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HYBRID ADVANCED OXIDATION PROCESS FOR WASTEWATER TREATMENT

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Abstract : Advanced oxidation process of organic pollutants in an aqueous environment is considered to be a green process. This mode of degradation of organic pollutants in an aqueous environment is considered for less use of chemical utilization and no need of extreme physical conditions. Extensive discharge of toxic organic pollutants in an aqueous environment by anthropogenic activities has posed major health implications for both human and aquatic lives. Hence, lots of research and efforts are in progress to improve the efficiency of degradation and mineralization of organic contaminants. Being an extensively used advanced oxidation process, ultrasonic irradiation can be utilized for complete mineralization of organic pollutants by coupling/integrating it with homogeneous and heterogeneous photocatalytic processes. In this consideration, scientists have reported on sonophotocatalysis as an effective strategy towards the degradation of many toxic environmental pollutants. The combined effect of sonolysis and photocatalysis has been proved that it it increase the production of high reactive-free radicals in aqueous medium which help in the complete mineralization of organic pollutants. In this manual, we provide an overview on the ultrasound-based hybrid technologies for the degradation of organic pollutants in an aqueous environment.

***IndexTerms*–Advanced Oxidation Process; Sonolysis; Sonophotocatalysis; Ultrasonics**

I. INTRODUCTION

The Tremendously development of industry, increased the number of industries as well as the amount of toxic effluents. Many treatment processes have been developed, they are not suitable for all categories of toxic organic compounds, which resist their attack. So, the Advanced Oxidation Processes (AOPs) are selected for the removal of organic substances such as pesticides, surfactants, coloring matter, pharmaceuticals and endocrine disrupting materials from the industrial and municipal wastewater. This review is mainly focused on analyzing the effectiveness of various types of AOPs such as Fenton process, H0,/UV, Photo Catalytic Oxidation (PCO), Super Critical Water Oxidation (SCWO), Ozone/UV, Ozone/H:OUV process aiming to mineralize or transform refractory molecules into other, which could be further biodegraded, is a matter of great concern. Hydroxyl radical is powerful and non-selective oxidant, plays as an important role in oxidizing the toxic organic material with its high oxidation potential.

HYBRID ADVANCED OXIDATION PROCESS (HAOP)

Hybrid-Advanced Oxidation process is a process made by combination of two or more AOP's in the treatment of wastewater for better results in the treatment. UV-based and chemical oxidation processes are preferred treatment technologies for the elimination of pollutants in drinking water and wastewater because they have special characteristics like flexibility, long-term stability, low costs, and controllability. In industrialized countries where more than 90 % of the wastewater is treated in centralized waste water treatment plants, these plants represent a major point source for emerging pollutants. A main innovation is the combination of different oxidation processes and appropriate post- treatment technologies. Example, ozone is a selective oxidant for particularly reactive towards functional groups with high electron densities, like those occurring in many emerging pollutants. The main disadvantage of the use of ozone in drinking water treatment is the when reaction take place it form the compound bromate in bromide-containing water. A combination of UV/H2O2 do not form bromate, but it requires 5-20 times more energy than an ozone process for the same quantity of pollutant transformation. A major drawback of oxidation processes is the it forms oxidation byproducts from matrix components e.g. aldehydes, ketones, etc., and the fact that emerging pollutants are not fully mineralized, resulting in transformation products (TPs).

ULTRASOUND-BASED HYBRID ADVANCED OXIDATION PROCESS (AOPs):

Ultrasound (US) was first used by Richards and Loomis for creating the concept of cavitation and degassing of water by accelerating the chemical reactions. Ultrasound used for many applications such as cell disruption, crystallization, atomization, degassing, polymerization, emulsification, nanotechnology, wastewater treatment, chemical reactions, food preservation, drug delivery and many more. The major advantages of ultrasonic irradiation are safety, high penetrability in water medium, high degradation efficiency and the use of relatively low energy. Being an extensively used AOP, many recent publications provide good reviews on the use of sonochemistry for wastewater treatment aspects. Babu et al. reported on combined AOPs such as sonolysis, sono-ozone process, sonophotocatalysis, sono-Fenton systems and sonophoto-Fenton methods for the degradation of

SONOLYSIS:

Sonolysis is the process of utilization of ultrasonic irradiation without the presence of catalysts, to produce HO+ in aqueou s media. Sonolysis is one of the best successful systems utilized for the degradation of organic pollutants in water The interaction between sound energy and dissolved bubbles in liquids leads to the growth of bubbles and subsequent near-adiabatic collapse, a process known as acoustic cavitation. Acoustic cavitation generates high temperature and pressure conditions wi thin the collapsing bubbles. In water, acoustic cavitation process generates HO+ radicals that could be used for the degradation of g anic pollutants.

