International Journal of ChemTech Research
CODEN(USA): IJCRGG ISSN : 0974-4290
Vol.5, No.2, pp 629-633, April-June 2013

ICGSEE-2013[14th – 16th March 2013]
International Conference on Global Scenario in Environment and Energy

Design And Performance Evaluation Of Solar Trickle Down Reactor For Cypermethrin Effluent Treatment

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Abstract: The feasibility of design and performance evaluation of solar trickle down photocatalytic reactor for degradation of cypermethrin pesticide was examined. The optimum operating conditions for treatment of aqueous solution containing 100 to 600 mg L^{-1} of cypermethrin were observed to be H_2O_2/COD molar ratio 2, and pH 3. The TiO_2 catalyst was coated over glass fibre mesh and was attached to that reactor. The testing was done with and without catalyst.Under the optimum operating conditions, complete degradation of the pesticide occurred in 1 min. Biodegradability (BOD5/COD) increased from zero to 0.36 in 60 min, and COD removal were 74.19 in 60 min. The study indicated that solar photocatalytic process can be used for pretreatment of cypermethrin pesticides in aqueous solution for further biological treatment.
Keywords : Solar trickle down flat plate reactor; cypermethrin; Glass fibre mesh coated TiO_2 catalyst; Chemical oxygen demand.

1.Introduction

In a context of energy crisis, due to the declining of oil era, water problems are expected to substantially worsen. Due to the close relationship between water and energy issues, water problems are also expected to contribute to increase the energy problems. Therefore, if solar energy has the highest potential among all the renewables and there is also the coincidence, all over the world, that where water stress and/or scarcity exists, also there are good levels of solar radiation. Conventional treatment processes do the phase transfer of the contaminant whereas solar detoxification process does the complete destruction of contaminants and usage of chemicals is also reduced in this case. It is needed to develop suitable technologies which would permit to use solar energy to simultaneously, help to solve the energy and water problems.

Nature has provided us with several means to tackle the environmental problems, which are the boomerangs of our own activities. In the recent years research on innovative methods for water treatment has moved from processes involving phase transfer towards process of complete destruction of the contaminants. The present work is aimed at

developing a solar process to reduce the maximum decontamination of wastewater containing pesticides using sunlight.

Non-concentrating solar collectors are static and non-solar-tracking. Usually, they are flat plates, often aimed at the sun at a specific tilt, depending on the geographic location. Their main advantage is their simplicity and low cost. Non concentrating collectors have concentration ratio of unity. They do not concentrate radiation, so the efficiency is not reduced by factors associated with reflection, concentration and solar tracking. Manufacturing costs are cheaper because their components are simpler, which also means easy and low-cost maintenance. Trickle-down flat plate is a type of non- concentrating collector based on a tilted plate facing the sun over which the water to be treated falls slowly, the catalyst is fixed on the plate surface.

In the near future, advanced oxidation processes (AOPs) may become the most widely used water treatment technologies for organic pollutants not treatable by conventional technologies due to the high chemical stability and/or low biodegradability of such Pollutants. These processes involve generation and subsequent reaction of hydroxyl radicals (·OH). Many oxidation processes, such as TiO_2 /UV, H_2O_2 /UV, Photo-Fenton, and ozone (O_3, O_3 /UV, O_3/H_2O_2) are currently employed for this purpose.

Cypermethrin

Cypermethrin is a synthetic pyrethroid used as an insecticide in large-scale commercial agricultural applications as well as in consumer products for domestic purposes. It behaves as a fast-acting neurotoxin in insects. It is found in many household ant and cockroach killers, including Raid and ant chalk.
Excessive exposure can cause nausea, headache, muscle weakness, salivation, shortness of breath and seizures. In humans, cypermethrin is deactivated by enzymatic hydrolysis to several carboxylic acid metabolites, which are eliminated in the urine. Worker exposure to the chemical can be monitored by measurement of the urinary metabolites, while severe overdosage may be confirmed by quantitation of cypermethrin in blood or plasma.
Properties:

Molecular formula $C_{22}H_{19}Cl_2NO_3$
Molar mass 416.30 g/mol
Appearance: Yellow-brown viscous liquid to semi-solid crystalline mass
Purity: The commercial preparation contains 94.2% Cypermethrin
Melting point: 80.5°C
Vapour pressure: $1.9x10^{-7}$ pascals at 20°C

Solar degradation of pesticides have been studied by many authors as given below:

Erick R. Bandala et al (2011) **[1]** have studied the degradation of oxalic acid in water. They have studied that the incidence angle affects the total amount of energy collected but does not reduce very much the efficiency of the reactors to use this energy.

