

Environmental Assessment of Shakkar and PENCH River of Chhindwara District & Photodegradation of River Water by Nano Catalyst

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Abstract: *In this research paper deals with work discussing about photo-degradation of river water by nano catalyst. This review discusses the utilization of photocatalysis for the degradation of water pollutants. Emphasis is placed on TiO₂ nanoparticles as a benchmark photocatalyst for the destruction of microorganisms and the degradation of a wide variety of organic compounds like phenolics, dyes, pesticides and pharmaceuticals. The mechanism of photocatalytic degradation is elucidated, underlining the importance of reaction kinetics for the efficient design of the processes. The effects of different reaction parameters on photocatalytic degradation are discussed. Surface modification of TiO₂ for visible light response doping and heterostructuring is outlined. Finally, the challenges in the implementation of this technology for “real” waste water systems are summarized. Photo-degradation is the process of alteration of materials by light, refers to the combined action of light and air. It is usually oxidation and hydrolysis. Nano Catalyst is used for water purification. In this research paper work we are going to discuss about water purification of Shakkar & Peach river of Chhindwara District, Mphilisi M. Mahlambi (2015). The South African National Water Act (Act number 36 of 1998) specifically states that water resources must remain fit for use on a sustainable basis and that their quality must be constantly monitored. Therefore the availability of water should be based not only on the quantity but also on the quality of the available water. However, due to agricultural, industrial, and domestic activities the quality of river water or groundwater continues to deteriorate due to pollution by hazardous materials.*

Keywords: Environmental, Assessment, Shakkar, PENCH River, Chhindwara District, Photodegradation, Nano, Catalyst etc

I. INTRODUCTION

The industrial revolution has led to the pollution of the natural resources in massive proportions. Environmental pollution caused by anthropogenic sources is a day-to-day problem faced by both developing and developed countries. Among the different types of pollution, air and water pollution from the point source contribute a major share of the overall imbalance of the ecosystem. Common pollutants are usually toxic organic compounds like chlorinated and non-chlorinated aliphatic and aromatic compounds, dyes, detergents and surfactants, agro wastes like insecticides, pesticides and herbicides, disinfection byproducts, volatile organic compounds, plastics, inorganic compounds (e.g., heavy metals), noxious gases and pathogens (e.g., bacteria, fungi and viruses). Hence, strict environmental regulations on the use of these recalcitrant pollutants and their safe disposal drives the research community to develop clean and green processes to degrade the pollutants before they are discharged into the atmosphere and water bodies. This review examines “photocatalysis” as an advanced oxidation process for the degradation of different kinds of organic pollutants for environmental remediation. Photolysis involves the use of ultraviolet (UV) or visible light radiation to effect chemical transformations. Photocatalysis uses a catalyst, usually, a semiconductor oxide to accelerate the photoreaction.

Water pollution is defined as the direct or indirect introduction of substances into the water bodies. These pollutants may be harmful to human health or the quality of aquatic ecosystems thus affecting the use of amenities and other legitimate uses of water. The sources of water pollution are categorised as either a point source or nonpoint source

(diffuse sources). Point source water pollution occurs when the polluting substance is emitted directly into the water system, for example, a pipe that spews sewage directly into a river, while nonpoint source (NPS) pollution refers to diffuse contamination which occurs when pollutants enter a water system through runoff, for example, when fertiliser is washed into a river by surface runoffs. Water pollutants can be classified as physical (odour, colour, solids, or temperature), biological (pathogens), or chemical (organic or inorganic compounds). Organic pollutants are of more concern than the other types because of their carcinogenic and mutagenic effects even after exposure to minute concentrations **Mphilisi M. Mahlambi** (2015).

