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Emerging Pollutants in Aquatic Environment: Source, Effect, and Challenges in Biomonitoring and Bioremediation- A Review

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ABSTRACT: Emerging contaminants are distributed in to the environment from various anthropogenic activities. These Emerging contaminants (ECs) are mainly composed of products, such as pharmaceuticals, personal care products (PCPs), surfactants, plasticizers, pesticides etc. The present conventional system of waste treatment are not designed to treat these contaminants. Complex structure of these pollutants and their existence at low concentration makes them untraceable and hence found to be difficult in removal of these by present waste treatment. These chemicals are considered as threat to human health and environment. Therefore, disposal and treatment of these chemicals of emerging concern have been a key concern in the field of water treatment and its reuse. Biosensors can be used for biomonitoring of these contaminants with of biological system. Bioremediation plays an important role in the treatment of these pollutants of emerging concern. This review discusses about the sources, effects, and challenges in biomonitoring and bioremediation related to these emerging contaminants.

Keywords: Emerging contaminants, Endocrine disruptors, Wastewater treatment, Pharmaceutical compounds.

INTRODUCTION

Water is one of the most essential things for the existence of life. As it is already known that population of world is increasing at rapid rate, so there is also an increasing demand for clean, safe water. So the quality of the water is vital in the protection of health of all form of living being. In the starting years of 1800's, along with the advancement of science and technology, a new kind of pollutant was discovered in the aquatic environment and in other water resources which was later termed as Emerging contaminants (ECs) [Du et al., 2015]. Some of the worst problems which could arise due

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to these ECs include hormonal interference in aquatic animals, genotoxicity, endocrine disruption, and immune toxicity [Mortensen et al., 2014; Bilal & Iqbal, 2019].

With the discovery of so-called "emerging" pollutants, it begin to be seen as dangerous problems for the environment and thus a widespread consensus of this kind of contamination was felt [La Farree et al., 2008; Rasheed et al., 2018]. These are Emerging contaminants are 'any synthetic or naturally occurring chemical or any microorganism that can't be monitored easily in the environment, but has the potential to enter the environment and cause known or suspected adverse ecological and/or human health effects [Rosenfeld & Fleng, 2011]. These Emerging contaminants (ECs) is mainly composed of products, such as pharmaceuticals, personal care products (PCPs), surfactants, plasticizers, pesticides etc. Removal of these from its product source in short time is seen to be very difficult task [Wilkinson et al., 2017]. However, in this regards legislative intervention by the government may proof as a blessing in disguise. USA, China, Canada, Germany, and Japan, are the leading countries in which the research on ECs have been done on large scale [Bao et al., 2015]. One of the main resources of emerging contaminants which is released into water sources and which later ends up in deterioration of soil, groundwater, seas, and oceans [Suárez et al., 2008]. Despite of being at very low concentrations, ECs (due to complex matrices) have diverse chemical properties. Till now, there is lack of efficient and advanced methods for determination of ECs, which is mainly due to the reason of its complex matrices and its presence at very low concentration and this is very reason why ECs still stand as a riddles [Alexander et al., 2012; Schmidt, 2018]. Since concentrations of these pollutants are very low, even though there is need to care of these ECs and their adverse effects because as the world population is increasing, release of these EC's are also going to be increased. As antibiotics are capable of formation of resistant bacteria at very low concentrations, it stands as the biggest trouble among all [Nazaret & Aminov, 2014]. These bacteria can make genes to shield them against antibiotics [Rizzo et al., 2013; Camargo et al., 2014].

