

Thickening is usually the first step in sludge treatment because it is impractical to handle thin sludge, a slurry of solids suspended in water. Thickening is usually accomplished in a tank called a gravity thickener. A thickener can reduce the total volume of sludge to less than half the original volume. An alternative to gravity thickening is dissolved-air flotation. In this method, air bubbles carry the solids to the surface, where a layer of thickened sludge forms.
Digestion

Sludge digestion is a biological process in which organic solids are decomposed into stable substances. Digestion reduces the total mass of solids, destroys pathogens, and makes it easier to dewater or dry the sludge. Digested sludge is inoffensive, having the appearance and characteristics of a rich potting soil.

Most large sewage treatment plants use a two-stage digestion system in which organics are metabolized by bacteria anaerobically (in the absence of oxygen). In the first stage, the sludge, thickened to a dry solids (DS) content of about 5 percent, is heated and mixed in a closed tank for several days. Acid-forming bacteria hydrolyze large molecules such as proteins and lipids, breaking them into smaller water-soluble molecules, and then ferment those smaller molecules into various fatty acids. The sludge then flows into a second tank, where the dissolved matter is converted by other bacteria into biogas, a mixture of carbon dioxide and methane. Methane is combustible and is used as a fuel to heat the first digestion tank as well as to generate electricity for the plant.

Anaerobic digestion is very sensitive to temperature, acidity, and other factors. It requires careful monitoring and control. In some cases, the sludge is inoculated with extra hydrolytic enzymes at the beginning of the first digestion stage in order to supplement the action of the bacteria. It has been found that this enzymatic treatment can destroy more unwanted pathogens in the sludge and also can result in the generation of more biogas in the second stage of digestion.

Another enhancement of the traditional two-stage anaerobic digestion process is thermal hydrolysis, or the breaking down of the large molecules by heat. This is done in a separate step before digestion. In a typical case, the process begins with a sludge that has been dewatered to a DS content of some 15 percent. The sludge is mixed with steam in a pulper, and this hot homogenized mixture is fed to a reactor, where it is held under pressure at approximately 165 °C (about 330 °F) for about 30 minutes. At that point, with the hydrolytic reactions complete, some of the steam is bled off (to be fed to the pulper), and the sludge, still under some pressure, is released suddenly into a "flash tank," where the sudded drop in pressure bursts the cell walls of much of the solid matter. The hydrolyzed sludge is cooled, diluted slightly with water, and then sent directly to the second stage of anaerobic digestion.[15,16,17]

Sludge digestion may also take place aerobically—that is, in the presence of oxygen. The sludge is vigorously aerated in an open tank for about 20 days. Methane gas is not formed in this process. Although aerobic systems are easier to operate than anaerobic systems, they usually cost more to operate because of the power needed for aeration. Aerobic digestion is often combined with small extended aeration or contact stabilization systems.

Aerobic and conventional anaerobic digestion convert about half of the organic sludge solids to liquids and gases. Thermal hydrolysis followed by anaerobic digestion can convert some 60 to 70 percent of the solid matter to liquids and gases. Not only is the volume of solids produced smaller than in conventional digestion, but the greater production of biogas can make some wastewater treatment plants self-sufficient in energy.
Dewatering
Digested sewage sludge is usually dewatered before disposal. Dewatered sludge still contains a significant amount of water—often as much as 70 percent—but, even with that moisture content, sludge no longer behaves as a liquid and can be handled as a solid material. Sludge-drying beds provide the simplest method of dewatering. A digested sludge slurry is spread on an open bed of sand and allowed to remain until dry. Drying takes place by a combination of evaporation and gravity drainage through the sand. A piping network built under the sand collects the water, which is pumped back to the head of the plant. After about six weeks of drying, the sludge cake, as it is called, may have a solids content of about 40 percent. It can then be removed from the sand with a pitchfork or a front-end loader. In order to reduce drying time in wet or cold weather, a glass enclosure may be built over the sand beds. Since a good deal of land

area is needed for drying beds, this method of dewatering is commonly used in rural or suburban towns rather than in densely populated cities.

Alternatives to sludge-drying beds include the rotary drum vacuum filter, the centrifuge, and the belt filter press. These mechanical systems require less space than do sludge-drying beds, and they offer a greater degree of operational control. However, they usually have to be preceded by a step called sludge conditioning, in which chemicals are added to the liquid sludge to coagulate solids and improve drainability.

Disposal

The final destination of treated sewage sludge usually is the land. Dewatered sludge can be buried underground in a sanitary landfill. It also may be spread on agricultural land in order to make use of its value as a soil conditioner and fertilizer. Since sludge may contain toxic industrial chemicals, it is not spread on land where crops are grown for human consumption.

Where a suitable site for land disposal is not available, as in urban areas, sludge may be incinerated. Incineration completely evaporates the moisture and converts the organic solids into inert ash. The ash must be disposed of, but the reduced volume makes disposal more economical. Air pollution control is a very important consideration when sewage sludge is incinerated. Appropriate air-cleaning devices such as scrubbers and filters must be used.

