Estrogen in Water Supply: An Assessment of the Presence of Estrogenic Compounds in Drinking Water and Associated Human Health Risks

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Abstract

Estrogenic-containing or mimicking compounds in surface or drinking water is of particular interest when seeking answers to whether or not the present levels are adverse. An increase in the use of synthetic estrogen, estrogen mimicking compounds, and endocrine disrupting chemicals such as in pharmaceuticals and pesticides creates a rising concern for human health (Conley et al., 2017). For the purpose of this research, naturally occurring estrogenic compounds are ignored. As society uses more synthetically produced materials containing possible endocrine disrupting estrogenic compounds, a growing risk of negative consequences can result for aquatic life and evidently human health. Investigating the trends in change and sources of the issue allows for a deeper understanding of potential sources of the problem. Although drinking water treatment is substantial, the detectable estrogenic levels that may be present can pose harm such as reproductive problems and cancer (Conley et al., 2017). Current literature lacks the connection between well-established, detected estrogenic levels in water and if these levels pose concern. Determining that the current levels are worrisome by intertwining the research, poses a promise towards increasing reasoning for further research regarding the detected levels in water in order to control and decrease further effects. Compiling the information creates an incentive to argue for change to occur to combat the growing problem of the rise in estrogen such as facilitating more public awareness, increasing research, and proposing extensive use of successful water treatment techniques.

Keywords: estrogens, endocrine disrupting chemicals, water supply

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Introduction

Contaminating substances found in water supplies have increasingly become a focal point for many researchers due to the negative implications that the compounds create. Moreover, the recognition of estrogenic compounds and estrogen-like substances in water supplies is on the rise (Adeel, Song, Wang, Francis, & Yang, 2017). Understanding and analyzing the origin of the increase of estrogenic compounds in water is vital in posing interventions to address the problem. The available research will be examined to determine if there is a consensus on levels of estrogenic compounds that pose a risk to human health and associated health concerns. Research and reports will be reviewed to discern the range and average levels of estrogenic compounds found in the United States drinking water.

Although natural estrogen is present in the environment as a naturally occurring hormone found in various organisms, the rise in synthetic estrogen levels in the environment is a concerning risk factor (Adeel et al., 2017). Industrialization and pharmaceutical development sparked an increase in the use of estrogenic compounds and estrogen-like substances, creating an increase of estrogen contamination within the environment due to the excretion and disposal of these compounds (Wise, O'Brien, & Woodruff, 2010). The sources of these substances include chemicals such as endocrine-disrupting chemicals, animal hormones in agriculture, pharmaceuticals like birth control pills, and in fertilizer for plants, amongst many other uses. Of particular interest is endocrine disrupting chemicals and its impact on human health because these chemicals can mimic naturally occurring estrogen and build up over time (Demasi & Collins, 2015). Estrogenic compounds are endocrine disrupting chemicals. The problems

associated with these substances is that they may have exceeded capacity of the acceptable daily intake (ADI) for known concentrations that can be harmful (Adeel et al., 2017). The problem with relying on the ADI levels is that many estrogenic substances have no data available at the moment. Current gaps in the research indicate that the present levels found in drinking water supplies are largely unknown due to a lack of widespread monitoring and research (Adeel et al., 2017).

Tracking levels of estrogen-like compounds such as estrone, 17α-Ethinylestradiol (EE2), and 17β-estradiol (17β-E2) within the drinking water supply will serve as a foundation for understanding unintentional human exposure to estrogenic compounds from drinking water sources (Du et al, 2020). Research on the dose-response relationship will allow for a better understanding of the effects associated from drinking water exposures. Once these risk levels are established, it can help to inform legal drinking water standards to reduce the risk to those exposed through the water supply (Lecomte, Habauzit, Charlier, & Pakdel, 2017). Increased exposure to estrogenic contamination in the drinking water suggests increased complications with the function of the endocrine system creating an elevated risk for disrupting homeostatic mechanisms of the body leading to more problems (Vilela, Bassin, & Peixoto, 2018). Emerging details have indicated that elevated levels of estrogenic compounds in water are specifically associated with an increased risk of diseases such as breast cancer, thus signifying that the issue of estrogen contamination in drinking water should be a priority (Lecomte et al., 2017). Estimating a level of concern for estrogenic compounds in drinking water provides the opportunity to reduce negative health risks associated with elevated exposures.

This literature review aims to connect the sources of the increase in synthetic estrogenic compounds, the amounts of estrogenic compounds found in water supplies, and the levels that

pose health risks for humans. The impact of this research is substantial not only for human health, but also for ecological health. Current literature lacks a definitive association of the current levels of estrogenic compounds in drinking water and its effects on human health. If estrogenic compound levels are recognized and compared to levels the current research deems unsafe, it serves as a way to evaluate potential impacts on health. This can be done through this literature synthesis of secondary research.

