IWA - YWP WORKSHOP:

INNOVATIVE TECHNOLOGIES

A SURVEY OF NEW TECHNOLOGIES FOR WATER AND WASTEWATER TREATMENT

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Abstract:

Water is an essential substance for living systems as it allows the transport of nutrients and waste products in living systems. Research shows a clear correlation between diseases and the amount and types of fluids consumed, health-promoting properties of nutrients which can be added to water, optimal intake levels, and consumption patterns. Although three quarters of the Earth's surface is covered with water, most of that water is not suitable for human consumption. Today, hundreds of millions of people in vast regions of the world do not have access to water to meet their basic needs. Natural disasters also create conditions which limit the availability of water that is suitable for human consumption. Industrial processes use significant amounts of water which require treatment before discharging to surface water systems. Municipal wastewater treatment systems discharge their effluents which often impact the aquatic organisms. This paper provides a survey of new developments and innovations relative to water treatment for drinking purposes and wastewater treatment during the last few years. For drinking water treatment, the recent technological advancements relate to primarily filtration (media filtration and membrane systems), disinfection processes, ion exchange, and carbon adsorption processes. For wastewater treatment, a significant majority of recent developments relate to biological processes and advanced treatment technologies such as adsorption. A review of the recent patents show innovative designs for treatment units, efficient approaches for water quality, as well as nanotechnology applications for removing impurities and disinfection purposes.

Introduction

The concern over increasing needs for drinking water and awareness for development of systems to improve water quality both for drinking purposes and for effluents from wastewater treatment and industrial facilities have provided incentives to develop new technologies and improve performance of existing technologies. In this paper, the patents on treatment of water and wastewater approved during the period from 1999 to 2007 were reviewed. The patents surveyed were classified into two groups as technologies for water purification systems for drinking water, and technologies for treatment of wastewater. An assessment of the current and future outlook for development of new technologies, methods of treatment, equipment and instruments which can be used for water and wastewater treatment applications are presented.

Keywords: Water treatment, water filtration, ultrapure water, wastewater treatment, ion exchange, disinfection, sorption, membrane filtration, nanofiltration, wastewater.

WASTEWATER TREATMENT SYSTEMS

Municipal wastewater treatment processes involve primary treatment processes which include physical-chemical processes such as sedimentation, secondary treatment processes which include biological units such as activated sludge or trickling filters. Fig. (**1**) presents the treatment scheme for wastewater treatment. The treated water is disinfected before it is discharge to a receiving body. The sludge produced is typically dewatered for land application.

The wastewater treatment for industrial applications may involve treatment processes specifically designed to remove contaminants that are present in the industrial effluents. Examples of typical industrial wastewater treatment processes include sorption, membrane filtration, precipitation and pH adjustment.

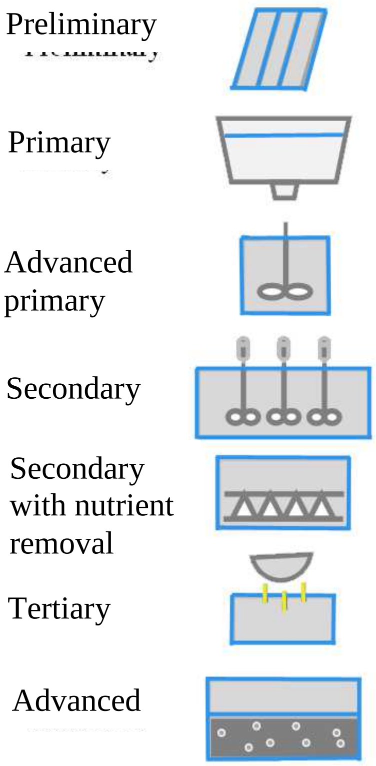
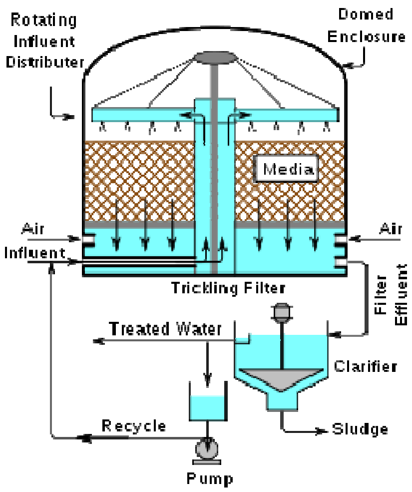