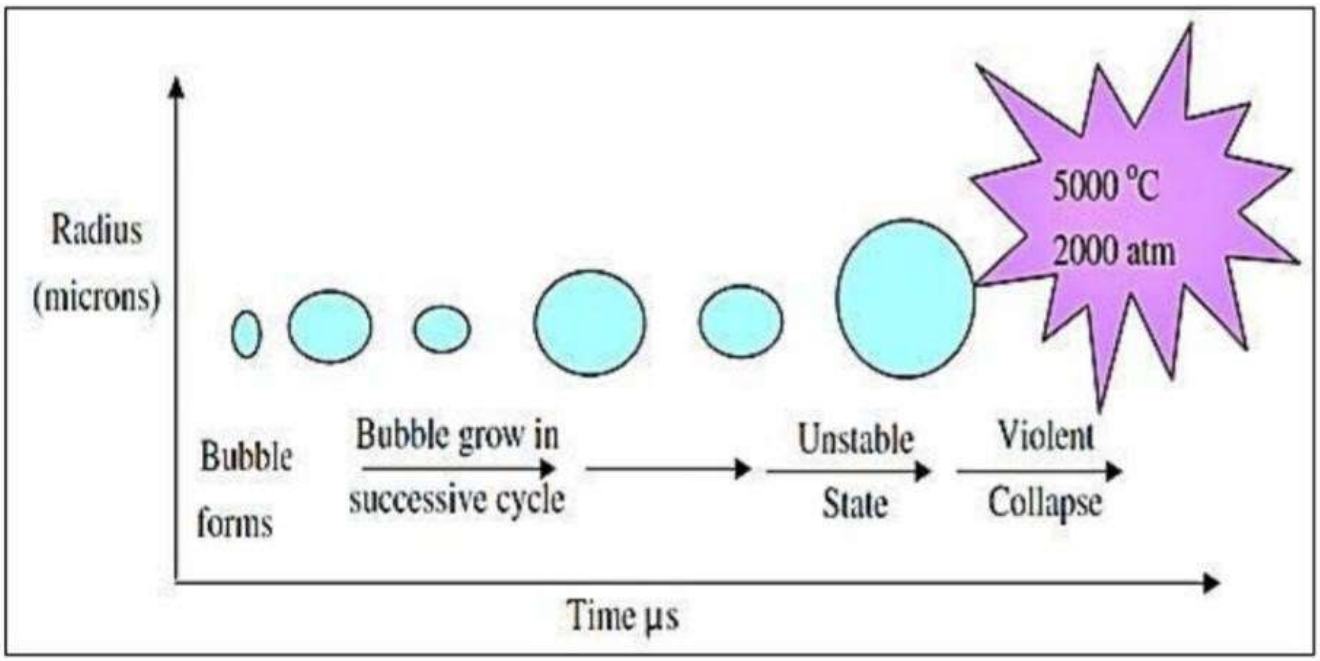

Figure 1: Ultrasound (US) waves induced cavation occurance and its collapse

pollutants. From report combination of US with one or more AOPs were found to exhibit great performance than that of individual AOPs. This may be due to the coordination between the hybrid AOPs. The application of ultrasound is extensively applied in wastewater treatment applications.

SONOCATALYSIS:

Rapid growth in nanotechnology has achieved a great deal of interest in environmental applications. Nanomaterials in various shapes or forms have a significant impact on the treatment of water and air quality in natural environment. A combination of nanocatalysts and ultrasonication to forn a heterogeneous sonocatalytic processes increase the degradation efficiency of organic pollutants to a huge extent. After that, they also increase the number of cavitation bubbles by acting as nucleation sites. The presence of catalysts can increase the number of free radicals generated, thus it result on the rate of degradation of organic pollutants. An acoustic cavitation process is useful for the generation of active catalysts. For example, the conversion of rutile to anatase TiO2 under ultrasonic irradiation is shown

