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A REVIEW ABOUT SEWAGE/WASTEWATER TREATMENT TECHNOLOGIES FOR SMARTCITIES

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ABSTRACT: For the development of smart cities users must concentrate their Sewage/Wastewater treatment process to ensure that it complies with regulatory guidelines. The main purpose of Sewage treatment process is to remove the various constituents of the polluting load: solids, organic carbon, nutrients, inorganic salts, metals, pathogens etc. Effective wastewater collection and treatment are of great importance from the standpoint of both; environmental and public health in a smartcity. Sewage/Wastewater treatment operations are done by various methods in order to reduce its water and organic content, and the ultimate goal of wastewater management is the protection of the environment in a manner commensurate with public health and socio-economic concerns. In this article, keeping in mind the idea of ideal smartcitiy Sewage/Wastewater treatment techniques, factors affecting selection and design Sewage/Wastewater systems are discussed briefly.

Key words: Sewage, Wastewater, Treatment.

INTRODUCTION

Sewage/Wastewater are essentially dependent on the water supply of the community after it has been fouled by a variety of uses[1]. From the standpoint of sources of generation, wastewater may be defined as a combination of the liquid (or water) carrying wastes removed from residences, institutions, commercial and industrial establishments, together with such groundwater, surface water and storm water as may be present[2]. Generally, the wastewater discharged from domestic premises like residences, institutions and commercial establishments is termed as “Sewage/Community wastewater”. It comprises of 99.9% water and 0.1% solids and is organic because it consists of carbon compounds like human waste, paper, vegetable matter etc. Besides community wastewater/sewage, there is industrial wastewater in the region. Many industrial wastes are also organic in composition and can be treated physico-chemically and/or by micro-organisms in the same way as sewage[1].

A Historical Perspective

Before the late 1800s, the general means of disposing human excrement was the outdoor privy while the major proportion of the population used to go for open defecation. Sewage treatment systems were introduced in cities after Louis Pasteur and other scientists showed that sewage borne bacteria were responsible for many infectious diseases[3]. The early attempts, in the 1900s, at treating sewage usually consisted of acquiring large farms and spreading the sewage over the land, where it decayed under the action of micro-organisms. It was soon found that the land became 'sick'. Later attempts included the discharge of wastewater directly into the water bodies, but it resulted in significant deterioration of the water quality of such bodies. These attempts relied heavily on the self-cleansing capacities of land and water bodies and it was soon realized that nature couldn’t act as an indefinite sink[4].

Methods of wastewater treatment were first developed in response to the adverse conditions caused by the discharge of wastewater to the environment and the concern for public health. Further, as cities became larger; limited land was available for wastewater treatment and disposal, principally by irrigation and intermittent filtration. Also, as populations grew, the quantity of wastewater generated rose rapidly and the deteriorating quality of this huge amount of wastewater exceeded the self-purification capacity of the streams and river bodies[5,6]. Therefore, other methods of treatment were developed to accelerate the forces of nature under controlled conditions in treatment facilities of comparatively smaller size. In general from about 1900 to the early 1970s, treatment objectives were concerned with :-

(i) The removal of suspended and floatable material from wastewater,

(ii) The treatment of biodegradable organics (BOD removal) and

(iii) The elimination of disease-causing pathogenic micro-organisms.

From the early 1970 to about 1990s, wastewater treatment objectives were based primarily on aesthetic and environmental concerns[1]. The earlier objectives of reduction and removal of BOD, suspended solids, and pathogenic micro-organism continued, but at higher levels. Removal of nutrients such as nitrogen and phosphorus also began to be addressed, particularly in some of the streams and lakes. Major initiatives were taken around the globe, to achieve more effective and widespread treatment of wastewater to improve the quality of the surface waters[7]. This effort was a result of -

(i) An increased understanding of the environmental effects caused by wastewater discharges and

(ii) A developing knowledge of the adverse long term effects caused by the discharge of some of the specific constituents found in wastewater.

Since 1990, because of increased scientific knowledge and an expanded information base, wastewater treatment has begun to focus on the health concerns related to toxic and potentially toxic chemicals released into the environment. The water quality improvement objectives of the 1970s have continued, but the emphases has shifted to the definition and removal of toxic and trace compounds, that could possibly cause long-term health effects and adverse environmental impacts. As a consequence, while the early treatment objectives remain valid today, the required degree of treatment has increased significantly and additional treatment objectives and goals have been added[4,8,9].

Why should Sewage/Wastewater be treated before disposal?

Sewage/Wastewater treatment involves breakdown of complex organic compounds in the wastewater into simpler compounds that are stable and nuisance-free, either physico-chemically and or by using micro-organisms (biological treatment)[2]. The adverse environmental impact of allowing untreated wastewater to be discharged in groundwater or surface water bodies and/or land is as follows -

(i) The decomposition of the organic materials contained in wastewater can lead to the production of large quantities of malodorous gases.

