1.0 Introduction

Indian Pharmaceutical Industry is world’s third largest in terms of the volume. India, being the largest exporter of generic drugs in volume terms, is also the third-largest API manufacturer, behind China and Italy. It is estimated that one out of five drugs sold globally has an Indian connection according to the Pharmaceutical Export Promotion Council (Pharmexcil). Nobody ever anticipated prescription drugs to pollute the world, except perhaps at the point of manufacture. Pesticides were the only recognised environmental pollutants employed in healthcare. The possibility of drugs polluting the world remains largely unknown, even among the educated. From effluent samples collected from Patancheru (a Hyderabad suburb; the world’s pharmaceutical manufacturing hub), the Larsson study [1] identified a number of drugs in alarming quantities. Among the 59 active pharmaceutical ingredients (API) tested, 21 were detected at levels greater than 1microgram/L. More than 11 drugs were detected at the highest level ever on the planet. The main sources of these pharmaceutical compounds are pharmaceutical industry, intensive farming and human excretion residues. Pharmaceutical compounds including antibiotics, hormones, preservatives and anaesthetics etc. have been identified in surface, ground, sewage and drinking water [2-9].

In recent years, several articles have been reported regarding the drugs/pharmaceuticals in the environment [10]. The presence of wide variety of drugs/pharmaceuticals and personal care products in waste water effluents and surface drinking water has been documented in literature [11–16]. Some studies also showed the presence of different mixtures of pharmaceuticals in waste and surface waters [11,13,17]. Several classes of drugs such as anti-inflammatory drugs, antibiotics, sulfa drugs, antifungal drugs, antidiabetics, barbiturates, β-blockers, diuretics, antihypertensive drugs,
hormones, lipid regulators, psychiatric drugs, histamine-blockers, topical products and antiseptics have been monitored and detected in surface waters [5–20]. Some drugs/pharmaceuticals have also been reported in drinking waters [21–23]. Although almost all of the pharmaceuticals are normally detected at low concentrations but their continuous discharge into the surroundings may increase the possibility of their synergistic effects with other pharmaceuticals or chemicals in the aquatic environment [24]. Thus an advanced with low cost and highly effective water treatment technologies are required to increase storage capacity of clean water.

Fig. 1 Routes of entry of pharmaceuticals in the environment (1 – exposure, 2 – fate and 3 – effects) [25].
Drug residues tend to build up in the environment and eventually accumulate in the bodies of terrestrial and aquatic organisms, drug residues originating from therapeutical use in human medical care are discharged into the aquatic system from municipal sewage treatment plants which act as point sources for surface water contaminations [26]. Many drugs not only resist their own degradation, but also interfere with the microbial degradation of other substances in sewage. This is because antibiotics kill friendly microbes which decompose organic waste. Another major concern is that microorganisms exposed to extraordinarily high concentrations of antibiotics evolve into extremely dangerous pathogens. Even the most developed countries are not entirely free from the environmental burden of pharmaceuticals; pharmaceuticals have been detected in surface, ground and drinking water [27]. In India, industrial effluents are handled by end-of-pipe treatment, which, like common effluent treatment plant, results in residual persistent organic pollutants and toxic metals in the treated water. The common treatment of effluents from heterogeneous industries results in a mixture of chemicals with unpredictable toxicology [28].

Recycling of waste waters is usually associated with the removal of suspended solids, health-threat coliforms and soluble refractory organic compounds but the process is both tedious and expensive to treat [29]. In current scenario water treatment technologies such as coagulation simply concentrate the pollutants present by transferring them from one phase to other, and not being completely “eliminated” [30]. Other conventional water treatment methods are sedimentation, filtration, chemical and membrane technologies, but these involve high operating costs and could generate toxic secondary pollutants into the ecosystem [31]. These concentrated toxic contaminants are highly redundant and have been concerned worldwide due to the increasing
environmental awareness and legislations.

Chlorination has been the most commonly and widely used disinfection process. The disinfection by-products generated from chlorination are mutagenic and carcinogenic not only to human health [32] but also to the aquatic and other land lives. Different compounds have been detected in municipal and pharmaceutical waste water; among them some are not biodegradable due to their resistance or toxic effects on microbial process. To overcome those problems and considering available economical sources different cost effective alternative treatment processes have been adopted, optimized and applied to both traditional and anticipated technologies required for waste water treatment.