Emerging technologies

Experts in the wastewater treatment sector have been working to implement established technologies and to improve environmental rules and regulations to meet water quality goals and human health protection. At the same time, the industry has also been transitioning to prepare for future challenges, such as climate change, changing populations, and aging infrastructure.

Improved treatment methods

Many older wastewater treatment facilities require upgrading because of increasingly strict water quality standards, but this is often difficult because of limited space for expansion. In order to allow improvement of treatment efficiencies without requiring more land area, new treatment methods have been developed. These include the membrane bioreactor process, the ballasted floc reactor, and the integrated fixed-film activated sludge (IFAS) process.

In the membrane bioreactor process, hollow-fibre microfiltration membrane modules are submerged in a single tank in which aeration, secondary clarification, and filtration can occur, thereby providing both secondary and tertiary treatment in a small land area.

In a ballasted floc reactor, the settling rate of suspended solids is increased by using sand and a polymer to help coagulate the suspended solids and form larger masses called flocs. The sand is separated from the sludge in a hydroclone, a relatively simple apparatus into which the water is introduced near the top of a cylinder at a tangent so that heavy materials such as sand are “spun” by centrifugal force toward the outside wall. The sand collects by gravity at the bottom of the hydroclone and is recycled back to the reactor.

Biological aerated filters use a basin with submerged media that serves as both a contact surface for biological treatment and a filter to separate solids from the wastewater. Fine-bubble aeration is applied to facilitate the process, and routine backwashing is used to clean the media. The land area required for a biological aerated filter is only about 15 percent of the area required for a conventional activated sludge system.[18,19]

Automation

Advanced wastewater purification processes involve biological treatments that are sensitive to processing parameters and to the environment. To ensure stable and reliable operations of physical, chemical, and biological processes, treatment plants quite often need to implement sophisticated technologies involving complex instrumentation and process control systems. Use of online analytical instruments, programmable logic controllers (PLC), supervisory control and data acquisition (SCADA) systems, human machine interface (HMI), and various

process control software allow for the automation and computerization of treatment processes with the provision for remote operations. Such innovations improve system operations significantly, thus minimizing supervision needs.
Environmental considerations

Natural treatments, energy conservation, and carbon footprint reduction are some of the key considerations for communities facing energy and electricity challenges. Green technologies and the use of renewable energy sources, including solar and wind power, for wastewater treatment are evolving and will help minimize the environmental impacts of human activities. Ecological and economical natural wastewater treatment and disposal systems have already gained importance in many places, especially in smaller communities. These include constructed wetlands, lagoons, stabilization ponds, soil filters, drip irrigation, groundwater recharge, and other similar systems. The simplicity, cost-effectiveness, efficiency, and reliability of these systems have provided potential applications for such environmentally friendly technologies.

Given that wastewater is rich in nutrients and other chemicals, sewage treatment facilities have gained recognition as resource recovery facilities, overcoming their former reputation as mere pollution mitigation entities. Newer technologies and approaches have continued to improve the efficiency by which energy, nutrients, and other chemicals are recovered from treatment plants, helping create a sustainable market and becoming a revenue generation source for wastewater processing facilities.

Concepts such as nutrient trading have also emerged. The intention of such initiatives is to control and meet overall pollution load targets for a given watershed by trading nutrient reduction credits between point and non-point source dischargers. Such programs can help to minimize nutrient pollution effects as well as reduce financial burdens on societies for costly treatment plant upgrades.

IV. CONCLUSION

Wastewater treatment is a process which removes and eliminates contaminants from wastewater and converts this into an effluent that can be returned to the water cycle. Once returned to the water cycle, the effluent creates an acceptable impact on the environment or is reused for various purposes (called water reclamation).[1] The treatment process takes place in a wastewater treatment plant. There are several kinds of wastewater which are treated at the appropriate type of wastewater treatment plant. For domestic wastewater (also called municipal wastewater or sewage), the treatment plant is called a Sewage Treatment. For industrial wastewater, treatment either takes place in a separate Industrial wastewater treatment, or in a sewage treatment plant (usually after some form of pre-treatment). Further types of wastewater treatment plants include Agricultural wastewater treatment and leachate treatment plants.

Processes commonly used in wastewater treatment include phase separation (such as sedimentation), biological and chemical processes (such as oxidation) or polishing. The main by-product from wastewater treatment plants is a type of sludge that is usually treated in the same or another wastewater treatment plant.[2]:Ch.14 Biogas can be another by-product if anaerobic treatment processes are used. Treated wastewater can be reused as reclaimed water. The main purpose of wastewater treatment is for the treated wastewater to be able to be disposed or reused safely. However, before it is treated, the options for disposal or reuse must be considered so the correct treatment process is used on the wastewater. Bangladesh has officially inaugurated the largest single sewage treatment plant (STP) in South Asia, located in the Khilgaon area of the city. With a capacity to treat five million sewage per day, the STP marks a significant step towards addressing the country's wastewater management challenges.[20,21]

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