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Review

Potential Risk Assessment of Pharmaceutical Waste: Critical Review and Analysis

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Abstract. Nowadays, pharmaceutical waste has been considered as an environmental micro pollutant due to its unavoidable occurrence in the ecosystem and has become a major health issue. Pharmaceutical products are formulated to therapeutically influence the physiological systems, however, their potential health concerns which contribute in increasing environmental pollution like other most potential environmental pollutants still needs to be taken under consideration by the healthcare professionals and environmental experts. So, the contamination of treated wastewater by pharmaceutical waste and outcome of these compounds in the agricultural environment are of increasing concern and potential risk for the ecosystem. With increasing utilization of treated wastewater and biosolids in agriculture, residues of pharmaceutical and personal care products in these reused resources may contaminate the food produced via plant uptake, constituting a route for human exposure. In this article, the occurrence and behavior of pharmaceuticals waste have been briefly reviewed. Moreover, major concerns associated with exposure of biological systems of both plant and animal origin to the pharmaceutical wastes contaminating the ecosystem have also been discussed here which concluded that standard procedures and protocols should be followed to dispose of the leftovers of pharmaceuticals and/or pharmaceutical wastes.

Keywords: pharmaceutical waste, pharmaceutical compounds, environmental pollutants

Introduction

Pharmaceuticals compounds are manufactured and used as medicine or drugs to cure, prevent and control the diseases (Bottoni *et al*., 2010; Kummerer, 2009b; Sammartino *et al*., 2008) and most of the administered therapeutic compounds are excreted unaltered and as active metabolites that can enter the ecosystem *via* sewage (Carlsson *et al*., 2006). Most importantly, the pharmaceuticals are designed to be therapeutically active at very low concentration, however, there is lack of information regarding detrimental effects of these pharmaceutical compounds and their wastes on the ecosystem (Allen *et al*., 2010). During the manufacturing of various pharmaceutical products, an excessive amount of waste is produced that is mostly drained out without any further treatment. During last many years, it has been recognized that pharmaceutical wastes are the new class of environmental contaminants of emerging concerns with toxic effects on terrestrial life (Fatta-Kassinos *et al*., 2011 a and b; Kummerer, 2009 a and b; Kolpin *et al*., 2002). Pharmaceutical waste contains various types of pharmaceuticals that belong to different classes of medicines but among them, the most important part is contributed by the presence of various types of antibiotics (Fatta-Kassinos *et al*., 2011 a and b; Kummerer, 2009 a; Gulkowska *et al*., 2008; Batt *et al*., 2007; Miao *et al*., 2004; Heberer, 2002; Jones *et al*., 2001) because of intensive use of antibiotics which has been considered as one of the main reason for potential antibiotic resistance in environment (Czekalski *et al*., 2012; Le Corre *et al*., 2012; Kemper, 2008; Brown *et al*., 2006; Diaz-Cruz *et al*., 2003).

Pharmaceutical wastes are commonly dumped both in the aquatic and the agricultural environments as a result of the human activities and discharge of wastewater effluents to the environment. In developed countries, pharmaceutical wastes are recognized as one of the

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main reasons for environmental pollution as it can directly contaminate the surface and groundwater. Several studies have found that variety of pharmaceuticals (Table 1) have been detected in surface water (Ebele *et al*., 2017; Boxall *et al*., 2004; Kolpin, *et al*., 2002; Daughton and Ternes, 1999). Besides water, pharmaceuticals compounds including their metabolites are known to be found in whole environmental systems such as water, wastewater, sediments and sludge (Santos *et al*., 2010). In this article, we have briefly described what are pharmaceutical wastes including their impact on the ecosystem.