Studies have proven that some pharmaceuticals are resistant to conventional biological treatment processes used by municipal wastewater treatment plants (WWTPs) and are subsequently found globally in treated wastewater effluents in concentrations from low ng L\(^{-1}\) to µg L\(^{-1}\)[33-36]. Therefore, a cost-effective treatment with simple operating and minimized maintenance is still desired. Advances in nanotechnology are generating novel materials with unique surface-active properties which may be beneficial in removing PPCPs from raw water sources [37-40].

2.0 Waste water treatment technologies

Photocatalytic degradation under UV irradiation and adsorption has become very useful and are being used for wide range of removal of contaminants. Advanced oxidation processes (AOPs) have already been used for the treatment of wastewater containing recalcitrant organic compounds such as pesticides, surfactants, coloring matters, pharmaceuticals and endocrine disrupting chemicals. Moreover, they have been
successfully used as pretreatment methods in order to reduce the concentrations of toxic organic compounds that inhibit biological wastewater treatment processes [41].

Highly reactive oxygen species (ROS) is generated as a result of the photo-induced surfaces for microbial inactivation. The charge separation on Titanium dioxide (TiO$_2$) and organic mineralization without creating any secondary pollution is well-documented. So far, the application of such analysis for waste water treatment is still experiencing a series of technical challenges [42]. TiO$_2$ is the most active photo-catalyst under the photon energy of 300nm. Other than these, the chemical and thermal stability of TiO$_2$ or resistance to chemical breakdown and strong mechanical properties have promoted its wide application in photo-catalytic water treatment

2.1 Photocatalytic degradation

Photocatalytic degradation is considered a promising, cleaner, and greener technology for the removal of toxic organic and inorganic pollutants from water and wastewater. In photocatalytic degradation a nontoxic semiconductor catalyst is employed. When the semiconductor is illuminated with radiation of an appropriate wavelength it becomes a powerful oxidant, which converts most of the organic materials into carbon dioxide and water. Photocatalytic degradation process is an eliminating process of organic compound in water by using the interaction between ultraviolet radiation and titanium dioxide (TiO$_2$) as catalyst. It has the potential for treating toxic organics in waste water. The technique has also been employed for the photomineralization of a large number of dyes such as methylene blue, direct and acid dyes, azo dyes, and a reactive black [44]. The photocatalytic degradation of different types of organic molecules on nontoxic TiO$_2$ has been analyzed in terms of Langmuir–Hinshelwood kinetics [45-51].
In the last few years, research on new methods for advanced waste water treatment has gone from processes involving phase transfer of a contaminant (e.g. activated carbon, air stripping, pyrolysis) to complete destruction of the contaminant. The possible application of photocatalytic destruction of the organic matter in water has been extensively investigated. [52, 53].

2.2 Photocatalysts

The nature of the photocatalyst determines the rate and efficiency of the process. The most commonly studied photocatalysts are TiO$_2$, ZnO, ZnS and CdS. Additionally, In$_2$O$_3$, SrTiO$_3$, SnO$_2$ and WO$_3$ have been used as photocatalyst but all showed lower levels of photo-activity [54] whereas SiO$_2$ and MgO are found inactive. Since most metal oxides and sulphides can undergo irreversible photo-corrosion on the surface [55], these semiconductors are not suitable for long-term treatment processes. Some metal sulphides may also be photocatalytic, but they have some weakness in terms of corrosion. Iron oxide may be inexpensive, but it can also be corroded. Zinc oxide is probably the closest competitor of titanium dioxide but its weaknesses are instability in some solutions and a tendency for its hydroxide to cover its surface, causing lower photocatalytic activities [56-61]. However, TiO$_2$ is an inert oxide and can be reused several times. Ti in TiO$_2$ is capable of reversibly changing its oxidation state from +4 and +3, and hence TiO$_2$ is more favoured compared to the other materials. TiO$_2$ (titania) is the most widely used because Titanium dioxide is synthetically manufactured instead of mined. Although TiO$_2$ exists in two forms, viz., anatase and rutile, anatase phase TiO$_2$ ($EBG = 3.2$ eV) is more active for photocatalysis applications, even though rutile phase TiO$_2$ ($EBG = 3.0$ eV) possesses a smaller band gap, indicating the possibility of
absorption of long wavelength radiation. This is because, the CB position of anatase TiO$_2$ is more negative compared to rutile, which results in the higher reducing power of anatase.