(ii) Untreated wastewater (sewage) containing a large amount of organic matter, if discharged into a river/stream, will consume the dissolved oxygen for satisfying the biochemical oxygen demand (BOD) of wastewater and thus, deplete the dissolved oxygen of the stream; thereby, causing fish kills and other undesirable effects[5].

(iii) Wastewater may also contain nutrients, which can stimulate the growth of aquatic plants and algal blooms; thus, leading to eutrophication of the lakes and streams and

(iv) Untreated wastewater usually contains numerous pathogenic, or disease causing microorganisms and toxic compounds, that dwell in the human intestinal tract or may be present in certain industrial waste. These may contaminate the land or the water body, where such sewage is disposed. For the above-mentioned reasons, the treatment and disposal of wastewater, is not only desirable but also necessary[5].

EXPERIMENTAL

Unit operations and processes in sewage treatment

The degree of treatment can be determined by comparing the influent wastewater characteristics to the required effluent wastewater characteristics after reviewing the treatment objectives and applicable regulations. The contaminants in wastewater are removed by physical, chemical and biological means[10]. The individual methods usually are classified as physical unit operations, chemical unit processes and biological unit processes. Although these operations and processes occur in a variety of combinations in treatment systems, it has been found advantageous to study their scientific basis separately because the principles involved do not change[3].

Physical unit operations

Treatment methods in which the application of physical forces predominates are known as physical unit operations. Screening, mixing, flocculation, sedimentation, floatation, filtration and gas transfer are examples of physical unit operations[8].

Chemical unit processes

Treatment methods in which the removal or conversion of contaminants is brought about by the addition of chemicals or by other chemical reactions are known as chemical unit processes. Precipitation and adsorption are the most common examples used in wastewater treatment[11]. In chemical precipitation, treatment is accomplished by producing a chemical precipitate that will settle. In most cases, the settled precipitate will contain both the constituents that may have reacted with the added chemicals and the constituents that were swept out of the wastewater as the precipitate settled. Adsorption involves the removal of specific compounds from the wastewater on solid surfaces using the forces of attraction between bodies[3,10].

Biological unit processes

Treatment methods in which the removal of contaminants is brought about by biological activity are known as biological unit processes. Biological treatment is used primarily to remove the biodegradable organic substances (colloidal or dissolved) in wastewater[6]. Basically, these substances are converted into gases that can escape to the atmosphere and into biological cell tissue that can be removed by settling. Biological treatment is also used to remove nutrients (nitrogen and phosphorus) in wastewater.

Classification of sewage/wastewater treatment methods

The unit operations and unit processes mentioned above are grouped together to provide various levels of treatment described below -

Preliminary wastewater treatment

Preliminary wastewater treatment is the removal of such wastewater constituents that may cause maintenance or operational problems in the treatment operations, processes, and ancillary systems. It consists solely of separating the floating materials (like dead animals, tree branches, papers, pieces of rags, wood etc.) and the heavy settle able inorganic solids. It also helps in removing the oils and greases, etc. from the sewage[2,4]. This treatment reduces the BOD of the wastewater, by about 15 to 30%. Examples of preliminary operations are:

- Screening and combination for the removal of debris and rags.
- Grit removal for the elimination of coarse suspended matter that may cause wear or clogging of equipment and
- Floatation / skimming for the removal of oil and grease.

Primary wastewater treatment

In primary treatment, a portion of the suspended solids and organic matter is removed from the wastewater. This removal is usually accomplished by physical operations such as sedimentation in Settling Basins[5]. The liquid effluent from primary treatment, often contains a large amount of suspended organic materials, and has a high BOD (about 60% of original). Sometimes, the preliminary as well as primary treatments are classified together, under primary treatment[7]. The organic solids, which are separated out in the sedimentation tanks (in primary treatment), are often stabilized by anaerobic decomposition in a digestion tank or are incinerated. The residue is used for landfills or as a soil conditioner. The principal function of primary treatment is to act as a precursor to secondary treatment[4].

Secondary wastewater treatment

Secondary treatment involves further treatment of the effluent, coming from the primary sedimentation tank and is directed principally towards the removal of biodegradable organics and suspended solids through biological decomposition of organic matter, either under aerobic or anaerobic conditions. In these biological units, bacteria will decompose the fine organic matter, to produce a clearer effluent[3]. The treatment reactors, in which the organic matter is decomposed (oxidized) by aerobic bacteria are known as Aerobic biological units; and may consist of:

- Filters (intermittent sand filters as well as trickling filters),
- Aeration tanks, with the feed of recycled activated sludge (i.e. the sludge, which is settled in secondary sedimentation tank, receiving effluents from the aeration tank), and
- Oxidation ponds and aerated lagoons.

Since all these aerobic units, generally make use of primary settled sewage; they are easily classified as secondary units. The treatment reactors, in which the organic matter is destroyed and stabilized by anaerobic bacteria, are known as anaerobic biological units and may consist of:

- Anaerobic lagoons, Septic tanks, Inhofe tanks, etc.

