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Recycling of Water: A Review on Wastewater Treatment

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ABSTRACT

Wastewater can be defined as the flow of used water discharged from homes, businesses, industries, commercial activities and institutions which are directed to treatment plants by a carefully designed and engineered network of pipes. This wastewater is further categorized and defined according to its sources of origin. Typically 200 to 500 liters of wastewater are generated for every person connected to the system each day. The amount of flow handled by a treatment plant varies with the time of day and with the season of the year.

The processes reviewed here include both those that remove pollutant contaminants in wastewater and those that destroy them. Using a wastewater treatment technology that removes, rather than destroys, a pollutant will produce a treatment residual. At wastewater treatment plant, this flow is treated before it is allowed to be returned to the environment, lakes, or streams. There are no holidays for wastewater treatment, and most plants operate 24 hours per day every day of the week. Wastewater treatment plants operate at a critical point of the water cycle, helping nature defend water from excessive pollution. Most treatment plants have primary treatment (physical removal of floatable and settleable solids) and secondary treatment (the biological removal of dissolved solids).

A short description about the primary treatment which includes screening, grit chambers and sedimentation tank whereas secondary treatment involves activated sludge, trickling filters etc. and also to measure of carbon removal in the wastewater treatment processes can be done by TOC, BOD, and COD is also discussed here.

Keyword: *Wastewater, primary treatment, secondary treatment, BOD, COD, etc.*

INTRODUCTION

Wastewater is defined by the Committee on Sewerage and Sewage Disposal of the American Public Health Association as "a combination of (a) the liquid wastes conducted away from residences, business buildings, and institutions and (b) from industrial establishments, with (c) such ground, surface and storm water as may be admitted to or find its way into the sewers[4]. This means that wastewater includes water from residential, industrial, and commercial sources. The water people use every day that goes down the drain from baths, sinks, dishwashers, and toilets accounts for only a portion of the total water usage.

Removal of solids from wastewater is necessary because as solid waste decays, it consumes oxygen and depletes the oxygen in whatever body of water it was added to, causing great harm to aquatic organisms. Treated wastewater can be reused in a variety of ways, such as, for drinking water, in industrial settings, or in agricultural settings[3].

Untreated waste-water generally contains high levels of organic material, numerous pathogenic microorganisms, as well as nutrients and toxic compounds. It thus entails environmental and health hazards and, consequently, must immediately be conveyed away from its generation sources and treated appropriately before final disposal. The ultimate goal of waste-water management is the protection of the environment in a manner commensurate with public health and socio-economic concerns[5].

At wastewater treatment plants, this flow is treated before it is allowed to be returned to the environment, lakes, or streams. Wastewater treatment plants operate at a critical point of the water cycle, helping nature defend water from excessive pollution. Most treatment plants have primary treatment (physical removal of floatable and settleable solids) and secondary treatment (the biological removal of dissolved solids).
Wastewaters after travelling through pipes to reaches to wastewater treatment plants, where it is either treated and returned to streams, rivers, and oceans or reused for irrigation and landscaping. At the plant, equipment and processes remove or destroy harmful materials, chemical compounds, and microorganisms from the water. Pumps, valves, and other equipment move the water or wastewater through the various treatment processes, after which they dispose of the removed waste material[6].

MEASURING WATER QUALITIES[7]

To measure carbon removal in these wastewater treatment processes, several approaches can be used. Carbon removal can be measured:

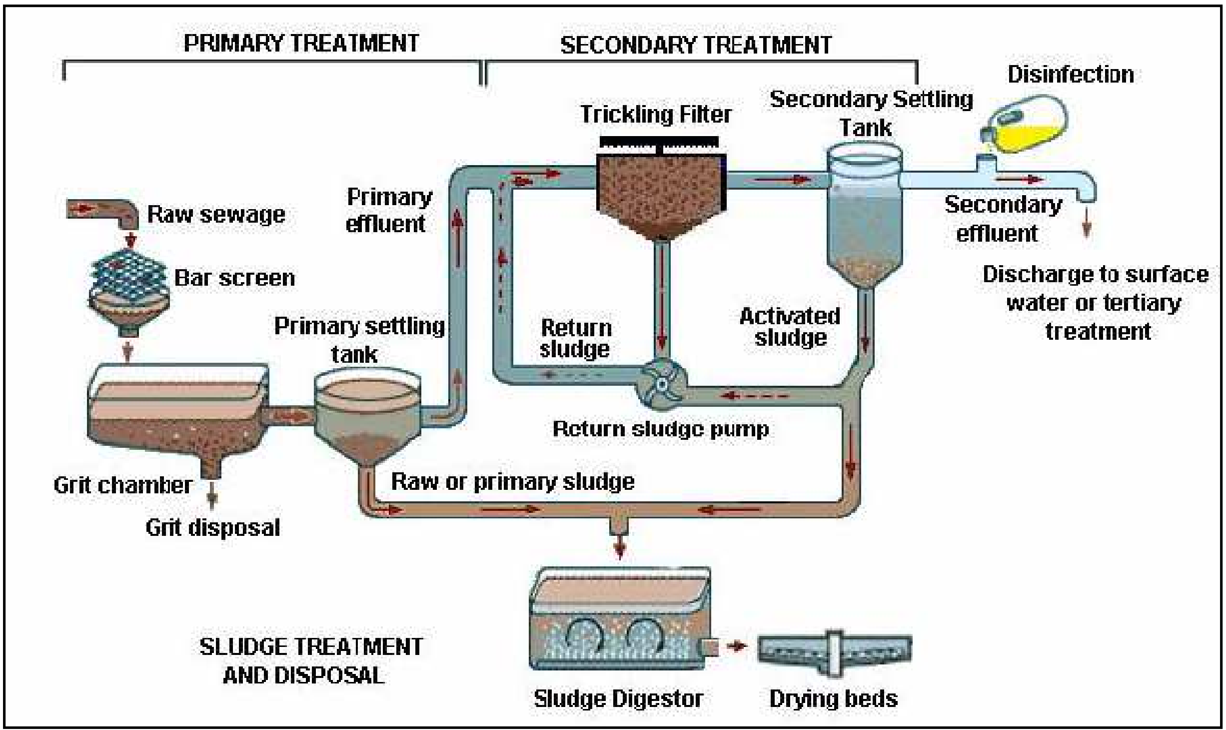
- As total organic carbon (TOC),
- As chemically oxidizable carbon by the chemical oxygen demand (COD) test,
- As biologically usable carbon by the biochemical oxygen demand (BOD) test,

The TOC includes all carbon, whether or not it is usable by microorganisms. This is carried out by oxidizing the organic matter in a sample at high temperature in an oxygen stream and measuring the resultant CO_2 by infrared or potentiometric techniques. The COD gives a similar measurement, except that lignin often will not react with the oxidizing chemical, such as permanganate, that is used in this procedure. The BOD test, in comparison, measures only the portion of the total carbon that can be oxidized by microorganism in a 5-days period under standard conditions.
The biochemical oxygen demand is an indirect measure of organic matter in aquatic environments. It is the amount of dissolved O_2 needed for microbial oxidation of biodegradable organic matter. When O_2 consumption is measured, the O_2 itself must be present in excess and not limit oxidation of the nutrients. To achieve this, the waste sample is diluted to assure that atleast 2mg/lit of O_2 are used while atleast 1mg/lit of O_2 remains in the test bottle. Ammonia released during organic matter oxidation can also exert an O_2 demand in the BOD test, so nitrification or the nitrogen oxygen demand (NOD) is often inhibited by 2-chloro-6-(trichloromethyl) pyridine (nitrapyrin). In the normal BOD test, which is run for 5days at 20C on untreated samples, nitrification is not a major concern. However, effluents are analyzed, NOD can be a problem.
In terms of speed, the TOC is fastest, but less informative in terms of biological processes. The COD is slower and involves the use of wet chemicals with higher waste chemical disposal costs. The TOC, COD and BOD provide different but complementary information on the carbon in a water sample. It is critical to note that these measurements, concerned with carbon and carbon removal, do not directly address concerns for removal of minerals such as nitrate, phosphate, and sulfate from waters. These minerals are having worldwide impacts on cyanobacterial and algal growth in lakes, rivers, and the oceans by the contributing to the process of eutrophication. The removal of dissolved organic matter and possibly inorganic nutrients, plus inactivation and removal of pathogens are important parts of wastewater treatment.