Fig.1 – Treatment technologies

Physical-Chemical Processes

Physical-chemical processes for wastewater treatment typically include sedimentation, dissolved air flotation, and centrifugation to remove suspended solids and chemical coagulation, chemical precipitation, pH adjustment to remove dissolved or colloidal matter, and air stripping to remove dissolved gases. The conventional wastewater treatment systems with primary sedimentation tank and activated sludge treatment may not be able to meet the treatment needs to meet effluent discharge standards. To improve the solids removal efficiency, Funakoshi *et al*. [1] developed a sewage treatment system with a floating filter medium to separate solid components in the sewage as shown in Fig. (**2**). The sewage flows upwardly in the treatment tank and is filtered through the floating filter media layer made of cylindrical mesh floating filter media which have a smaller specific gravity than the sewage. To wash the floating filter medium, air is jetted from the air jetting pipes to generate a circular flow to scape off solid components adhering to the filter medium. Kaltchev [2] developed a clarifier for liquids containing suspended matter.



The clarifier separates the suspended in two stages: by flotation--natural flotation (if the density of suspended solids density is lower than that of the liquid), or in combination with the dissolved air flotation technique; and then by filtration on a backwashable filter medium. Jangbarwala [3] disclosed a system for purifying wastewater effluent to remove suspended and dissolved solids, such as metal salts using electric field. Industrial processes, such as semi-conductor fabrication, generate wastewater with high concentrations of suspended and dissolved solids. The process involves filtering the water with a cross-flow membrane filteration system in the presence of an electric field to drive suspended particles away from the membrane surface. The membrane filter retains a significant fraction of the suspended solids. The permeate passes through a mixture of at least one cation-exchange resin and at least one anionexchange resin placed between a cation-selective membrane and an anion-selective membrane in the presence of an electric field. The electric field is used to drive the cations in the permeate through the ion-selective membranes, thereby producing deionized water.

The septic systems and sewage treatment plants in rural communities and small towns are aging fast and generally need to be replaced. Because the high cost of replacement, there is a need for an affordable, quality sewage treatment system for these communities. Thompson [4] developed a sewage filtration system for efficiently filtering wastewater from small residential areas without the use of additional sewage treatment plants. The system includes a conventional septic tank connected to each building structure's sewage system, a pair of two compartment tanks connected to the conventional septic tanks, and filtration unit. A chlorination line may be connected to system to chlorinate the filtered liquid prior to leaving the outlet line.

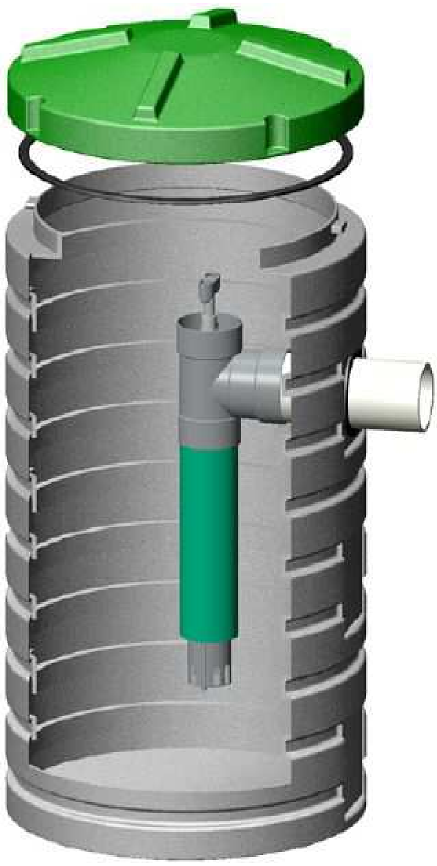


Fig.2 – Septic system

Wastewater from acidic hot springs in volcanic regions, acidic mine effluent and acidic underground water in regions of volcanic soil contain sulfuric acid formed by the oxidation of sulfur-containing substances and iron sulfide ores. Oishi [5] developed a method for treating acidic waste water, particularly mine effluent using a solid material that is obtained by solidifying a mixture of rock wool and an inorganic binder mainly containing at least one kind selected from silicates, hydroxides and oxides of alkaline earth metals and alkali metals and has a porosity of 50% or more. When brought into contact with acidic waste water containing iron ions and sulfate ions, this waste treating material neutralizes the wastewater and removes heavy metals such as iron and arsenic.