Methods and Materials

The basis of this research relied on secondary sources in order to form a literature synthesis. I narrowed my scope in finding research applicable to specific search terms in relation to estrogenic compound detection and contamination, including the sources of estrogen compounds in the environment, reported estrogen levels in U.S. drinking water, and human health risks. I reviewed peer-reviewed articles, books, and other credible published works that focused on synthetic estrogen to understand more about how these compounds contaminate drinking water. After compiling the research on environmental contamination of synthetic estrogen, I learned more about the current literature on the relationship between levels of estrogenic compounds and their effects on human health. The aim is to pinpoint thresholds that pose risks to humans and the environment. With more research, I was able to connect all of the aims and objectives together by determining whether the current levels found in U.S. drinking water exceed the levels that pose a risk to humans. There is a prominent gap in the literature that definitively links the risk levels with the current detected levels, but connecting these different parts gives rise to monitoring the problem in order to allow for solutions to be implemented.

Results

Trends and the Origins of the Problem

Understanding the sources of estrogenic compounds found in water is important for mitigating the causes and impacts. Due to industrialization and development, exposure levels to estrogen contaminants are on the rise. Trends over time have shown an increase in the use of estrogenic containing products with a triple in sales from 1960-1970 alone that are increasing progressively more every year (Stefanick, 2005). Contraceptives, industrial products, household cleaners, steroid use with animal farming, and many other factors lead to increased estrogen contamination in the environment (Lecomte, 2017). In particular, an increase in estrogen-like endocrine disruptors is indicated through studies showcasing the increased presence in the environment and food sources (Burkholder et al, 2007; Wise et al, 2010; Lecomte, 2017). Broadly speaking, some estrogen hormones are removed from wastewater such as 17β-estradiol as they can biodegrade due to chemicals, natural means, or by organisms within the system, but other estrogen hormones such as estrone are not removed since they cannot biodegrade on their own (Khanal et al., 2006).

The inability of estrogen compounds to fully biodegrade can cause buildup in the environment (Lecomte, 2017). Humans excrete estrogenic compounds from urine and feces and use products that release estrogen compounds into the environment at a rate of about 30,000 kg/year and agriculture and livestock release estrogenic compounds via urine, feces, fertilizers and antibiotics, and more at a rate of over 83,000 kg/year which means that these levels can breach into the environment at alarming rates (Lecomte, 2017). Widespread use of estrogenic compounds within various products and services establishes a way for the estrogen to get into the environment through various mechanisms and accumulate over time (Lecomte, 2017). Environmental estrogens include various forms. Chemical compounds come from home products such as cleaning products, industrial developments called xenoestrogens, agriculture and

livestock, and other pharmaceutical drugs (Chighizola & Meroni, 2011). Therefore, it is necessary to dive into more of the major sources of the release of the estrogenic compounds and the current detected levels present such as the overuse of everyday chemical products containing endocrine disrupting chemicals, the use of hormones in animal agriculture, and the widespread use of contraceptives to understand where the increase is coming from.

"Everyday" Chemicals

The use of chemicals within the world today is so vast that a complete understanding of the chemicals that are used may not fully be understood. Over 86,000 chemicals are used in U.S. commerce (United States Environmental Protection Agency, 2020) including chemicals used in foods, plastics, electronics, makeup products, books, household items, canned goods, and most other consumer products. While much is known about the exposures and health impacts of lead, for example, there are less comprehensive data on other chemicals such as endocrine disrupting chemicals. Hormones are key to human development and functioning but many issues arise such as when endocrine disrupting chemicals (EDCs), synthetic compounds that can mimic natural hormones, interfere with normal processing (Frick, 2012). Bisphenol A (BPA), a chemical found in various widely used plastics, is just one example that can mimic naturally occurring estrogen due to their structural similarities (Barrett, 2014). The National Institute of Environmental Health Sciences introduces other EDC commonly found in everyday products such as polyfluoroalkyl substances (PFAS) found in industrial products such as non-stick pans, phthalates used in cosmetics, triclosan found in anti-microbial products, and dioxins used in herbicides, amongst many other products.

Products that contain some derivatives of estrogen or estrogen-like compounds are more widespread than initially thought to be (Frick, 2012). Excretion containing the estrogenic

compounds occurs with all of these various sources, especially due to veterinary medications and hormone therapy drugs per a study done by Wise et al. (2010). Over time these sources continue to be used which has a direct correlation to their increased presence in the environment. The problem with studying the estrogenic levels in the water supply is that current literature often fails to compile together various sources to definitely assess and elucidate the current problem, associated health concerns, and the implications of current actions.