2.3 Photocatalyst: TiO$_2$

TiO$_2$ is an opaque white pigment. This has been widely used to make products as diverse as paper, plastics, lipstick, toothpaste, and pharmaceutical tablets. The photocatalytic properties of titanium dioxide were discovered by Akira Fujishima in 1967. The process on the surface of the titanium dioxide was called the Honda-Fujishima effect. The main reason for the use of TiO$_2$ bulk [62], nanoparticles [63] and surfaces [64] in various applications as a wide bandgap semiconductor together with good experimental access to well-ordered crystals and single crystalline surfaces [64]. This activity is also used in applications like wastewater treatment [62] or heterogeneous catalysis [64, 65].

2.4 Catalyst mechanism

TiO$_2$ has been shown by many researchers to be very effective as a photocatalyst. UV radiation strikes the TiO$_2$ particle exciting an electron from the ground state to an excited state. At this point an electron acceptor, typically oxygen, accepts the excited electron leaving an electron hole on the surface of the TiO$_2$. This hole is then available to accept electrons from OH$^-$ ions, oxygen, or water to create the hydroxyl radicals. These radicals then oxidize the pollutants in the water. The following equations describe the process using OH$^-$ as the precursor for the radicals and then the effects of the radical formation.
3.0 Electron accepter: $\text{H}_2\text{O}_2$

Hydrogen peroxide is a potential additive to the photocatalytic process that has been studied in depth. Addition of $\text{H}_2\text{O}_2$ has produced widely different results under experimental conditions. Hydrogen peroxide has been shown to increase the rate of mineralization of target compounds eleven fold [66]. However, it has also been shown to decrease the rate of photocatalysis [67]. This wide variance is not surprising based on Equations 7 – 9 [68].

\[
e^- + \text{H}_2\text{O}_2 + \text{H}^+ \rightarrow \text{H}_2\text{O} + \text{OH}' \quad \text{(vii)}
\]

\[
\text{H}_2\text{O}_2 + \text{OH}' \rightarrow \text{H}_2\text{O} + \text{HO}_2' \quad \text{(viii)}
\]

\[
\text{HO}_2' + \text{OH}' \rightarrow \text{H}_2\text{O} + \text{O}_2 \quad \text{(ix)}
\]

Equation (vii) shows hydrogen peroxide as an electron acceptor similar to that of oxygen. Research has found that the use of $\text{H}_2\text{O}_2$ can help make up for a lack of oxygen [69] Equation (vii) also shows the production of a hydroxyl radical, which is also a benefit to the photocatalytic process. Equations (viii) and (ix) demonstrate the problem with hydrogen peroxide; it will consume hydroxyl radicals meant for attacking the target pollutants.
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4.0 Adsorption

Adsorption is a process in which a substance, in gas or liquid phase, accumulates on a solid surface. It is based on the capability of porous materials with large surfaces to selectively retain compounds on the surface of the solid. Adsorption is a surface phenomenon with common mechanism for organic and inorganic pollutants removal. When a solution containing absorbable solute comes into contact with a solid with a highly porous surface structure, liquid–solid intermolecular forces of attraction cause some of the solute molecules from the solution to be concentrated or deposited at the solid surface. The solute retained in adsorption processes is called adsorbate, whereas, the solid on which it is retained is called as an adsorbent. This surface accumulation of adsorbate on adsorbent is called adsorption. This creation of an adsorbed phase having a composition different from that of the bulk fluid phase forms the basis of separation by adsorption technology.

The exact nature of bonding in adsorption depends on the species involved, but the adsorption process is generally classified as:

- Physisorption: It is a type of adsorption in which the adsorbate adheres to the surface through Van der Walls interactions.
- Chemisorption: It is a type of adsorption whereby a molecule adheres to a surface through the formation of a chemical bond.

Adsorption takes place primarily on the walls of the pores or at specific sites inside the particle. As the pores are generally small, the internal surface area is greater than the external area. Separation occurs because differences in molecular weight, shape or polarity cause some molecules to be held more strongly on the surface than others. In
many cases, the adsorbate is held strongly enough to allow complete removal of that component from the fluid [70].

