Synergistic Impact of Endocrine Disrupting Compounds (EDC's) On Environmental Facilities: A Mini Review

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***Abstract*— *Endocrine disrupting compounds, EDCs, are recently recognized micropollutants in the field of environmental engineering These compounds are known to interfere with the delicate balance of the endocrine system of animals and man, causing variety of undesirable outcomes. The ever growing concern about the micropollutants in the different environmental facilities like water, wastewater, air etc. has made the mankind to take up case specific research to know the complete cause-effect relationships of EDC's on wildlife and humans. The trace amount of the micropollutants in terms of Nano grams per liter is tested for its negative effects on the same. The futuristic impact of the EDC's are; the interactive toxicological studies and the formation of the undesirable by products by mixing of one or more EDC's. Wastewater treatment plants (WWTPs) are assumed to be one of the main sources of various micropollutants in aquatic environments through their insufficient cleaning processes. Most WWTPs are not designed to completely eliminate micropollutants, especially when only conventional processes are employed. The removal efficiency of WWTPs varies depending on the physicochemical characteristics of the pollutants and on the treatment processes involved. Present paper reviews the fate, occurrence and the treatment efficiencies with regards to the selected EDC's and elucidates the theory behind the concern about the EDC's as an emerging micropollutant in the environmental facilities.*

Keywords — *Acetaminophen, Carbamazepine, Endocrine Disrupting Compounds (EDC's), Estrogen, Progesterone, Wastewater treatment plants (WWTPs).*

I. Introduction

Micropollutants are organic substances whose toxic, persistent and bioaccumulative properties may have a negative impact on organisms in the aquatic environment, wildlife and humans. They encompass a large group of pollutants of varying chemical characteristics that can be found ubiquitously in water and wastewater. Both endocrine disrupting compounds (EDC's) and pharmaceuticals are considered as the emerging micropollutants. Although they exist at very low concentrations, they can be harmful to the health of living organisms told by John Ashby et al., in 1997 EDC's are capable of interfering with the natural hormonal systems of animals and humans. Suspected health effects include an increased risk of breast, testicular, and prostate cancers, reproductive disorders, immune and hormonal disorders, obesity, fewer male offspring, diabetes, metabolic disorders, and cardiovascular disease. Evidence of these health effects comes from correlations between the prevalence of EDC's and increasing incidence of the disorder, observations of these effects in animal populations, and laboratory studies. Every year hundreds of new chemicals of unknown toxicity are released into the environment. Recently, a considerable attention has been focused on endocrine-disrupting compounds (EDC's), which constitute a wide group of environmental micropollutants that are able to mimic or antagonize the effects of endogenous hormones (estrogens and androgens), or to disrupt synthesis and metabolism of endogenous hormones and hormone receptors at a very low concentration. Studies have shown endocrine disruptors to adverse effects in animals, giving rise to indication that even low-level exposure might cause similar effects in human beings. Because of this, the detection of endocrine disrupters is an important area of research for environmental monitoring and control.

The emerging contaminants include persistent organic pollutants, micro constituents, cyanotoxins, pesticides and herbicides, disinfection by-products, endocrine-disrupting chemicals (EDC's), pharmaceuticals and personal care products (PPCPs), and a host of other compounds. The rapid technological advancement, rapid increase in human population, inadequate wastewater treatment facilities, poor agricultural practices, inadequate land use acts, and rapid urbanization coupled with drought occasioned by global climate change have created water pollution problems on a level that have not been seen before. Almost every industrial process involves the production and release of huge quantities of half a dozen or more of those mentioned pollutants in one form or the other into the aquatic and terrestrial environment. The most frequent occurrence is the increasing accumulation of pharmaceuticals and EDC's that have overloaded and tainted the various receiving water bodies (Dana et al., 2008) The fact that many known and suspected endocrine disrupting chemicals (EDCs) are being found at environmentally significant concentrations in the effluent of wastewater treatment plants (WWTPs) is receiving increasing attention in public and regulatory arenas.