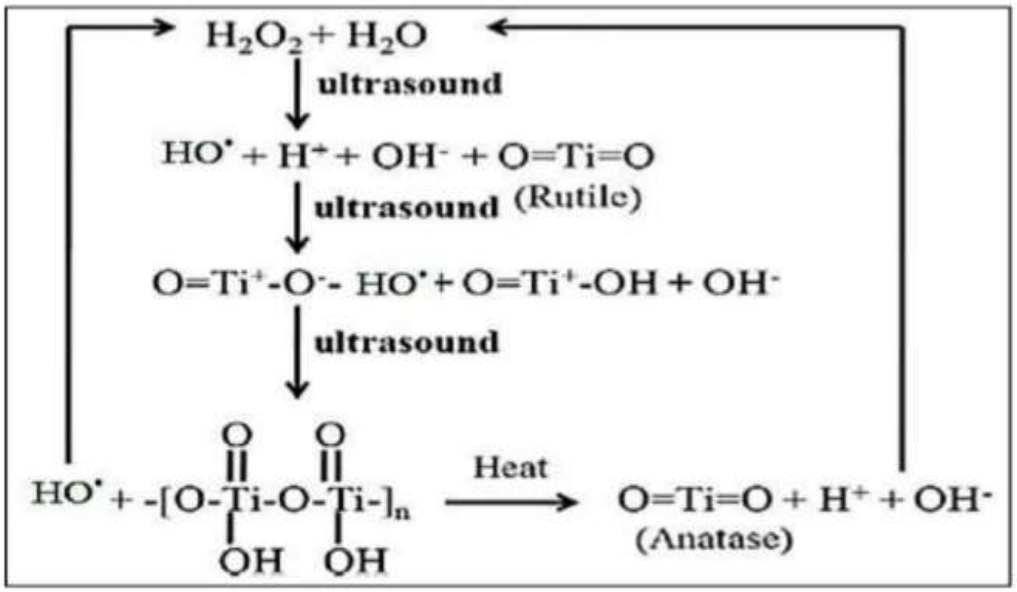

Figure 2: The probable conversion of rutile to anatase TiO2 under ultrasonic irradiation.

SONOPHOTOCATALYSIS

Sonolysis is simple process therefore it has gain much attention towards the organic pollutant degradation. The photocatalyt ic process is considered as one of the greatest technolog ies for wastewater treatment processes. While sonolysis is an convenient and effevtive process for the degradation of hydrophobic

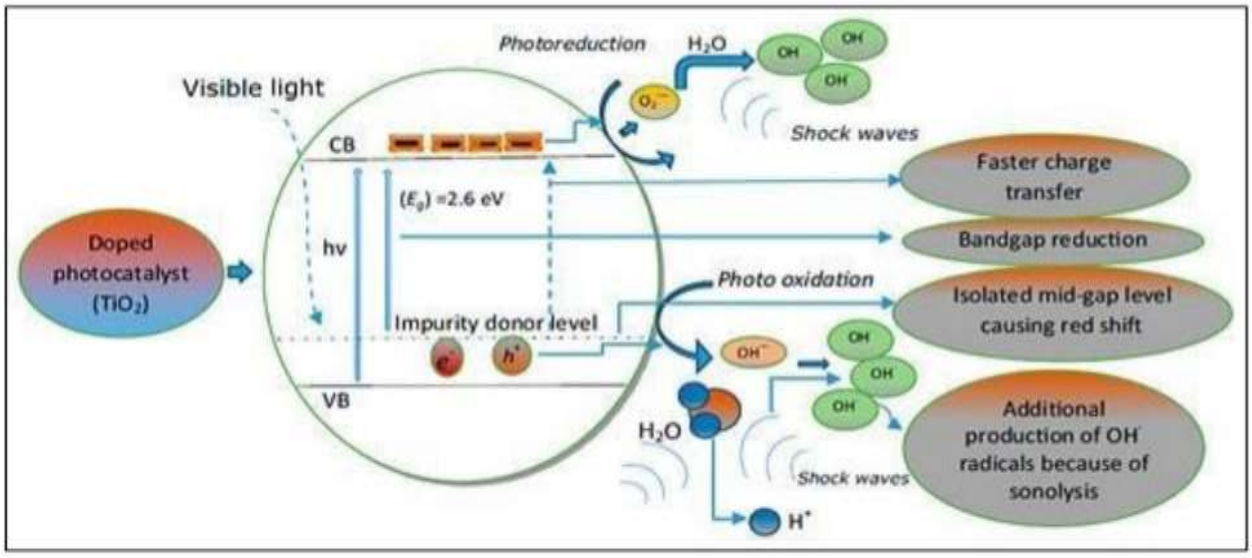

Figure 3: Graphical representation of synergetic effect during a sonophotocatalytic degradation process using doped semiconductor oxide.

pollutants, its potency towards deliquescent compounds is weak. Hydrophobic compounds sorb to the cavitation bubble interface and area unit expeditiously connected by HO+ radicals generated on bubble collapse. photocatalysis is associate economical method for the degradation of deliquescent compounds since they need advantageous sorption to the comparatively polar chemical process surfaces. therefore, a mix of sonolysis and photocatalysis, sonophotocatalysis, it facilitate to beat the disadvantages of the individual processes and mix the benefits of those processes. A schematic summary illustration of synergistic impact throughout sonophotocatalysis exploitation doped semiconductor metal compound is shown in

II ADVANCED OXIDATION PROCESS :

Advanced chemical reaction processes (AOPs) were initial projected for potable water treatment within the Nineteen Eighties, that area unit outlined because the chemical reaction processes involving the generation of hydroxyl group radicals (OH·) in decent amount to impact water purification. Later, the AOP construct has been extended to the aerophilous processes with sulphate radicals (SO4 ·−). totally different from common oxidants like chemical element and gas that have a twin role of remotion and medical aid, AOPs area unit applied primarily for destruction of organic or inorganic contaminants in water and waste material. though AOP inactivation of pathogens and infective indicators are studied, they're seldom utilized for medical aid as a result of these radicals have too short half-life (on the order of microseconds), in order that the desired detention times for medical aid area unit prohibitory because of very low radical concentrations. once AOPs area unit applied for waste material treatment, these radicals, as a strong oxidant, area unit expected to sufficiently destruct waste material pollutants, and remodel them to less and even non-toxic merchandise, thereby providing associate final answer for waste material treatment

- Hydroxyl Radical-Based AOPs.

