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Wastewater Treatment Process by Physicochemical Methods

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ABSTRACT: Physicochemical processes of wastewater treatment are most evident in the primary treatment facilities of a wastewater treatment plant. Flow equalization, a method to improve wastewater treatment processes, balances out the process parameters, such as flow rate, organic loading, strength of wastewater streams, pH, and temperature over a 24-hour period. This review categorizes the basic types of flow equalization systems. It describes physicochemical wastewater treatment processes such as screening, floatation, sedimentation, coagulation and flocculation, filtration, adsorption, chemical oxidation, membrane separation and ion exchange in detail. For organic-rich food and agricultural wastewater. For organic-rich food and agricultural wastewater, biological treatment has unrivaled advantages. However, physicochemical processes are still important in treating this type of wastewater streams. The ultimate choices of physicochemical processes for a given treatment task are largely dependent upon the deliberate consideration of technological and economical facts within the constraints of treatment requirements and regulatory compliance.

KEYWORDS: physicochemical, wastewater, treatment, economical, technological, equalization, strength

I. INTRODUCTION

Contaminated water contains particles of different sizes which can be classified as dissolved (< 0.08 μm), colloidal (0.08 - 1 μm), supracolloidal (> 100 - 100 mm) and settleable (> 100 μm) (1 and 2).

The type of treatment selected depends on the size of particles present in the wastewater. In practice, treatment efficiency also depends on particle size.

Solids of the size that are visible to the naked eye can be separated either by settling under the influence of gravity or by flotation, depending on the relative densities of solids and water. They may also be easily separated by filtration. However, very fine particles of a colloidal nature (called colloids, size < 1 μm) which have high stability are significant pollutants. The reason for this stability is that these particles have electrostatic surface charges of the same sign (usually negative). This means that repulsive forces are created between them, preventing their aggregation and subsequent settling. It has therefore proved impossible to separate them by settling or flotation. It is not possible to separate these solids by filtration because they pass through any filter. However, separation by physico-chemical treatments is possible.

Physico-chemical treatment of wastewater focuses primarily on the separation of colloidal particles. This is achieved through the addition of chemicals (called coagulants and flocculants). These change the physical state of the colloids allowing them to remain in an indefinitely stable form and therefore form into particles or flocs with settling properties (3, 4 and 5).

Stages of The Physico-Chemical Process

The physico-chemical process consists of coagulation, flocculation and sedimentation stages (Figure 1). However there may be configurations where all stages are carried out in the same unit (6, 7, 8, 9 and 10).

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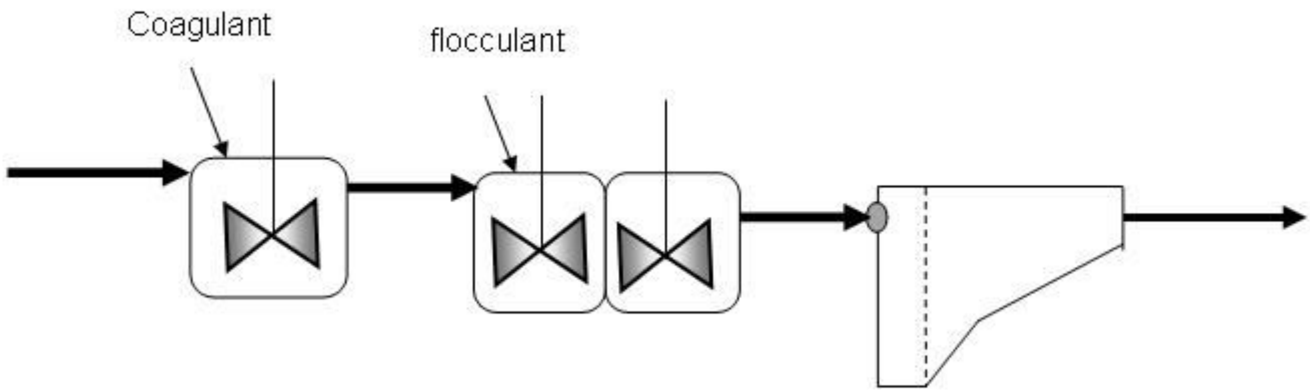

Figure 1. Components of conventional physico-chemical treatment (Adapted by reference 9).

