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Review Article

A Review on Research and Studies on Kinetics of Biological Reactions with Emphasis on Substrate Utilization

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ABSTRACT

Biochemical reactions are utilized in wastewater treatment and synthesis of many compounds such as lactic acid, citric acid, ethanol etc. The biochemical reactions used in wastewater treatment are characterized by substrate concentration, biomass concentration, retention time, cell mass concentration and growth rate. The rate of substrate utilization and cell growth defines the effectiveness and kinetics of biological reactions. Monod growth kinetics is often used for explaining kinetics of substrate utilization. Many investigators have carried out investigations on biological reactions and their kinetics. Current review summarizes research carried out on kinetics of substrate utilization and cell growth in biological reactions.

Key words: Substrate, cell mass, growth, organic matter, biodegradation, fluidized bed bioreactor.

INTRODUCTION

Synthesis of various compounds and wastewater treatment are two areas where biological reactions are predominant. Low temperature, high purity and less energy consumption are key aspects of biological reactions. Bio based product industry is experiencing fast growth. [1-3] Wastewater treatment for removal of organic compounds contains biological treatment as major step. [4-8] Suspended growth process and attached growth process are two types of biological processes. In many water treatment processes membrane bioreactors are used. Membrane bioreactors are also used in anaerobic treatments and methane conversions. [9-13] Many compounds such as ethanol, lactic acid, citric acid, vinegar etc. are synthesized by using biological pathways. [14-18] The current review summarizes research and a study on kinetics of biological reactions in varies applications.

BIOLOGICAL REACTIONS: AN INSIGHT INTO RESEARCH AND STUDIES ON KINETICS

Parthiban studied kinetics of biological fluidized bed anaerobic reactor. [19] He carried out detailed studies and analysis of the kinetics for different start up conditions of the anaerobic digestion of wastewater. The waste water under consideration was prepared synthetically. For a bacterial support, he used mesoporous granulated activated carbon. His investigation revealed that half order kinetics was suitable for substrate utilization. He observed that, during start up of the reactor the process followed half order substrate utilization model. For start up and methane formation without acclimation, the order was 0.2. For remaining start up period it followed Langmuir Hinshelwood model. Prakash and Sochan carried out an investigation on bio-

decomposition and bio-kinetic characterization. [20] They treated tannery wastewater. They studied biotransformation reactions during anaerobic decomposition. For this, they studied various aspects such as bacterial growth kinetics, substrate utilization, and kinetic models. They found that the BOD reduction can be increased by proper maintenance of required alkalinity. With maintenance of alkalinity and volatile acids in the digester, they obtained more than 94 percent BOD removal. They found that the kinetics of decomposition followed first order rate equation. Marques et.al treated synthetic wastewater in attached growth process. [21] They used Monod growth equation and evaluated bacterial growth and biomass yield parameters. In certain limit rate of substrate removal, rate increased with organic load. They also found that the moving bed bio-film reactor provided two times more substrate removal capacity than activated sludge process. These reactors are suitable and close to realization of possibility of building a wastewater treatment plant in small areas. Rao et.al carried out studies on biokinetics of removal of BOD and COD from domestic sewage. [22] They used fluidized bed bio reactor. They also studied the removal of biological oxygen demand (BOD) and chemical oxygen demand (COD) from municipal wastewater using a laboratory scale model of fluidized bed bioreactor. Three different packing supports namely MBBR media (plastic), Pumice stones, and foam Pieces of uniform shape and size were used by them. In their investigations, they observed that the bio-kinetic reactions taking place in the reactor confirm to first order rate of equations. They found that foam pieces were good alternative material compared to the commercially available MBBR media which is made up of plastic. Okpokwasili and Nweke carried out studies on microbial growth and substrate utilization kinetics. [23] They found that removal of chemical contaminant, increase in microbial biomass and subsequent biodegradation of the contaminant are results of substrate utilization. According to them, optimization of several controlling factors is key to successful treatment protocol. For understanding and management of contaminated sites and industrial effluents, it is envisaged to model the controlling factors. Olaoye and Kolawole carried out an investigation on ethanol formation from glucose biomass in batch culture. [24] Their emphasis was on modeling of the kinetics. They used unstructured models. They observed that Logistics model and Gompertz model fitted in experimental data. According to them, utilization of mathematical model will contribute to a better understanding of effects of various factors affecting the production of ethanol. They considered optimal growth conditions and neglected inhibitory effects of substrate and product were neglected. Wittrup provided an insight into biological rate laws. [25] Contois investigated the kinetics of bacterial growth. [26] His emphasis was on population density and specific growth rate of continuous cultures. According to kinetic equations proposed by many investigators, the specific growth rate of a population growing under conditions of nutrient limitation as a function only of the concentration of the limiting nutrient. But many other investigation support the theory that specific growth rates of bacterial populations are also functions of population density. In order to model the bacterial growth more satisfactorily, the effect of population density upon specific growth rates of bacterial populations was studied in detail by them. Mardani et al carried out an investigation on activated sludge processes on municipal wastewater. [27] They also determined corresponding biokinetic parameters. They investigated three biological treatment processes such namely conventional, extended aeration, and contact stabilization. They also determined bio-kinetic parameters of the process. They carried out experiments with two different MLSS concentrations in aeration tank. They studied the parameters such as the yield

coefficient (Y), decay coefficient (kd), maximum specific growth rate and saturation constant (Ks) for conventional activated sludge process. They observed that the values of the coefficients were within the range of those reported in the literature for the conventional and contact stabilization processes. They obtained 83 and 92.5%, COD removal in conventional process. The COD removal obtained in extended aeration process was 88 and 93.8 percent. Torretta et.al used oxygen uptake rate method for studying biological kinetics in a conventional municipal waste water treatment plant. [28] They evaluated the biological process for the removal of biodegradable pollutants. They found that the kinetic parameters agreed with the literature ranges.

CONCLUSION

The BOD reduction can be increased by proper maintenance of required alkalinity. Investigators found that the moving bed biofilm reactor provided two times more substrate removal capacity than activated sludge process. Also it was concluded that utilization of mathematical model will contribute to a better understanding of effects of various factors affecting the production. Studies reiterate that specific growth rates of bacterial populations are also functions of population density. The rate of substrate utilization and cell growth defines the effectiveness and kinetics of biological reactions. Monod growth kinetics is often used for explaining kinetics of substrate utilization. Many investigators have carried out investigations on biological reactions and their kinetics. Current review summarizes research carried out on kinetics of substrate utilization and cell growth in biological reactions.

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