What are pharmaceuticals wastes. Pharmaceutical industry is one of the main component of chemical enterprise that produce diverse collection of pharmaceutical products not only for the better health of human beings, but also for the betterment of veterinary life by manufacturing therapeutic veterinary compounds along with wide range of nutraceuticals that are being used for long as they are known to have a wide range of therapeutic potentials (Khetan and Collins, 2007). However, the major concern is the fate of these pharmaceutical compounds after their manufacturing and use as they are released into the environment through various routes (Boxall, 2004). Pharmaceutical effluents are the waste that are produced by the pharmaceutical industry during the process of drugs manufacturing. The combining steps involved in drug manufacturing which may include processing, extraction, purification and packaging can generate air emanation, solid and liquid wastes. Therefore, pharmaceuticals and their deteriorated products have been identified in most lakes, coastal waters, and rivers, and even in populated areas, more-over, they have also been detected in groundwater and drinking water (Pandey *et al*., 2014). Studies have reported that some pharmaceuticals are continuously reaching the surface water (Ottmar *et al*., 2010; Loos *et al*., 2009) and among most common sources respon-sible for contamination of environmental systems by the pharmaceuticals are household waste, wastewater treatment plants, hospitals, industrial units and animal breeding farms. The utilization of these treated effluents for crop irrigation, along with land utilization of manure and biosolids, accelerates the introduction of these compounds into arable lands and crops (Carvalho *et al*., 2014). A huge list of scientific studies is available in which it has been reported that pharmaceuticals wastes have potential negative effects on both human health and the aquatic environment

Table 1. Pharmaceuticals detected in surface water (Boxall, 2004)

Type of pharmaceutical compounds	Names of pharmaceutical compounds detected	Maximum amount of pharmaceutical compounds detected (μg/L)
Antibiotics	Chloramphenicol	355
	Chlortetracycline	690
	Ciprofloxacin	30
	Lincomycin	730
	Norfloxacin	120
	Oxytetracycline	340
	Roxithromycin	180
	Sulphadimethoxine	60
	Sulphamethazine	220
	Sulphamethizole	130
	Sulphamethoxazole	1900
	Tetracycline	110
	Trimethoprim	710
	Tylosin	280
Antacids	Cimetidine	580
	Ranitidine	10
Analgesics	Codeine	1000
	Acetylsalicylic acid	340
	Carbamazepine	1100
	Diclofenac	1200
	Aminopyrine	340
	Indomethacine	200
	Ketoprofen	120
	Naproxen	390
	Phenazone	950
Antianginal	Dehydronifedipine	30
Antihypertensive	Diltiazem	49
Antidepressant	Fluoxetine	12
Antihyperlipidemic	Gemfibrozil	790
Antidiabetic	Metformin	150
Antipyretic	Acetaminophen	10000
Anti-inflammatory	Ibuprofen	340
Antiseptic	Triclosan	150
Beta blockers	Betaxolol	28
	Bisoprolol	2900
	Carazolol	110
	Metoprolol	2200
	Propanolol	590
	Timolol	10
Bronchodilator	Clenbuterol	50
	Fenoterol	61
	Salbutamol	36
Contraceptive	17a-Ethinylestradiol	4.3
Ectoparasiticides	Cypermethrin	85100
	Diazinon	58000
	Emamectin benzoate	1060
Lipid regulators	Bezafibrate	3100
	Clofibrate	40
	Gemfibrozil	510
Stimulant	Caffeine	600
X-ray contrast media	Diatrizoate	100000

(Götz *et al*., 2019; Harris *et al*., 2012; Kummerer, 2009b; Kraigher *et al*., 2008; Schwarzenbach *et al*., 2006; Boxall, 2004; Dokianakis *et al*., 2004; Richards *et al*., 2004; Kolpin, *et al*., 2002). Even a small concentration of pharmaceutical wastes is very critical and pose a potential risk for terrestrial life, moreover, trace amounts of these wastes are found to change the emergence and behaviour of aquatic-dwelling organisms (Ternes *et al*., 2004). It has been reported that various pharmaceutical compounds are the hormones or cover up the properties of hormones, and they have the ability to feminize or masculinize fish (Ternes *et al*., 2004). In some cases, it has been observed that male fish can also synthesize a protein that is typically only found in female fish for egg production (Gilbert, 2012). The impact of neuroactive pharmaceuticals is also an important area of study. Some of these studies have proposed that this group of pharmaceuticals may change the reproductive behaviour of fathead minnows which could potentially contribute to reducing their populations. Furthermore, the accumu-lation of neuroactive pharmaceutical metabolites has been observed with the proposal of negative impacts on brain tissues in white suckers as well as brook trout. Ultimately, the other drugs like, anti-inflammatory drugs and diclofenac, have shown to have the damaging effects on gills and lungs of the fish (Gilbert, 2012).