WATER TREATMENT PROCESSES

The aerobic self-purification sequence that occurs when organic matter is added to lakes and rivers can be carried out under controlled conditions in which natural processes are intensified. This often involves the use of large basins (conventional sewage treatment) where mixing and gas exchange are carefully controlled.
Conventional wastewater treatment normally involves primary, secondary, and tertiary treatment:

Fig.1: Stages of wastewater treatment



- **Primary Treatment** can physically remove 20 to 30% of the BOD that is present in particulate form. In this treatment, particulate material is removed by screening, precipitation of small particulates, and settling in basins or tanks. The resulting solid material is usually called sludge[7].

1. **Screening**
The raw influent first goes through a self-cleaning screen and then into one end of a shallow and rather fast moving basin so that sand and gravel can settle out. The screen removes coarse and floating solids from the sewage. The screen must be cleaned regularly and the removed solids must be burned, ground and digested, or buried[1].
2. **Grit chamber**
A chamber in which the velocity of waste flow is reduced to a point where the denser sand and other grit will settle out, but the organic solids will remain in suspension. The settled material is buried or used for fill[1].
3. **Primary settling tank**
These are usually large tanks in which solids settle out of water by gravity where the settle-able solids are pumped away (as sludge), while oils float to the top and are skimmed off. The velocity of flow is reduced to about 0.005 m so that the suspended material will settle out with a detention time of 11/2–21/2 hours because longer periods usually result in depletion of dissolved oxygen and subsequent anaerobic conditions[1].
4. **Sludge digestors**:
The sludge which settles in the sedimentation basin is pumped to the sludge digestors with a temperature of 30–35ºC. Continual adding of raw sludge is necessary and only well-digested sludge should be withdrawn, leaving some ripe sludge in the digestor to acclimatise the incoming raw sludge[1].
5. **Drying beds:**
Digested sludge is placed on drying beds of sand (*see* figure 2–8) where the liquid may evaporate or drain into the soil. The dried sludge is a porous humus-like cake which can be used as a fertiliser base[1].

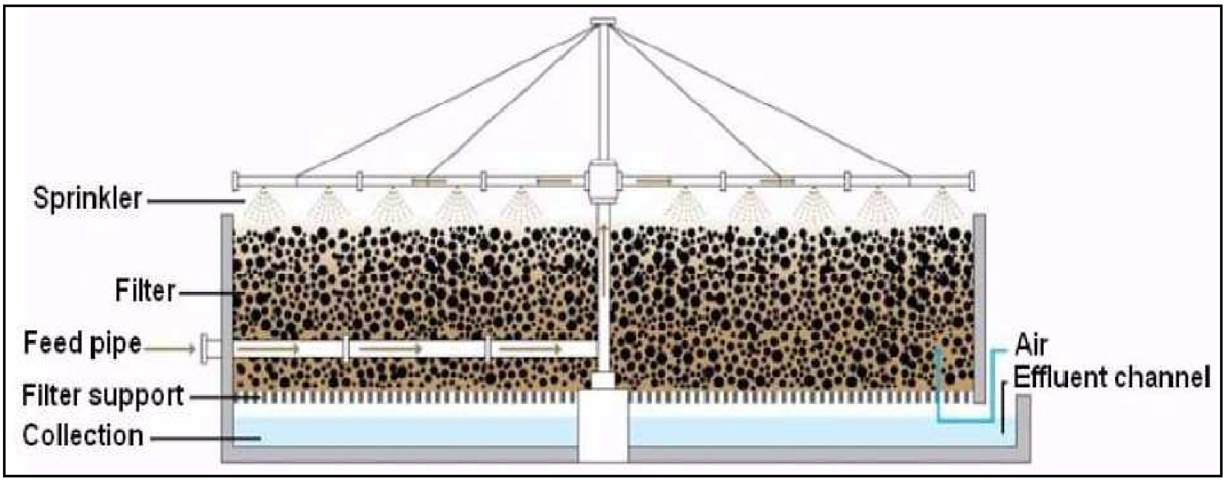
- **Secondary Treatment** is used after primary treatment for the biological removal of dissolved organic matter. About 90 to 95% of the BOD and many bacterial pathogens are removed by this process. Several approaches can be used in secondary treatment to biologically remove dissolved organic matter. All of these techniques involve similar microbial activities. Under aerobic conditions, dissolved organic matter will be transformed into additional microbial biomass plus carbon dioxide. Under ideal conditions the microorganisms will aggregate and form a settable floc structure. Minerals in the water also may be tied up in microbial biomass. When microorganisms grow, flocs can form. A healthy settable floc will be compact. In contrast, poorly formed floc can have a network of filamentous microbes that will retard settling.