Lack of proper biomonitoring system is the main problem associated with these emerging pollutants. Currently, various research are being performed in order to develop biosensors that can easily detect these pollutants and can help in further process of treatment related to these. Biosensor, includes a biological component that provides the signal by the help of which pollutants get analyzed and hence get detected. After detection, bioremediation can play an important role regarding the transformation of these toxic contaminants as compared to conventional treatment methods.If the ECs are not being considered as a biggest challenge now, then the environment can face its adverse effects without any proper and effective treatment. World Bank has already predicted that by 2050, these resistant bacteria can kill 10 million people each year and can push as much as 28 million of people into poverty [Bloom et al., 2017]. It is worth mentioning that antibiotics is not the only ECs upon which we have to concern, there are many other in the list, but how to do it remains a dilemma. One way can be by preparing a priority list like EU commission has done by keeping the track record of compounds and updating it each year [Decision, 2015]. This way can proof to be reasonable until we come across a limited number of compounds.

Categories of Chemicals of Emerging Concern

In order to satisfy the human need, various categories of chemicals are being used for the production of cosmetics, personal care products, cleansing products, and pharmaceuticals. Beside these products, various chemicals are used to manufacture

pesticides, insect repellents, synthetic hormones, artificial sweeteners [Kolpin et al., 2002]. Most of the above mentioned chemical compounds have been investigated to have endocrine disrupting property and moreover, till now, no such regulation has been made for proper utilisation of these. Endocrine Disrupting Chemicals (EDCs), PCPs, and pharmaceutical products have been classified as emerging pollutants. Because even at very low concentration range (ng/L to μg/L), these pollutants have the potential to cause adverse effect on environmental and human health. The effect of emerging contaminants on human health has been shown in Table 1. Only European countries have taken significant step that has been mentioned in the European Water Framework Directive (EC Directive 2000/06/EC) and daughter directive 2008/105/EC (EC 2008) in order to reduce the level of emerging micro-pollutants present in the water [Directive, 2000; Parliament, 2008].

Table 1. Health effects of Emerging Contaminants

Emerging Contaminants	**Health Effects**
Bisphenol A (BPA) — used in epoxy resin and polycarbonate plastics	Proven to have estrogenic effects in rats [Dodds & Lawson, 1938] and hormonal effects which increase breast cancer risk in human [Krishnan et al., 1993]. Reported to act as anti-androgen that causes feminising side-effects in men [Sohoni, & Sumpter].
Alkylphenols (i.e. nonylphenol)— used in detergents	Mimicking estrogen and disturbing reproduction by increasing number of eggs produced by Minnos and vitellogenin levels [ENDS, 1999].
Butylated Hydroxyanisole (BHA) — used as a food Antioxidant	Estrogenic to breast cancer cells, rainbow trout estrogen receptor and stimulates human estrogen receptor [Jobling et al., 1995].
Fragrances (musk)	Musk xylol — proved carcinogenic in a rodent bioassay and significantly absorbed through human skin [Bronaugh et al., 1998]. Musk ambrette may damaging the nervous system [Kirschner, 1997].
Polychlorinated biphenyls (PCBs) —— used in electrical equipment	The metabolites able to mimic estradiol (female hormone) [Jacobson & Jacobson., 1997] and cause carcinogenic [Harrison et al., 1995]. Exposure was reported to cause delayed brain development and IQ decrease in children [Routledge et al., 1998].
Preservatives, i.e., parabens (alkyl-phdroxybenzoate)— used for anti-microbiological preservatives in cosmetics, toiletteries and even foods Disinfectants/antiseptics, .i.e., triclosan — used in toothpaste, handsoaps, acne cream)	Shows weak estrogenic activity [Routledge et al 1998]. Found in the receiving waters [Okumura & Nishikawa., 1996], that cause toxic, biocide (kill microorganism) and also cause bacteria resistance development towards triclosan [McMurry et al., 1998].
Antibiotics (such as penicillin, sulfonamides, tetracylines)	Shown to cause resistance among bacterial pathogens [Witte, 1998] that lead to altered microbial community structure in the nature and affect higher food chain [Daughton & Ternes., 1999].
Estrone and 17-β estradiol (steroidal estrogens) and 17-α ethynylestradiol (synthetic contraceptive) — contained in contraceptive pills	Cause feminization which observed for fish in sewage treatment [Witte, 1998]. The discharge causes mimicking estrogen/hormone effect to non-target

