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SE-E - Best Practice in Sewage and Effluent Treatment Technologies

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Short Description

This manual has tips and tricks to help you to install an effective Sewage and Effluent Treatment system.

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1. **Wastewater – Introduction**
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This chapter introduces the reader to the earth's ecological system and the impact of water on the system. It also describes the water-use cycle which leads to wastewater generation, the related health and environmental concerns, as well as the nature of regulations to monitor the generation and discharge of wastewater.

Objectives

After studying this chapter, you will be able to

- Understand the basics of earth's ecological system
- Appreciate the specific influence of wastewater on the ecosystem
- Understand the water utilization cycle which leads to wastewater generation
- Gain familiarity with the concerns generated all over the world by the issues related to wastewater management
- Understand the basic nature of the regulations being set up and imposed to monitor and control wastewater discharge
- Understand the planning consideration pertaining to wastewater systems

1. Earth's ecological system

The earth is a spherical mass essentially made of solids and liquids. It is surrounded by a gaseous layer, about 650 km thick, termed the *atmosphere*. The combined system of earth and atmosphere consists of a large number of elements such as living organisms, air, water, soil, minerals, etc, collectively called the *ecosystem*. Living or biological systems depend on non-living systems for their survival. The science of the relationship of all these elements of the ecosystem is known as *ecology*.

Within the ecosystem, water is present over and below the surface of earth in liquid form and also in the atmosphere in essentially gaseous form, known as *vapor*. This entire collection of water in the system, irrespective of its form, is termed the *hydrosphere*. We know that the existence of living organisms is limited to only a few kilometers above and below the earth's surface. This narrow zone is termed the *biosphere*. Incidentally, the majority of the water in the entire ecosystem, in all its forms taken together, is found in the biosphere. This relationship of earth, atmosphere and biosphere is shown in Figure 1.01.

Figure 1.01

Relationship of earth, atmosphere and biosphere

1.1.1 Water – effect on ecology

All the biological elements of the ecological system, whether plants or living organisms, depend on the availability of a number of elements for their survival. The air is needed by all biological organisms to survive. Similarly, water is needed by almost all living organisms for direct consumption as well as to help the survival and growth of other elements that can be used as food by living organisms . Overall, a balance is maintained in the system by maintaining a fixed ration between all the elements. This is known as the ecological balance and is responsible for the existence of all the elements in the system at any instant of time. However, whenever any disturbance takes place in the ecological balance of the universal system, the ratios of the organisms in the universe change to adjust to the new environment. This has been the prime reason for the periodic extinction of certain plants and species.

Since water is one of the major components of the ecosystem, any change in its overall availability or variation in its characteristics is certain to place the ecological balance under threat.

More than 7000 years ago during the Neolithic age, human beings graduated from being hunter/gatherers and following a nomadic existence in sympathy with the migration patterns of the herds of prey animals, to a more sedentary lifestyle. This was made possible by the development of cultivation and harvesting of crops and the domestication of certain livestock.

This development was the start of urbanisation, which profoundly altered not only the history of man, but also the character of the entire planet. Cultivation and urbanisation eventually brought about the development of commerce and trade, thus allowing man to specialize and develop a complex inter-dependent social structure as it exists today.

The very success of this development has brought about its own problems. One of the earliest was, and continues to be, the problem of accumulation of waste materials in a densely populated area, with associated aesthetic and health implications.

As far back as the Roman era, water-carried sewage was introduced in urban areas to remove excreta in a hygienic and nuisance-free manner. For this, the water used to be transported to a town by a system of canals, pipes and aqueducts; human excreta was mixed into it and the mixture, called *sewage*, was discharged to the nearest river or stream. The stream eventually carried the waste to the sea. This system is still being followed in modern cities and towns.

This system, however, has a problem. The rivers or streams that are used as carriers of sewage are also the source of water supply to the population lining their banks. As a substantial quantity of sewage often mixed with industrial effluents is discharged into it, the quality of the available water deteriorates. Such water may turn unfit for human consumption as well as for irrigation. The shortage of water fit for these crucial purposes can disturb the ecological balance and thus is not sustainable in the long run; hence the need to monitor the quality of the wastewater discharged.

In addition, large and densely populated urban areas are regularly being established. This not only has increased the amount of waste, but has also resulted in a severe shortage of water for both consumption and recreational purposes. Consequently, it has been necessary for some time to minimize and try to eliminate degradation of water. This has led to the development of increasingly sophisticated means of wastewater handling and treatment.

1.1.2 Wastewater generation

Human communities generate waste in several ways. One is the solid waste generated by the inhabitants. The other is liquid waste – essentially the water supplied for various purposes mixed with certain ingredients post use. These water applications can be classified as below.

- Domestic applications – In their houses, people flush their toilets, take showers, wash their dishes and perform many other normal tasks that feed the sewer systems. These activities essentially generate sewage containing human excreta, kitchen waste, laundry waste, etc.
- Institutional applications – these generate biomedical waste, soap-water, pharmaceutical waste, etc.
- Industrial applications – these have the potential to generate vast varieties of waste, depending on the nature of the industry creating the waste. The prominent effluent generating industries are chemicals/petrochemicals, mineral/metal processing, dyes, pigments, thermal power, nuclear power, tanneries, etc. The effects on water from the effluents discharges from these industries can be far reaching.

