



Derleme Makalesi/Review Article

Endocrine Disruptors as Emerging Contaminants and Education to Reduce Health Risks

Endişe Yaratan Kirleticiler Olarak Endokrin Bozucular ve Sağlık Risklerini Azaltmak için Eğitim

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Öz

Amaç: Bu derlemenin amacı endişe yaratan kirleticilerin sebep olduğu, özellikle de bu gruptaki endokrin bozucular, sağlık tehlikelerinin önemini ortaya koymak ve sürekli eğitimin sağlık çalışanları ve toplumun geneline eğitim verilmesi gereğidir.

Gereç ve Yöntem: Derleme EDC araştırmalarında son gelişmeleri ortaya koymakta, açık kaynaklarda uluslararası mevzuat ve toplum sağlığı için popülasyonun ve sağlık sektörü çalışanların eğitim ihtiyacını sunmaktadır.

Bulgular: EDC'lerin dahil olduğu endişe yaratan kirleticiler çok geniş bir gruptur, olumsuz etkileri insan ve çevre sağlığını etkilemekte hatta birkaç nesli kapsamaktadır. Giderek annelerin ve gebelerin eğitimine ihtiyaç duyulmaktadır, buna toplumun bütün kesimlerinin de katılması toplumun EDC maruziyetini azaltarak sağlıklı toplum olmasının önünü açacaktır. Milli, bölgesel ve uluslar arası seviyelerde mevzuat düzenlemeleriyle maruziyet azaltılmalı, toplumun genelinde bilinç artırılmalıdır. Sağlık çalışanları için ihtiyaca dayalı kanıtlı eğitim programları bilgi ve bilinç eksikliklerini giderecektir.

Sonuç: Global seviyede iklim krizinin bütün popülasyonları etkilemesiyle, dünya çapında harekete geçilmeli ve EDC'lerin olumsuz sağlık etkilerini azaltacak yönetim ve mevzuat konularında koordinasyon yapılmalıdır.

Anahtar Kelimeler: Endokrin bozucu, Sağlık profesyoneli, Sağlık riski, Eğitim

Abstract

Objective: Aim of the present review is to present significance of health risks incurred by emerging contaminants, and more specifically the endocrine disruptors for continued education of health professionals, and the general public.

Materials and Methods: The review included general state-of-the-art of EDC research, international regulations and studies in the open literature concerning training and education of public and health sector workers.

Results: Emerging contaminants where the EDCs belong are a wide range of materials with several generation health impacts both to humans and the environment. There is an increasing need for mothers', pregnant women's and all parts of society to mitigate EDC exposure for a healthy population. Regulatory measure at national, regional and international levels will ensure exposure reduction, while increasing awareness in the population. Continued evidence-based education programmes designed for needs of health professionals will close knowledge and awareness gaps.

Conclusions: With climate crisis affecting every population at the global level, world-wide action and coordination is necessary to manage, reduce exposure and adverse health effects of endocrine disruptors.

Keywords: Endocrine disruptor, Health professional, Health risk, Education

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INTRODUCTION

As industry boosts with upsurge of global production in materials and goods, contaminants of emerging concern (EC) have threatened both animal and human health, as well as livelihood and sustenance of ecosystems. The EC group of chemicals/compounds/pollutants include a vast array of diverse materials including endocrine disrupting compounds (EDC), engineered nanomaterials, plasticizers, radionuclides to name a few. EDCs, which “are exogenous agents or mixtures that interfere with the synthesis, secretion, and action of natural hormones, consequently causing adverse health effects in an intact organism, its progeny, or (sub)populations”¹. Along this line a new definition for a “potential endocrine disruptor” has also been made by the United Nations. The IOMC (INTER-ORGANIZATION PROGRAMME FOR THE SOUND MANAGEMENT OF CHEMICALS) report of 2012 was the first consensus report and provides the global status of scientific knowledge on exposure to and effects of EDCs². Clearly EDCs are global threat to public health and need immediate action to protect human and animal life. The European Union (EU) also perceived the necessity of looking at EDCs from a different toxicological view and has joined the international scientific community and authorities for discussion and develop legislation to regulate it. Along this line, the Commission adopted a Communication on 7 November 2018 to confirm citizen protection and the environment from hazardous materials. Adoption of the strategy on EDCs since 1999 was further elaborated and adopted as the 7th Environment Action Programme (EAP) in 2013 by the European Parliament and the Council, and provides for the harmonisation of hazard-based criteria for the identification of EDCs. The Commission has adopted a new watchlist of substances in surface waters suspected of posing a risk to the environment and human health([https://environment.ec.europa.eu/news/new-substances-added-eu-surface-water-](https://environment.ec.europa.eu/news/new-substances-added-eu-surface-water-watchlist-2025-03-03_en)