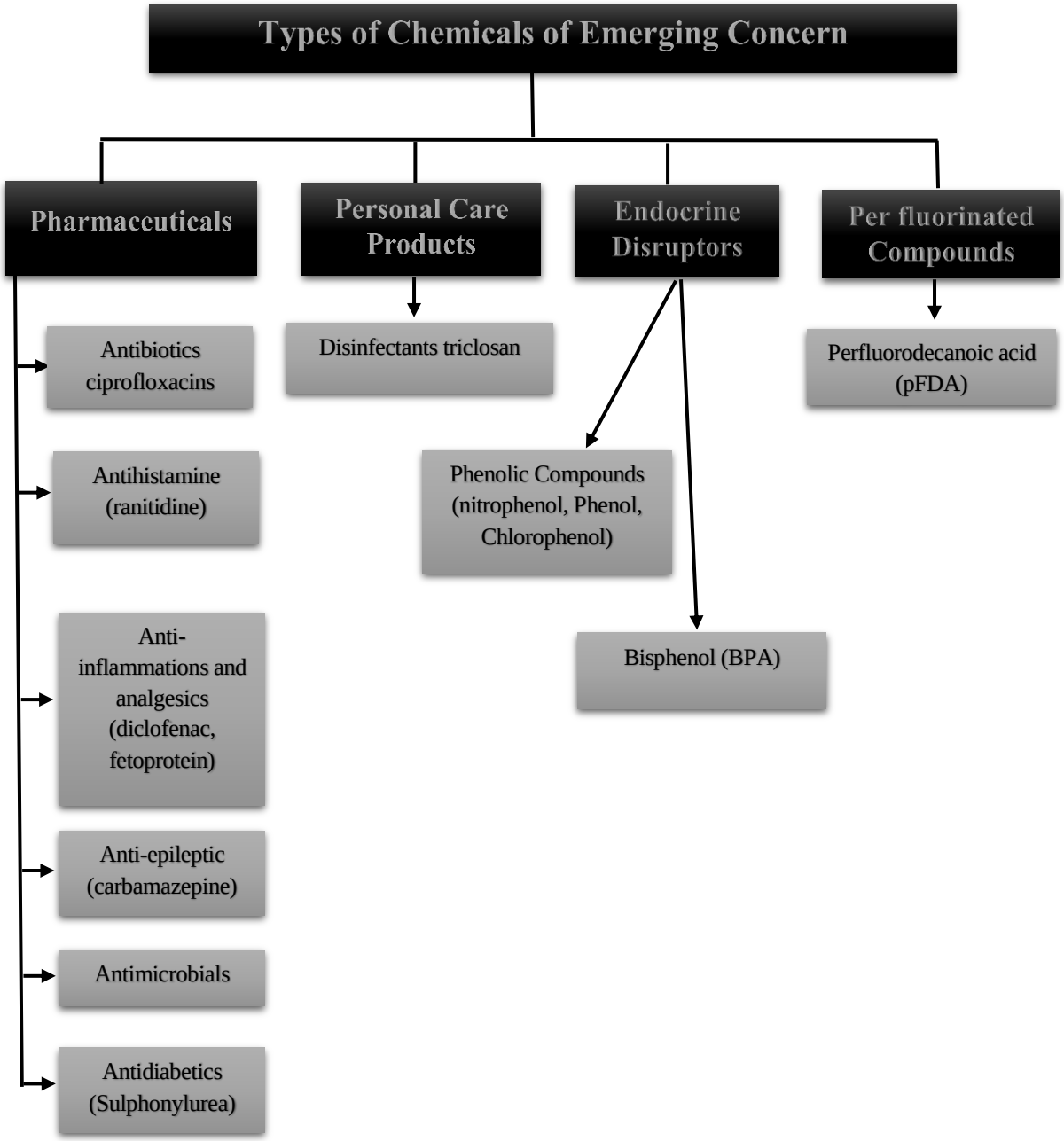

Fig. 1. Various Categories of Emerging Contaminants

Developing countries are yet to settle with the need to institutionalize their environmental regulatory structure on emerging micro-pollutants [Pomiès et al., 2013]. Through recent monitoring studies, presence of these micro pollutants in the water have been founded in various developing countries [Sorensen et al., 2015; Olujimi et al., 2012]. Fig. 1 shows different categories of chemicals of emerging concern present in environment.

