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Textile Waste as an Endocrine Disrupter: An Overview

Dr. Pratibha Pareek

Lecturer in Zoology, S.P.S.B. Government College, Shahpura, Bhilwara, Rajasthan, India

ABSTRACT: Humans and wildlife must regulate how their bodies function to remain healthy in an ever-changing environment. They do this through a complicated exchange between their nervous and endocrine systems. The endocrine systems in humans and wildlife are similar in that they are made up of internal glands that manufacture and secrete hormones. Hormones are chemical messengers that move internally, start or stop various functions, and are important in determining sleep/wake cycles, stimulating or stopping growth, or regulating blood pressure. Some of the most familiar hormones in humans or wildlife are those that help determine male and female gender, as well as control the onset of puberty, maturation, and reproduction. An endocrine disruptor interferes with, or has adverse effects on, the production, distribution, or function of these same hormones. Clearly, interference with or damage of hormones could have major impacts on the health and reproductive system of humans and wildlife, although not all of the changes would necessarily be detrimental. Textile finishing industry wastewaters contain micropollutants such as endocrine-disrupting chemicals in addition to the conventional pollutants since advanced manufacturing activities provide additional features to the textiles to make them shrink-proof, water-proof, wrinkle-proof, rot-proof, distasteful to moths, and mildew, flame-resistant, etc. Endocrine-disrupting chemicals can interfere with the endocrine system, exert endocrine-modulating behavior, and cause adverse health effects, even when exposed to low doses. Therefore, treatment of endocrine-disrupting chemicals is a major concern for textile finishing wastewaters since they cannot be completely removed by widely applied conventional treatment technologies; but rather by using membrane filtration, advanced oxidation, and adsorption technologies. This study aims to investigate the performance of nano-filtration

KEYWORDS: textile, endocrine, disruptors, wastes, hormones, pollutants, treatment, nano-filtration

I. INTRODUCTION

The pollution attributable to the textile industry is widely known as a major cause for environmental concern. However, there is less awareness surrounding the environmental impacts of chemical usage within this industry, despite the fact that 10% of textile-related chemical substances may pose a threat to human health.[1,2] These include substances such as the perchloroethylene found in dry-cleaning fluid, polyfluorenes used for stain resistance, and the pesticides used to grow plant-based resources such as cotton as well as many others.

In order to address harmful chemical use within the textile and other industries, the Strategic Approach to International Chemicals Management (SAICM) – a global, voluntary initiative meant to support nations with the sustainable management of chemicals – was formed in 2006 during the World Summit on Sustainable Development.

In 2011, an intersessional process was initiated at the International Conference on Chemicals Management (ICCM) to determine a path forward targeting the responsible management of chemicals and waste beyond 2008, as the current mandate of the SAICM was set to expire in 2008. Due to the current COVID-19 pandemic, the fourth meeting of the intersessional process has been delayed, but many recommendations for the post-2008 chemicals and waste framework have been proposed.[3,4]

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Currently, a variety of regulations are in place pertaining to the general use of chemicals, including the Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH) Regulation in the European Union, the Toxic Substances Control Act in the United States, and the MEP Order 7 in China.

Within the textile industry, many private standards, certification systems and labels (SCLs) have emerged for the purpose of production- and product-related chemicals management.

Unfortunately, these current efforts have proven insufficient. It is anticipated that by 2025, the amount of waste produced by worldwide cities will be over three times the amount produced previously in 2009. Additionally, the chemical industry has become the second largest manufacturing industry in the world, with global production nearly doubling between 2000 and 2012.

While global efforts have fallen short of the SAICM general targets for 2008, it is important that these targets are extended and adapted to include current issues such as endocrine-disrupting chemicals, perfluorochemicals including perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) from textile microplastic shedding, highly hazardous pesticides, and nanomaterials as well as many others.[5,6]

Several issues have emerged as shared priorities among stakeholders for the development of the post-2008 chemicals and waste framework, including increased involvement of downstream chemical users, alignment with the United Nations 2030 Sustainability Agenda, and improved focus on scientific evidence to support all targets and goals.

In their report, Chemicals and Waste Governance Beyond 2008, the Nordic Council of Ministers identified several options for the format of this new framework, ranging from the development of another legally non-binding instrument to support governments in their work to implement Agenda 2030 to the formation of a new international agreement targeting hazardous chemicals and waste by the ICCM.⁴ No matter the path forward, effective information management was highlighted as a key to success in order to ensure access to essential information for taking action toward the sustainable management of chemicals and waste as well as the dissemination of important health and safety information for all chemicals on the market.