S. Malato et al (2009)**[2]** has studied for ethamidophos mineralized in sunlight Pesticide-Tamaron 50®, 50% Methamidophos, PO_4^{3-} , TiO_2 catalyst. They have reported that the oxidation of the organics enhanced by use of electron scavenger.

Sixto Malato et al (2008)**[3]** have studied the use of sunlight to produce OH radicals. chlorophenols, chlorinated solvents, pesticides and cyanide decomposition of organic and inorganic contaminants.

Tianyong Zhang et al (2011)**[4]** have tested for degradation of the pollutant without visible light absorption for Sodium benzene sulfonate, TiO_2. They have observed the elimination of TOC followed pseudo first-order kinetics in the initial stages.

John V. Anderson et al (2010)**[5]** have treated hazardous chemicals in aqueous solution and those that destroy chemicals in the gas phase.

Sixto Malato (2011) have studied the degradation charcteristics of 10 commercial pesticides It gives the estimation of contaminants and destroys them effectively.

S Malato et al(2010)have studied the degradation of Vydate L®, 24% oxamyl pesticide.Oxamyl is completely photodegraded.

R. Bauer et al (2001)**[7]** have carried out studies to predict the oxidizing properties of UV irradiated TiO_2. Al doped TiO_2 powders showed better performance than undoped samples.

Wolfgang Gernjak (2009)**[8]** studied the possibility of treatment by advanced oxidation processes for Phenolic compound vanillin, protocatechuic acid, syringic acid, p-coumaric acid, gallic acid and l-tyrosine. All compounds were completely

mineralized, No non-degradable intermediates produced.

Blake D.M. et al (2008) [10] have tested three specific pesticides (imidacloprid, pyrimethanil and formentate) with purity>95% using tio2 slurries in cpc photoreactor . Radiometer at certain angle for data evaluation. Degradation is plotted as a function of amount of energy imidacloprid,pyrimethanil and formentate. The process is effective when applied to complex mixtures of pesticide. Numerous intermediates are formed in during mineralization at different concentration.

Cypermethrin, a least water soluble pesticide, was selected as a model contaminant because such compounds are very difficult to remove from environmental systems by conventional means. Solar Trickle down reactor is a type of solar thermal collector in which a heat transfer fluid drips out of header pipe at the top of the collector, runs down the collector absorber and into a tray at the bottom where it drains to a storage tank. So the objective was to treat cypermethrin effluent using solar trickle down reactor with a low cost and energy efficient reactor.

2. Methodology

The solar radiation instruments like Pyranometer, Global UV radiometer and log box were used.The different instruments are connected to the log box which is further connected to the pc.The instruments are kept so as to have an exposure to sunlight and then the pc is switched on and the software is started to take the reading with different setup values and the readings are taken for the day to check the solar radiation intensity ,solar radiation flux density and for measuring sun's diameter at different times .The readings are downloaded at different intervals of time so as to prevent loss of any data.

The fabrication of the solar trickle down reactor was done. A wooden instrumental setup with an inclination of 13^{o} corresponding to the Latitude of Manipal (Latitude: 13.348^{o}N and Longitude: 74.78^{o}E) was fabricated. Aluminium is the only metal that is highly reflective throughout the ultraviolet spectrum. Hence, the instrument top was covered with aluminium sheet to ensure maximum reflection. Inorder to ensure uniform distribution of catalyst, the glass fibre mesh coated with catalyst were spread over the reactor. Different concentrations of cypermethrin wastewater were taken and circulated at definite time intervals.