Hydroxyl radical is that the most reactive oxidant in water treatment, with associate chemical reaction potential between two.8 V (pH 0) and one.95 V (pH 14) vs. SCE (saturated chloride conductor, the foremost unremarkably used reference electrode). OH· is incredibly nonselective in its behavior and speedily reacts with various species with the speed constants on the order of 108–1010 M−1 s−1. Hydroxyl group radicals attack organic pollutants through four basic pathways: radical addition, chemical element abstraction, negatron transfer, and radical combination. Their reactions with organic compounds turn out carboncentered radicals (R· or R·–OH). With O2, these carbon-center radicals is also remodeled to organic peroxyl radicals (ROO·). All of the radicals any react accompanied with the formation of additional reactive species like H2O2 and super compound (O2 •−), resulting in chemical degradation and even mineralization of those organic compounds. As a result of hydroxyl group radicals have a awfully short lifespan, they're solely in place created throughout application through totally different ways, together with a mix of oxidizing agents (such as H2O2 and O3), irradiation (such as actinic ray or ultrasound), and catalysts (such as Fe2+). Radical generation mechanisms of the most important AOPs for waste material treatment area unit in brief summarized below.

- Ozone based mostly AOPs.

Ozone (O3) may be a sturdy chemical agent itself with associate chemical reaction potential of two.07 V vs. SCE. However, direct O3 chemical reaction may be a selective reaction, with typical reaction rate constants of one.0 × 100– 103 M−1 s−1 eight, during which O3 preferentially reacts with the ionizing and unrelated variety of organic compounds, instead of the neutral kind. beneath sure conditions, OH· is created from O3 to initiate the indiscriminate chemical reaction (indirect mechanisms). totally different elaborated mechanisms are projected to elucidate the advanced OH· generation, and therefore the overall reaction involving OH· generation is expressed as below.

$3O3 + H2O \rightarrow 2OH + 4O23O3 + H2O \rightarrow 2OH + 4O2$ (1)

In the presence of other oxidants or irradiation, the OH· yield can be significantly improved. For Example, in the so-called peroxone (O3/H2O2) system, the O3 decomposition and OH· production Are enhanced by hydroperoxide (HO2−) produced from H2O2 decomposition.

$H2O2 \rightarrow HO2- + H+$ (2)

$HO2- + O3 \rightarrow OH. + O2- + O2$ (3)

In the O3/ultraviolet (UV) irradiation, H2O2 is generated as an additional oxidant primarily

Through O3 photolysis (Eq. 4)

$O3 + H2O + hv \rightarrow H2O2 + O2$ (4)

As a consequence, OH· can be generated, at a minimum, through three pathways: (1) ozonation

(Eq. 1); (2) O3/H2O2 (Eqs. 2 and 3); and (3) photolysis of H2O2, as shown in Eq. 5.

$H2O2 + hv \rightarrow 2OH$ (5)

- UV-Based AOPs.

Hydroxyl radicals is initiated by photons within the presence of catalysts or oxidants. The foremost common catalyst is titanic oxide (TiO2), a RO-type semiconductor. TiO2 particles ar excited to provide positive holes within the valence band (hv + vb) with AN aerophilous capability, and negative electrons at the physical phenomenon band (e – cb) with a subtractive capability, as follows:

TiO2 + hv → e^−cb + hv^+vb

With the reactions of OH−, H2O, and O2·− at the surface of TiO2, these holes and electrons can further form hydroxyl radicals.

$$hv_{+vb} + OH_{-(surface)} \rightarrow OH\cdot\ hv_{+vb} + H_2O_{(absorbed)} \rightarrow OH\cdot + H_{+}e{-}cb + O2(absorbed) \rightarrow O2\cdot- H2O + hv \rightarrow OH\cdot + H\cdot$$

- Fenton-Related AOPs.

Among these metals that are able to activate H2O2 and turn out chemical group radicals in water, iron is that the most often used. Within the alleged Fenton method, H2O2 reacts with Fe2+ to come up with robust reactive species. The reactive species made are historically recognized as chemical group radicals, although alternative substances like ferryl ions ar planned. The Fenton-

$$Fe2+ + H2O2 \rightarrow Fe3+ + OH\cdot + OH-\ \ Fe3+ + H2O2 \rightarrow Fe2+ + HO\cdot2 + H+$$

$$OH\cdot + H2O2 \rightarrow HO\cdot2 + H2O$$

$$OH\cdot + Fe2+ \rightarrow Fe3+ + OH-\ \ Fe3+ + HO\cdot2 \rightarrow Fe2+ + O2H+$$

$$Fe2+ + HO\cdot2 + H+ \rightarrow Fe3+ + H2O2$$

$$2HO\cdot2 \rightarrow H2O2 + O2$$

Related chemistry for water and sewer water treatment has been mentioned thoroughly elsewhere. The classical Fenton radical mechanisms primarily involve the subsequent reactions