Coagulation (or rapid mixing)

Derived from the Latin coagulare meaning driving together, coagulation refers to destabilization or neutralization of the negative charges contained in the wastewater by the addition of a coagulant applied during rapid mixing (which can vary from 250 - 1500 s-1) and a very short contact time (times ranging between 5 - 60 s) (4, 7, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20). The quantity of coagulant applied during coagulation depends on the quality of water (domestic or industrial). In the case of domestic water, commonly used doses are < 50 mg/L, while for industrial water the dose is very variable.

The most commonly used coagulants are ferric chloride (11, 22, 23, 24, 25 and 26), ferric sulfate (24 and 27), aluminium sulfate (7, 14, 28, 29 and 30), aluminium polychloride (10, 13, 14, 16, 28 and 29), sodium aluminate mixtures of organic and inorganic compounds, lime and the more recently studied application of iron polychloride (21 and 31).

Flocculation (or slow mixing)

This is derived from Latin floculare, referring to the formation of flocs and bridges. In this stage, previously formed flocs group together, increasing in volume and density, allowing them to be sedimented. This is achieved by applying a gradient (10 to 100 s-1) and a contact time varying between 15 min and 3 h (3, 7, 11, 15, 16 and 17).

-By the movement of particles themselves (Brownian motion). In this case flocculation is referred to as perikinetic or natural convection (5, 10 and 32).

- By the movement of the fluid containing the particles, inducing their movement. This is achieved by agitating the mixture. This mechanism is referred to as orthokinetic or forced convection flocculation (3, 11, 16 and 18).

During the flocculation stage, chemicals referred to as flocculants are applied (assisted flocculation). These products allow flocs to come together and adhere, increasing their size and density. Flocculants can be classified by their nature (mineral or organic), their origin (synthetic or natural) or their electric charge (anionic, cationic or non-ionic).

Organic flocculants of natural origin are derived from natural products such as alginates (seaweed extract), starches (plant grain extracts) and cellulose derivatives. Their effectiveness is relatively low.

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Those of synthetic origin are long chain macromolecules, soluble in water, formed by the association of simple synthetic monomers, some of which have electric charges or ionisable groups. For these reasons they are referred to as polyelectrolytes. These products are highly efficient and recommended concentrations are 0.05% -0.1% for solid products, 0.1% - 0.2% for liquid dispersion and 0.5% - 1.0% for liquids in solution. Applied in excess they may harm the flocculation process (5, 14, 15, 18, 28, 32, 33, 34, 35 and 36).

II. DISCUSSION

Sedimentation

This is the stage of floc removal by solid - liquid separation. For this, low, medium and high rate settlers are commonly used (17, 20, 34, 37 and 38). The rate is determined by the speed at which water and sludge are produced by the system.

Determination of Design and Operating Conditions Using "Jar Tests"

There are many aspects (physico-chemical properties of the wastewater of interest) that affect the performance of physico-chemical treatment. These can be determined by traditional laboratory jar tests (7, 9, 18, 22, 32, 40, 41 and 42) or by RoboJar systems (39). The system consists of six jars of the same size to which varying doses of coagulant are added at the same time. The system implements a rapid mixing sequence for a predetermined time followed by slow mixing for a set time and finally a settling sequence. After this, the supernatant is drained. Jar tests give a good approximation of the actual treatment process and the rapid mixing, slow mixing and sedimentation conditions of a real plant.

At the beginning, middle and end of the treatment tests, it is necessary to evaluate the efficiency of the process. This is achieved by measuring traditional parameters such as TSS, COD, pH, conductivity, turbidity, alkalinity, BOD, nutrients (N and P), thus establishing the efficiency of the system. Other parameters of greater accuracy such as particle size distribution (13, 15, 30, 43, 44 and 58), zeta potential and/or electrophoretic mobility (32) may also be used.

Applications

Physico-chemical treatment may constitute a single stage in the wastewater treatment process or be added as an additional treatment process during pre-treatment (to improve the biodegradation of wastewater in the biological process and secondary treatment (such as polishing).

Physico-chemical processes have been implemented for over 100 years (45). However in 1930, these processes were replaced by biological processes due to the high costs incurred by the treatment of large quantities of sludge (46). Recently, they have been reintroduced for various purposes: the elimination of phosphorus (17, 44, 45 and 47) for effluent being discharged to the sea, obtaining average quality effluent at lower cost than conventional treatments and for water used for agricultural irrigation (9, 20, 33 and 34), for potabilization (10 and 49), industrial water treatment (24 and 50) conditioning of sludge (primary and/or secondary) (23, 26, 27, 51 and 52). The resurgence of these processes is also due to increased recognition that the cost of treatment should be consistent with the desired efficiency, as progress in the synthesis of flocculation polymers with high efficiencies has been achieved at a lower cost (33).