Out of these units, only anaerobic lagoons make use of primary settled sewage, and hence, only they can be classified under secondary biological units. Septic tanks and Inhofe tanks, which use raw sewage, are not classified as secondary units. The effluent from the secondary biological treatment will usually contain a little BOD (5 to 10% of the original), and may even contain several mg/L of DO. The organic solids/ sludge separated out in the primary as well as in the secondary settling tanks are disposed off by stabilizing under anaerobic conditions in a Sludge digestion tank[6,8].

Tertiary/ advanced wastewater treatment and wastewater reclamation

Advanced wastewater treatment, also called tertiary treatment is defined as the level of treatment required beyond conventional secondary treatment to remove constituents of concern including nutrients, toxic compounds, and increased amounts of organic material and suspended solids and particularly to kill the pathogenic bacteria[11]. In addition to the nutrient removal processes, unit operations or processes frequently employed in advanced wastewater treatment are chemical coagulation, flocculation, and sedimentation followed by filtration and chlorination. Less used processes include ion exchange and reverse osmosis for specific ion removal or for the reduction in dissolved solids. Tertiary treatment is generally not carried out for disposal of sewage in water, but it is carried out, while using the river stream for collecting water for re-use or for water supplies for purposes like industrial cooling and groundwater recharge[9].

Nutrient removal or control

The removal or control of nutrients in wastewater treatment is important for several reasons -

- Wastewater discharges to confined bodies of water cause or accelerate the process of eutrophication,
- Wastewater discharges to flowing streams tax oxygen resources for the removal of nitrogenous BOD thereby depleting the aquatic life, and
- Wastewater discharges when used for groundwater recharging that may be

used indirectly for public water supplies could cause health problems like blue baby diseases in children.

The nutrients of principal concern are nitrogen and phosphorus and they can be removed by biological, chemical, or a combination of processes. In many cases, the nutrient removal processes are coupled with secondary treatment, for example, metal salts may be added to the aeration tank, mixed liquor for the precipitation of phosphorus in the final sedimentation tanks, or biological denitrification may follow an activated sludge process that produces a nitrified effluent[8].

Toxic waste treatment/specific contaminant removal

Physico-chemical treatment such as chemical coagulation, flocculation, sedimentation, and filtration reduces many toxic substances such as heavy metals. Some degree of removal is also accomplished by conventional secondary treatment[10]. Wastewaters containing volatile organic constituents may be treated by air stripping or by carbon adsorption. Small concentrations of specific contaminants may be removed by ion exchange.

Factors affecting selection and design of sewage/ wastewater treatment systems

The collection, treatment and disposal of liquid waste (sewage) are referred to as Sewerage. Sewage systems include all the physical structures required for collection, treatment and disposal of the wastes. In other words, discharged waste waters that are collected in large sewerage networks, transporting the waste from the site of production to the site of treatment comprise Sewage treatment networks (Sewerage system). The most important factors that should be borne in the mind before the selection and design of any sewage/ wastewater treatment system are -

Engineering factors

- Design period, stage wise population to be served and expected sewage flow and fluctuations,
- Topography of the area to be served, its slope and terrain; tentative sites available for treatment plant, pumping stations and disposal works.
- Available hydraulic head in the system up to high flood level in case of disposal into a river or high tide level in case of coastal discharges[10],
- Groundwater depth and its seasonal fluctuations affecting construction, sewer infiltration,
- Soil bearing capacity and type of strata to be met in construction, and
- On site disposal facilities, including the possibilities of segregating sullage and sewage and reuse or recycling of sullage water within the households[9].

Environmental factors

- Surface water, groundwater and coastal water quality where wastewater has to be disposed after treatment,
- Odour and mosquito nuisance which affects land values, public health and well being, and
- Public health considerations by meeting the requirements laid down by the regulatory agencies for effluent discharge standards, permissible levels of microbial and helminthic quality requirements and control of nutrients, toxic and accumulative substances in food chain[8].

Process consideration

- Wastewater flow and characteristics,
- Degree of treatment required,
- Performance characteristics, and
- Availability of land, power requirements, equipments and skilled staff for handling and maintenance.

Cost consideration

- Capital costs for land, construction, equipments etc., and
- Operating costs including staff, chemicals, fuels and electricity, transport, maintenance and repairs etc.

CONCLUSION

The ultimate goal of wastewater management is the protection of the environment in a manner commensurate with public health and socio-economic concerns. Based on the nature of wastewater, it is suggested whether primary, secondary and tertiary treatment will be carried out before final disposal. Understanding the nature of wastewater is fundamental to design appropriate wastewater treatment process, to adopt an appropriate procedure, determination of acceptable criteria for the residues, determination of a degree of evaluation required to validate the procedure and decision on the residues to be tested based on toxicity therefore, it is necessary to ensure the safety, efficacy and quality of the treated wastewater which is the basic requirement of smart cities.

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