Multiple Mechanisms Occurring During AOPs For Wastewater Treatment:

Besides OH· or SO4 ·−-based oxidation, other mechanisms simultaneously occurring during the AOP treatment may remove target pollutants in wastewater. The contribution of the non- radical oxidative mechanisms in the contaminant removal may be dominant or insignificant, depending on the AOP type and reaction conditions. Mechanisms concurrently occurring in different AOP treatments are summarized in Table 1.

AOP types	Oxidant for advanced oxidation	Other occurring mechanisms
O_3	OH·	Direct O_3 oxidation
O_3/H_2O_2	OH·	Direct O_3 oxidation H_2O_2 oxidation
O_3/UV	OH·	UV photolysis
UV/TiO_2	OH·	UV photolysis
UV/ H_2O_2	OH·	UV photolysis H_2O_2 oxidation
Fenton reaction	OH·	Iron coagulation Iron sludge-induced adsorption
Photo-Fenton reaction	OH·	Iron coagulation Iron sludge-induced adsorption UV photolysis
Ultrasonic irradiation	OH·	Acoustic cavitation generates transient high temperatures (≥5000 K) and pressures (≥1000 atm), and produce H· and HO_2·, besides OH·
Heat/persulfate	SO_4 ·−	Persulfate oxidation
UV/persulfate	SO_4 ·−	Persulfate oxidation UV photolysis

Fe(II)/persulfate	$SO_4^{\cdot-}$	Persulfate oxidation Iron coagulation Iron sludge-induced adsorption
OH^-/persulfate	$SO_4^{\cdot-}$/ $OH^{\cdot}$	Persulfate oxidation

Table 1: Major mechanisms for organics removal during wastewater treatment by different AOPs.

III. LITERATURE:

Previous studies are done on the Hybrid AOP's that are studied for the Literature Review. that are tabulated and has been studied and briefed regarding.

Combination of sonolysis with different advanced chemical reaction processes The major disadvantages of sonolysis area the potency of the processes. so as to create it energetically a lot of economical and a lot of applicable, hybrid techniques between sonolysis and different advanced chemical reaction processes were developed. the foremost chemical reaction processes together with this class area unit ozonolysis and photocatalysis (Wang et al. 2012). Recently, the chemistry treatment technologies are according together with ultrasound (Adewuyi 2005a; Thokchom et al. 2015b). The hybrid techniques area unit able to meet several of the disadvantages of each the processes. The hybrid techniques according for the degradation of pharmaceutically active compounds area unit summarized in Table two.

Sono-ozonolysis

In the case of sono-ozonolysis processes, a lot of chemical group radicals are generated within the medium thanks to the ultrasound iatrogenic decomposition of gas. It conjointly enhances the mass transfer of gas from gas part to the liquid part. Thus, it enhances the reaction of gas with the waste material within the liquid region. The quick degradation of antibacterial

$$O3(g) \rightarrow O2(g) + O(3P)(g)$$

$$O(3P)(g)+H2O \rightarrow 2\cdot OH$$

drug was discovered within the case of ozonolysis and with the addition of catalyst additionally to the gas (Wang et al. 2011, 2012). The catalyst used was iron ore. The impact of power, gas flow, gas concentration, pH, peroxide and t- butyl alcohol was investigated. The apparent rate constants were raised with the applied power. The power, gas flow, gas concentration and hydrogen ion concentration area unit directly associated with the degradation rate. The peroxide addition may enhance the speed of degradation. however it's found to be minimized with increase within the initial concentration of antibacterial drug and also the presence of hydroxyl group scavenger as within the previous cases (Wang et al. 2012). The distinction within the degradation was investigated with gas, sonoozonolysis and sonocatalysis/ozonolysis. The ozonolysis was degradation was enhanced from zero.096 to 0.115 min-1 and zero.129 min-1 once combined with sonocatalysis. Once these 3 techniques area unit coupled along, the degradation becomes a lot of speedy. The degradation was performed thrice with identical conditions and also the same catalyst. identical tendency was discovered. The physical effects of ultrasound ought to clean the chemical change surface and enhance the reusability of the catalyst (Wang et al. 2011). The degradation of sulpha by ozonolysis, sonolysis and also the combination of sonolysis and ozonolysis is already established (Guo et al. 2015). The presence of ultrasound alone doesn't show any modification on the degradation. however gas showed vital degradation potency. once ultrasound is coupled to gas, a speedy removal was discovered. The quicker removal of 3 prescription drugs like diclofenac, sulpha and carbamazepine by ozonolysis, sonolysis associate degreed sonoozonolysis severally and in mixed resolution is an encouraging result (Naddeo et al. 2015). The degradation is increased thanks to the synergistic impact of sonolysis and ozonolysis. The impact of varied in operation conditions on degradation of diclofenac in waste throughout sonolysis, ozonation and their synergistic impact was conjointly investigated. The according result's terribly encouraging in terms of mineralization of the compound (Naddeo et al. 2012) Sonocatalysis and sonophotocatalysis. Photocatalysis may be a promising and economical technology for the degradation of organic contaminants. once a semiconductor is exposed to actinic ray radiation, the transfer of electrons from the valence band to the conductivity band takes place. As a results of this, associate degree electron–hole combine is created. These species then migrate into the catalyst and endure varied reactions. the outlet reacts with the water molecule to create hydroxyl group, and also the negatron reacts with the gas to create superoxide radical ion (Fox and Dulay 1993; Hoffmann et Schneider et al. 2014). Various reactions involved in photocatalysis are given in