This study was initiated to review literature for the occurrence, distribution, environmental as well as health implications and removal techniques of the EDC's in the environmental facility with major focus on wastewater environment.

II. Sources of EDC's In Environmental Facilities

EDC's are both naturally occurring and man-made compounds present in the environment. Naturally occurring EDC's include natural hormones viz. estrogen, progesterone and testosterone which are found in humans and animals. Oestrogen (estrone, 17-beta estradiol & estriol) and progesterone are responsible for female sexual development whereas testosterone is responsible for male sexual development. Phytoestrogens (genistein, zearalenone, coumestrol), substances contained in some plants such as alfalfa sprouts and soya beans also show oestrogen-like activity when ingested by the body. Manmade EDC's consist of synthetic hormones, industrial chemicals, pesticides, compounds used in the plastic industry, pharmaceutical products (oral contraceptives) and in consumer products, and other industrial by-products and pollutants (John Ashby et al., 1997). There are different sources of endocrine disrupters in the environment like water, air and soil. Many endocrine disruptors persist in the environment and accumulate in fat, categorized as persistent organic pollutants (POPs). POPs are a set of chemicals that are toxic; persist in the environment for long periods of time and bio magnify as they move up through the food chain. The greatest exposures come from eating fatty foods and fish from contaminated water (John Ashby et al., 1997). Numerous potential sources of EDC to the environment have been documented, including, pharmaceutical industry, other industry and manufacturing, land application of municipal biosolids, landfills and associated leachates, livestock and aquaculture operations, domestic septic systems, latrine and vault toilets, and municipal and industrial wastewater treatment plants.

III. Biology of The Biology of Endocrine-Disrupting Compounds

The endocrine system is a major regulator of growth, physical development, and sexual development in humans and wildlife. It also plays important roles in ongoing functions, such as cardiovascular and kidney function, and in environmentally induced responses, such as the stress response. The endocrine system works within the body through a complex chemical messaging system. The basic chemical messengers of the endocrine system are known as hormones. Hormones are released from various glands into the bloodstream and travel to receptors in target tissues, where they bind and initiate a response in the target organ or tissue. Any disruption in the normal functioning of this chemical messaging system can result in serious health impacts in one or more of the functions that the endocrine system controls. Metabolism of certain nutrients can be altered, behavioral patterns can change, and sexual differentiation and sexual characteristics can be altered or even reversed. Endocrine disruption occurs through many mechanisms; two common mechanisms are, the EDC binds to a hormone's receptor on the surface of cells in the target tissue. Timing of exposures is also critical, as exposures during development likely lead to irreversible effects, whereas the effects of adult exposures seem to go away when the EDC is removed. Tissues and creates an unintended response. The EDC binds to a hormone's receptor and blocks the binding of the natural hormone to its intended receptor, stopping the normal response in the cells of the target tissue that would have occurred if the natural hormone were allowed to bind. Thus, EDCs act like hormones. Like hormones, which act via binding to receptors at very low concentrations, EDCs have the ability to be active at low concentrations, many in the range of current human and wildlife exposures. EDCs can exert effects on more than estrogen, androgen and thyroid hormone action. Some are known to interact with multiple hormone receptors simultaneously. EDCs can work together to produce additive or synergistic effects not seen with the individual chemicals. EDCs also act on a variety of physiological processes in a tissue specific manner and sometimes act via dose–response curves that are non-monotonic (nonlinear). Indeed, as with hormones, it is often not possible to extrapolate low-dose effects from the high-dose effects of EDCs. Sensitivity to endocrine disruption is highest during tissue development. It is important that these specific characteristics of EDCs be taken into account when the toxicity of a chemical with potential EDC activity is assessed.