Hormones in Agriculture

The Food and Drug Administration (FDA) allows the use of natural estrogen and synthetic estrogen in various hormonal drugs in animals. The agricultural industry relies heavily on the use of antibiotics and synthetic hormones to help maintain the growth of the animals in large numbers and increase their efficiency and productivity of the meat and animal product productional levels (Burkholder et al., 2007). The industry is vast and wide, yet the realities behind their use of some estrogenic containing compounds is quite alarming due to the repercussions that these uses have on the surrounding environment. Estrogen contamination comes from livestock runoff through the use of synthetic hormones called exogenous hormones that help with meat and dairy farming, and other agricultural processes with the use of hormones to help with better growth (Chighizola & Meroni, 2011). Samples of poultry farming runoffs were shown to include high levels of estrogen hormone 17β-estradiol as well as other chemicals such as aluminum sulfate (Nichols et al., 1997). Other research indicates the presence of estrogenic compounds used to promote animal growth like estradiol, testosterones, trenbolone acetate, melengestrol acetate, and zeranol in runoff and surrounding farm areas (Qu et al., 2012). Most of these estrogenic compounds are synthetic and used for the purpose of promoting the growth of animals.

Contraceptive Pill Use, Compliance, and Overprescribing

Within the past decade or so, there has been an increasing concern with the use of contraceptives due to the presence of estrogenic compounds that are excreted from the body into the environment. Common contraceptive pills taken by millions of women often include natural estrogen and progestin combined with synthetic ethinyl estradiol (Wise et al., 2010). The development of the hormonal contraceptive pill has significant positive applications within the world today but it is important to also address negative concerns. The pill has numerous societal, economic, and health benefits, which influence its use. The first component of negative concerns begins with the doctors who overprescribe the estrogen-containing medications to individuals, especially when women begin receiving the pill at younger ages (Wise et al., 2010). Some women are in imminent need such as for preventing pregnancy, balancing hormone levels, or lessening menstrual side effects but other individuals are given the medication when it is not required (Demasi & Collins, 2015). A national health statistics report that studied women from 2006-2010 stated that using the pill is more common among younger individuals, aged 15-19, who are not fully aware of the potential negative implications of not taking the medication as prescribed (Jones, Mosher, & Daniels, 2018). Therefore, compliance becomes an issue as more women are receiving the pill, not all women are following the directions properly and face contaminating the environment unknowingly if they dispose of their unused pills in improper ways such as flushing them down the toilet or throwing them away. More women in general, not dependent on age, are also receiving the pill in addition to the increase with younger adults (Jones et al., 2018). According to the Centers for Disease Control and Prevention, over 60 percent of women aged 15-49 used some form of contraception, with a majority using the pill (Centers for Disease Control and Prevention, 2018). Combined with the misuse and

overprescribing to individuals that do not require the pill, along with the decrease in compliance creates major implications for the future.

How Estrogenic Compounds Enter the Water Supply

The two main ways that estrogenic compounds breach into the water supply is through wastewater and agricultural runoff. Wastewater is water that comes from sanitary sewer systems and includes urine and fecal waste from humans. There are various sources that cause an increase in estrogenic compounds found in drinking water. Various factors involved within the exposure come from human use including about every aspect of an individual's life including household products, food products, medication use, and more (Wise et al., 2010). Estrogenic compounds are excreted into the water supply either due to urine and fecal excretion, runoff from household products, contamination with disposed products, or disposing of unused pills in improper ways (Wise et al., 2010). Research shows that there is an increased number of women taking the pill which has caused an increased level found in the environment. All of these additional estrogenic compounds get into the environment via a wastewater treatment plant that becomes part of the water supply used by humans (University of Minnesota, 2017).

Agriculture runoff deals with contaminated water leaving the animal farms and breeching into the environment and other systems from fecal waste, ponds containing waste and manure fertilizers used for crops. Some research indicate that increasing levels of hormones used in agriculture lead to various problems such as huge areas of runoff from pastures and other livestock operations with elevated contamination levels of synthetic estrogen that can lead to getting into the water supply indirectly and build up over time if no further intervention and/or action is proposed (Burkholder et al., 2007). One such study was researched as far back as the 1990s where researchers found elevated levels of 17β-estradiol runoff from a poultry farm

pasture that seeped into the ground environment (Nichols, 1997). Waste from agricultural livestock led to runoff and waste containing heavy metals, secreted hormones, EDC pesticides, antibiotic remnants, and various other contaminants especially from swine and cattle feedlots and manure (Burkholder et al., 2007). By compiling together studies at Pennsylvania State University's wastewater system, researchers discovered higher concentrations of estrogen in the soils contaminated with agricultural runoff compared to non-agricultural soils (Woodward, 2014).