When these processes occur with lower O_2 levels or with a microbial community that is too young or too old, unsatisfactory floc formation and settlings can occur. The result is bulking sludge, caused by the massive development of filamentous bacteria such as *Sphaerotilus* and *Thiothrix,* together with many poorly characterized filamentous organisms. These important filamentous bacteria form flocs that do not settle well, and thus produce effluent quality problems[7].

1. Trickling filters:

A trickling filter is a fixed bed, biological filter that operates under (mostly) aerobic conditions. Pre-settled wastewater is 'trickled' or sprayed over the filter. As the water migrates through the pores of the filter, organics are degraded by the biomass covering the filter material.

Figure 2: Trickling filter



The liquid effluent from the primary settling tank is passed to the secondary part of the system where aerobic decomposition completes the stabilisation. The incoming wastewater is sprayed over the filter with the use of a rotating sprinkler then the filter media goes through cycles of being dosed and exposed to air depleting oxygen within the biomass and the inner layers may be anoxic or anaerobic. Depending on the rate of flow and other factors, the slime will slough off the rocks at periodic intervals or continuously, whenever it becomes too thick to be retained on the stones. A secondary settling basin is necessary to clarify the effluent from the trickling filter. The overall reduction of BOD for a complete trickling filter system averages around 80–90 per cent[1].

2. Secondary settling tank:

With the majority of the suspended material removed from the sewage, the liquid portion flows over a weir at the surface of the secondary settling tank. Chlorination of the effluent from the secondary settling tank takes place in accordance with state and local laws. Depending on the location most laws require that a free available chlorine (FAC) residual (usually 0.2 mg/L) be maintained after a 30-minute contact period. This contact period is obtained through the use of chlorine contact chambers which are designed to provide a 30-minute detention time. From the chlorine contact chamber the treated sewage is normally discharged into a receiving body of water[1].

