TECHNOLOGIES THAT TRANSFORM POLLUTANTS INTO INNOCUOUS COMPONENTS: COMBINED BIOLOGICAL /CHEMICAL METHODS

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Keywords: Advanced oxidation processes, biological treatment, chemical treatment, combined treatment processes, disinfection, flocculation, oxidation, reduction, refractory compounds.

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Summary

Industrial wastewaters are frequently complex, commonly being variable and high in pollutant loading, and often containing materials toxic or resistant to the organisms on which biological processes depend. These factors, coupled with space restrictions not uncommonly encountered on industrial sites, have encouraged the application of physico-chemical techniques or combined with biological techniques wherever

possible.

Investigations on utilizing some form of combined chemical and biological process range from polluted groundwater to highly specialized industrial wastewater. The chemical processes applied include neutralization, coagulation-precipitation, chemical oxidation, chemical reduction, electrochemical processes, demulsification, disinfection, hydroxyl radical mediated advanced oxidation processes, as well as ozone, hydrogen peroxide, permanganate and natural sunlight, and so on. Biological processes include aerobic and anaerobic processes, suspended growth and attached growth systems. The microorganisms used include mixed and pure cultures.

Combination of chemical and biological processes leads to greater and more thorough destruction of many organic pollutants in wastewater. Pretreatment usually enhances the second process. Initial chemical oxidation can destroy compounds that would limit the effectiveness of the biological unit, and may produce intermediates, which are suitable to further degradation. Examples finding adverse effects due to pretreatment have also been identified. These effects may be due to the formation of toxic by-products or recalcitrant compounds, or chemical removal of compounds for which biological removal is more efficient.

1. Introduction

A wide range of processes is available for the treatment of water and wastewater. The selection of individual treatment stages and the entire concept of treatment depend primarily on the water quality of the source used, its productivity, and consumers' requirements.

There are many organic compounds, chiefly synthetic ones, that are not amenable to biological treatment either because they are toxic to the microorganism population at the concentrations present or because of their metabolic inertness. It is in the treatment of organic material of this nature and in the treatment of certain inorganic pollutants that chemical oxidation processes are used to their greatest advantage. It should be pointed out that in chemical oxidation processes it is not always, necessary or even particularly desirable that the organic content of the offending waste be removed entirely. Frequently all that is necessary is that toxic or biologically inert materials be modified sufficiently by chemical oxidation degradation to enable them subsequently to be treated biologically, since for non-toxic biodegradable material biological treatment offers distinct economic advantages. Of course, there are occasions when simply modifying the organic content is inadequate, and the requirement may be to reduce the total organic load significantly before discharge.

Integration of chemical and biological treatment processes is the optimal approach, and it is easy to find lots of examples in practice. For example, chemical treatments can be used to reduce the pollutant level of an industrial discharge to make it acceptable to biological treatment processes. Furthermore, when the biologically refractory compounds present in the influent, it is essential to use the more robust degradation treatment offered by chemical reaction, or adsorption, or both.

2. Chemical Treatment Processes

Industrial wastewater are frequently complex, commonly being variable and high in pollutant loading, and often containing materials toxic or resistant to the organisms on which biological processes depend. These factors, coupled with space restrictions not uncommonly encountered on industrial sites, have encouraged the application of physico-chemical techniques or combined with biological techniques wherever possible.

Chemical processes are the most important unit operations in treatment of drinking water supplies. Surface waters require chemical coagulation to remove turbidity, color and taste- and odor-producing compounds. During water treatment, hardness can be reduced by lime-soda ash softening and iron and manganese removed by chemical oxidation. Distillation and reverse osmosis are employed to concert saltwater and brackish groundwater to fresh water. To meet chemical drinking water standards, organic compounds can be removed by activated-carbon adsorption. Other chemical processes as health benefits are fluoridation and corrosion control to reduce the dissolution of lead into drinking water.

Selected chemical processes also are applied in wastewater treatment, water reclamation, and conditioning of waste sludge. Chlorine disinfection of both drinking water and wastewater effluents is a major common chemical treatment. In water reclamation, wastewater can be clarified by chemical coagulation or lime precipitation. Polymers are commonly applied to wastewater sludge to allow release of water during thickening and de-watering.

Chemical treatment techniques are very important, often used as alternatives or supplements to biological ones. For convenience in relation to pollution treatment operations, chemical processes can be divided into two main classes.