Besides these, the rainwater collected on the earth’s surface also contributes to wastewater generation. This water can contain elements such as soil, pesticides/insecticides, etc, though the effect is only seasonal. A schematic diagram of wastewater generating sources along with the respective discharges is shown in Figure 1.02.

Since ingredients added to water during its application can either be liquid or solid, the wastewater can be classified as a fluid with both liquid and solid phases. As we will observe, these phases require different kinds of treatment.

Figure 1.02

Wastewater – sources and discharge

1. Wastewater – impact and regulations

As we now understand that water is an important part of ecological system, the adverse effect of wastewater on the ecology can be profound.

1.2.1 Impact

Depending on its source, the nature of raw wastewater can be fairly benign to dangerously hazardous towards human health and the environment. Since living beings on earth are dependent on the existence of water for their survival, the impact of water degradation can be deep. Here, it is important to make clear that when we use the term ‘water’, it means the kind of water fit for use for the specific purpose. In the case of human beings, it has to be potable water for direct consumption. In the case of animals, some characteristics may be compromised to a certain extent but it still has to be free from total degradation. In the case of water used for irrigating plants and crops, it needs to be free from toxic elements.

As observed earlier, a number of factors have jointly contributed to the rapid degradation in water quality. These are listed below.

- With industrialization came the utilization of water in industry. Effluent discharge from these has made a major contribution towards water contamination.
- Civilization has adopted the water-carriage system to transfer domestic and institutional sewage. As the very purpose of water-borne sanitation is

to remove offensive waste products from urban areas, it clearly could be expected to contain large amounts of such ‘pollutants’. This has resulted in a heavy load of sewage being discharged into water bodies.
- With the advancement in agriculture and farming, the application of pesticides, insecticides and chemical fertilisers is on the rise. The rainwater falling on the fields captures these elements which add to the water bodies along with surface run-off.

These contaminants are present not only in the form of suspension, which could be readily removed by procedures such as screening and/or sedimentation, but also in the dissolved form. The contaminants include relatively large organic molecules and reduced nitrogen compounds, the latter either bound in proteinaceous material or present as free and saline ammonia. Very large numbers of various pathogenic micro-organisms are also found in the wastewater.

In its untreated form, domestic wastewater possesses a heavy oxygen demand and consequently cannot be discharged without adequate treatment. Unless the oxygen demand of the effluent is adequately met through suitable treatment, the disinfection of the effluent by chemical oxidants, such as chlorine, remains problematic and economically unviable.

The systematic treatment of wastewater prevents nuisances such as offensive odorsodours, fly-breeding, development of acidic conditions in soil receiving the discharge that renders it impervious to water, development of anaerobic conditions in receiving watercourses, etc. Consequently, effluent presents a health hazard.

The magnitude of water available for plants and living beings is an important factor influencing their time on earth. The overall amount of water available in all its form does not change significantly in the medium term of, say, a few decades. What has the potential to change more rapidly is the extent of its contamination, which can alter the ecological balance on the earth. The adverse effects of this impact are already being felt.

1.2.2 Regulatory environment

Up until the middle of the twentieth century, wastewater generation was essentially caused by municipal sources. This situation has changed post industrialization. The overall effect is the generation of more hazardous effluent.

The factor that has brought the issue of water pollution onto center stage is the increased capability and effectiveness of the detection system. This capability has gone up substantially in the last few decades. Though the exact effect of a number of chemical substances on living beings is still a matter of study, the belief about their being harmful is firm. Incidentally, water and wastewater treatment technology itself has not kept pace with the advances in detection capability and a lot is still left to be desired. However, the trend indicates a change in outlook. The realization is setting in that water contamination should best be controlled at the source itself. The effect of this is the worldwide creation of comprehensive legislative provisions and statutes on the subject.

The concern about wastewater treatment and control is a recent phenomenon. It has only been since the early part of the twentieth century that people have started realizing the need for a scientific approach to the treatment of wastewater. From then till the seventies, the focus was on undertaking treatment with the following objectives.

- Elimination of harmful pathogenic organisms
- Removal of floating, colloidal and suspended materials
- Treatment of biodegradable organics

Post the seventies, awareness about environmental damage started creeping in. Various governments turned proactive and a number of legislations were formulated. For instance, the United States government implemented the Federal Water Pollution Control Act Amendments of 1972, proposing substantial changes in wastewater treatment and management. Several more governments followed. During the decades of the seventies and the eighties, wastewater treatment objectives were primarily based on environmental issues. The earlier objectives involving the reduction of harmful bio-organisms and suspended solids also continued with more vigour. Issues relating to the handling of nutrients, such as nitrogen and phosphorus, also began to be addressed particularly in the case of the inland rivers and streams. Governments undertook major programs in order to have more effective and widespread treatment of wastewater that helped improve the quality of surface waters. The result is the setting up a number of treatment plants and handling facilities. A typical wastewater treatment facility is shown in Figure 1.03.