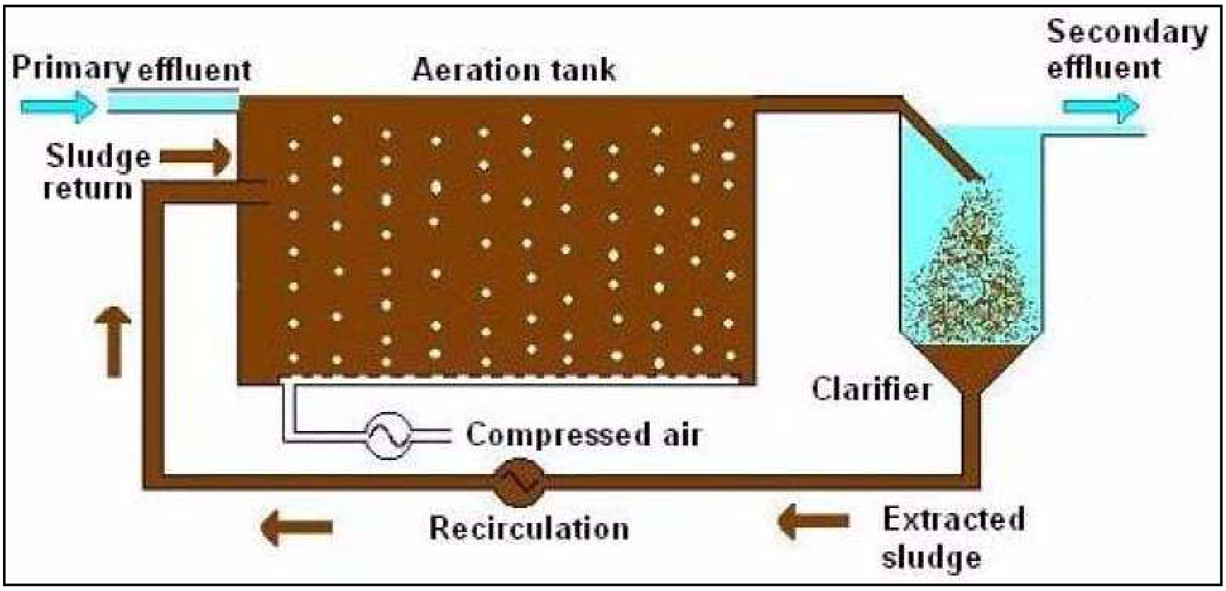
3. **Activated sludge[7]**

Microorganisms play a critical role in the functioning of activated sludge systems. The operation is dependent on the formation of settable flocs.

- If the plant does not run properly, poorly settling flocs
- Can form due to such causes as low aeration, sulfide, and acidic organic substrates. These flocs do not settle properly because of their open or porous structure. As a consequence, the organic material is released with the treated water and lowers the quality of the final effluent.

An aerobic activated sludge system involves a horizontal flow of materials with a recycle of sludge- the active biomass that is formed when organic matter is oxidized and degraded by microorganisms. Activated sludge systems can be designed with variations in mixing. In additions, the ratio organic matter added to the active microbial biomass can be varied. A low rate system (low nutrient input per unit of microbial biomass), with slower growing microorganisms, will produce an effluent with low residual levels of dissolved organic matter. A high rate system (high nutrient input per unit of microbial biomass), with faster growing microorganisms, will remove more dissolved organic carbon per unit time, but produce a poorer quality effluent.

Fig.3: Activated sludge system



Aerobic secondary treatment also can be carried out with a trickling filter. The waste effluent is passed over rocks or other solid materials upon which microbial films have developed, and the microbial community in these films degrades the organic waste. A sewage treatment plant can be operated to produce less sludge by employing the extended aeration process. Microorganisms grow on the dissolved organic matter, and the newly formed microbial biomass is eventually consumed to meet maintenance energy requirements. This requires extremely large aeration basins and extended aerations times. In addition, with the biological self-utilization of the biomass, minerals originally present in the microorganisms are again released to the water.

All aerobic processes produce excess microbial biomass, or sewage sludge, which contains many recalcitrant organics. Often the sludge from aerobic sewage treatment, together with the materials settled out in primary treatment, are further treated by anaerobic digestion. Anaerobic digestions are large tank designed to operate with continuous input of untreated sludge and removal of final, stabilized sludge product. Methane is vented and often burned for heat and electricity production. This digestion process involves three steps:

- The fermentation of sludge components to form organic acids, including acetate.

- Production of methanogenic substrates: acetate, CO_2, hydrogen.
- Metanogenesis by the methane producers. These metanogenenic processes, involve critical balances between oxidants and reductant.

➢ **Tertiary Treatment[7]**

It purifies wastewater more than is possible with primary and secondary treatments. It is particularly important to remove nitrogen and phosphorus compounds that can promote eutrophication. Organic pollutants can be removed with activated carbon filters. Phosphate usually is precipitated as calcium or iron phosphate. Excess nitrogen may be removed by "stripping", volatization as NH3 at high pHs. Ammonia itself can be chlorinated to form dichloramine, which is then converted to molecular nitrogen. In some cases, biological processes can be used to remove nitrogen and phosphorus. A widely used process for nitrogen removal is denitrification. Here nitrate, produced under aerobic conditions, is used as an electron acceptor under conditions of low oxygen with organic matter added as an energy source. Nitrate reduction yields nitrogen gas and nitrous oxide (N_2O) as the major products. Currently there is a great deal of interest in anaerobic nitrogen removal processes. These include the anammox process where ammonium ion (used as the reductant), is reacted with nitrite (the oxidant) produced by partial nitrification. By use of this process, as carried out in Holland, the partial nitrification step gave a 53% transformation to nitrite, and no nitrate production. When reacted with the ammonium ion in the anammox process, a total of 80% of the beginning ammonium ion was converted to N_2 gas, showing the value of this new technology. For phosphorus removal, aerobic conditions are used alternately in a series of treatments, and phosphorus accumulates in specially adapted microbial biomass as polyphosphate. Tertiary treatment is expensive and usually not employed except where necessary to prevent obvious ecological disruption.