Using this type of process it is feasible to remove 80 to 90% of total suspended solids (TSS), 40 to 70% of BOD5, 30 to 40% of COD and 17 to 100% of nutrients (N and P), depending on the dose and type of coagulant used (2, 7, 9, 17, 26, 33, 34, 47, 53 and 54). Heavy metals may also be removed by these processes, but the removal efficiency depends on the metal type and concentration (17, 33 and 55). Recently, these processes have been used to remove pathogens such as helminth eggs and have proven to be capable of removing up to 2 log concentration (20, 33, 34 and 48). In addition they are very efficient when used to remove bacteria (0-1 log unit), viruses and protozoa (1-3 log units in each case) (33 and 48). Current studies are focusing on their use for the removal of emerging contaminants (50, 56 and 57).

III. RESULTS

Coarse-and-Fine Materials Separation Utilizing Screens and Strainer
Screens and strainer remove solid contaminants from wastewater. These mechanical processes separate solid pollutants such as diapers, hair, and wet wipes from the wastewater stream. Before the treatment of industrial wastewaters, strainer separate textile fibers, paper labels, plastic residuals, and production residues such as potato peels and other scraps and wastes.
Depending on the area of application, coarse or fine screens are used. They clean the wastewater by means of parallel rods. Strainer feature grits, screens, perforations and meshes of varying sizes. Coarse strainer (> 20 mm) to micro (<0.05 mm) separate solid substances as large as human waste to as small as sand and tiny sludge particles from the wastewater stream.
Extremely important is the mechanical preliminary cleaning in the treatment of sanitary wastewaters. (42,43,44) Fibers suspended in the wastewater pose a particular challenge, especially the extremely tear-resistant textile fibers of wet wipes and non-woven materials. They tend to build up, potentially creating blockages and enormous damage to pumps and mixers.
DAS Environmental Expert works closely with its clients when choosing the right drum screens and self-cleaning screens to prevent damage to their treatment technology. This eliminates unnecessary maintenance from the outset and saves costs.

Mechanical Separation of Solid Substances through Filtration
Filtration separates solid substances from fluids. To this end, the mixture passes through a filter made of paper; whereas, technical applications typically utilize filters made from textiles or metal. Sand filters, cloth filters and drum screens are also frequently used as filtration systems.
Filtration systems remove organic and inorganic suspended solids, sands and dusts from wastewater. Wastewater technology employs this mechanical separation process to drain sludge in filter presses, among other processes. Filtration, typically in multistage processes, is also used for the purification of surface water to provide domestic and potable water.
Membrane filtration is another mechanical separation process in which a membrane functions as the filter medium. This method is typically used to separate very fine particles.
Wastewater Treatment through Membrane Technology

Membrane filtration separates and concentrates dissolved and un-dissolved substances from wastewater. This separation is performed under pressure. Due to its specific pore size, the membrane retains particles and molecules of a certain size. Different methods of membrane filtration are used for water purification, wastewater treatment, process water recycling, and the collection of recyclables in the recovery of valuable substances.(50,51,52)

IV. CONCLUSIONS

Microfiltration is employed to separate particles, bacteria and yeasts. It is also used for cold sterilization and for the separation of oil-water emulsions.
Ultrafiltration is an important method for the treatment of wastewater and potable water. It serves to separate particles, microorganisms, proteins and turbidities from the water. Ultrafiltration is used in the Membrane Activation Reactor (MBR). For instance, ultrafiltration is used to clean water in swimming pools. Since the build up of clogging deposits on the membrane can be prevented, more and more pre-existing wastewater treatment systems are being complemented with ultrafiltration as a final step. When retrofitting older wastewater treatment plants, the ultrafiltration step can be positioned directly inside or as a separate stage after the activation tank in order to replace subsequent treatment steps or to increase the treatment capacity of the biological wastewater treatment.
Nanofiltration retains viruses, heavy metal ions, large molecules and very fine particles. The method is used for water softening and the treatment of potable water.
Reverse Osmosis is an important process to concentrate landfill wastewaters, treat potable water in rural areas that are not connected to a pipeline network, desalinate seawater and decalcify boiler water in power plants. This method concentrates substances that are dissolved in fluids by applying pressure through a semi-permeable membrane that reverses the process of osmosis. When the applied pressure is higher than the respective osmotic pressure, the molecules of the solvent diffuse

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to the side of the membrane where the dissolved substance is already less concentrated. Reverse osmosis is also used to produce ultrapure water.(56,57)

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