The adsorption process of the adsorbate molecules from the bulk liquid phase into the adsorbent surface is presumed to involve the following stages:

- Mass transfer of the adsorbate molecules across the external boundary layer towards the solid particle.
- Adsorbate molecules transport from the particle surface into the active sites by diffusion within the pore–filled liquid and migrate along the solid surface of the pore.
- Solute molecules adsorption on the active sites on the interior surfaces of the pores.
- Once the molecule adsorbed, it may migrate on the pore surface through surface diffusion [53].

### 4.1 Adsorbent materials in water treatment processes

Adsorption is a commonly used method in water treatment and other separation processes. Among other methods, adsorption is fast and simple in operation. The key factor for the adsorption process is the choice of adsorbent. A good quality adsorbent should have fast kinetics of interaction with the adsorbate, porous structure resulting in high surface area and high adsorption capacity. Another important aspect in adsorptive water treatment processes is the regeneration of spent adsorbent.

A variety of agricultural waste has been used for adsorptive removal of pollutants. In India, agriculture is the primary occupation, agricultural waste biomass are abundantly available. Several studies have been carried on the use of modified
agricultural products for adsorption of heavy metal and dyes from aqueous solution such as modified chitosan [71], peanut skin [72], apple waste [73], wool fibre [74], sunflower stalk [75], linseed flax straw [76]. Recently, great effort has been contributed to develop new adsorbents and improve existing ones like cassava waste [77], rice straw, coconut husk, rice husk, bagasse, tree bark [78], gram husk [79], and wheat husk [80]. Substrates such as maize cob [81], china clay [82], chitin [83], refuse derived fuel [84], chromium waste sludge [85], agricultural residues [86], coirpith [87], waste products like alum sludge, hyposludge [88], activated petroleum coke [89], neem leaf powder [90], bentonite and modified bentonite [91], spent brewery grains [92] have been used for the removal of pollutants from waste water advantageous mainly due to their widespread availability and cost effectiveness.

4.2 Carbon nanotubes

Carbon nanotubes have become the focal point of widespread scientific research owing to their outstanding chemical, mechanical and physical properties. Carbon nanotubes (CNTs) are cylinder-shaped macro-molecules with a radius as small as a few nanometres, which can be grown up to 20 cm in length [93]. The walls of these tubes are made up of a hexagonal lattice of carbon atoms analogous to the atomic planes of graphite.

Single-walled carbon nanotubes (SWCNTs) are nanometric cylinders consisting of a single graphene sheet wrapped up to form a tube. They were discovered in 1993 [94,95]. The discovery of SWCNTs opened a new field of interest.

Carbon nanotubes (CNTs) are relatively new adsorbents that can adsorb trace pollutants from wastewater. Considerable attention has been focused on adsorption by
CNTs of contaminants such as Zn\(^{2+}\) [96], Cd\(^{2+}\) [97], Pb\(^{2+}\) [98,99], Cu\(^{2+}\) [108,109], fluoride [100], arsenate [101], trihalomethanes [102], 1,2-dichlorobenzene [103], xylene [104], trihalomethanes [124], 1,2-dichlorobenzene [125], dyes [105], and pharmaceuticals [106]. Understanding adsorption equilibrium, kinetics and thermodynamics is critical to the design and operation of adsorption processes. Early works have presented only equilibrium and kinetic adsorption data and a few studies have measured the thermodynamic parameters of adsorption by CNTs. Li et al. [107] and Peng et al. [125] investigated the thermodynamics of adsorption of Pb\(^{2+}\) and 1,2-dichlorobenzene onto CNTs, respectively. Wu [127] and Wu [121] elucidated the thermodynamics of adsorption of C.I. Reactive Red 2 and Cu\(^{2+}\), respectively. Lu et al. [107] analyzed the thermodynamics of adsorption of trihalomethanes by CNTs. Few studies have investigated adsorption of dyes by CNTs and simultaneously determined equilibrium and thermodynamic parameters; however, no study has determined the parameters that govern adsorption of direct dyes.

Geometrically, CNTs especially SWCNTs have four different spaces which act as possible adsorption sites for binding of foreign components [108-110].