Organic Pollutants Organic contaminants have become of more concern due to the inability of conventional water-treatment technologies to completely decompose these contaminants in aqueous media. The ubiquitous appearance of organic contaminants in sewage effluents, groundwater, drinking water, and sludge poses a significant threat to humans and aquatic organisms. Volatile organic compounds are known to be toxic and carcinogenic and have been implicated in the depletion of the stratospheric ozone layer while also contributing to global warming. These pollutants have been reported as being mutagenic and hence are responsible for the emergence of antibiotic resistance bacteria and genes. Some organic pollutants are referred to as persistent organic pollutants because when they enter the environment, they do not readily break down and may remain there for very long periods of time, polychlorinated biphenyls and may enter the food chains and accumulate to levels detrimental to organisms that are high up in the food chain. Also organic pollutants are a serious threat because they can be transported from the source of contamination through air as vapour or as dust particles by water currents or sediments and released in a new environment. Some of these organic pollutants eventually contaminate groundwater and surface waters; however, groundwater contamination is likely to be the primary source of human contact with these toxic chemicals. Generally, exposure to organic contaminants could be through breathing, through ingestion, through drinking, or by skin contact.

Natural Organic Matter- Natural organic matter is an agglomeration of organic compounds that naturally occur when animal and plant material break down. Natural organic matter consists of a wide range of compounds with diverse chemical properties (due to geographic origin and age of the decomposing organism) and occurs in all natural water sources. Natural organic matter components are a heterogeneous mixture of complex organic materials which consists of both hydrophilic and hydrophobic components. The hydrophilic components are microbial by-products and contain a higher proportion of aliphatic carbon and nitrogenous compounds with relatively high charge density such as amino acids and proteins as well as polysaccharides. Humic substances constitute the more hydrophobic fraction of Natural organic matter and exhibit relatively high specific ultraviolet absorbance values due to the presence of a relatively large proportion of aromatic carbon, phenolic structures, and conjugated double bonds. Due to the complexity of Natural organic matter no single tool can give its definitive structural or functional information. Nondestructive spectroscopic techniques appear to be the most useful analytical techniques for Natural organic matter characterization. Treatment options for the removal of Natural organic matter include coagulation, the use of magnetic ion-exchange resins, activated carbon, membrane filtration, and advanced oxidation processes. Characterisation of the structure and reactivity of Natural organic matter is vital because its presence creates problems in the quality of drinking water as well as in water-treatment processes. The presence of Natural organic matter results in an increased coagulant and disinfectant dosage resulting in increased sludge. It also increases biological growth in water-distribution networks and may also result in increased levels of heavy metal complexes and adsorbed organic pollutants. Furthermore, the presence of Natural organic matter causes membrane fouling as well as aesthetic and malodour problems in water. The organic acids that result from the oxidation of Natural organic matter have the capability to corrode turbines and engineering systems and this affects transportation of contaminants. Thus, understanding the impact of Natural organic matter in water-treatment processes is vital for human health and water-treatment plants as well as industrial processes where pure water is a prerequisite (Niu, Bihui, Ningfen Wang, Yuming Chen, Min Yu, Ziliang Hou, Zhongguo Li, and Yian Zheng, 2021).

Nano photocatalysts in Water Treatment Due to industrial and geographical reasons there is always a difference in the quality of water across the world. It is therefore acceptable that there is no possibility of one solution that can solve all the problems of water contamination. Thus, in the design for water-treatment technologies, nanotechnology will always play a key role. The intrigue of nanotechnology is the ability to control the manipulation of nanoscale (approximately 1 nm to 100 nm) structured materials and integrate them into large material components, systems, and architecture that

have novel properties and functions. The merits of using semiconductor photocatalysts in their nanorange far outweigh their use in their bulk form. For example, in the case of adsorption where surface sites of the adsorbent are utilised, diffusion is usually hindered due to the lack of a porous structure in the bulk materials. This is because the surface-to-volume ratio increases drastically with the decrease of the adsorbent from bulk to nanodimensions. Also, new physical and chemical properties emerge when the size of a material is reduced to the nanoscale level. The surface energy per nanoparticle increases significantly in the nanorange. This increase in surface energy directly results in an increase in contaminant removal even at low concentrations. The use of nanocatalysts also results in less waste generation, especially in posttreatment, since less quantity of nanomaterial will be required compared to its bulk form. Furthermore, with the use of nanomaterials, novel reactions can be accomplished at nanoscale due to an increase in the number of surface atoms which is not possible with its analogous bulk material, for example, the degradation of pesticides by nanoparticles which cannot be done by the metals in their bulk form.

II. OBJECTIVES

The main objective of photodegradation of water of Shakkar and Pench River of Chhindwara district. In this research paper discussed photocatalytic degradation of organic pollutants is 15 promising technology due to its advantage of degradation on pollutants instead of their transformation under ambient conditions.