Types of pharmaceutical waste. According to classification made by RCRA (Resource Conservation and Recovery Act) for hazardous substances, pharmaceutical waste has been included in two lists, the P and U lists. These both lists contain commercially avaliabe pharmaceutical products. P-listed pharmaceutical waste include commercial products that have been recognized as acutely hazardous products under RCRA. The primary inclusion criterion for P-listed product; an acutely hazardous agent with an oral lethal dose of 50 mg/Kg (LD50) or less. Arsenic trioxide, epinephrine, physostigmine, nicotine or warfarin are few examples of the active pharmaceutical agents included in P-list. There are also some other drugs included in U-list. To categorize the pharmaceutical waste into U-list, two conditions must be satisfied. Firstly, the discarded pharmaceutical drug waste must contain a sole active ingredient and secondly, It has not been used for its intended purpose. Chloral hydrate, cyclophosphamide, daunomycin are few examples of drugs included in U-list (Smith, 2002). Common pharmaceutical waste streams are given in Fig. 1.

Pharmaceutical wastes as general environmental micropollutants. Environmental pollutants like antibiotics, analgesics, antiepileptic, antiseptics, beta-blockers, antihypertensive, hormones, contraceptives, psychotherapeutics and antivirals are considered as general environmental micropollutants (Halling-Sorensen *et al*., 1998). Antibiotics, anti-inflammatory drugs, lipid regulator agents, contraceptives, beta-blockers, cancer therapeutics and other hormones are the pharmaceutical groups that are most frequently detected in treated effluents from wastewater treatment plants (Fatta-Kassinos *et al*., 2011). The widely used drugs against musculature pain and inflammatory disorders are 2-[3-(2-methylpropyl)phenyl] propionic acid, commercially obtainable as ibuprofen (IBP). IBP is not destroyed in a municipal water treating station so, it is a determined pollutant (Fent *et al*.,2006).To revealed the sewage effluents, IBP has pharmacological impacts on aquatic fauna and originates in rainbow trout (Brown *et al*., 2006).

Although, the low concentrations of pharmaceuticals are generally present in ground and surface water wastes (from nanograms to micrograms/litre), but the constant discharge of pharmaceuticals and their degradation products into the environment from different pathways makes them pseudo-persistent (Grassi *et al*., 2013) Some studies have shown that long term exposure of small concentrations of some pharmaceuticals can bring toxic or other kinds of effects on terrestrial and aquatic

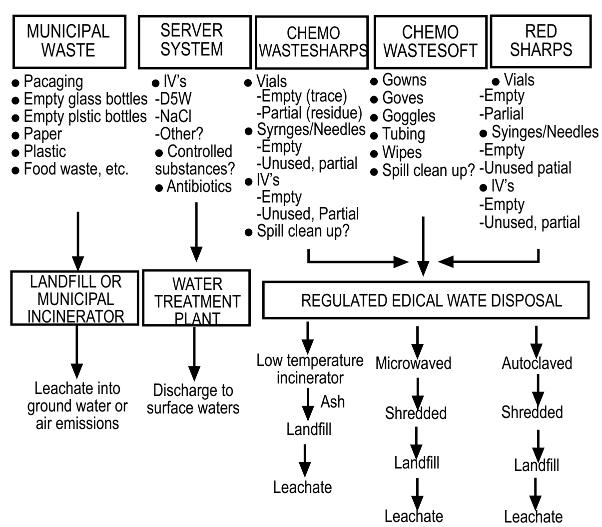

Fig. 1. Common pharmaceutical waste streams. Adopted from (Smith, 2002).

organisms (Fatta-Kassinos *et al*., 2011a) pharmaceutical effluents, which are reversibly absorbed to soil, might be taken up by plants (Fatta-Kassinos *et al*., 2011b) and transferred to animals and humans. The important concern of this study is that antibiotics and antibiotic-resistant bacteria may be introduced into the drinking water systems, resulting in a potential threat of human exposure (Harris *et al*., 2012; Halling-Sorensen *et al*., 1998).