- **Internal sites** → these sites are found within the hollow structure of tubes and available only when ends of the tube are open.
- **Interstitial channels** → these sites are easily accessible for the adsorbate species and found in the interior space of the bundle between individual nanotubes.
- **External grooves** → the grooves present on the periphery of a nanotube bundle and the exterior surface of the outer most nanotubes, where two adjacent parallel tubes meet.
Exposed surface site or outside surface → outside surface site is highly accessible for the adsorbate and found on the curved surface of individual nanotubes on the outside of the nanotube bundles.

A comparative study of MWCNTs and SWCNTs as nano-adsorbents for the removal of reactive blue 4 (RB4) textile dye from aqueous solutions was performed as a function of effects of pH, shaking time and temperature [111]. The optimum adsorption was found to be at pH 2.0 and at 4 h contact time for both adsorbents. The equilibrium data were best fitted to the Langmuir isotherm model with the maximum sorption capacity for RB4 occurring at 323 K being 502.5 and 567.7 mg/g for MWCNT and SWCNT, respectively. SWCNTs showed higher adsorption capacity for RB4 than MWCNTs because the specific surface area and total pore volume of SWCNTs were 114.3% and 91.9% higher than that for MWCNTs, respectively.

4.3 Unsaturated polyester resins (UPRs)

The first unsaturated polyester resins were synthesised in the 1930’s. Carlton Ellis found that unsaturated polyester prepolymer could be mixed with styrene, and copolymerised into a rigid polymer. Unsaturated polyester resins (UPRs) are one of the most important thermostat materials used in composites industry for the preparation of moulding compounds, laminates, coatings, and adhesives. Since their inception some 75 years ago. Unsaturated Polyester Resins are manufactured by condensation reaction between acids like Isophthalic Acid, Phthalic Anhydride, Maleic Anhydride and glycols like Propylene Glycol, Di-ethylene Glycol, Mono-ethylene Glycol, etc. at temperature 210 - 230°C in stainless steel reactor under nitrogen atmosphere. During reaction water is
formed which is regularly removed in order to remove traces of un-reacted glycols and water.

**4.4 Nanotalc**

Talc is a naturally occurring mineral, a layered hydrous magnesium silicate of general empirical formula $\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$, that is broken up and usually ground to a fine powder. Talc is a white, apple green, gray powder with luster pearly or greasy. It has a high resistance to acids, alkalies and heat. The hydroxy groups normally are internal to the magnesium layer and are not accessible to water except at the edges of the silicate sheet. Thus, conventional talc powder is a hydrophobic material that easily blends and disperses with organic media including polymers but is not easily dispersed in aqueous solvents. The talc initial particle size is not of great importance, but preferably the initial median particle size is about $0.5 \mu m$ to about $10 \mu m$ and a specific surface area (SSA) of about $5 \text{ m}^2/\text{g}$ to about $20 \text{ m}^2/\text{g}$.

**5.0 Review of literature**

Organochlorine compounds like dichloromethane (CH2Cl2), chloroform (CHCl3), carbon tetrachloride (CCl4) and trichloroethylene (TCE, C2HCl3) were the first organic pollutants degraded using photocatalysis [112, 113]. These toxic organic compounds are widely used as solvents, pesticides and refrigerants. Photocatalytic degradation of different classes of organic compounds has been studied in various review articles [114-118].

Dyes are the most widely used organic substrates to test the photocatalytic activity of nano-sized catalysts. This is because of the simplicity in the analysis of the
dyes. Dyes find numerous applications in our daily life in clothing, food, paper, leather, cosmetics, plastics, drugs, electronics and printing. Nearly 80% of the synthetic dyes produced in the world are consumed by the textile industry. Biodegradation methods are effective in reducing the biological oxygen demand of the effluent, but reducing the chemical oxygen demand and toxicity to permissible levels is a challenging task. Hence, the role of AOPs in the degradation of dye waste waters is very critical. Many reviews exclusively discuss the degradation of different class of dyes under UV and visible light exposure, [119-121] various parameters that affect the degradation of dyes [122] and modified TiO$_2$ for the degradation of dyes [123].