A freshly coated TiO_2 impregnated woven glass fiber mesh supported on an inclined support forms the main element of the system. The reactor will be operated in a continuous recirculatory mode and is kept facing the sun. A reservoir tank is located at the base of the reactor which supplies a particular amount of solution to the inlet of the reactor using a ½ HP centrifugal pump. Low flow rate are decided to be used where the solution will pass through the coated mat where photochemical reactions take place and then to the reservoir. A bypass valve can also be used for low flow rates and flow indicators can also be used to keep a check on the flowrates. The sampling was done by using cod digestion.

Fig 1 : Solar Trickle down flat plate reactor

3. Results And Discussion

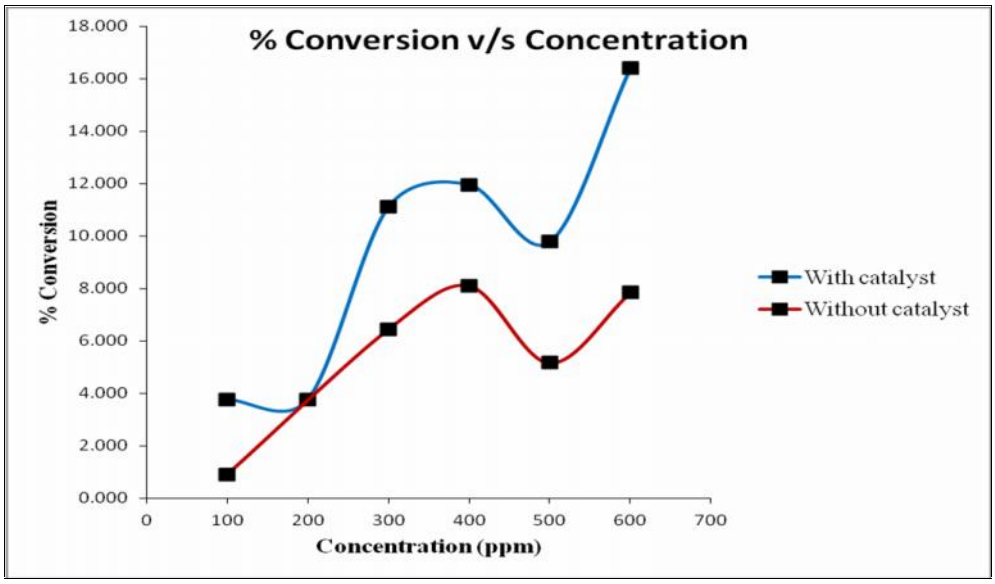
The solar radiation experiment is carried out in Manipal, Karnataka, India- 576104. Latitude is 13.3536 N and longitude is 74.7439 E. Solar radiation data has been measured against time.
From this data we can observe the variation of the solar radiation intensity over a period of time for few days. We can observe that the radiation intensity increases as the day progresses and is maximum around 01:30pm and then it goes down around 04:00pm.Also UV radiation its very high in manipal hence quite useful for the solar detoxification process which is favored by high intensity.

Concentration of cypermethrin after treatment
Without catalyst
Table 1 : Comparison of concentration before and after treatment without catalyst.

Concentration (ppm)	Observed (ppm)
100	99.09091
200	195.4545
300	282.7273
400	366.3636
500	465.4545
600	540.9091

With catalyst
Table 2: Comparison of concentration before and after treatment with catalyst.

Concentration (ppm)	Observed (ppm)
100	97.27273
200	190.9091
300	231.8182
400	331.8182
500	404.5455
600	440.546



5. Conclusion

The solar degradation experimentation of the cypermethrin containing wastewater on the solar trickle down reactor was carried out and we have compared the concentration levels before and after the experiment was conducted. We conclude from this experiment that there was a considerable decrease in the level of pollutants and hence the method is quite effective in the treatment of wastewater.

By ensuring greater available photocatalyst surface area, increasing contact time, and maintaining turbulent conditions and sufficient oxygen supply, a greater improvement in processing rate could be achieved. Degradation was solar light dependent suggesting that the dominant removal mechanism is due to photocatalytic degradation. The kinetics of the reactions was tested and the reactions were observed to be following first order kinetics.

Further studies in this field can be carried out by varying the material of construction, studying the effect of increase in concentration of catalyst.

6. References

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