[watchlist-2025-03-03_en](https://environment.ec.europa.eu/news/new-substances-added-eu-surface-water-watchlist-2025-03-03_en)). Furthermore EDCs impact several generations, therefore training of health professionals based on ONE HEALTH principle, informing the general public about health risks, obesity, infertility, impact on the hormonal system and similar other adverse effects, and has become essential at the international level.

This review provides a general perspective on emerging contaminants, more specifically the EDC group, health impacts and the concern accumulated at the international level, to draw attention to public awareness and education for health sector professionals for mitigating risks for a sustainable society. A general consensus is that global action with a multidisciplinary approach for combatting reproductive and developmental outcomes of EDC exposure is the key to reducing health risks.

EDC EXAMPLES and MECHANISMS of ACTION

Environmental health and its’ consequences for animal and human health necessitates all health workers and decision makers to elaborate management and mitigation strategies backed by regulatory aspects to raise awareness in the public, strengthen scientific collaboration and coordination at the national, regional and international levels. Diverse agents can be emerging contaminants, their mechanisms of action vary considerably and since they are usually present as a “cocktail” in environmental media, analytical techniques have to overcome sensitive, robust methodology challenges. Machine learning methods, omics technologies do support prediction of EDC related adverse effects; not any method offers the robust, accurate and reliable determination of EDCs in the mixtures. Another problem is their significant health impacts at very low levels of exposure. Common examples of EDCs have been reviewed²⁻⁴. The list has organic chemicals, plasticizers, metals, flame retardants, a very variable list. Main physiological effects are through interaction

with hormones, hormone receptors, signalling pathways and hormone responsive cells. Some typical examples are phthalates and bisphenol A with interference in estrogen and androgen signaling pathways, changing levels of estradiol, testosterone and typically inhibiting ovarian follicle development and spermatogenesis. They affect both female and male reproductive systems, together with adverse effects on embryonic development at certain windows of embryo development. Hormonal disruption are expanded to other cellular and tissue level mechanisms: triggering production of reactive oxygen species (ROS) to cause damage through oxidative stress, mitochondrial dysfunction, epigenetic modifications, interruption of cell division-meiosis and mitosis, and apoptosis/necrosis. Unequivocally not a single biomarker can be used for diagnosis, monitoring or treatment investigation.

The wide spectrum of reproductive outcomes affect different life stages, are transferred to several generations and are mostly associated with environmental exposure; further complicating pathophysiology. Typical health outcomes (metabolic and thyroid effects, neurodevelopment, cardiovascular, immunological interferences, infertility, PCOS, endometriosis, uterine fibroids, menopause, and gynecologic cancer) and impaired fertility in both sexes are recognized and evidence based on environmental EDC exposure. On the animal and food side hormone/antibiotic accumulation in meat products such as chicken, pork, beef, salmon, other seafood and shellfish may contain residues of estradiol benzoate beyond minimum admissible limits^{3,5}. Considering the possibility of complex EDC mixtures, additive, synergistic and cumulative effects should be expected. The potential long-term exposure impacts due to bioaccumulation and biomagnification are the worst risks.