The presence of the photocatalyst greatly enhanced the degradation rates of the drugs. The photocatalytic degradation kinetics of antivirus drug lamivudine in aqueous TiO$_2$ dispersions is investigated successfully [124]. Results indicated that degradation efficiencies of lamivudine were highly affected by TiO$_2$ content and initial lamivudine concentration. Photocatalytic degradation of imazaquin in an aqueous suspension of titanium dioxide as catalyst has been studied and reported the results [125] effects of initial concentration and pH on the degradation rate were investigated. Tetracycline structure was effectively degraded by TiO$_2$ photocatalysis using different kinds of light sources and small amounts of catalyst [126] Greater oxidation was observed when the UV lamp and solarium were used. Partial mineralization and a slight pH increases was also observed. Total inactivation of the antibiotic was reached after 1-h irradiation using UV and solarium lamps. Therefore, TiO$_2$-based photocatalysis emerges as a feasible way to inactivate antibiotics, as a pre-treatment prior to further biological treatments. Adsorption and photocatalytic degradation of 15 different pharmaceuticals in the presence or absence of UV using titanium dioxide (TiO$_2$) anatase and rutile nanowires
as well as commercially available TiO\textsubscript{2} (P25) nanoparticles. [16] The kinetic adsorption studies demonstrate adsorption. It is observed that UV-exposed anatase-phased nanowires were more effective at degrading venlafaxin, atorvastatin, ibuprofen, naproxen, gemfibrozil, lincomycin, norfluoxetine, diclofenac, and trimethoprim, while the rutile-phased nanowires were more effective for fluoxetine and norfluoxetine [127]. Several pharmaceuticals have been shown to degrade due to the action of sunlight [128-129]. The most extensively studied of these compounds is the analgesic/anti-inflammatory drug diclofenac, which has been shown to degrade in the aquatic environment due to ultraviolet (UV) light. Other compounds such as the antimycotic drugs naftifine, sulbentine, cloxiquin, tolnaftate, and chlorphenesin have also been shown to be light sensitive [130] and an overall elimination rate of 0.03 day\(^{-1}\) due to photochemical degradation was observed for triclosan [131] Yong Song Cao et al.\textsuperscript{43} investigated the photocatalytic degradation of chlorfenapyr in aqueous suspension of TiO\textsubscript{2} with and without the use of hydrogen peroxide at two different monochromatic UV irradiations (300 and 350 nm).

Removal of different pharmaceuticals has been investigated in the presence or absence of UV was comparatively studied using titanium dioxide (TiO\textsubscript{2}) anatase and rutile nanowires as well as commercially available TiO\textsubscript{2} (P25) nanoparticles [132]. The nanomaterials evaluated differed in photocatalytic efficiency by compound, with the UV-exposed anatase-phased nanowires being more effective at degrading venlafaxin, atorvastatin, ibuprofen, naproxen, gemfibrozil, lincomycin, norfluoxetine, diclofenac, and trimethoprim, while the rutile-phased nanowires were more effective for fluoxetine and norfluoxetine. Studies on clofibric acid photodegradation showed that the presence of nitrates and humic acids in water increases pharmaceutical degradation rate due to radical
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generation [133]. The presence of TiO$_2$ in photocatalytic treatments also facilitates the degradation of clofibric acid into numerous aromatic and aliphatic subproducts [134-135].

The combination of TiO$_2$ with an adsorbent such as activated carbon (AC) could have several benefits: because AC is able to adsorb a wide range of synthetic organic compounds and transfer them progressively to the TiO$_2$ [136]. Synergistic effect of TiO$_2$-AC on the removal of five different pharmaceuticals (sulfamethoxazole, carbamazepine, clofibric acid, diclofenac, and ibuprofen) from water, and the best overall removal was obtained.

Adsorption is dependent on both, hydrophobic and electrostatic interactions of the pharmaceutical with particulates and microorganisms.