Impact of pharmaceutical waste on ecosystem. The long term revelation of minimum concentrations of some pharmaceuticals can induce toxic or other kinds of effects on terrestrial and aquatic organisms (Fatta-Kassinos *et al*., 2011a and b). Pharmaceutical residues, which are reversibly adsorbed in the soil, may be taken up by plants (Fatta-Kassinos *et al*., 2011b) and transferred to the animals and human beings. Recently, it has been noticed that antibiotics and antibiotic-resistant bacteria may be introduced into the drinking water systems, resulting in potential risk for human beings (Harris *et al*., 2012). In rivers and streams, exposure of antibiotics may decrease the biodegradation of plant material, which serves as the primary food source for aquatic fauna, and may change important ecosystem processes such as nutrient transformations (Richards *et al*., 2004).

Many pharmaceutical and personal care products (PPCPs) are not thoroughly removed during wastewater treatment and become visible in treated wastewater or sludge (Oulton *et al*., 2010; Kim and Aga, 2007). However, PPCPs may contaminate food products by plant uptake, through irrigation or biosolids amendment, leading to potential human exposure (Wu *et al*., 2016). In greenhouse and field studies, PPCPs were found to be taken up and accumulated in plants (Wu *et al*., 2016; Goldstein *et al*., 2014; Malchi *et al*., 2014). In Table 2 (Boxall, 2004) we have briefly summarized the subtle effect of various types of pharmaceutical compounds on the ecosystem. The results of studies reported in Table 2 indicate that pharmaceutical compounds once released into the ecosystem, significantly exhibit their effects on various species in ecosystems.

Pharmaceutical waste as a risk to human health. Intentionally, almost all pharmaceuticals are designed to exhibit their effects (either stimulatory and inhibitory) on various physiological responses of the body, but when these pharmaceuticals as leftovers are released into the environment, they may also have adverse effects on non-target organs of various species in the ecosystem (Khetan and Collins, 2007). Continuous release and long term exposure of pharmaceuticals may result in the hazardous effects on various species in ecosystems that ultimately leads to posing a potential risk on human health which may be associated with being consumed as contaminated drinking water over a long time (Lee *et al*., 2019; Dorne *et al*., 2007). The impact of pharmaceutical waste on human health is based on the nature and type of pharmaceutical present in wastewater and the duration of exposure of pharmaceutical. Though in several cases, the water shortage has resulted in the practice of wastewater reuse, and the drinking water has been exposed to have parts per million or trillion levels of pharmaceuticals (Luo *et al*., 2014). Wastewater reprocess involves treating wastewater so that it can be used again instead of consuming the scant resource of ground water. However, these wastewater reuse processes are not planned to eliminate the trace levels of pharmaceuticals. A study was conducted to observe that human could potentially be affected by trace levels of pharmaceuticals. In this study, a mixture of 13 different pharmaceuticals also found in treated effluent wastewater was exposed by human embryos. Physical changes in the shapes and appearance of the cells were observed which indicated that even low levels of pharmaceutical waste exposure can exert prospective impact on human beings (Lee *et al*., 2019; Pomati *et al*., 2008; Pomati *et al*., 2004). At present, there is no such kind of specific regulatory agency and guidelines to control and monitor the existence of pharmaceuticals in environment, but the results of several studies conducted on the impact of pharmaceutical waste on human health are very alarming (Schwab *et al*., 2005; Webb *et al*., 2003; Schulman *et al*., 2002) which, indicate that the exposure of pharmaceutical waste in the ecosystem should be individually monitored and evaluated regularly to prevent associated adverse events (Schwab *et al*., 2005).