(1) Transformation reaction

The first type of chemical processes may be termed transformation reactions, in which the chemical species of interest is modified by chemical reaction completely, so that it is irreversibly converted to a different compound. An example of this kind of reaction is as follows:

$$CN^- + ClO^- \rightarrow CNO^- + Cl^-$$

(2) Phase transfer

A second class of reaction involves not only chemical reaction but is designed also to achieve phase transfer. A typical example here would be the precipitation of an insoluble compound by addition of a chemical to a soluble species, as a means of removing the pollutant. Another example would be the adsorption of a compound from a solution phase on to a solid phase.

2.1. pH Adjustment

The term 'pH' is used to indicate the degree of acidity of aqueous solutions. It is defined as:

$$pH = -\log_{10} [H^+]$$

where: $[H^+]$ is the hydrogen ion concentration.

It should be pointed that pH as measured is an indication of the hydrogen ion 'level', but it is not simply related to hydrogen concentration, and is only approximately related to a hydrogen ion activity.

The process of pH adjustment, or called neutralization, constitutes one of the primary forms of treatment for wastewater, and is practiced in some manner in practically all treatment plants. However, neutralization alone of organic acids and bases may not generally constitute an adequate form of treatment when the COD or BOD or any toxic characteristics of the materials are not also reduced. In these cases it may be important to remove or to modify the offending material (or to reclaim it). Apart from a biological degradation procedure, chemical degradation may be employed, as may precipitate in some cases, this latter being most commonly achieved in the case of acids by the addition of non-toxic heavy metal salts.

The choice of a reagent for pH adjustment in a treatment plant depends on several factors: cost, ease and safety of storage and handling, effectiveness, buffer characteristics and availability, just to take the most important ones.

The three major base reagents in use are hydrated calcium hydroxide, sodium carbonate and sodium hydroxide, each having its own advantages and disadvantages.

The two most commonly used acid reagents for pH adjustment are sulfuric acid and hydrochloric acid.

2.2. Chemical Oxidation

The original definition of oxidation as the chemical combination of oxygen with a substance to form an oxide was subsequently extended to include combination of other electronegative elements such as chlorine with substances, and the abstraction of hydrogen from substances. The definition is now generalized in terms of the removal of electrons from an element or compound. Reduction is conversely defined as the removal of oxygen or other electronegative elements, addition of hydrogen or electropositive elements or, more generally, as a gain of electrons.

2.2.1. The Role of Oxidation

The ultimate fate of all pollutants discharged to the environment is dictated by the relative thermodynamics stability of such material compared to the stability of possible reaction products. In the aerobic aquatic ecosystem to which most material is discharged, the relative bond energies suggest that in the case of organic molecules the final products will be carbon dioxide, water, and oxy-anions such as sulfate and phosphate. Unfortunately, many of these natural changes take place very slowly. The object of oxidative treatment processes is frequently to accelerate these changes by exploiting chemical and biochemical principals in order to surmount the kinetic restraints, which are responsible for the slowness of some of the reactions.

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Biographical Sketch

Wang Jianlong is an associate Professor in Department of Environmental Science and Engineering at Tsinghua University, Beijing, Peoples' Republic of China. He received his Ph.D degree in Environmental Chemical Engineering from Harbin Institute of Technology in 1993 and carried out the postdoctoral work in Tsinghua University. He gives a lecture on Environmental Microbiology for undergraduate students and lectures on Modern Environmental Biotechnology for graduate students. He carries out the research works in the State Key Joint Laboratory of Environmental Simulation and Pollution Control. His research interests are mainly in the following areas: (1) novel technology of biological wastewater treatment which is high efficiency, low cost and suitable for Chinese practical conditions; (2) nitrogen removal of high-concentrated nitrogen-containing industrial wastewater; (3) application of bioadsorption technique to the removal of heavy metal ions from wastewater; (4) application of bioaugmentation technique to remediation of contaminated soil and improving the removal efficiency of recalcitrant organic compounds from industrial wastewater; (5) BOD biosensor. He has done several researches on the biodegradation of refractory organic compounds by immobilized microbial cells. He was or is in charge of several projects supported by: National Natural Science Foundation of China; International Foundation for Science, National High Technology Development Plan (863 project), State Commission of Science and Technology; State Education Commission and the like. His present researches are focused on modern environmental biotechnology, such as the separation, purification and characterization of enzymes relating to the degradation of recalcitrant compounds, application of molecular biology techniques to detection and monitoring of specialized microorganisms in the bioreactor or in the field. He is also interested in environmental ethics, such as the relationship of human being and the nature. He is the author or co-author of over 100 technical papers and research reports. He has published two books and has written several chapters in other books.