The process is capable of removing a wide range of organic pollutants such as micropollutants such as endocrine disrupting compounds. Although significant amount of research has been conducted on TiO₂ photocatalysis at laboratory scale, its application on industrial scale requires certain limitations.

However the application of this treatment is constrained by several factors such as wide band gap (3.2eV), lack and inability of efficient and cost-effective catalyst for high photon-efficiency to utilize wider solar spectra. The effect of variables is required to be further studied in real water matrix to achieve representative results. The results achieved can be used to optimize the process and design appropriate reactor for potential large scale applications.

The use of solar radiation has to be improved by virtue of the design of the photo reactor in order to reduce the cost of treatment. Further research to investigate the degradation of the real water constituents is required to better comprehend the process applications.

Elangovan, Mugunthan, et. al. (2021) "Photocatalytic degradation of diclofenac using TiO₂-CdS heterojunction catalysts under visible light irradiation." Summary - In this research work author represented,

Rani, Manviri, et. al.(2021) discussed that "Degradation of Pesticides Residue by Engineered Nanomaterials." Summary - In this research work author represented, Leal, Joana F., et. al.(2020) studies that "TiO₂-rGO nanocomposite as an efficient catalyst to photodegrade formalin in aquaculture's waters, under solar light." In this research work author represented, Formalin or hydrate of formaldehyde, a common disinfectant used in aquaculture, is not able to absorb sunlight, therefore its photodegradation must be catalyzed.

Wang, et. al. (2020) reported that "Mechanism Insight into enhanced photodegradation of pharmaceuticals and personal care products in natural water matrix over crystalline graphitic carbon nitrides." Ulyankina, Anna, et al. (2020) "Photocatalytic degradation of ciprofloxacin in water at nano-ZnO prepared by pulse alternating current electrochemical synthesis." In this research work author represented,

Nguyen, Van-Huy, et. al. (2020) "Tailored photocatalysts and revealed reaction pathways for photodegradation of polycyclic aromatic hydrocarbons (PAHs) in water, soil and other sources." In this research work author represented,

Zyoud, Ahed H., et. al.(2019) studies that "Kaolin-supported ZnO nanoparticle catalysts in self-sensitized tetracycline photodegradation: Zero-point charge and pH effects." In this research work author represented, Bianchi, Claudia L., et. al.(2018) discussed that "Micro-sized TiO₂ as photoactive catalyst coated on industrial porcelain grès tiles to photodegrade drugs in water." In this research work author represented, **Mphilisi M. Mahlambi** (2015). Photocatalytic

Degradation of Water Pollutants Using Nano-TiO₂ The industrial revolution has led to the pollution of the natural resources in massive proportions. Environmental pollution caused by anthropogenic sources is a day-to-day problem

faced by both developing and developed countries. Among the different types of pollution, air and water pollution from the point sources contribute a major share of the overall imbalance of the ecosystem. Ravikrishnan Vinu et. al.(2011).

The photo catalytic degradation of various organic compounds like aliphatic and aromatic compounds, dyes, pesticides, pharmaceutical compounds and the destruction of micro organisms are extensively discussed.

Ravikrishnan Vinu et.al., (2011). The degradation of methylene blue in aqueous solutions has been re-examined as a method to characterize the photocatalytic activity of transparent TiO₂ coatings. Increasing irradiation intensities leads to a change in the observed kinetic behavior from zero-order to pseudofirst-order regarding the concentration of methylene blue. This is due to a diffusion inhibition of methylene blue.

III. STUDY MATERIAL AND METHOD

The mechanism of UV photocatalysis is well-documented, and the following reactions represent the key steps in the generation of charge-carriers and hydroxyl radicals, which mediate photocatalytic reactions. A pictorial representation of the mechanism of TiO₂ photocatalysis is shown in Fig. 1. Charge-carrier generation:

Charge-carrier generation:-



Charge-carrier trapping:-

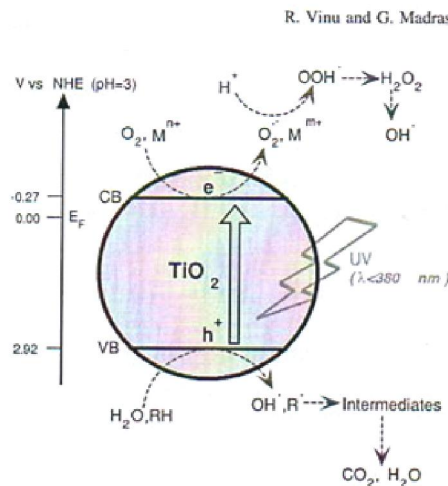


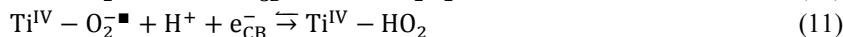
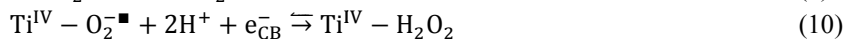
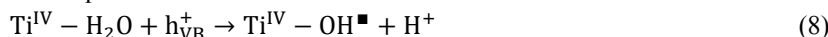
Fig. 1 Mechanism of photocatalysis on the surface of TiO₂

in presence of Ultra Violet radiation.

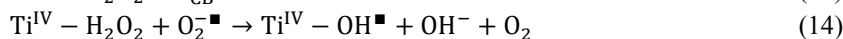
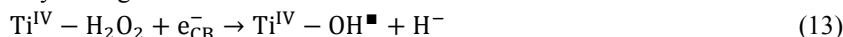
Electron-hole recombination:-



Reactions in aqueous medium:-



Photocatalytic Degradation of Water Pollutants:-



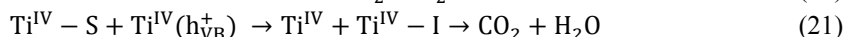
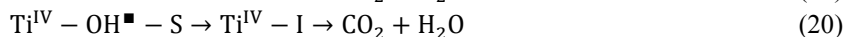
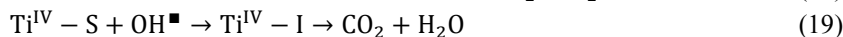
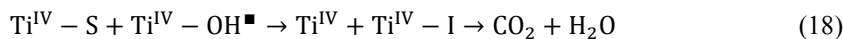
Adsorption-desorption of a reductant (e.g., any organic substrate S):-