CONCEPTUAL APPROACH OF BOD AND COD[1]

The amount of oxygen necessary for the stabilisation (decomposition) of organic material in sewage under aerobic conditions is called BOD indicating the amount of organic matter present in the sewage. The BOD test is a measure of the oxygen requirements of bacteria and other organisms as they feed upon and cause decomposition of organic matter. A high BOD will result in water becoming anaerobic (depleted of oxygen), therefore a measure of the organic load placed on the treatment facility. Industrial non-organic wastes can also deplete oxygen in the water, and this is measured by the chemical oxygen demand (COD) test.

- COD is a measure of the oxidisability of waste, expressed as the equivalent amount in oxygen of a strong oxidizing agent consumed by the waste under fixed laboratory conditions. The dichromate reflux method is preferred over other methods using other oxidants such as potassium permanganate because of:

a. Its superior oxidizing ability,

b. Applicability to a wide range of wastes, and

c. Ease of use.

In the dichromate reflux method, a predetermined amount of waste is dissolved or dispersed in water and oxidised by potassium dichromate in a strong sulphuric acid medium with silver sulphate as the catalyst under reflux for two hours. The residual dichromate is determined by titration with standardised ferrous ammonium sulphate. In the case of wastes containing chlorine, mercuric sulphate is added to reduce chloride interference. The result of analysis for COD is expressed in mg/L (ppm).

- BOD is normally expressed in mg/L or parts per million for a specified time and temperature, the standard being five days at 20ºC. The five-day, 20ºC BOD does not represent the total demand of a sample for oxygen. Only about two-thirds of the total oxygen demand of a domestic sewage sample is satisfied in five days at 20ºC, and almost all of the demand in 20 days at 20ºC. It would be very time-consuming to attempt to determine the total demand by incubating samples for 20 or more days. For this reason the five-day BOD test has been accepted as a practical standard.

The five-day BOD test is used as a control at nearly all sewage treatment facilities. The adequacy and degree of sewage treatment may be judged by the total reduction that occurs in the five-day BOD of the sewage as it flows through the sewage treatment facility. Also, standards are established by various governmental control agencies which set limits on the five-day BOD of treated sewage that may be legally discharged into a receiving stream.

The general procedure for determining a BOD involves filling two BOD bottles with the water sample that has had its pH corrected to 7, and any chlorine present neutralized with three drops of a one per cent solution of sodium thiosulphate. DO is measured in the first bottle at time zero, and in the second bottle after five days storage in the dark at 20ºC. The difference between the two when multiplied by the dilution factor gives the BOD in mg/L or ppm. This is the oxygen consumed by microorganisms in the sample as they digest the organic matter present, over five days at 20ºC. A rapid BOD can be determined in two and a half days at 37ºC and this has been determined to be equivalent to the five day test at 20ºC.

INSTRUMENTATION AND CONTROL IN WASTE-WATER TREATMENT FACILITIES:

Waste-water treatment processes are characterized by continuous disturbances and variations that cannot be detected by manual measurements with the precision and within the time span necessary for maintaining proper operation of the facility. Typical process disturbances include process inputs and conditions such as variable flow rates, chemical and biological composition, temperature and density[2].

Following components are used as instrumentation:

a) **Measuring devices-** Measuring devices, referred to as sensors, include instruments that sense, measure or compute the process variables. These variables fall into three categories: physical (flow, pressure, level, temperature, etc.), chemical (pH, oxidation-reduction potential, turbidity, specific conductance, dissolved oxygen, chlorine residual, and so on) and biological (oxygen consumption rate, TOC reduction rate, sludge growth rate, etc.)

b) **Signal-transmitting devices -** The function of a signal-transmitting device is to transmit a process variable signal from a sensor to a readout device or controller. The signal may be transmitted *mechanically*, by means of the movement of a pen, indicator, float or cable, *pneumatically* by means of a detector or an amplifier, or *electronically* by means of voltage and current, pulse duration, or tone.