Irrigation of pharmaceutical wastes. Pharmaceutical effluents from wastewater treatment systems may also be used for land irrigation in arid and semi-arid regions of the world (Fatta-Kassinos *et al*., 2011a) and the biosolids products in the wastewater treatment systems may also be utilized as fertilizer on arable land (Du and Liu, 2012; Harris *et al*., 2012). In the same way, fertilizer from animal manure which contains residue of veterinary antibiotics is scattered on agricultural land that contributes to the release of pharmaceutical leftovers into the environment (Kumar *et al*., 2012). Pharmaceutical left overs, which are reversibly adsorbed in the soil, may be taken up by plants (Fatta-Kassinos *et al*., 2011) and in this way, transferred to the animals and humans. Treated wastewater and biosolids are widely used for agricultural irrigation and soil fertilization, respectively, especially in the regions next to the large metropolitan areas (Wuana and Okieimen, 2011).

Impact of pharmaceutical waste on food products. Utilization of biosolids in agriculture and treated wastewater, effluents of PPCPs in these reused resources

Table 2: Subtle effect of pharmaceutical compounds on ecosystem (Boxall, 2004)

Type of pharmaceutical compound	Name of pharmaceutical compound	Reported subtle effects	References
Anorexic	Fenfluramine	Enhances testicular maturation and, increases release of serotonin in crayfish and stimulates the production of gonad-stimulating hormone	(Daughton and Ternes, 1999)
Synthetic steroid	17a-Ethinylestradiol	Endocrine-disrupting effects on invertebrates, reptiles and fish	(Young *et al*., 2002)
	Methyltestosterone	Impersex, reduced fecundity, oogenesis, spermatogenesis in snails	(Schulte-Oehlmann *et al*., 2004)
Parasiticide	Avermectins	Adults insects: loss of water balance, disruption of feeding and reduced fat accumulation, delayed ovarian development, decreased fecundity and impaired mating Juvenile insects: delayed development, reduced growth rates, development of physical abnormalities, impairment of pupariation or emergence and a loss of developmental symmetry	(Floate *et al*., 2005)
Antibacterials	Tetracyclines, macrolides and streptomycin	Antibacterial resistance measured in soil bacteria obtained from sites treated with pig slurry	(Sengelov *et al*., 2003)
	Tylosin	Impacts on the structure of soil microbial communities	(Westergaard *et al*., 2001)
	Erythromycin	Inhibition of growth cyanobacteria and aquatic plants	(Pomati *et al*., 2004)
	Tetracycline	Inhibition of growth cyanobacteria and aquatic plants	(Pomati *et al*., 2004)
	Sulphamethazole	Inhibition of basal EROD activity in cultures of rainbow trout hepatocytes	(Laville *et al*., 2004)
Parasiticide	Fenbendazole and Cypermethrin	Impact on dung decomposition	(Sommer and Bibby, 2002)
Anti-inflammatory	Ibuprofen	Stimulation of growth of cyanobacteria and inhibition of growth of aquatic plants	(Pomati *et al*., 2004)
Lipid regulator	Fenofibrate	Inhibition of basal EROD activity in cultures of rainbow trout hepatocytes	(Laville *et al*., 2004)
	Clofibrate	Inhibition of basal EROD activity in cultures of rainbow trout hepatocytes	(Laville *et al*., 2004)
Analgesics	Carbamazepine	Inhibition of basal EROD activity in cultures of rainbow trout hepatocytes. Inhibition of emergence of Chironomusriparius	(Laville *et al*., 2004; Nentwig *et al*., 2004)
	Diclofenac	Inhibition of basal EROD activity in cultures of rainbow trout hepatocytes	(Laville *et al*., 2004)
Beta blocker	Propanolol	Weak EROD inducer in cultures of rainbow trout hepatocytes	(Laville *et al*., 2004)
Antianxiety drug	Diazepam	Inhibition in the ability of dissected polyps from the cnidarian Hydra Vulgaris to regenerate a hypostome, tentacles and a foot	(Pascoe *et al*., 2003)
Cardiac glycoside	Digoxin	Inhibition in the ability of dissected polyps from the cnidarian Hydra Vulgaris to regenerate a hypostome, tentacles and a foot	(Pascoe *et al*., 2003)
Calcium channel blocker	Amlodipine	Inhibition in the ability of dissected polyps from the cnidarian Hydra Vulgaris to regenerate a hypostome, tentacles and a foot	(Pascoe *et al*., 2003)