AWARENESS RAISING, EDUCATION and EVIDENCE-BASED ADVICE TO REDUCE HEALTH RISKS

The baseline: Avoiding and minimizing environmental exposure to EDCs can be achieved by health workers of all disciplines and levels (examples are midwives, clinical practitioners, veterinarians, dentists, food scientists, pharmacists, life sciences specialists, public health specialists to name a few). These professions have the leading role. The initial stage can be started with informing the general public about potential EDC exposure from their household materials and practices such as using teflon and/or plasticware cooking utensils either to prepare food or to warm in the microwave. Biocides, pesticides, air quality/air filters, solvent residues and other chemicals such as paints, upholstery, personal care products should also be included in the information lists. Advice for alternative materials and campaigns by administration and regulatory agencies are at the heart of public awareness and health counseling. Sound mitigation strategies and results obtained will definitely convince the population. The main risk is that they should conceive that EDCs are toxic chemicals and can accumulate at home. The individual can be persuaded for lifestyle modifications for improvement of health, well-being and healthy next generations. Climate change crisis as the number one global problem, and should also be emphasized.

Second stage necessitates healthcare worker education and training in environmental exposures; vocational and higher education level instruction in their programmes will be the key to professional development. Endocrinologists should be supported by other professionals, education sector, decision-makers and society all together since both EDC classes/groups and/or health impacts are wide spectrum. Wieers et al.⁶ developed a survey

and based on their results, have proposed integrating the United Nations Sustainable Development Goals (SDGs) into education programmes of life sciences, medicine, pharmacy, and biomedical sciences. Both academic staff and students participated in the study. Medical students expressed the view that SDGs could be a means of raising awareness about broader global issues to better serve the patients and enhance their future medical practice.

EDC AWARENESS and EXPOSURE in HEALTH PROFESSIONALS

Measurement of the level of awareness in health workers is the prerequisite in design of target group specific training and education programmes. The multidisciplinary field of EDC impacts, mitigation and risk can be carried out by effective risk communication for public health and prevention of environmental exposure encounters. Tan et al.⁷ developed and tested validity and reliability of an EDC awareness scale (EDCA) for allied health professionals with the WHO “One Health” perspective and applied it to all health professionals. The constructs measured were general, impact, exposure in the field of EDCs. Using EDCA Kocabas et al.⁸ studied awareness levels of medical school students and graduate physicians, and reported that the physician group scored higher than the students in EDC awareness and total scores. Impact and exposure-protection subscales showed similar results, no difference between groups. The authors were of the opinion that medical schools in Türkiye did not have environmental health topics, more specifically EDCs, in their curriculum. Another conclusion of the study was that students and physicians participants with pre-existing medical conditions were more sensitive to EDCs and other environmental risks. They used Healthy Life Awareness scale to indirectly determine the individual health concerns. Physician candidates and professionals would benefit from structured training to recognize and advocate EDC health

risks. If inclusion in formal professional training is not possible postgraduate seminars, workshops, continuing medical education programmes and mobile apps can be beneficial. The EDC awareness scale developed by Tan et al. was also used by Tuğgüm et al.⁹ with participants receiving health education (college and higher education) and health sector professionals. The scores were not statistically significant between students and healthcare staff. They reported some familiarity with EDCs but knowledge levels were low. The authors recommended incorporation of EDC modules to healthcare provider’s curricula.

TARGET GROUPS and EDC EXPOSURE

The significance of reaching all socioeconomic levels to increase public awareness is the main crucial key to reduce long term health threats to public life. Since exposure routes and sources are common and the population is at potential risk both life quality of individuals and their next generation progeny due to high sensitivity to EDC exposure during critical development apertures. Exposure reduction can be achieved both by public awareness and regulatory control to prevent EDC health impacts to humans, animals and the environment¹⁰. First-year family medicine residents’ knowledge and behaviors concerning EDCs were evaluated by applying an e-learning module; enhanced achievements in all and improved behavior showed facilitating training for EDCs to raise knowledge levels of physicians. The participants were able to identify EDC classes, self confident in approaching populations at high risk, could communicate exposure locations and routes of entry¹¹.