Pharmaceuticals

Pharmaceuticals are any blended or natural chemical compounds intended to cure and prevent the spread of diseases as well as enhancing human and creature life [Maletz et al., 2013]. Pharmaceuticals have been classified as active substances and are given to animals in order to enhance their growth rate and feeding efficiency [Daghrir & Drogui, 2013]. In human and animal body, pharmaceuticals have different

applications and metabolism, chemical structure and behaviour [Fawell & Ong, 2012; Jiang et al., 2013]. Various compounds associated to pharmaceuticals have been detected in the freshwater and wastewater worldwide [Miller & Meek, 2006; Watkinson et al., 2009; Vulliet & Cren-Olive 2011; Mutiyar & Mittal 2014].

Antibiotics (ciprofloxacin), anti-epileptic (carbamazepine), anti-diabetics (sulfonylurea), anti-inflammatories antimicrobials (penicillins), and analgesics (ketoprofen, diclofenac), antihistamine drugs (ranitidine and famotidine) and antiulcer, anti-anxiety/hypnotic agents (diazepam), lipid regulators (Clofibrate) are the few classifications of pharmaceuticals on the basis of their therapeutic uses [Esplugas et al., 2007; Kanakaraju et al., 2014], Nonsteroidal anti-inflammatory drugs (NSAIDs), anticonvulsants, antibiotics and lipid regulators are the main four classes of pharmaceuticals out of 24 which are predominantly found in water, that are used for humans and animals [Mompelat et al., 2009]. Moreover, recently pharmaceuticals have been categorised as anti-inflammatories and analgesics (paracetamol, ibuprofen), antiepileptics (carbamazepine), antidepressants (benzodiazine-pines), b-blockers (atenolol, metoprolol), lipid lowering drugs (fibrates), antiulcer and antihistamines drugs (famotidine), antibiotics (tetracyclines), anticancer drugs (cyclophosphamide, ifosfamide), antipyretics, tranquilizers and stimulates by Bruce et al. and Rivera-Utrilla et al [Bruce et al., 2010; Rivera-Utrilla et al.,2013]. There are more than 5000 substances related to pharmaceuticals that have been synthesised and are made available to humans and animals [Van Doorslaer et al., 2017]. The main issue related to pharmaceuticals is their chronic toxicity effects. These compounds are not easy to be degraded biologically and are soluble in water and hence are found in wastewater and freshwaters. Concerns related to pharmaceutical substances in the environment have been started to discuss since 1990s [Bound & Voulvoulis, 2005; Glassmeyer & Furlong, 2005; Larsson et al., 2007; Heberer & Feldmann 2005].

Personal Care Products

Personal care products are manufactured from variety of active and inert substances which includes both prescribed as well as non-prescribed pharmaceuticals that are used by human for personal care purposes and animals for veterinary purposes [Jiang et al., 2013]. It consists of different products like synthetic hormones, sun screens, analgesics, cosmetics, insect repellent, shampoos, toiletries, preservatives, fragrances, lipid regulators and steroids. From above mentioned form of products, most of them are familiar to us, as they are readily used in our daily life. Personal care products are different from some pharmaceuticals in the way of its application as they are used directly on our body in order to change or we can say improve our body appearance, taste, and odour, unlike other pharmaceuticals which are ingested. We can categorize personal care products into two categories namely polycyclic musks and parabens, which are being used to prevent decay of bacteria [Fawell & Ong, 2012]. In addition to this, a number of disinfectants like chloroprene and triclosan are used by industries in manufacture of different consumer products in the form of hand soap, sportswear, air fresheners, lotions, toothpaste, plastics, medical disinfectants, mouthwash and toys [Fawell & Ong, 2012; Houtman, 2010].In the same way, alkylated siloxanes and benzophenone are assimilated in hair care products and sun screen lotions.