Adsorption-desorption of an oxidant (e.g., metal ion):-



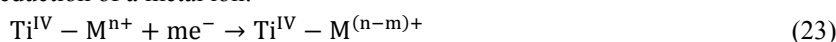
Photooxidation of a reductant :-



Adsorption-desorption of the organic intermediate :-



Photoreduction of a metal ion:-



When TiO_2 or any semiconductor oxide is irradiated with UV light of energy greater than or equal to its bandgap, valence band holes and conduction band electrons are produced (reaction 1). Hoffmann et al. have found by laser flash photolysis studies that the characteristic time scale for this charge-carrier generation reaction is of the order of femtoseconds. The charge carriers generated get trapped on the TiO_2 surface, which occurs over a time scale of tens of nano seconds (ns). Reaction 2 represents the trapping of the holes by the surface hydroxyl groups present in TiO_2 , and reactions 3–4 represent the reversible trapping of the electrons on the surface of TiO_2 (shallow traps), and the irreversible trapping or relaxation of the electrons in the bottom of the conduction band (deep traps), respectively. Ti^{IV} denotes the four coordinated surface functionality of TiO_2 or the “active site”. An important reaction that competes with the charge carrier trapping is the electron–hole recombination reaction. As shown by reactions 5–7, electron–hole recombination can occur either at the surface states of the TiO_2 , or in the bulk medium due to the delocalization of the electrons and holes from the surface. This is one of the most detrimental reactions in photocatalysis as this affects the interfacial charge transfer processes and hence the quantum efficiency of the photoprocess. Hence, several techniques have been adopted to modify the semiconductor surface to increase the lifetime of the charge carriers by introducing surface trapping sites by the deposition of noble metals or transition metals. Due to the contact between the semiconductor and the metal, electrons flow from the conduction band of the semiconductor to the metal, until the Fermi levels of the two materials are aligned. This results in enhanced charge-carrier separation. In an aqueous medium, valence band holes can react with the surface adsorbed water molecules to form hydroxyl species (reaction 8), and the trapped conduction band electrons can react with the dissolved oxygen in the system to form superoxide radicals (reaction 9). These superoxide radicals then undergo a series of reactions 10–14 with the solvated protons and the conduction band electrons to form hydrogen peroxide, hydroperoxy radicals, hydroxyl anions and hydroxyl radicals. Thus, hydroxyl radicals are generated by both the hole and electron pathways of photocatalysis. When the reactions are carried out in a non-aqueous (organic) medium, the surface bound hydroxyl species present in the semiconductor plays a major role (reaction 2), and the contribution of reactions 8–14 for the overall oxidation of the substrate is negligible. The next reaction in the sequence is the adsorption of the target material (oxidant or reductant) onto the active sites of the photocatalyst. This is one of the crucial steps in heterogeneous photocatalysis as the reactions take place on the surface of the semiconductor photocatalyst. This is followed by the oxidation of the reductant and the concomitant reduction of the oxidant by the attack of hydroxyl radicals and conduction band electrons, respectively. The characteristic time scales for the above two processes are of the order of 100 ns and ms, respectively. This shows that the oxidizing powers of VB holes and hydroxyl radicals are always higher than that of the reducing power of the conduction band eover, these interfacial electron transfer steps compete with the electron–hole recombination reaction (10 ns), and hence, the practical efficiency or quantum yield is always lower than that of the theoretical yield. Reactions 18–21 denote the different possibilities by which the surface bound or solvated hydroxyl radicals and the VB holes can attack and degrade organic materials. Initially, organic intermediates are formed, which, on longer exposure to UV radiation, undergo mineralization to form CO_2 and H_2O . Once the reaction is complete, the unreacted reactants, intermediates and the products desorb from the surface of the catalyst (reactions 15–17, 22). Similarly, when metal ions

are present in the system, they are reduced to their thermodynamically stable oxidation states by the conduction band electrons (reaction 23). This opens up a possibility to reduce the metal ions from their toxic to non-toxic states (e.g., Cr⁶⁺–Cr³⁺) by photocatalysis. Therefore, the overall photocatalysis reaction can be represented by reaction 24, wherein, the oxidants are reduced and the reductants are oxidized by the action of UV radiation on the semiconductor photocatalyst.

IV. DISCUSSIONS

Semiconductor Photocatalytic Materials

Several metal oxides (TiO₂, ZnO, MoO₃, CeO₂, ZrO₂, WO₃, α-Fe₂O₃, SnO₂, SrTiO₃) and metal chalcogenides (ZnS, CdS, CdSe, WS₂, MoS₂) can be used as photocatalysts. However, energetics dictates that, for a semiconductor photocatalyst to be active, the redox potential of photogenerated VB holes must be sufficiently positive to generate hydroxyl radicals and that of conduction band electrons must be sufficiently negative to generate superoxide radicals. The band structure diagram of the different materials, which have been tested for the photooxidation of organic compounds. It is clear that, TiO₂, ZnO, SrTiO₃ and CdS exhibit favorable bandgap positions compared to the other materials. The material selection is also based on the stability of the material toward photocorrosion. For example, ZnO and CdS have only one stable oxidation state (+2), and are prone to decomposition by VB holes. Furthermore, ZnO undergoes incongruous dissolution, yielding Zn(OH)₂ on the surface, thereby leading to the deactivation of the material over a period of time [18]. However, Ti in TiO₂ is capable of reversibly changing its oxidation state from +4 to +3; hence, TiO₂ is more favorable compared to the other materials. Between the two common crystal structures of TiO₂, viz., anatase and rutile—anatase phase TiO₂ is widely used in photocatalysis while rutile phase TiO₂ is used in pigments. Although rutile phase TiO₂ possesses a smaller band-gap energy (3.0 eV) compared to anatase phase (3.2 eV), indicating the possibility of the absorption of longer wavelength radiation, the former exhibits a higher photoactivity because of the position of the CB edge, which is more negative. This shows that TiO₂-anatase possesses a higher reduction power compared to that of TiO₂-rutile. In addition to the above advantages, other factors like its non-toxic nature (environmentally benign), low cost and the ease of synthesis makes TiO₂ the “photocatalyst of choice” for photocatalytic degradation reactions.