IV. EDC's: As Persistent Micropollutants In The Environment

Debate over what actually defines an EDC is still ongoing, it is generally accepted that the three main classes of endocrine disruption endpoints are estrogenic (natural estrogen blocked or mimicked), androgenic (natural testosterone blocked or mimicked), and thyroidal (thyroid function affected directly or indirectly). The majority of research to date has focused on estrogenic compounds, though disruption of androgen or thyroid function may prove to be of equal or greater importance biologically. Currently, the scientific community is drawing conclusions about the relative hazards of potential EDC's. EDC's indicates that humans and domestic and wildlife species have suffered adverse health consequences from exposure to environmental chemicals that interact with the endocrine system. Health problems have been identified primarily in domestic or wildlife species with relatively high exposures to organ-o-chlorine compounds, including DDT and DDE.

V. Exposure And Effects Of EDC's on Humans

It is difficult to compare and integrate results from diverse human studies, because data are often collected at different time periods, using different experimental designs and under different exposure conditions. Often exposure data are completely lacking. Of particular concern is the lack of exposure data during critical periods of development that influence later functioning in adult life. Furthermore, the concentrations and potencies of endogenous hormones and phytoestrogens are generally higher than those of exogenous chemicals. Despite these difficulties, exposure to EDC's has been suggested to play a role in adverse health outcomes, and concerns remain. The following examples illustrate these concerns, Reproductive Effects: A number of studies report a decline (since the 1930s) in human sperm quality in several countries. Studies to date have been retrospective. Several meta-analyses of existing studies reached different conclusions, and the issue remains controversial. Available human and experimental animal studies demonstrate that high-level exposure to certain environmental chemicals can impair fertility and increase the rate of spontaneous abortion, but the relationship to endocrine disruption remains speculative.

Temporal increases in the frequency of development abnormalities of the male reproductive tract, particularly cryptorchidism and hypospadias have been reported, but the role of exposure to EDC's is unclear. Endometriosis: Exposure to certain EDC's has been reported to be associated with endometriosis, but the studies remain equivocal. Neural Function: Data from human and experimental animal studies clearly indicate that exposure (particularly prenatal exposure) to certain EDC's (e.g., PCBs) can have adverse effects on neurological development, neuroendocrine function, and behavior. Some of these effects appear to result from altered thyroid or neurotransmitter function, but in most instances endocrine mechanisms have not been demonstrated. Similar effects can also result from exposure to chemicals that induce developmental neurotoxicity but have no known endocrine action. Immune Function: Exposure to environmental chemicals, including certain EDC's, has been shown to alter immune function in humans and animals. However, it is not clear whether such impaired function is due to endocrine-mediated mechanisms. Cancer: Temporal increases in the incidence of certain cancers listed below in hormonally sensitive tissues in many parts of the industrialized world are often cited as evidence that widespread exposure of the general population to EDC's has had adverse impacts on human health. Endometrial Cancer: Limited available data do not support a causative role for EDC's in endometrial cancer. Testicular Cancer: Temporal increases in the incidence of testicular cancer have been reported in certain countries, but rates vary considerably among countries. However, EDC exposure data for critical periods are lacking. Prostate Cancer: Exposure to certain pesticides and organochlorines has been linked to increases in the incidence of prostate cancer in a few limited studies, but most studies have found no association, and the mechanism is unknown. Thyroid Cancer: A direct association between exposure to EDC's and thyroid cancer has not been demonstrated. Overall, the biological plausibility of possible damage to certain human functions (particularly reproductive and developing systems) from exposure to EDC's seems strong when viewed against the background of known influences of endogenous and exogenous hormones on many of these processes.

Furthermore, the evidence of adverse outcomes in wildlife and laboratory animals exposed to EDC's substantiates human concerns. The changes in human health trends in some areas (for some outcomes) are also sufficient to warrant concern and make this area a high research priority, but non-EDC mechanisms also need to be explored.