In last few decade due to continuous usage of PCPs, a massive amount of Personal care products either in their original or transformed form make their way into water and identified in waste water treatment plants. These metabolites are converted into different forms like

some of them are reduced to harmless compounds, for example, carbon dioxide and water which are mostly inorganic in nature within a waste water treatment plant and some of them due to their lipophilic nature and non-biodegradability adhere to other hydrophilic compounds gets partially adsorbed onto sedimentation sludge [Jiang et al., 2013]. While a portion of it gets released to the receiving water in the waste water treatment plant either in original form or metabolized form, which is more persistent to the environment.

Generally, Micro-pollutants make their way into the aquatic environments i.e., surface water due to recreational activities like swimming, and also due to daily activities like bathing, showering along with other technological process [Larsson et al., 2007; Kasprzyk-Hordern et al., 2009; Rahman et al., 2009]. We all know the ill effect of PCPs on our environment and water system but still, there discharge is unregulated and they are carelessly thrown in our immediate environment. The condition further deteriorates in developing countries due to improper regulations and lack of strict supervision as there is no regulatory frame work.

Endocrine Disrupting Chemicals (EDCs)

Endocrine glands, hormones, and receptors are the main part of Endocrine systems which help in regulating the physiological activities of body like reproductive processes [Flint et al., 2012]. A hormone secreted by Endocrine glands gets disturbed by certain compounds. These compounds have been named as endocrine disrupting compounds and are also called as endocrine disrupting chemicals, or endocrine disruptors, or endocrine modulators. EDCs are natural or chemical compounds that may link with the oestrogenic receptors and enhance or obstruct the hormones from proper working [Jackson & Sutton, 2008]. Cosmetics, toothpaste, detergent, plastic bottles, polyvinylchloride pipes, children toys among others are the main manufactured product in which these xenobiotics compound are present. They causes adverse effect on endocrine systems of fishes and other aqueous animals [Piva & Martini, 1998]. These effects may be cumulative and have the possibility of appearing and showing its symptoms in subsequent generations and then these effects may be irreversible. Though, most of the EDCs are synthetic organic chemicals which have be present in the environment because of anthropogenic activities (e.g., Bisphenol A) but, these can be generated naturally e.g., estrone.

Sources and Effects of Chemicals of Emerging Concern

Emerging concern chemicals enters the environment through multiple point and non-point sources (such as mining activities, hospitals, pharmaceutical industries, and health service centres, or agricultural practices [Agunbiade & Moodley, 2014]. In metropolitan areas sewer overflows, disposal of animal waste, run-off from farmland and septic tank effluents are the other sources through which emerging pollutants enters the environment. The various other routes through which these contaminant enters the environment includes cleaning agents, household use and disposal of personal care products, unused drugs in the sewerage system or septic tank [Swartz et al., 2006; Labadie et al., 2007; Dougherty et al., 2010]. Sources of different emerging micro pollutants and important classes in the aquatic environment has been shown in Table 2. Most of these compounds are passed in the same form (unchanged) enters the terrestrial environment [Barnes et al., 2002; Pryor et al., 2002; Harrison et al., 2006]. These chemicals along with their metabolites have been detected in the aquatic life in thousands of numbers and in many cases, effect of these metabolites have been founded to be more dangerous than the original compounds [Daghrir & Drogui, 2013].

Table 2. Emerging pollutants sources and important classes [Luo et al., 2014].