Synthesis and Properties of TiO₂

Different methodologies are being adopted for the synthesis of TiO₂. Many studies have concentrated on the synthesis of “nano-sized” TiO₂ for applications in photocatalysis. The importance of the nanometer regime stems from the fact that the physical, chemical, electrical and optical properties of the materials change immensely from the macroscopic to the nanoscale. One important property of nanoscale materials is the high surface to volume ratio of the material, which is beneficial to catalysis. This results in catalytic materials with high surface area and high porosity, which can promote high reaction rates owing to the high level of interaction of the reactants on the surface. Another important property is the efficient transport of the electrons and holes across the band gap of the material, which is governed by quantum confinement. The bandgap of the photocatalyst also dictates the wavelength at which the material can be excited. Hence, lower bandgap energies are beneficial for visible light absorption. TiO₂ photocatalysts have been synthesized in different shapes and morphologies, which include, nanoparticles, nanorods, nanotubes, nanopillars and nanowire arrays, nanobowls, nanowhiskers, aerogels, nanosheets, opal and inversed opals [12, 14]. The synthesis routes can be broadly classified as solution phase and gas phase techniques. Solution phase synthesis is the most preferred technique for the preparation of TiO₂ in the form of powders and thin films. Some of the solution phase techniques are the precipitation method, hydrothermal synthesis, solvothermal synthesis, sol–gel method, sol method (nonhydrolytic sol–gel), micelle and inverse micelle method, combustion synthesis, electrochemical synthesis, sonochemical synthesis and microwave synthesis methodologies. Gas phase technique is widely employed for the synthesis of thin film samples. Some of the gas phase techniques are chemical vapor deposition (CVD), physical vapor deposition and spray pyrolysis deposition. Each of the above synthesis methods possesses a unique advantage over the other techniques, and the characteristics of the final product vary from one method to another. The review article by Chen and Mao discusses each of the above synthesis techniques in detail, with particular emphasis on the morphology, size, shape and properties of the final TiO₂ product obtained in each method. Presents a representative list of the different techniques adopted for the synthesis of

TiO₂. These works elucidate that the final properties of TiO₂ nanoparticles like the phase composition (anatase : rutile), particle size, porosity, surface area, band gap and surface hydroxyl content can be tailored by varying the reaction conditions like: the precursor compound (TiCl₄, titanium(IV) isopropoxide, etc.), fuel (glycine, oxalyl dihydrazide, hexamethylene tetramine in the case of solution combustion synthesis), hydrolyzing agent (in the case of sol-gel synthesis), molar composition of the reactants, reaction temperature, reaction time (ageing time), calcination temperature and presence of gas atmosphere (air, Ar, NH₃). One of the synthesis methodologies that has been proven to yield nano- TiO₂ with enhanced characteristics is the solution combustion method (CS TiO₂),

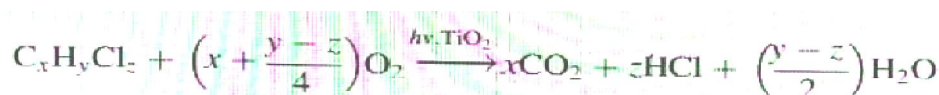
UV Photocatalytic Degradation of Organic Compounds

Chlorinated organic compounds like chloroalkanes were the first organic compounds to be degraded by photocatalysis. Besides being widely used as solvents, pesticides, refrigerants and in plasticizers and plastics, these organo-chlorine compounds are toxic and accumulate in the environment. Hsiao et al. demonstrated complete mineralization of dichloromethane (CH₂Cl₂), chloroform (CHCl₃), carbon tetrachloride (CCl₄) and trichloroethylene in the presence of TiO₂, to HCl and CO₂. They observed that the chloride ions generated during the reaction act as inhibitors for the conversion of chloroalkanes.