Wet oxidation is a process for treating wastewater in the presence of oxygen at a high temperature under high pressure to oxidize and/or decompose oxidizable substances in the waste water. The wet oxidization treatment method for cleaning wastewater in liquid phase is a slow process when a catalyst is not used. Shiota *et al*. [6] developed a catalyst for the treatment of wastewater by wet oxidation. The catalyst comprises activated carbon, (a) component and (b) component (also referred to as "second component"). The oxidation of organic and/or inorganic oxidizable substances in waste water is accomplished with an oxygen containing gas in the presence of the catalyst under pressure while waste water retains the liquid phase thereof at temperature of 50 to less than 170ºC. Hashimoto *et al*. [7] also disclosed a method and catalyst for treating wastewater by wet oxidation. The invention is applicable for wastewater treatment to remove organic or inorganic substances regardless of their concentration by wet oxidation process. Therefore, the reaction should be conducted at high temperatures under high pressure and the reaction times are relatively long. This limitation often necessitating use of a large system and increases the operation cost. The catalyst developed by Hashimoto *et al*. [7] is capable of increasing the reaction rate and moderating the reaction conditions.

Biological Methods

Biological methods are used for treating domestic and industrial waters by conversion of dissolved and suspended substrates into biomass which is separated and removed from the water. The disposal/reuse methods of the residues (biomass) require pre-treatment which generally consists of digestion, thickening and dehydration with conditioning, to increase the solid concentration to 20% to 40% is attained. The economic benefits could be significant when the water content of the residuals is reduced. Kotsaridou *et al*. [8] developed a method to reduce the residues generated in biological water treatment systems. The process use macromolecular carbohydrates and vitamins at a quantity of 0.0014 to 14 mg/kg of dry activated sludge per day. The conventional trickling filter utilizes a film of biomass fixed on a filter media to remove and aerobically convert organic matter to carbon dioxide, water and additional biomass and to oxidize ammonia to nitrates. The filter media typically comprises rock, wood, or corrugated plastic that maximizes the surface area of biomass for wastewater treatment.Recycling of the settled biomass is not required. A number of trickling filters collapsed due to weak media. Good records and data associated with the trickling filter are essential in locating, identifying, and applying the proper corrective measure to solve problems. Ruppel [9] developed a system to enable a plant operator to assess biomass development, determine the optimum flushing rates and distributor speed options friendly to the biomass itself and to promote optimal sloughing and address concerns regarding media performance. The invention provides a filter media tower assembly comprising a first portion and a second portion, wherein the first portion is suspended within the second portion. The first portion is a removable media tower or cage for holding filter media, and the second portion is a media tower guide support structure. The media used may be corrugated structural plastic media, random dump media, stone, or any media commonly used in the art of trickling filters or water cooling systems. The design allows the weight of accumulated biomass on filter media to be more accurately and easily determined in real time, without substantial disruption of the filtration process. Furthermore, the removable media tower allows for inspection of actual biomass composition, as well as easy maintenance, repair or replacement of filter media. Okamoto *et al*. [10] developed a as the biological growth media in the aeration chamber.

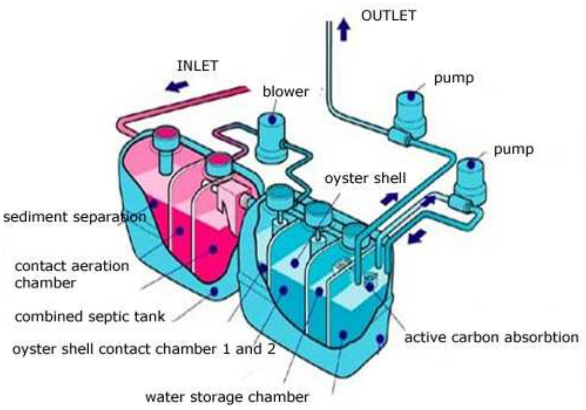


Fig 3 – Oyster shell aeration chamber

Wastewater is fed to and purified in the shell contact aeration chamber. Shells with the motherof- pearl layer on the inner surface is removed are used as microbial carrier. The rough surface of the shells has a high affinity to microorganisms. The treated wastewater purified in the aeration chamber described above is transferred to the activated carbon adsorption chamber where the wastewater is effectively decolorized. A denitrification chamber is provided upstream of the shell contact aeration chamber.

Matheson [11] disclosed a process which involves adding sulfur-containing oxygen scavenger to the source water stream and use of a biostimulant for the microorganisms. The process uses a biological denitrification process. Figure **4** presents a schematic of the innovative denitrification process. The bioreactor comprises of an open topped vessel with packing-type media. Bacteria effective for biological denitrification are attached to and supported on media.

The oxygen scavenger works with the bacteria contained in lower bed portion to remove the dissolved oxygen contained in the source water stream. The biological breakdown of nitrate and nitrite compounds in bioreactor produces a nitrogen gas product. Park *et al*. [12] developed a method for treating high-concentrated organic wastewater, such as night soil or livestock wastewater, which has high levels of nitrogen and phosphorous. The treatment process comprises of an equalizing tank, stripping of ammonia selectively from the wastewater, fermenting non-degradable organic material, carrying out Anammox reaction of ammonia in the wastewater with nitrogen dioxide, denitrificating the wastewater, solid-liquid separation steps.