As noted by the Government of Switzerland in their document regarding The role of private standards, labels and certification mechanisms in the Post 2008 Chemicals and Waste Framework, the SAICM 2008 focused on goals related to the entirety of the chemicals industry. However, the post-2008 chemicals and waste framework would be enhanced by a sector-specific approach that involves both upstream and downstream stakeholders for improved reach, speed and efficacy. This approach could improve results in many industries, including the textile industry, which would benefit from the improved coordination of SCLs as well as stronger policy-focused targets, in order to achieve sound chemical and waste management.[7,8]

II. DISCUSSION

Endocrine-disrupting compound is named by the U.S. Environmental Protection Agency (EPA) as “an agent that interferes with the synthesis, secretion, transport, binding or elimination of natural hormones in the body that are responsible for the maintenance of homeostasis, reproduction, development and/or behavior” . Many chemicals have been identified as endocrine disruptors and they have been active for the past decade. These chemicals are related to many chronic diseases like breast cancer, ovarian problems, thyroid eruptions, testicular carcinoma, diabetes, reproductive abnormalities, nerve damage, obesity and many homeostatic imbalance .

Environmental endocrine disruptors (EEDs) are compounds altering the physiological function of endocrine system in both human and wild life. They can impact endocrine system by targeting different levels of the hypothalamic-

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pituitary-thyroid/gonad/adrenal axes, inhibiting or stimulating the production of hormones, or changing the way hormones travel through the body, the effects can range from hormone receptors to hormone synthesis or metabolism, so the EEDs can have negative health implications on human . Over the years, scientists, physicians and governments are paying more and more attention to potential links between exposure to EEDs and certain endocrine-related diseases, resulting form that exposure [9,10] to many EEDs is now ubiquitous, coupled with suggested trends for increased rates of some endocrine-related diseases.

Endocrine disruption is a major cause for obesity, which further associate with metabolic disorders, such as diabetes, dyslipidemia, cardiac arrest hypertension, hyperinsulinemia and insulin resistance Glucose metabolism includes estrogenic receptors ($ER\alpha$ and $ER\beta$) as the key parameters. Estradiol (E2) and some EEDs (pesticides, dioxin and BPA) are similar in the way attacking these receptors to evoke changes of glucose homeostasis and insulin release , so any EED targeting these receptors can damage the normal glucose homeostasis, giving a necessary clue for diabetes .

Indeed, there is a growing body of literature involving EEDs such as PCBs, BPA, dioxin and pesticides with the incidence of metabolic syndrome, obesity and diabetes . Epidemiological studies established a link between type 2 diabetes mellitus (T2DM) and low-level environmental exposure to some dioxin and PCBs, which mainly accumulate in adipose tissue . The rapid rise in obesity and diabetes in young suggests that the influence of early-life exposure to EEDs may play an important role in the development of abnormal. Verhulst et al. demonstrated that cord blood PCB and DDE concentrations were associated with increased BMI or change during early childhood (from ages 1 to 3 years) . A cross-sectional study included 3,390 adults aged 40 yr or older indicated that BPA was positively associated with generalized obesity, abdominal obesity, and insulin resistance . [11,12] Actually, even low doses of BPA have been indicated to damage α -cells of the pancreas which produce glucagon controlling glucose metabolism, thus the low doses of BPA can link to type 2 diabetes and obesity by causing hyperinsulinemia .Huang et al. thought that exposure to dioxin being recognized as an EED is a risk factor for diabetes mellitus (DM), independent of age and BMI in both men and women . A kind of cross-sectional data reported several positive associations between PAE metabolites and obesity in girls . Al-Othman et al. confirmed the association between the body burden of the pesticide hexachlorocyclohexane (HCH) and the risk of T2DM in a sample of 280 adult subjects from Saudi Arabia .

Growing evidence also suggests that EEDs may affect not only the exposed individual but also the children and subsequent generations. However, EEDs cause a significant challenge to environment and human health. Consequently, due to their wide commercial use and adverse effect to human health the Endocrine Society had published a scientific statement indicating that endocrine disruptors pose a “significant concern for public health” . More research is in urgently needed to provide important insights into the etiology of these chronic disorders caused by EEDs, playing an important role in the design of effective prevention strategies.[13,14]

III. RESULTS

In recent years, man-made compounds referred to as endocrine disrupting chemicals (EDC) have attracted the attention of the scientific world. These chemicals can change the development and function of the endocrine system, and affect the binding, transport, production, and removal of hormones from the body. Most of the studies conducted so far have focused on the carcinogenic effects of EDCs and their effects on the reproductive system of fish and mammals. According to the US Environmental Protection Agency (EPA), EDCs with the ability to mimic hormones are defined as exogenous agents that can interfere with the production, secretion, transport, binding, metabolism, or elimination of hormones in the body responsible for the maintenance of homeostasis and regulation of developmental processes. Therefore, the endocrine system is mostly affected by these exogenous chemicals. Endocrine disruptors can be stored in adipose tissues. For this reason, it is essential to make strict rules to minimize the effects of EDCs on the environment and public health. Humans and animals can be exposed to EDCs in many ways in daily life. The negative effects of EDCs on health have been revealed in many studies in literature. In a global world where science and technology are advancing so rapidly, it seems nearly impossible not to be contaminated with these chemicals.