Table 1 Comparison of the physicochemical properties of combustion synthesized TiO₂ (CS TiO₂) with commercially available TiO₂ samples

TiO ₂	BET surface area, m ² g	Crystallite size, nm	pH zpc	Surface hydroxyl conten
CS TiO ₂	150	8±2 nm	2.4	15.6% total wt. los
DP-25 (80% A: 20% R)	50	A—37; R—90	6.3	1.4% (TGA); 163 (FTIR)
Hombicat UV 100	290	5	6.0	843 (FT-IR)
Junse	9.7	34	4.4	52 (FT-IR)
Aldrich Anatase	9.2	37	4.2	4 (FT-IR)
Millenium PC 10	11	75	-	-
Millenium PC 50	50	25	-	-
Millenium PC 100	89.6	21	5.9	505 (FT-IR)
Millenium PC 500	287	-10	6.2	-
Tronox A-K-1	90	20	-	-
Ishihara ST-01	340	11	5.8	719 (FT-IR)

A Langmuir–Hinshelwood kinetic model was proposed to find the adsorption and degradation rate coefficients of the chloroalkanes and the chloride ions. The relative order of degradation of the chloromethanes is: CHCl₃ > CH₂Cl₂ > CCl₄. A general stoichiometric reaction for the photocatalytic degradation of any organochlorine compound can be written as :



Regulator of lipids in the blood, is still detected in lakes and rivers, even after 21 years of persistence in the environment. Therefore, photocatalysis has emerged as an alternative for the effective degradation and mineralization of these persistent organic pollutants. The different pharmaceutical compounds that were subjected to photocatalytic degradation using TiO₂ are listed. The degradation of a wide class of compounds has been studied, and many studies have optimized the reaction parameters like pH, O₂ concentration and TiO₂ loading for maximum conversion of the parent drug compound. Most of these studies have also established the pathway of degradation of the pharmaceutical compounds, by following the evolution of the intermediates via mass spectroscopy. A generalized conclusion in each of the above studies is that the time taken for the complete mineralization of the pharmaceutical compound was longer compared to the removal of the parent compound. Calza et al. studied the photocatalytic degradation and ecotoxicity of amiloride, a diuretic agent, and concluded that although amiloride is non-toxic, the degradation intermediates were

toxic compounds. Similar results were also observed for salbutamol, indicating the importance of complete mineralization of the drug to CO_2 , H_2O and inorganic ions. The pathway of degradation of diclofenac, a non-steroidal anti-inflammatory drug.

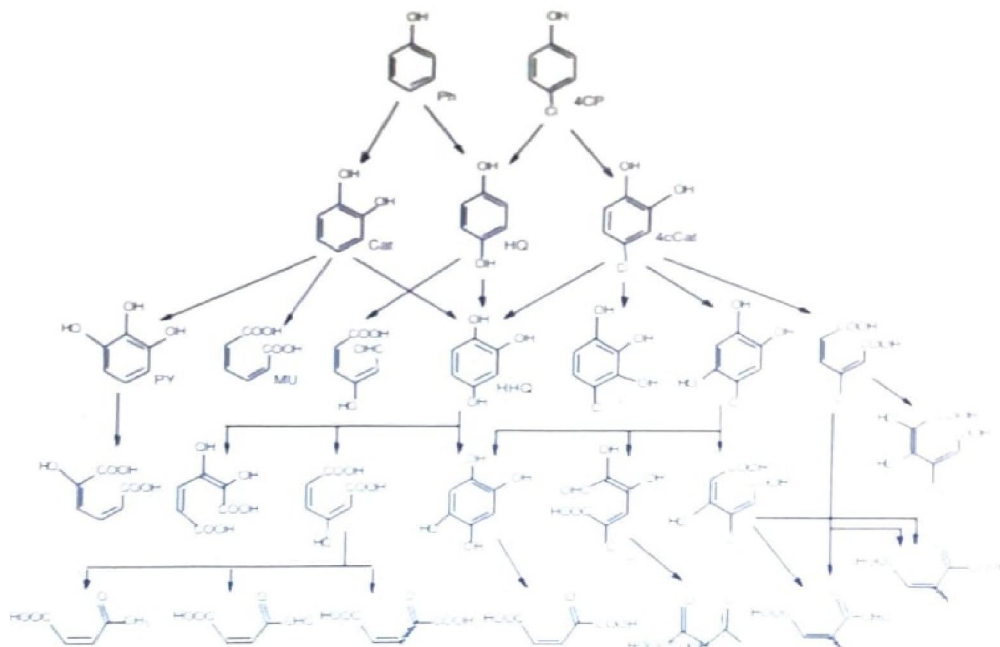


Fig. 2 Detailed pathway of degradation of phenol and 4-chlorophenol adapted from different studies. Some of the primary and secondary intermediates are identified as Ph—phenol, 4CP—4-chlorophenol, Cat—catechol, HQ—hydroquinone, 4cCat—4-chlorocatechol, PY—pyrogallol, MU—muconic acid and HHQ—hydroxyl hydroquinone. Degrades to smaller organic acids like oxalic acid, maleic acid, succinic acid, fumaric acid, acrylic acid, etc. Finally, these acids mineralize to CO_2 and H_2O after long exposure periods.