The use of activated carbon adsorption offers a further possible option to remove organic pollutants such as pharmaceuticals from wastewater. In fact, activated carbon in powdered or granulated form is able to remove unpolar and polar pollutants, e.g., drugs and even diagnostics like x-ray-contrast media from aqueous solutions because of the large adsorptive surface of the carbon which interacts with the comparable structural elements in the drug molecules [137]. Onal et al. [138] studied the adsorption of naproxen sodium onto activated carbon. Adsorption of naproxen sodium onto activated carbon increased slightly with an increase in temperature, indicating that the process is endothermic. Several studies have been carried out to investigate the removal of pharmaceutical active compounds in ultrapure and natural water. Typically, the adsorption capacity determined in ultrapure water is a starting point, by which the characteristics of both adsorbent and adsorbate can be well defined and compared. However, in real drinking water treatment situations, adsorption would be influenced by water quality parameters, and operation conditions. In this section, the most relevant
studies to date are summarized. Adam et al. [139] investigated the removal of seven antibiotics using PAC – Calgon WPH Pulv. in ultrapure water and river water. The percent removal of each of the antibiotics for PAC dosages of 10 and 20 mg/L ranged from 57% to 97%. The isotherms of carbamazepine, bezafibrate, clofibric acid and diclofenac were determined by Ternes et al. [140] in ultrapure and ground water with equilibrium liquid concentrations ranging from 0.1 -100 μg/L using a pulverized granular activated carbon (PGAC). Among the four selected PhACs, carbamazepine, a neutral drug, showed the highest affinity to PGAC in ultrapure water.

6.0 Subject matter of the thesis

Following drugs have chosen as the model compounds:

A. Balsalazide (anti-inflammatory)
B. Rifabutin (anti-tuberculosis)
C. Ranitidine (Antacid)

A. Balsalazide

![Chemical Structure of Balsalazide]

(A)

**Chemical Formula:** \((E)-5-[[4-[[2-carboxyethyl]amino]carbonyl]]\) phenyl]azo]-2-hydroxybenzoic acid.
Balsalazide is an anti-inflammatory 1, 2 (gastrointestinal) drug. It is available in the form of disodium hydrate. Balsalazide was developed in 1983 [141]. It is used in the treatment of mild to moderate active ulcerative colitis. It can also be used as an enema for local action [142]. There are some adverse effects of the balsalazide, such as bleeding from rectum, pale skin, weakness, fever, stomach pain, cramps, or bloody diarrhoea, and less serious side effects may include headache, sleep problems (insomnia), nausea, vomiting, stomach pain worsening colitis symptoms. Balsalazide is chemically

B. Rifabutin

![Chemical Structure of Rifabutin](image)

*Chemical Formula:* 4-deoxo-3, 4-[2-spiro-(N-iso- butyl - 4 - piperidyl) - 2, 5 - dihydro - 1H -imidazo] - rifamycin-S).

Rifabutin is well known antibiotic drug and it is on the World Health Organization's List of Essential Medicines, a list of the most important medication needed in a basic health.[143] Rifabutin have activity against Mycobacterium avium intracellular isolated from patients with AIDS. Rifabutin, an antimycobacterial compound active
against Mycobacterium avium and multidrug resistant Mycobacterium tuberculosis strains was selected as a model drug. Rifabutin primarily used in the treatment of tuberculosis and in the treatment of mycobacterium avium complex disease, a bacterial infection most commonly encountered in late-stage AIDS patients.

**C. Ranitidine**

![Chemical Structure of Ranitidine](image)

**Chemical Formula:** \( N\text{-}[2\text{-}[[5\text{-}[(dimethylamino)methyl]furan-2yl]methyl]\text{ sulphanyl}]\text{ ethyl}\text{-}N\text{'}\text{-}methyl\text{-}2\text{-}nitroethene\text{-}1,1\text{-}diamine\text{ hydrochloride.}

Ranitidine is classified as a drug of high environmental concern due to its occurrence in a variety of aquatic environments. ranitidine inhibits the action of histamine on the H2-receptors of parietal cells and reduces the gastric acid secretion under daytime and nocturnal basal conditions. It is widely prescribed for the treatment of peptic ulcer, reflux oesophagitis and dyspepsia [144]. It has identified in effluents, in several water treatment plants with a mean concentration. Investigations demonstrate that even under ideal conditions, the ranitidine is only partially biodegradable with an efficiency of 71% of degradation within 28 days. As a consequence, ranitidine is not biodegradable in water treatment plants, with accumulation on water surfaces, where sunlight can change partially its structure, which can generate persistent and toxic photoproducts [145]; so
why the ranitidine is taken for a model compound in this study.

Ranitidine HCL is purchased from Cadila pharmaceuticals pvt. Ltd with the brand name of aceloc. It is freely soluble in water. For adsorption studies of ranitidine, Adsorbent Nano talc (NT) was procured from M/s Innovation Centre of Applied Nanotechnology, Pune.
7.0 References


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