Radio/microwave transmission has recently been developed and put into practice. This transmission method is particularly advantageous where the gathering points are scattered over a large area and where telephone lines are either not available or prohibitively expensive. Electronic and radio/microwave control systems are becoming more attractive for a number of reasons[2].

c) **Data display readout -** Readout devices display the transmitted operation in a configuration that is usable by the operator. The most common types of readout devices are indicators, recorders, and totalizers on panels or computer screens. The data display is placed either locally, close to the equipment site, or at a central operating room for the whole facility.

d) **Control systems -** control systems may be discrete or continuous. In discrete control, the status of equipment and status changes (digital measurement) are correlated with a preset value or programmed of events. The operation may be initiated manually by the operator, using a push button, or automatically by an internal process-generated event. Continuous control, on the other hand, requires analog measurement for its input and manipulates a final control element as its output. The control element may be feedback and feed forward control loops and control systems or controllers. The devices automatically regulate the control variable[8].

e) **Data acquisition systems -** Data acquisition systems effectively accumulate, format, record, and display data transmitted from sensors. Modern data acquisition systems commonly referred to as Supervisory Control and Data Acquisition (SCADA) systems, can provide accurate, impartial documentation of process measurements and operator actions. In addition to data accumulation and processing, SCADA systems can produce the necessary process corrections such as chemical solutions, air supply, pump scheduling, and so on.

f) **Artificial intelligence -** New technological advances have made it feasible to use artificial intelligence for the monitoring and control of operations in a waste-water treatment plant. Three systems have been developed for that purpose, namely, expert systems, fuzzy control systems, and neural networks. Expert systems were the first to be developed, followed by fuzzy control systems. Neural networks are relatively new and have not yet been extensively developed for use in waste-water management[9].

g) **Application in the waste-water treatment plant -** There are many factors that determine the need for instrumentation and control elements in wastewater systems. These factors include the size of the facility, hours of manned operation, complexity of the process, reliability requirements, and availability of instrumentation maintenance personnel. Ultimately, most of the resultant decisions are made on an economic basis. The decision to use instrumentation, automation, and control in waste-water treatment systems should be made early in the conceptual design phase of a facility, as it influences the design of the entire system; the size and configuration of existing vessels, tanks, channels, pipes and mechanical equipment will frequently have to be substantially altered to accommodate good instrumentation and control practices[2].

h) **New directions -** As new and more sophisticated instrumentation is developed, waste-water characterization is likely to improve in the years to come. With devices that can measure values of micrograms and even nanograms per liter, contaminants that are present only in trace amounts will be accurately detected. Improved characterization of waste-water, made possible by more sensitive detection methods and advanced analytical techniques, will also yield more knowledge about the behavior of waste-water constituents and their relationship to process performance. This is especially true for biological treatment processes, where microbiological techniques, including RNA and DNA typing, help optimize process performance. As process modeling becomes more accurate, the design and operation of waste-water treatment facilities will be greatly enhanced[6].

CONCLUSION

Waste-water treatment is becoming ever more critical due to diminishing water resources, increasing waste-water disposal costs, and stricter discharge regulations that have lowered permissible contaminant levels in waste streams. The treatment of waste-water for reuse and disposal is particularly important for all the regions of the world.

Effective waste-water collection and treatment are of great importance from the standpoint of both environmental and public health. Extensive research activity in this field has led to significant improvement and diversification in the processes and methods used for waste-water treatment and sludge management. The present study begins with brief descriptions of the various technologies commonly used for waste-water treatment.

Wastewater includes water from residential, industrial, and commercial sources. The water people use every day that goes down the drain from baths, sinks, dishwashers, and toilets accounts for only a portion of the total water usage. . Treated wastewater can be reused in a variety of ways, such as, for drinking water, in industrial settings, or in agricultural settings. Untreated waste-water generally contains high levels of organic material, numerous pathogenic microorganisms, as well as nutrients and toxic compounds. It thus entails environmental and health hazards and, consequently, must immediately be conveyed away from its generation sources and treated appropriately before final disposal. The ultimate goal of waste-water management is the protection of the environment in a manner commensurate with public health and socio-economic concerns.

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