Innovative and Parametric Optimization for Photo–Catalytic Process

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ABSTRACT

Researchers have been exploring deeply the complexity of the slurry phase photo-catalysis process. The process has been understood at depth, yet it hasn't been optimized. Researchers have been unable to define a single performance parameter that can control the entire photo-catalysis process. In the present paper parameters of concern in a slurry phase photo-catalytic reactor have been reinvestigated. Based upon this a Universal Performance Parameter for the process has been defined. The literature exploration revealed that the parameters of concern of the photo-catalysis process are tightly interwoven and the whole process is very complex. Researchers have even suggested parameters that are reactor configuration dependent. . in the present work an approach is proposed to generate universally applicable and reactor configuration independent parameters. This approach will make the process analysis simple and will be dependable for the researchers in future.

KEYWORDS *: Slurry phase reactor, Photo –catalysis process, Universal process performance parameter.*

INTRODUCTION

Biodegradable organics are easy to be removed by biological treatment. Polysaccharides, lignin, phenolic material, cellulose, detergents, dyes pesticides, dyes etc and various organics having less solubility and resonant ring structures are known as refractory organics. They are very much resistant to biological decomposition. They offer hardship in wastewater treatment may be industrial or municipal [1]. Their concentration in wastewater is increasing with time. They cannot be handled by conventional wastewater treatment methods [1]. Such organics can be destructed using the strong photo-produced oxidation power of semi-conductor metals particulary TiO_2. This has been first reported by Frank and Bard [2]. In course of time researchers recognized many more semiconductors like ZnO, CuO_2, WO_3, Al_2O_3-CeO_2 and Fe_2O_3 [3 – 11], $CaBi_6O_{10}/Bi_2O_3$, MoO_3, ZnS, and CdS.

TiO_2 is considered as the most appropriate material as photo-catalyst. This is because of it is working in wider band gap; it has bio - chemical inertness, and it is photo-catalytically stabile. Moreover it is available easily and economical [12, 13].

During 1980s the researchers gave much recognition to the process of Slurry phase reactors (powdered TiO2 photo-catalysis). Later in 1990s Fujishima and their coworkers gave the idea of thin film based photo-catalysis in which the catalyst is deposited on a substrate [13]. Many more modifications of photo-catalysis reactors and their hybrids are in use presently [14 - 17].

Today slurry phase photo-catalytic reactors are the basic mode with several advantages [18 – 24]. They are simple in process modeling [25]. Researchers have identified the main parameters involved in the process as catalysts concentration, pH, temperature, dissolved oxygen level, organic pollutant concentration, wavelength of activation energy (light) and light intensity [12 – 14]. A simple slurry type reactor is schematically shown in figure 1.

The fig 1 also depicts pathway of UV radiation. The source of UV radiation may be Sun or lamp. This is the simplest case of reactor configuration. Modifications are also there [26 -28].

The photo-catalysis is essentially driven by the photon of specific wavelength photon. Hence the availability of radiation 'everywhere' in the reactor is crucial. Thus the transmissivity of the slurry phase is very important. The transmissivity is a function of concentration of catalyst, pollutant and turbidity [29 – 31].

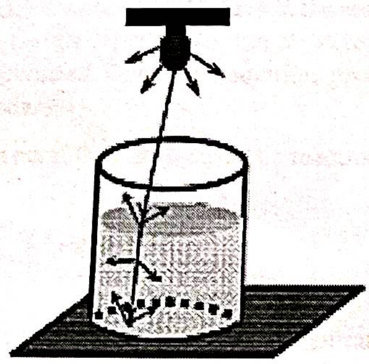

Figure 1: Simple slurry phase photo-catalytic reactor

An prototype design of photo-catalytic reactor requires optimization of all the process parameters as mentioned formerly. Most of the researchers have investigated these parameters independently and based upon their findings they have proposed optimum values. Some of the important works of this type are reported by [32 – 40]. It has to be noted that the process of photo-catalysis very is complex and its parameters are interdependent. In true sense parameters cannot be independently optimized. The parameters need to be optimized by a holistic approach. The present paper discusses the complex and interwoven nature of process parameters. It also puts forth the concept of a performance parameter. The parameter is simple and universally applicable.