VI. Effects Of EDC's on Wildlife

Several field and laboratory studies have shown that exposure to certain EDC's has contributed to adverse effects in some wildlife species and populations. These effects vary from subtle changes in the physiology and sexual behavior of species to permanently altered sexual differentiation. Most of the data come from Europe and North America. Aquatic species are affected also negative effects has been observed in terrestrial species. Some adverse effects observed in certain species are likely to be endocrine mediated, but in most cases, the causal link between exposure and endocrine disruption is unclear. Examples include the following, Mammals: Exposure to Organ-o-chlorines (PCBs, DDE) has been shown to adversely Impact the reproductive and immune function in Baltic seals, resulting in marked population declines. Birds: Eggshell thinning and altered gonadal development have been observed in birds of prey exposed to DDT, resulting in severe population declines. A syndrome of embryonic has been observed in fish-eating birds and can be directly related to PCB exposure, but the precise linkage to endocrine function is uncertain.

Reptiles: A presumed pesticide spill in Lake Apopka (Florida, USA) provides a well-publicized example of potential EDC effects on population decline in alligators. Various gonadal and developmental abnormalities are being observed which have been attributed to high levels of various organochlorine contaminants that disrupt endocrine homeostasis. Fish: There is extensive evidence that chemical constituent present in pulp and paper mill effluents and sewage treatment effluents can affect reproductive endocrine function and contribute to alteration in reproductive development. A variety of mechanisms (e.g., hormone–receptor interactions, interference with sex steroid biosynthesis, altered pituitary function) are involved, but precise modes of action or the causative chemicals are still poorly understood. Studies in wildlife have been proposed as "sentinels" of human exposure to EDC's. However, given the diversity of wildlife, caution must be taken in extrapolating the responses to EDC's, as research has focused primarily on only a few species of wildlife. Also, potential effects of EDC's on wildlife tend to focus on the individual, whereas ecological risk assessments focus on populations and communities.

VII. Overview of Treatment Alternatives for the Micropollutants.

No specific treatment is now available to assure the complete removal of various micropollutants due to their diverse properties. Reliable processes that are able to eliminate both bulk substances as well as micropollutants are yet to be developed. In general, the techniques available for treating micropollutants in aqueous solution are very diverse and frequently one or more treatment techniques are required to degrade these compounds. Depending on the nature of the pollutant, feasible treatment can be chosen. An overview of the current treatment options is present in the following sections to reveal the performance of each technique for micropollutants removal and to identify the need for improvement.

A. Coagulation–flocculation:

Most micropollutants have been reported to be poorly removed during coagulation–flocculation processes. Exceptions were some musk's, a few pharmaceuticals (e.g. diclofenac). Neither coagulant dose nor operation temperature influenced the removal of MP's significantly. Despite the minor differences among different types of coagulants at different doses reported that the addition of 25 mg/L $FeCl_3$ achieved optimal results in most cases. Also, Aluminum sulfate is effective in eliminating some hydrophobic pharmaceutical compounds (Yunlong Luo et al., 2014)

B. Activated carbon adsorption:

This technique has also great potential for treatment of secondary effluent and has proved to be more effective in removing micropollutants in comparison with coagulation–flocculation process. Both powdered activated carbon (PAC) and granular activated carbon (GAC) have been widely used in adsorption processes which can be affected by the properties of both adsorbate (KOW, pKa, molecular size, aromaticity versus aliphaticity, and presence of specific functional groups) and Adsorbent (surface area, pore size and texture, surface chemistry, and mineral matter content) (Lubomira Kovalova et al., 2013)

C. Ozonation and Advanced Oxidation Processes (AOPs):

Due to the refractory nature of some micropollutants, conventional physicochemical and biological treatments are not able to provide adequate elimination of these compounds. To overcome the problem, Ozonation and AOPs can be considered. These are effective redox technologies which demonstrate some superiority over conventional treatments, such as high degradation rates and non-selectivity. These processes have disinfecting effects, which are essential for water reuse applications. Since oxidation processes do not commonly result in complete mineralization of micropollutants, the major concern of applying these processes is the formation of oxidation by-products (or transformation products) from micropollutants. Research data indicated that the by-products generally have low concentration levels as well as insignificant estrogenic and antimicrobial activity compared to the parent compounds to further reduce parent compounds and oxidation by-products, biological post-filtration (sand filtration or activated carbon filtration) can be considered.