Adolescents are the vulnerable target of EDC exposure; to this end an intervention mapping framework (COPE ADOS program) was developed to increase adolescent levels of EDC knowledge, attitude, and skills. The need analysis results showed significant knowledge gaps and misconceptions in EDCs. The outcome was participant high school students accessed the 15 educational tools and attitude,

risk perception, self-efficacy and skills were improved with higher knowledge levels, equipping the adolescents for EDCs health impacts¹². Maternal dietary exposure to EDCs during pregnancy and adverse outcomes in children's health have been reviewed¹³. Another review reports personalized (at home) intervention program to reduce EDC exposure in child bearing women¹⁴. Importance of avoidance and lifestyle behavioral changes were the key to reduce EDC exposures. The Korean CHildren's ENvironmental health Study (Ko-CHENS) scheme identified pregnant women's lifestyles in association with selected prenatal concentrations of EDCs using a machine learning approach. Using perfume and makeup, eating habits by pregnant women increased prenatal EDC exposure¹⁵. Males as well as females are the targets of EDC exposure impacts with potential to interfere with altered ovarian function, early puberty (adverse effect on puberty timing), polycystic ovary syndrome, and infertility, prevention can only be achieved through reduced EDC exposure and public awareness. Overall a multidisciplinary approach to improve our understanding, prediction and prevention of EDC risks depends on research, education and training and better regulatory governance¹⁶. Bisphenol A and paraben exposure of pregnant women were investigated with reference to income and education level in Taiwan¹⁷. Use levels and exposure of pregnant women to EDCs were measured using urinary concentrations and were significantly higher in the lowest income group; education level results were high use of rinse-off personal care products, drawing attention to socioeconomic level and EDC exposure through personal care products. Zivancevic et al.¹⁸ studied perceptions and awareness of EDCs among mothers in Serbia, and found that they do not have expected knowledge such as EDC exposure, sources, categories, nor they are in the EDC exposure reduction mind-sets. The researchers draw attention to knowledge gaps in the general population and concluded that maternal

education will benefit mothers and their offsprings in risk reduction due to EDC exposures. Majority of participants agreed to public being informed about EDC health impacts, and were willing to support education programs during routine clinical visits and medical check-ups.

CONCLUSION and PROSPECTS

EDCs, the emerging contaminants, represent a wide array of chemicals/materials, are present in small amounts but form complexes threatening all life forms and their future generations. Additive and synergistic effects increase risks and impediments in analytical methodology. The chronic health and environmental impacts at low and environmentally relevant concentrations should be the most significant issue in cumulative effects. Furthermore plastic pollution (including micro- and nanoplastics) is so wide spread and plasticizers widely used, adding further combined exposure, biofilm development for pathogens and augmented with climate change and global warming. Regulatory action at international level with effective legislative measures are necessary to protect health and environment¹⁹. Vulnerability of children and pregnant women to prenatal EDCs exposure leads to adverse behavioral effects, developmental defects, mental and distressed psychomotor development necessitates extra special informing programmes for pregnant women. The media can be integrated to public awareness programmes as resources. To ensure their status to be "sufficiently informed". The perception of "natural is good" does not always hold to be true. National level actions and regulatory measures can be backed by guides developed by international agencies such as the European Union. EU presently has four regulations for EDC identification; and is advancing to phase out animal testing to alternatives such as new approach methodologies (NAMs)²⁰. As we have already discussed, the necessity of raising awareness in the general public, increasing knowledge levels of health workers and custom designed education modules/programmes, the endocrinology and pediatrics specialties together with midwives and other support health professions are the primary professional groups

to lead the public health protection of populations from EDCs²¹.

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