$$TiO2 + hv \rightarrow h+ + e- \quad VB\ CB$$

$$h+ + (H2O)ads \rightarrow \cdot OH \quad e- + O2 \rightarrow O\cdot^{-}_{VB}$$

CB 2

The recent reports showed that the degradation of pollutants by photocatalysis isn't solely thanks to the hydroxyl however conjointly thanks to the supply of assorted different reactive species like holes and negatron (Schneider et al. 2014). Therefore, it will be used as Associate in Nursing economical technique for the removal of pollutants. The key steps concerned in photocatalysis are: (a) transfer of chemicals from liquid section onto the catalyst surface; (b) sorption of the reactant on the catalyst surface; (c) reaction within the adsorbable phase; and (d) activity of the ultimate product (Fox and Dulay 1993; Hoffmann et al. 1995; Schneider et al. 2014). A quickly developing hybrid technique for the environmental rectification is that the sonophotocatalysis (Adewuyi 2005a, b). In general, the nanoparticles have a bent to accumulate within the interface region. Thus, once the catalyst is additional to the sonochemical reaction medium, the reactants take up powerfully to the chemical process surface and move toward the extremely reactive interface region. additionally to the current result, the presence of catalyst will act as a nucleation website and should induce the expansion of microcavity, and thus, the cavitation potency goes up. once the ultraviolet radiation|ultraviolet

illumination|UV|actinic radiation|actinic ray} light is introduced to the on top of system, it enhances the formation of hydroxyl from the chemical process surface. Similarly, the ultrasound will increase the chemical process area, and it reduces the deactivation of the catalyst thanks to its cleanup result. The coupling of sonolysis and photocatalysis is named sonophotocatalysis. Thus, the benefits of each techniques will be combined, and hence, it becomes a additional economical technique for the removal of extremely deliquescent compounds in water (Adewuyi 2005a, b; Gogate 2008).

Sonocatalytic degradation of analgesic by sonochemically synthesized Sm-doped ZnO nanoparticles was checked. share|the share|the proportion} removal exaggerated with increase within the proportion of Sm within the catalyst and reached a most percentage of hour at zero.4 you look after Sm3+. The degradation proportion is exaggerated to eighty two, 89, seventy three and ninety six you tired of the presence of oxidants like H2O2, S2O82-, HSO5- and IO4-, severally, and is probably going thanks to the formation of extra aerobic species (Eskandarloo et al. 2016). The degradation of ofloxacin in secondary effluent by sonophotocatalysis by varied the operational parameters like unhearable power intensity, TiO2 loading, pH, varied gases (N2, O2 and Ar) and H2O2 concentration was according (Hapeshi et al. 2013). The degradation and mineralization potency of photo-Fenton and photocatalysis were compared with varied hybrid processes like sonophoto-Fenton, sonophotocatalysis and TiO2/Fe2+/ H2O2 with TiO2/Fe2+/ultrasound for isobutylphenyl propionic acid. As way because the organic carbon removal cares, the photo-Fenton, sonophotocatalysis and TiO2/Fe2+/ultrasound showed higher potency. This study showed that the hybrid system is Associate in Nursing economical technique for the speedy mineralization of microcontaminants (Me´ndez-Arriaga et al. 2009). The degradation of sulpha is increased once the ultrasound is as well as zero-valent iron and persulfate

(Zhou et al. 2016; Zou et al. 2014). Moreover, once of these area unit combined along, ninety six when} the initial compound is degraded after sixty min. varied factors like [persulfate]/[Fe0], pH, initial concentration, input power and reaction temperature were thought of. sensible performance was according within the quantitative relation 1:0.2–1:1 below pH scale three. As according within the previous cases, the degradation rate is minimized to eight to check out higher concentration of one hundred mg L-1 and exaggerated with the applied power (Zou et al. 2014). so as to ascertain the sensible relevancy of the tactic in effluent treatment, this work is extended and therefore the result of water matrixes like inorganic ions and chelating agents like ethylenediaminetetraacetic acid and ethanedioic acid was investigated. The degradation rate was exaggerated from zero.28 to 0.41 min-1 and zero.164 min-1 within the presence of ethanedioic acid and ethylenediaminetetraacetic acid, severally. The presence of low concentration of chloride particle increased the degradation to zero.4 min-1. different ions suppressed the degradation proportion. This study planned that this scientific method is convenient in effluent treatment with advanced matrix compared to different oxidization technique (Zhou et al. 2016).