D. Membrane processes:

Although microfiltration (MF) and ultrafiltration (UF) are proved processes to efficiently eliminate turbidity, micropollutants are generally poorly removed during UF and MF, as the membrane pore sizes are much larger than the molecular sizes of micropollutants. In comparison with MF and UF, Nano filtration (NF) and reverse osmosis (RO) have much 'tighter' structures. NF and RO are widely used for tertiary treatment to remove high contaminant levels. However, NF and RO membranes are still somewhat permeable to some relatively small micropollutants. The elimination efficiency of NF membranes was very close to that achieved by RO membranes. The average retention efficiency by tight NF was 82% for neutral contaminants and 97% for ionic contaminants, while RO was able to achieve 85% removal of neutral contaminants and 99% removal of ionic contaminants.

E. Membrane bioreactor:

Membrane bioreactor (MBR) process is the combination of activated sludge biological treatment and membrane filtration (MF and UF). MBRs are able to effectively remove a wide spectrum of micropollutants including compounds that are resistant to activate sludge processes. This is because they are able to retain sludge to which many compounds are adhered, the membrane surface can also intercept the compounds and the longer retention time in MBRs may promote microbial degradation of the compounds. The removal of micropollutants in MBR can be affected by a number of factors, such as sludge age and concentration, existence of anoxic and anaerobic compartments, composition of the wastewater, operating temperatures, pH and conductivity.

F. Attached growth treatment processes:

Attached growth technology is best alternative to activate sludge processes for wastewater treatment which involves attached growth on inert carriers either fixed or mobilized in suspension of the reactor. Biofiltration seems a compelling biological technique for micropollutant removal. Commonly used systems in water and wastewater treatment include trickling filter, sand filtration and biological activated carbon. A biological activated carbon filter is typically composed of a fixed bed of Granular activated carbon serving as the carrier for bacterial adhesion and growth. The results demonstrated biological activated carbon filter had a great potential for removal of pharmaceuticals and personal care products (e.g. diclofenac, carbamazepine, sulfamethoxazole and gemfibrozil) removal (>90%) and reduction of the potential risk of environmental and/or human health impact.

VIII. CONCLUSIONS

It has been shown in this study that EDC's, which are allegedly environmentally suspect causing gender shifts or cancer in man and biota, are actually treatable by conventional treatment processes. Those which are biodegradable, such as natural hormones or acetaminophen, may completely be eradicated from the environment while those which are not degradable simply change phases during treatment. It can be hypothesized that discrepancy between the results of the conventional and MBR plants may be associated with the microbial population composition. Another noteworthy finding was on anaerobic digestion of sludge, where most EDC's adsorbed onto sludge was not effectively degraded in the anaerobic digester environment. The threat with EDC in the environment is seen due to interaction of their occurrence, distribution and life cycle impacts. Although advanced treatment technologies, such as adsorption processes, AOPs and membrane processes, have been demonstrated to be promising alternatives for micropollutant removal, there are two issues associated with the applications of advanced treatments: high operation costs and formation of by-products and concentrated residues. Moreover, to effectively predict the impact of micropollutants on the receiving environment, a comprehensive understanding and modeling of micropollutants fate is needed. There is global transport of EDC's through natural processes (ocean and air currents) as well as through commerce, leading to worldwide exposure of humans and wildlife to EDC's. This study calls for the need of more research in understanding the effects of EDC's on humans. It is the order of the day that that Multi Criteria Evaluation technique should be adopted to arrive at the co-exposures of the humans and the wild life to the EDC's instead of correlations with the previous studies. Sewage epidemiology can be promising for further studies related to the EDC's life cycle in the environmental facilities.

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