Category	Important classes	Sources
Personal care products	Fragrances, disinfectants, UV filters, and insect repellents (triclosan)	Domestic wastewater (from bathing, shaving, spraying, swimming)
Pharmaceuticals	Nonsteroidal anti-inflammatory drugs (NSAIDs), lipid regulator, anticonvulsants, antibiotics, and β blockers	Domestic wastewater (from excretion), and hospital effluents
Steroid hormones	Oestrogens	Domestic wastewater (from excretion)
Industrial chemicals	Plasticisers, fire retardants (bisphenol-A; phthalates	Domestic wastewater (from leaching out of the material)
Surfactants	Non-ionic surfactants	Domestic wastewater (from bathing, laundry, dishwashing and etc.), industrial wastewater (from industrial cleaning discharges)

Current designed wastewater systems have been founded to be less efficient in treating these compounds from the system. The problem with these compounds is due to their complex structures and low concentration in water. Because of higher persistency in the aquatic environment, these micro-pollutants impart negative impacts upon living organisms. Impact of these pollutants includes; birth defects, prostate cancer, feminisation of male or masculinizing of female, long duration toxicological effects, thyroid, and other cancers and increase in bacterial resistance to antibiotics [Marcoux et al., 2013]. These compounds also leads to cancers and low sperm count in the species that are found in the terrestrial environment [Klaper & Welch, 2011]. Therefore, there is need of global attention towards the source, pathways of entrance in environment and health related effects that have been developed due to these toxic and xenobiotics. Further, global environmental regulatory bodies need to establish laws regarding utilisation and discharge limits of these compounds [Agunbiade & Moodley, 2014].

Occurrence of emerging contaminants in Aquatic Sources in India

Up till now, a total of 19 pharmaceutical based pollutants have been measured all over India in drinking water, surface water, and wastewater sources. Wastewater treatment plants in New Delhi and Ujjain (Central India), lakes, rivers and wastewater of Hyderabad (north-western India) and Kaveri, Tamiraparani and Vellar Rivers (southern India) so far has been utilised as monitoring stations. Wastewater treated from Hyderabad treatment plant has shown maximum of 12 pharmaceuticals having concentration of more than 1 μg/l, as the treatment plant treats wastes from pharmaceutical industries located nearby. Ciprofloxacin, citalopram and cetirizine were found to be in high concentration with values up to 14, 0.43, and 2.1 mg/l respectively [Schulz & Schmoldt, 2003].

For groundwater sampling, six wells were taken in to account and two samples from each well were collected. Through the various investigations, it was founded that wells contained a high concentration of pharmaceuticals (i.e. up to 28 mg/l of cetirizine and 14 mg/l of ciprofloxacin). 4 out of these 6 wells are currently being utilised as source of drinking water because of inadequate alternatives. The State Pollution Control Board is aware of the illegal dumping of pharmaceutical waste and acknowledges the significance of the problem [Boralkar et al., 2004]. However, no remedial actions plan till yet has been suggested by any of the researchers even after monitoring of these chemicals was done 2009. Presence of ciprofloxacin, sparfloxacin, ampicillin, cefuroxime and gatifloxacin has been investigated in one of

the reports in freshwater and wastewaters of Delhi's Yamuna River in northern part of India [Mutiyar & Mittal, 2014]. Seven antibiotics were also investigated in one of the work and they have tried to develop a relation between consumption and development of antibiotic resistance in *E. coli* present in these waters. Four out of seven antibiotics, were detected in the wastewater samples and belonged to fluoroquinolone group. Ciprofloxacin was present in highest concentration (236.6 µg/L) [Diwan et al., 2010].

Biomonitoring and Biosensors

Bioassays, biomarkers, and microbial community analyses together are constituted as a biomonitoring tools. These biomonitoring tools have excellent tendency of reducing and regulating the concentration of emerging pollutants. Therefore they have potential for increasing confidence in the risk assessment of both regulated and emerging chemical pollutants. Environmental monitoring and screening can be parallelly achieved by the sensors developed to determine several analytes.