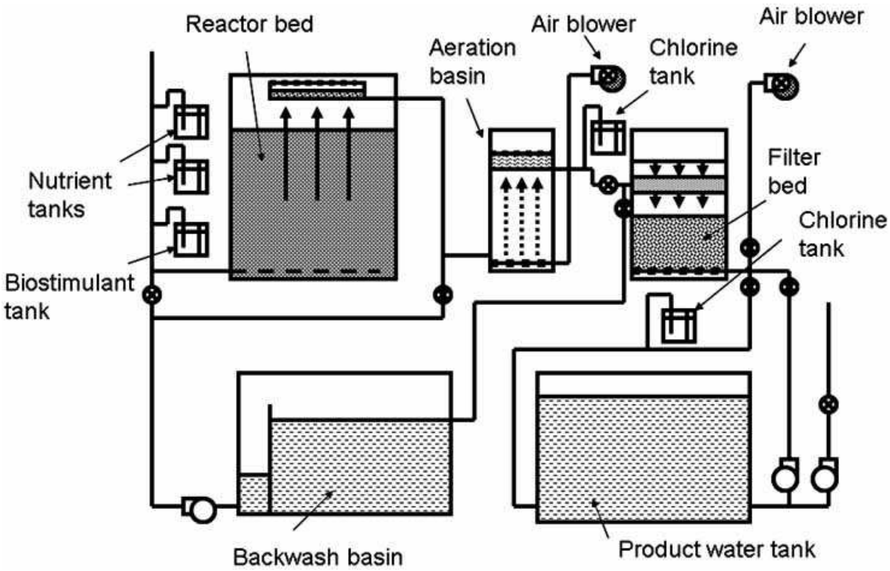


Fig.4 – Improved denitrification process

Analytical methods for water and wastewater quality analysis

Analyzing contaminants in a water supply can often take significant time to complete, and furthermore is often difficult to carry out. Present techniques and apparatus generally require much time to obtain measurements or readings of water supply contaminants. Water utilities are confronted with the task of maintaining contaminants at reduced levels, while, at the same time, controlling the levels of treatment compounds to maintain a safe concentration for consumption by users or ultimate discharge of the water into the ecosystem. Often strict government regulations must be met so as to have a minimum acceptable level of contaminants and maximum acceptable levels of treatment chemicals. Dissolved organic matter is an important component in a water system that must be carefully monitored and controlled due to its relationship with the contaminants. Kaplan [13] disclosed a method for measuring concentrations of contaminants aqueous water system using a bioreactor. The bioreactor containing the biofilm provides a measure of the amount of the dissolved organic carbon which is biodegradable. A bed facilitates the regulation of water flow through the bioreactor, and an autosampler allows for the measurement of total organic carbon, inorganic carbon an oxygen, between sample inflow and sample outflow at specified time intervals. Titmas [14] developed a new method for separating dissolved materials (i.e., organic and inorganic solids and volatile constituents) from aqueous solutions. The method first extracts water from the flow stream (i.e., sample) being treated using a crystallization system which freezes the water onto a continuous loop wire rope and withdraws the wire rope from the chamber containing the feed stream. The concentrated solution is then heated to remove water at reduced pressures to separate the materials from the liquid medium.

Future developments

The recent patents applicable for wastewater treatment adrress improvements for ease of operation, reliability, cost, size, maintainability, improved water quality, and analytical methods. There are also patents that show applications of nano technology especially in the areas of disinfection, ion exchange, and detection methods. With the increasing demand for drinking water and requirements for improved quality, more strict regulations for effluent discharge limits, and environmental awareness for water quality impacts, the research and development in water and wastewater technologies will increase in the coming years. The majority of the recent patents address the improvements for current technologies such as filtration and disinfection.

The recent trends indicate that there will be new requirements to monitor and perhaps regulate the emerging groups of contaminants which are not currently regulated (i.e., microconstituents which originate from over the counter drugs entering wastewater systems). In the near future, the technological advancements are likely to be aligned with the anticipated requirements to improve water quality.

With the advancements in materials science, nano technology, and information technology; it is likely that there will be new developments in the area of membranes filtration, disinfection/ oxidation methods, ion exchange resins, sorption technologies, as well as water management methods utilizing information and telecommunication technologies with remote monitoring and control capabilitlies.

Acknowledgement

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