Table 2: Overview of the various hybrid methods for pharmaceutical removal from aqueous solutions

Pharmaceuticals	Hybrid method	Operational parameters	Catalysts	Major findings	References
Tetracycline	Sono-ozonolysis	Freq. = 20 kHz, Power = 142.8 W L^{-1} , $[O_3]$ = 45.6 mg L^{-1} , pH 7, C0 = 400 mg L^{-1} , Gas flow rate = 35 L h^{-1} , Temp = 25˚C		91 % COD reduction was observed with an apparent rate constant of 1.04 min^{-1}	Wang et al. (2012)
	Sonocatalysis/ ozonolysis	Freq. = 20 kHz, Power = 85.7 W L^{-1} , $[O_3]$ = 13.8 mg L^{-1} , pH 7,	Goethite	100 % Removal efficiency, 30 % TOC reduction and good toxicity	Wang et al. (2011)

		$C0 = 100$ mg L^{-1} , Gas flow rate = 30 L h^{-1} , Temp = 25°C, [catalysts] = 0.5 g L^{-1}		reduction	
	Sonocatalysis	Freq. = 20 kHz, Power = 80 W, pH 3.7, $[Na_2S_2O_8]$ = 200 mM, C0 = 100 mg L^{-1} , Temp = 25°C, [catalysts] = 1gL^{-1}	Fe_3O_4	The degradation efficiency increased to 89 % After third cycle, the degradation efficiency is 74 %	Hou et al. (2012)
	Sonocatalysis	Freq. = 35 kHz, Power = 80 W,	TiO_2 and H_2O_2	100 % TOC reduction within	Hosein i et al.
		$C0 = 75$ mg L^{-1} , $[TiO_2]$ = 0.1–0.5 g L^{-1} , $[H_2O_2]$ = 20–100 mg L^{-1}		75 min	(2013)

Diclofenac	Sono-ozonolysis	Freq. = 20 kHz, Power = 400 W L^{-1} , $[O_3]$ = 31 gh^{-1} , pH 7, C0 = 40 mg L^{-1} , Temp = 25˚C		39 % TOC reduction with rate constant 0.211 mg L^{-1} min^{-1} , which is comparable with sonolysis and higher than ozonolysis	Naddeo et al. (2009a, 2012)
	Sonocatalysis	Freq. = 617 kHz, Power = 90 W, pH 3, C0 = 45 mg L^{-1} , Temp = 20 ±1˚C, [catalysts] = 1gL^{-1}	TiO_2, SiO_2, SnO_2, and titano silicate, ZnO, FeZnO	84 % of the initial compound was degraded in the presence of catalysts	Hartmann et al. (2008)
	Sonocatalysis	Freq. = 861 kHz, Power = 100 ± 3 W, pH 3.0, C0 = 30 lM, Temp = 20 ± 1˚C, Iron superoxide = 0.001 mM, zero-valent iron = 8.9 mM, divalent	Iron superoxide Enanoparticles, Reactive divalent iron and Reactive	The mineralization efficiency in the presence of iron species follows the order zero-valent (22 %)\superoxide (30 %)\divalent (43 %)	Gu¨yer and Ince (2011)

		iron = 0.01 mM	zero-Valent Iron		
Sonophotocata ly sis	Freq. = 213 kHz, power density = 55 mW L^{-1}, C0 = 0.07 mM, catalyst dose = 1gL^{1}, pH 6.5	TiO_2, FeZnO	100 % TOC removal was attained in the presence of catalyst	Madhav an et al. (2010b)	
Sonoelectro ch em ical	Freq. = 850 kHz, power = 94.1 W L^{-1}, C0 = 50 lg L^{-1}, pH 5.8, electrical voltage = 2.8 V, Pt electrode;		90 % of the degradat i on observe d with rate constant 0.505 min^{-1}	Finkbein er et al. (2015)	
Acetamino p hen and Naproxen	Sonocatalysis	Freq. = 28, 580 and 1000 kHz, Power = 180 ± 3	Powder e D activate d	In the case of sonocatalysis, the rate of decay	Im et al. (201 4)

		W, pH 3.7, C0 = 5 lM, Temp = 25 ± 1°C, [catalysts] = 10 mg L^{-1}	carbon And biochar	increased from 0.46 × 10^{-1} to 0.932 × 10^{-1} min^{-1} for acetaminophen and 0.962 × 10^{-1} – 2.363 × 10^{-1} min^{-1} for naproxen. Similarly, it is increased to 1.256 × 10^{-1} min^{-1} for acetaminophen and 3.512 × 10^{-1} min^{-1} for naproxen	