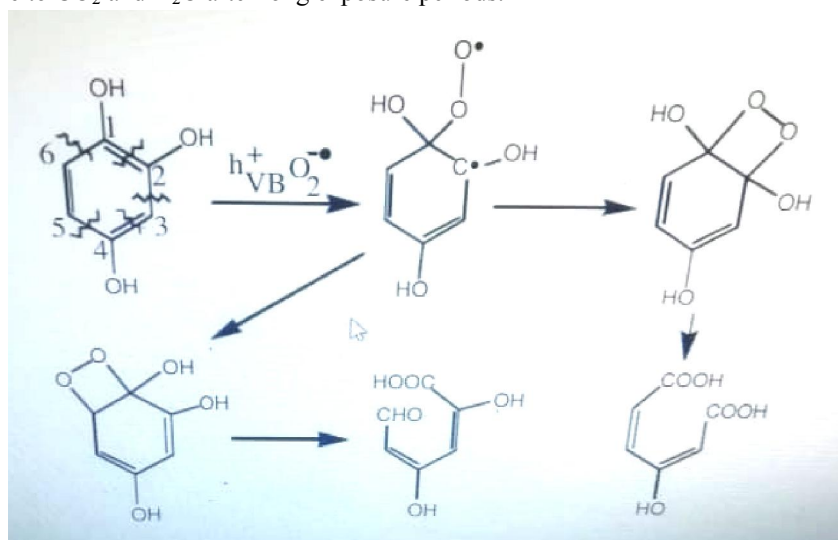


Fig. 3 Mechanism of cleavage of benzene ring in hydroxy hydroquinone, resulting in the formation of carboxylic acids and aldehydes. The possible sites of ring cleavage are represented by broken lines. Sivalingam et al. studied the effects of different substituents like chloro group, nitro group and methyl group on the kinetics of photocatalytic degradation of phenol, and concluded that the order of degradation is: pentachlorophenol, trichlorophenol, dichlorophenol, 4-chlorophenol & 2-chlorophenol, 2-methyl phenol & 3-methyl phenol, phenol. Similarly, Priya and Madras conducted a thorough study on the effect of multiple substitutions of the above groups on the degradation of phenol. Their results

indicate that chloro-methylphenols (cresols) degraded much faster compared to chloro-nitrophenols, which was attributed to the ring deactivating nature of the nitro group for the hydroxyl radicals to react with the phenolic compound.

Another interesting conclusion of their study shows that the degradation is independent of the position of the substituents, but depends on the nature of the substituent group. In another study, it was found that chloro and hydroxy-substitution in nitrobenzene accelerated the degradation rate, while nitro-substitution resulted in a reduced degradation rate of nitrobenzene. Other important organic compounds, which have attracted interest in the past decade, include dyes, pesticides and pharmaceutical compounds. The forthcoming sections will examine the various studies on the photocatalytic degradation of these pollutants.

V. CONCLUSION

Overall, this review brings to attention the advancements of titania nanoparticles in their use for water-treatment processes. These advancements thus serve as techniques that can be used in conjunction with the present water-treatment technologies to alleviate the problems associated with pollutants in drinking water systems. Also, since titania can degrade organic pollutants while simultaneously oxidising heavy metal species, it serves as a cheap dual process that can be further explored to realize the potential of TiO₂ in water-treatment processes. Furthermore, titania provides a cheaper alternative that can be used in conjunction with the already existing water-treatment technologies, especially membranes. Also the use of titania based systems is a better alternative for the use since it harnesses the green solar energy and thus reduces the environmental waste due to the use of chemicals. The ability of TiO₂ nanoparticles to completely deal with organic pollutants without producing recalcitrant by-products has thus opened new research avenues to be pursued.

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