Figure 1.03

Typical wastewater treatment facility

During this period, the increased understanding of the adverse environmental effects caused by wastewater discharges was helpful in the implementation of these programs. This was supported by a better appreciation of the unfavorable long-term effects caused by the discharge of some specific constituents. As a result, significant improvements were recorded in the quality of both surface and sub-surface water in several regions of the world.

In the last two decades of the twentieth century, the work pertaining to the earlier decided water-quality improvement objectives continued. The emphasis shifted towards classification, treatment and removal of constituents that may cause long-term health effects on living beings and can cause adverse environmental impacts. As a result, the degree of treatment desired went up significantly and additional treatment objectives got added.

1.3 Wastewater Management System

Any wastewater management system can be divided into the following:

- Wastewater collection
- Wastewater treatment
- Wastewater disposal

To elaborate on these terms, *collection* refers to intercepting all the wastewater and transporting it to one or more locations for further processing.

Treatment refers to the physical, chemical or biological processes, or their combination, that are used to bring harmful content of the wastewater to acceptable limits.

Disposal refers to the discharge of the wastewater to a land or water body, either with or without treatment.

All these steps are discussed in detail in subsequent chapters.

1.34 Planning

Wastewater system planning is done at different levels, as is listed below:

- National level
- Provincial level
- Regional level
- Local level

At each level, the institutions responsible for planning have different responsibilities. The national and provincial level bodies decided overall priorities. The regional level body determines the distribution of available resources and for setting up the system. For individual locations, this is done on the basis of the assessment made and recommendation given by the local bodies. The local bodies are also made responsible for setting up and operating the wastewater system.

1.34.1 Planning considerations

As stated above, the national and provincial level planning decides the overall norms for the treatment and disposal of the wastewater system. The parity in the standards ensure that all regional level and local level bodies adopt a similar approach towards the development and setting up of the wastewater system. The provincial body also studies the following.

- Potential to set up a system that caters to more than one region
- Possibility of merger/integration of the current local systems to improve their effectiveness
- Order of priority between a number of local/regional projects

The planning to set up individual wastewater systems is normally the responsibility of the regional and local bodies. In order to undertake the planning, the following aspects are given consideration.

Physical aspects – This investigation is carried out at the local level. Existing maps and plans are used apart from site reconnaissance. The following information is gathered during this study.

- Topography and contours
- Soil and subsoil conditions
- Existing underground utilities

Fiscal aspects – This investigation is carried out at local and regional levels. The basic information gathered is:

- Estimate of investment required
- Outstanding liabilities
- Current obligations for the water/wastewater segment
- Current tariff structure and potential of revision
- Availability of fresh loans or grants

Development aspects – This investigation is carried out at the regional and provincial levels. The investigation studies the following aspects:

- Population and demography including future trends
- Current industrial and commercial activities
- Planned land use on the basis of potential available
- Socio-economic data

1.34.2 Financing

The cost of the wastewater system consists of the following.

- Project cost – inclusive of cost incurred on investigations, land acquisition, capital cost of the physical assets, design cost, consultant’s fees, interest cost, etc. These are normally one time costs.

- Operation and maintenance (O&M) costs – inclusive of cost of energy to operate the system, manpower cost, consumable cost, repair cost, spare costs, etc. These are recurring costs.

The financing plan for any wastewater project is prepared after determining all the above costs. Item-wise estimates for the project cost as well as O&M costs are prepared for the purpose, always allowing for unforeseen expenses and contingencies. Future O&M costs are suitably modified to take care of inflation. The financial plan for the project is thus developed by evaluating sources of funds.

To take care of project implementation and its O&M, the following sources can be tapped for funding.

- Internal resources available with the local/regional body
- Loans form the government
- Loans from (development) financial institutions
- Grants from the government
- Grants from multilateral bodies like the World Bank
- Borrowing from capital market through issue of bonds
- User charges on the basis of tariff structure

Financing is an important aspect of wastewater planning, since large capital investment is needed for the development and setting up of a completely integrated wastewater management system. In order to recover the capital invested, financing expenses and operation and maintenance expenses, a user levy is applied. There are a number of methods to apply this levy. In the case of household sewage, this levy is fixed in relation to the treated water consumed as the sewage quantity produced is a function of the water consumed. In the case of industrial wastewater, the rate can be fixed per connection or on the basis of the actual quantity measured.

1.4 Summary

Water is an important element in the earth's ecological system. Rapid industrialization has been putting severe pressure on the ecological system by loading the water sources with pollutants. This approach has limited sustainability and this fact is clearly being recognised. A number of stringent regulations and norms are being imposed on polluting agencies. We have studied all these aspects in this chapter. Apart from this, we have gone through the planning considerations pertaining to wastewater system and the arrangement for its financing.

In subsequent chapters, we will come across the technical and the planning related approaches being adapted to effectively deal with the situation.