Biosensors as a whole can be denoted as system, which have potential of tendency to detect the present of a substrate by making use of biological components, which then provides signals [Gu et al., 2004; Bilal et al., 2019]. These bio sensing techniques are becoming more and more utilized techniques as consequences of which vast expansion studies and research are being done on these. These studies led to development of the modern bio sensing devices not only for environmental monitoring but for genetic engineering and sensor for cell development as well. For example it is accepted that many endocrine disruptors, as agonists or antagonists, can bind to the estrogen receptor (ER). Therefore, the study of the chemical binding capacity of the ER would prove to be useful in screening or testing the potential toxicity of these substances on the environment and thus taking advantage of this property biosensors for endocrine disruptors have been developed [Martins et al., 2013; Scognamiglio et al., 2012].

There is urgent tendency for the development of large scale biosensors clusters because in real-time monitoring of multiple species would be recommended. To understand the effects of the pollutants (emerging) at the molecular level, modern technologies are being used. DNA Microarrays which are being used in ecotoxicogenomics are one of such technology [Poynton & Vulpe, 2009]. Furthermore, the detection of pollutants and its concentration can be investigated by developing molecular biomarkers. The modern day techniques, which not only allows the determination of contamination bio accessibility but also the prediction of microbial degradation is a crucial part of environmental (bio) monitoring [McAllister & Semple, 2010].

Innovative Approaches in Bioremediation of Emerging Pollutants

A process in which biological organism plays a key role in the improvement of environment is called environmental bioremediation [Chaudhry, 1994; Bloom & de Serres, 1995]. Many microorganisms can degrade the energy level of these environmental pollutant so as to make use of these undesirable environmental pollutants as food sources. Thus, these microbes acts as a bio-remediator for the environment because they biodegrade the pollutant to obtain energy.

The terms bioremediation and biodegradation are not to be confused. Biodegradation directly refers to the breaking down of the materials enzymatically (not necessarily waste). Whereas, bioremediation means chemical degradation of pollutants by microorganisms [Ahmed et al., 2017]. The process, co-metabolism, requires an ample supply of the preferred food substrate and also requires that the degrading enzymes come into contact with the waste by waste

absorption or by enzyme secretion. The simple information required to enhance natural biodegradation is knowledge of the microorganisms present in a given site, their growth requirements, and how these organisms interact with one another and their environment.

The most appropriate method for concentration and containment of pollutants depend on water content of pollutant. Bioremediation of emerging pollutants is a developing field of great importance for the future acceptance [Bilal et al., 2017]. Environmental hazards which occur due to accumulation of the toxic waste can be reduced by this biological technologies [Bilal, 2019; Liu et al., 2019]. Studies have shown that the biological solutions involve the action of microbes, plants, and animals under specific conditions that include both abiotic and biotic factors, as these can helps in achieving mineralization, transformation or immobilization of contaminants [Gavrilescu, 2010; Gavrilescu & Chisti, 2005; Bilal et al., 2019]. As a consequence of insufficient information being available, at now it is difficult to suppose that the environmental impacts of traces of chemicals would be minimized or removed.

In the aquatic ecosystem, environment pollution control can be obtained by following the practices of the well-established activated sludge wastewater treatment, as the conventional treatment systems (activated sludge) is proved to be less efficient in removing EDCs from wastewater [Gavrilescu & Chisti, 2005]. As a drawback of conventional systems, membrane bioreactors (MBRs) can be used as alternate options in because they have proved to be more efficient in removing toxic compounds which are fails to be removed or biodegraded in conventional activated sludge systems [Barrios-Estrada et al., 2018]. For example, algae-based bioreactors can be used for removal of pharmaceuticals-based ECs from wastewater either completely or partially [Tolboom et al., 2019].