may also pollute food products through the uptake of pharmaceutical compounds and their metabolites by plants, constituting a path for human exposure (Goldstein *et al*., 2014). Eleven PPCPs have found to be recalcitrant to metabolism, including caffeine, dilantin, acetaminophen, meprobamate, atenolol, primidone, trimethoprim, DEET, carbamazepine, diazepam, and triclocarban, where, caffeine is found to be the most familiar pharmaceutical among them (Schrezenmeir and deVrese, 2001), whereas drugs like diclofenac (Rijkers *et al*., 2010), clofibric acid, acetaminophen, carbamazepine, aspirin, IBP, atorvastatin, fluoxetine, gemfibrozil, 17 ß-ethynylestradiol (Shaha *et al*., 1995) have also been found in the surface and wastewater (Snydman, 2008; Saarela *et al*., 2000). In rivers and streams, exposure to antibiotics may change important ecosystem processes such as nutrient transformations by decreasing the biodegradation of plant material, which serves as a primary food source for aquatic fauna (Richards *et al*., 2004).

Disposal of pharmaceutical waste. Environment and health are directly interlinked however, they are themselves directly or indirectly affected by pharmaceutical effluents and/or leftovers especially in the locality of pharmaceutical industrial zones. Medical institutions such as research institutes and hospitals produce a considerable amount of harmful waste. If wastes are not properly managed, patients and health care workers are at the highest risk of acquiring infection from sharps and contaminations of the environment with several drug-resistant microorganisms (Kot-Wasik *et al*., 2007). By different ways, pharmaceuticals are discharged after application in their native form or as metabolites and enter aquatic systems. The main pathway of pharmaceuticals discharge from humans is ingestion, excretion, and disposal by wastewater. Municipal wastewater is the main route that carries pharmaceuticals after regular use and discarding of unutilized medicines into the environment. Hospital wastewater, wastewater from manufacturers and landfill leachates may include significant concentrations of pharmaceuticals (Holm *et al*., 1995). Pharmaceuticals not readily despoiled in the sewage treatment plant, are being discharged in treated effluents resulting in the contamination of rivers, lakes, estuaries and rarely, ground water and drinking water. When this sewage sludge is applied to agricultural fields, drainage and runoff into surface water, it may cause contamination of soil. In addition, veterinary pharmaceuticals may penetrate in the aquatic system by manure application as a fertilizer to the fields and consequent runoff and also by direct application in aquaculture (fish farming). However, these compounds are not satisfactorily eliminated by the wastewater treatment methods which are currently used (Jjemba, 2002). In this way, these compounds are dispersed into the receiving water bodies from where they are discharged into the environment. So, the uptake and transfer of these compounds through food chains are almost nonexistent (Harris *et al*., 2012; Boxall *et al*., 2004). Studies on antibiotics have shown that up to 95% of antibiotic compounds can be released unaltered into the sewage system. Furthermore, higher concentrations of antibiotics can cause alteration in microbial community composition and eventually affect the food chains. Non-steroidal anti-inflammatory drugs (NSAIDs), like ibuprofen, naproxen and diclofenac are widely used and consequently are frequently detected in sewage, surface water and may also be found in groundwater system. Similarly, Ibuprofen, Ketoprofen, Naproxen, Indomethacin, Diclofenac, Acetylsalicylic acid and Phenazone have been found in surface water system (Patneedi and Prasadu, 2015; Tambosi *et al*., 2010).