The experimental conditions and major results area unit highlighted supported the reportable literature

Sono-Fenton method

Ultrasound in addition to Fenton chemical agent utilizes the benefits of those 2 strategies to get a lot of •OH radicals and may effectively improve the degradation rate of organic pollutants. conjointly cavitation offers further mechanism in terms of shift within the system, which might facilitate in removing a number of the chemicals that area unit refractory to group radicals. Also, the mass transfer resistances related to the Fenton based mostly processes may well be eliminated thanks to the turbulent conditions gift within the reactor. within the case of advanced Fenton method, solid particles offer further nuclei for the cavitation phenomena and thence the quantity of cavitation events occurring within the reactor is increased leading to a ulterior improvement within the cavitational activity and thence information superhighway physical /chemical effects. Table two depicts a number of the applications of cavitation (Acoustic and Hydrodynamic) combined with Fenton method for the waste matter treatment illustrating the sort of waste matter, instrumentation used, optimum operative parameters and also the vital findings of the work.

Sonophotocatalysis

In the case of photocatalytic chemical reaction, the foremost common drawback associated is that the reduced potency of photocatalyst with continuous operation presumably thanks to the sorption of contaminants at the surface and interference of the ultraviolet activated sites, that makes them unprocurable for the destruction. inaudible irradiation are often used at the same time with ultraviolet irradiation for correct continuous cleanup of the catalyst surface throughout the photocatalytic operation. The combined method of sonochemical and photocatalytic chemical reaction offers higher results as compared to individual technique as each the techniques area unit supported the mechanism of generation of free radicals and its ulterior attack on the waste matter species. If the 2 modes of irradiations area unit operated together, a lot of free radicals are out there for the reaction thereby increasing the rates of reaction.

IV.CONCLUSION:

The degradation of RR eleven and RY sixteen, victimization Fenton and Electro-Fenton method and hybrid systems together with ultrasound/ultraviolet irradiation sources has been dispensed. The observations of those investigations clearly demonstrate the importance of selecting the optimum degradation parameters to get a high degradation rate, that is crucial for any utilisation of hybrid system. The degradation rate was influenced by several factors such as: initial peroxide concentrations, initial iron concentrations, pH, current density and initial dye concentration. The results of this studies square measure as summarized below:

- Fenton's method can be applied for the degradation of RR eleven and RY sixteen. Degradation rates of RR dye eleven and RY dye sixteen by suggests that of Fenton method are often expressed as a pseudo first- order reaction with reference to dye concentration. the speed of degradation was found to be most in acidic medium (pH=3). Optimum H2O2 and Fe2+ concentration for the degradation of RR eleven and RY sixteen (100 mg l-1) was found to be zero.9 g l-1and forty mg l-1,25 mg l-1 and zero.5 g l-1 severally. Higher initial iron concentrations showed negative impact on dye degradation. the colour and COD removal were ninety four try to seventy one nada severally.

- The results obtained for Fenton's method weren't satisfactory for higher dye concentrations. but it might be possible to use Fenton's method as pre treatment step together with alternative treatment ways.

- The use of ultrasound in Fenton method may be a sensible various. The study reveals that any acceleration of RR eleven and RY sixteen degradation are often achieved by this hybrid system. This will increase the number of reactive radical species inducement reaction of the substrate and degradation of intermediates and is principally to blame for the determined action. principally ultrasound contributes through cavitation to the cut of H2O2 created by sonolysis. This will increase the number of reactive radical species inducement reaction of the dye and degradation of intermediates and is principally to blame for the determined action. The amounts of peroxide and Fe2+ used square measure but that of Fenton's method by twelve nada, twenty try to twenty nada, five hundredth for RR eleven and RY sixteen severally, while not effectuality loses. Degradation rates of RR eleven and RY sixteen by suggests that of Sono-Fenton method are often expressed as a pseudo first-order reaction with reference to dye concentration.

- The limitation of photofenton method was the influence of initial concentration of the dye answer on the speed of degradation. The photodegradation rate is determined to decrease with increasing initial concentration the colour removal for RY sixteen and RR eleven dye concentration of three hundred mg-1 were to eighty eight try to eighty nada severally.

V. Scope for Future Work.

In the present investigation, attempts were made to compare the efficiency of the various processes and select the best one and apply for the textile industry waste. Since the present investigation has successfully paved ways for the development of hybrid systems for treatment of textile industrial effluent, much light is thrown on to extend the further research on the following:

- Another possible development of this work would be to go on exploring the efficiency of different Electrodes in PhotoElectro-Fenton process, for more effective treatment of textile dyes.
- By properly combining different possibilities, hybrid techniques can be developed for specific problems. Finally, other hybrid systems using advanced oxidation processes could be applied in order to study their efficiency in the degradation enhancement of the textile wastewater.

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