Over the last years the growing presence of endocrine disrupting compounds in the environment has been regarded as a serious sanitary issue. The more and more frequent detection of these compounds in the effluents of wastewater

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treatment plants poses the risk associated to their persistence into the aquatic systems as well as to their adverse effects on both public health and environment.[15,16]

As conventional systems do not allow their efficient removal, great attention has been raised towards their possible treatment by Advanced Oxidation Processes (AOPs). They rely on the action of hydroxyl radicals, which are highly reactive species, able to oxidize recalcitrant and non-biodegradable pollutants.

AOPs can either provide contaminant partial degradation or their complete removal. As their effectiveness has been proved for a wide spectrum of both organic and inorganic pollutants, they are considered a suitable option for the treatment of contaminated aqueous media, especially when combined with conventional biological processes.

In the last years the detection of increasing amounts of non-conventional pollutants in wastewater, surface water as well as drinking water has raised great concern. These contaminants, which are mainly associated to the use of substances such as pharmaceuticals, personal care products, hormones, are usually found in very low concentrations but their adverse effects on both human health and environment have been largely documented [1, 2]. For most of these contaminants there is still a regulatory lack, so that they are generally addressed as emerging contaminants [3].

The reduction of their presence into the environment could be pursued by either reducing the use of these substances or removing the amount which enters the water cycle. However, as emerging contaminants are related to products commonly used in everyday life, contamination control could be achieved by adequate wastewater treatments.

Conventional wastewater treatment plants are not designed to remove substances as complex as emerging contaminants, so that many of those are released along with wastewater effluents, posing a risk to both public health and environment.[17,18]

In municipal wastewater effluents concentrations of emerging contaminants have been found to range between 0.1 and 20 mg/L [4]. The identification of proper systems to promote their removal from urban wastewater is therefore necessary. To this end, either the upgrading of existing plants or the implementation of new technologies can be used [5].

Among the solutions that have been studied for the removal of these pollutants [6], Advanced Oxidation Processes (AOPs) are a suitable option. Their application has been studied for the degradation of several kinds of emerging contaminants, including pharmaceuticals [7, 8], personal care products [9, 10] pesticides [11, 12], organotin compounds [13], perfluorooctanoic acid [14], hormones [15, 16], surfactants [17, 18], dyes [19, 20].

Most of these contaminants are addressed as endocrine disrupting compounds (EDCs), defined by the Organization of Economic and Cooperative Development (OECD) as “an exogenous substance or mixture that alters the function(s) of the endocrine systems and consequently causes adverse health effects in an intact organism, or its progeny or (sub) populations”

IV. CONCLUSIONS

In order to improve the cost-effectiveness of energy-consuming AOPs, the use of alternative systems has been studied. A step in this direction has been proved by the use of renewable energy sources to power the processes as exemplified in the case of solar photocatalysis. Similarly, the proper combination of AOPs can be a suitable strategy.

Coupling different advanced oxidation systems allows the reduction of the extent of single processes, without hampering overall degradation yields. On the contrary, different combinations of AOPs have been reported to result in synergistic effects, which enhance the removal rates and/or the degradation yields of EDCs. Moreover, when chemical processes are involved in combined systems, lower reagent dosage determines a reduction in inhibiting by-products formation.[19,20]

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Further studies should be directed towards the in-depth analysis of the mechanisms behind by-products formation from the application of different AOPs and their combination to EDC contaminated wastewaters, as well as to the evaluation of their toxicity. Results would realistically address the choice of the most suitable AOPs for the treatment of aqueous matrix contaminated by different kinds of EDCs. They would also suggest the most suitable application of AOPs as pre- or post-treatment when they are intended to be applied in combination with conventional biological systems for the upgrade of existing plants.

To this end, evaluation of the operating costs associated to different technological solutions is necessary.

Application of AOPs to degrade EDCs in aqueous media is likely to be an expensive venture: initial concentrations of contaminants are so low that treatment cost per unit mass can be much higher than the one associated to less effective conventional processes.[21,22]

In order to reduce treatment costs, the segregation of wastewater flows originated from different sources appears interesting. The separation of wastewater streams, differently characterized in terms of EDC types and concentrations, would allow the identification of the most efficient process for their removal, along with the reduction of the flow rates to be processed. This in turn would result in the reduction of the specific treatment costs.

Such a strategy could improve the competitiveness as well as a more sustainable application of AOPs, which could be limited to specific user bases, thus providing a solution for the expected enhanced water quality demand.[23,24]

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