Optimization of catalyst concentration

It is a well – established fact that the reaction rate is directly dependent on catalytic concentration. The (photo)-catalysis phenomenon essentially takes place catalyst surface. In semiconductor photo-catalysis the reaction occurs with the liberation of electron from catalysis surface. The electron emission takes place effectively only from catalyst particle in nano-size. Thus the effective catalyst concentration must be interpreted in terms of specific surface area of nano- particles. A good catalyst must have larger surface area per unit mass/volume.

Higher concentration of catalyst may even have retarding impact on the reaction. The higher concentration will make the slurry excessively turbid thereby reducing the radiation accessibility in the remote areas of the reactor. Thus the optimum catalyst concentration found thorough an experimentation is specific to the intensity of radiation.

In fact the optimum catalyst concentration is also dependent upon pH of the slurry because pH greatly influences the agglomeration/separation of catalyst particle which in turn decides the effective surface area available for reaction [29, 34, 35].

The Optimum Concentration of Organic Pollutant

Many researchers have worked on this aspect [41, 42]. On one side higher concentration of pollutant will increase interaction probability of it with the hydroxyl radical. Therefore the reaction rate will be more. Simultaneously higher concentration of pollutant will decrease the radiation penetration thus the overall reaction rate will be less. Hence the value of optimum pollutant concentration depends on radiation intensity and catalyst concentration.

The Optimum Radiation intensity

The photo-catalysis is light driven. Ideal sufficient photons should be available on every point on the catalyst surface at all times so that they can keep all the conduction band electrons emitted. This is the higher limit of photon intensity. More light will be unused and wasted. Effect of light intensity on kinetics of the reaction kinetics has been studied [43 - 47].

The optimum light intensity is also a function of catalyst concentration. Catalyst particles reflect and scatter the light thus causing less light to be available in the remote zones of the reactor. At the same time the light is also attenuated by pollutants in wastewater. Therefore the optimum light intensity is a function of the both, the catalyst concentration and the pollutant concentration.

The process parameter

The objective of this paper is to evolve the concept of a process parameter which is reactor configuration independent and describe the process kinetics effectively. In order to do this, radiation attenuation function for the given concentration of catalyst and pollutant need to be determined experimentally. This will enable estimating the light intensity at any location in the reactor. This way a radiation profile for the reactor can be established. Practically the reaction kinetics can be determined at grid points in the reactor and the values can be integrated. Else, the average light intensity can be obtained from the radiation profile and efficiency estimation can be done.

In general the photo-catalytic reaction can be described as

$$\frac{dC}{dt} = \frac{(C_O - C_t)}{\square t}$$

Where C_0 and C_t are the concentrations of pollutant initially and at time t. The equation is specific to the design and operating parameters including surface area of catalyst particles, concentration of organic material, average intensity of radiation, pH etc. While working with the photo-catalysis process, it is desirable that one for the given source of UV light and depth of reactor, one finds out working concentration of catalyst and organic pollutant and then the other parameters are optimized one by one. Then only the reaction kinetics will be independent of reactor configuration and universally acceptable.

CONCLUSION

Photo-catalysis is rapidly getting popularity for wastewater treatment. The parameters of concern are large in number and highly interwoven. It is not feasible to deal them separately. Rather it is irrational. The researcher and plant design engineers are advised that in order to develop universally acceptable kinetic parameters of the process, they must first decide the working range of catalyst and pollutant concentration for the intensity of UV Light available. This should be decided from the transmissivity considerations. It is recommended to develop a radiation attenuation function for the catalyst concentration and pollutant concentration being used. They must also decide the depth of reactor from practical consideration. Then other parameters can be sequentially optimized.

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