Toxicity of pharmaceutical waste. Pharmaceuticals may be toxic, but this toxicity among plant species is really dependent on the absorption kinetics of the particular pharmaceutical compound, the soil organic material content and the pH of the soil. Therefore, the occurrence of antibiotics in arable soils could potentially impact plant growth and development as well as soil microbial activity (Lee and Choi, 2019; Kumar *et al*., 2012; Jjemba, 2002). The active components in pharmaceuticals are transformed partially in the bodies of humans and animals and thus are excreted as a mixture of metabolites and bioactive forms into the sewage systems (Du and Liu, 2012; Kim and Aga, 2007). In rivers and streams, exposure to antibiotics may decline the biode-gradation of plant material, which perform as a primary food resource for the aquatic region and may change the important ecosystem processes such as nutrient transformations (Gulkowska *et al*., 2008; Richards *et al*., 2004).

Aquatic ecotoxicity of pharmaceutical compounds depends upon the type and quantity of individual pharmaceutical compound. A detailed study on the ecotoxicity of various types of pharmaceutical compounds notably, steroid hormones, antibiotics, antidepressants, antiepileptic drugs, NSAIDs, lipid-lowering drugs and beta-blockers have been briefly described by Khetan and Collins (2007). This study indicates that pharmaceutical compounds may actively contribute to the ecotoxicity individually.

Degradation of pharmaceutical waste. Degradation of pharmaceutical waste in an ecosystem depends upon the physicochemical properties of the parent compound, environmental factors and last but not least the presence of natural microbial organisms present in an ecosystem that might have the ability to degrade the pharmaceutical compound (Onesios *et al*., 2009; Gros *et al*., 2007). Microbial community is one of the most important biodegraders for a variety of compounds and makes these compounds beneficial for other organisms as they may work as nutrients for them (Megharaj *et al*., 2011). Microbial organisms are essential in the overall process of biodegradation of pharmaceutical compounds by contributing to the quality state of the ecosystem. Therefore, it is mandatory to maintain the microbial community for the fruitful biodegradation of pharmaceutical wastes and any change in microbial ability to degrade the pharmaceutical waste may produce negative. Result in the ecosystem processes (Rodarte-Morales *et al*., 2012; Lahti and Oikari, 2011; Reed and Martiny, 2007). There are various methods and/or techniques to degrade the wastes of pharmaceutical compounds, but the most important are microwaving, incineration, deep burial, autoclaving and chemical disinfection. These methods have been briefly described by Kapoor (2015).

Conclusion

It has been found from various studies that pharmaceutical compounds and/or leftovers reach the environment and can be considered as environmental micropollutants. Various pharmaceutical production facilities have been recognized as sources of high environmental concentration of pharmaceuticals. Generally, pharmaceutical industries produce a huge amount of wastes during manufacturing and maintenance operations. Pharmaceuticals have been detected in wastewater treatment plant effluents and drinking water sources. A trace amount of pharmaceuticals in drinking water for longer duration may cause considerable adverse effects to the human health and aquatic life, though concentrations of pharmaceuticals detected in drinking water (in nanogram per liter range) are of lower magnitude than the minimum therapeutic dose. As the concentration of pharmaceuticals are very small generally in parts per trillion, no special attention has been given on the impact of pharmaceutical waste. However, its impact on the environment cannot be neglected. It is very important to highlight the facts that are critically responsible to be involved in the contamination of the environment and ecosystem with pharmaceutical waste/left overs. Moreover, from a practical point of view, it is mandatory to regularly monitor the disposal pattern and procedure of pharmaceutical wastes and leftovers in the environment. The standard procedures and protocols should be followed to dispose of the leftovers of pharmaceuticals and/or pharmaceutical wastes. In addition to this, environmental assessments should also be taken into account for the removal of pharmaceutical wastes and leftovers from the wastewater and sewage in order to reduce the potential risk for the ecosystem.

Conflict of Interest. The authors declare they have no conflict of interest.

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