Furthermore the elimination of these EDCs by MBRs before disinfection may result in removal effectiveness of 96% in municipal waste-water, as compared to 85% efficiencies obtained in a conventional treatment plant, However, MBRs may be ineffective for the removal of several compounds if the sludge retention time (SRT) is extended [Caliman & Gavrilescu, 2009; Spring et al., 2007]. As there is growing cases of outbreaks of infectious waterborne diseases, these are becoming a challenge to both the water and public health sector. Therefore there is urgent need of the development of new (bio) technologies for water treatment and monitoring biological micro pollutants and in this regard novel concepts are starting to emerge [Forrez et al., 2011; Poynton et al., 2008]. The co-metabolism of estrogenic compounds during nitrification may be useful in the removal of pollutants of pharmaceuticals and personal care products (PCPs), While usage of other heterotrophic bacteria may be beneficial to further degrade the intermediate metabolites of these micro pollutants produced by the action of aerobic nitrifiers [Forrez et al., 2011; Stahl & de la Torre, 2012].

Discussion Related to Emerging pollutant: an India Context

Pharmaceuticals, PCPs, and EDCs have been measured so far in the aquatic sources of India. Each category of compounds showed contamination concern because of the risk associated to them or because of the violation of standard regulations. Pharmaceutical pollutants have been founded as serious concern in the region of Hyderabad, India. These contaminant in high concentration causes harmful effect on the environment by three ways (Larsson, 2008). Firstly, the antibiotics present in wastewater damages the metabolic activities or induce toxicity, which even leads to killing of microorganisms that impairs the wastewater treatment process. The second aspect is the contamination of the environment,

particularly microbial ecosystems. Thirdly, presence of antibiotics in such a wide range in the environment leads to development of antibiotic-resistant microorganisms.

In order to maintain the microbial population in the treatment plant, raw sewage containing human pathogens is added at the influent (approximately 20% of the incoming load). Moreover, conventional activated sludge process in which the sludge is recirculated in the wastewater treatment plant.

As the pharmaceutical products manufactured in this area are exported to various parts of the world, therefore remediation of the problem especially because of concern related to antibiotic resistance becomes international responsibility [Fick et al., 2009]. From economic perspective, it may not seem worthwhile to discharge milligram-scale pharmaceuticals into the river. However, the input for pharmaceutical production is very small compared with the cost of the final product, which led to huge savings in the industry. These savings can be compared with investment and operational costs of a treatment plant producing clean effluents (Larsson, 2008). Triclosan (TCS) concentration has been founded to be highest so far in the world in the Tamirapani River. Ecotoxicological assessment of various compounds in the Tamirapani River was done by calculating the hazard quotient (HQ) that expresses the risk to a human receptor from exposure of such chemicals. Higher TCS of HQ > 1 has been reported for aquatic life at all sites. High risk on algal communities because of the high level of pharmaceuticals, in the range of 3,800 to 5,160 ng/l in Tamariparani River has been founded [Ramaswamy et al., 2011]. Therefore, from this review, it seems that identifying the sources of these compounds is also a concern in India for which detail monitoring of remaining aquatic sources is required for which research centers in India along with cooperation of regulatory bodies such as the Central Pollution Control Board (CPCB) and the National River Conservatory Directorate (NRCD) should increase scope of their conventional monitoring of such toxic compounds.

Conclusion and Future Perspective

Presence of endocrine disrupting chemicals has been founded in the global water cycle. These compounds cause harm to environment and also found to have malignant effect on aquatic species. The effect of these chemicals with continuous consumption are not known by many humans. Accordingly, preparatory guidelines are beneficial as they creates long-term harm to environment and human health. There should be increase in involvement of various ministries, agencies, and department with responsibility of protecting the environment from these chemicals. Higher health risk involving chemicals should be banned.

There is need of more research requirement so that a more efficient hybrid system for degradation and removal of these contaminants from municipal water system. Majority of the organic loads from treatment plants are still removed by using membrane bioreactors or conventional activated sludge. This secondary treatment setup is required to be equipped with more advanced treatment system which may have combinations of chemical, physical or biological methods so that emerging contaminants can be removed from the system. Still, more research is needed to be done so that a more reliable method for toxicity test even at low concentration of these contaminants can be done more easily.

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CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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