When looking at the current mechanisms used for wastewater treatment, it is often assumed to be effective for removing typical natural substances. According to Dr. Paige Novak, a professor at University of Minnesota that specializes in environmental estrogens, the problem associated with the current treatment plants is that the initial design of detection and removal is flawed since most of these compounds are only present in very small amounts such as part per trillions (University of Minnesota, 2017). With time these compounds continue to build up in the environment and spread globally posing compromise for the future. Understanding the origin to the issue, the mechanisms of action, and piecing together implications associated with the increase, create further incentive and pinpoint where to fix the problem.

Detected Levels in the Water

A definitive answer to the problem of elevated estrogen in the water is unknown to researchers at the moment. There is some research on levels in some water supplies, but it is insufficient to provide firm conclusions on average levels. Some research indicates the acceptable daily intake for some estrogenic compounds such as 17β-E2 for adults to be 3 μg/day (Adeel et al., 2017). Acceptable daily intakes for some other estrogenic compounds are not established due to lacking data available for the recommended intake of EE2 (Adeel et al., 2017).

Chromatography and mass spectrometry are efficient identification methods of estrogenic compounds in drinking water supplies. Although levels may be detected in some situations, the biological implications that occur are not widely known (Lecomte, 2017). Thus, more research must be initiated to begin to piece together the detected levels and determine if they are safe or not to pose changes for the future.

Detection Using In Vitro Bioassays

There is a limit of the availability of reports that measure estrogenic activity in the water. Researchers found that treatments for drinking water methods vary in terms of how well they remove estrogenic compounds from the water supply (Wise et al., 2010). Exploring different ways to detect estrogen levels is vital in trying to ascertain the current problem. Yet, with the few studies as early as 2004, the data collected shows that such small doses were present in 19 surface water samples in the United States but that evidence was deemed below the initial detection limit (Wise et al., 2010). Therefore, the current available detection limits are not indicative of the actual level that may cause harm since they are found at levels that are known to potentially cause harm, meaning that estrogenic compounds of concern may continue to go unnoticed. A better detection limit is necessary to detect the trace amounts of potentially harmful compounds.

Estrogenic containing compounds such as hormones can be found within the environment at low doses, so careful collection of data is important for accuracy and success (Guo et al., 2017). The use of in vitro bioassays for detecting estrogen levels in the drinking water was explored to see its effectiveness and whether or not the levels in the water were within normal range. The majority of the detected estrogen were below the limits that were previously established, whereas five had quantifiable levels of estrogen that were deemed unsafe (ranging

from 0.18–0.29 ng/L of estrone [E1]) (Conley et al., 2017). This is just one estrogenic compound that, if present and combined with other EDCs present in various levels, could accumulate and cause an increase above the accepted intake threshold. This technique was overall successful in determining the levels of some estrogenic compounds in the water but the source failed to have a large enough population to have definitive results to determine all present levels. An increased use of this technique could create positive repercussions for the future of detecting dangerous levels of estrogenic compounds (Conley et al., 2017). Other forms of bioassay techniques can also be used to discern these ranges as they are useful currently in detecting other compounds too (Guo et al., 2017).

Normally bioassays are used to determine the quantities of pollutants in a sample, without examining the effects that the pollutants might have on the environment and human health. Therefore, in order to assess both, Neale et al. (2017) used in vitro bioassay-based research in order to determine the concentration of estrogenic pollutants in the water and its effects on living organisms. Through the bioassay used, the results were similar to previous findings in that there were more chemical substances that affect biological processes than the normal monitoring programs assessed on a regular basis (Neale et al., 2017). Therefore, there must be more research and studies looking at a broader range of estrogenic chemicals and their biological effects due to the relatively increased presence of these materials in the water. Furthermore, even more techniques should be explored as the ability to use more ways provides a means to increase the detection rate of estrogenic compounds which in turn creates further data to assess the risks of the increase (Barber, Vajda, Douvill, Norris, & Writer, 2012).

Great Lakes Contamination

As established above, there are many successful ways that scientists can detect estrogenic levels in the water supply. Barber et al. (2012) focused their research on the Great Lakes, trying to determine potential estrogenic contaminants and their effects on aquatic life. The Great Lakes were found to contain less studied contaminants such as17β-estradiol, estrone, and 17α-ethinylestradiol, hormone-mimicking chemicals containing estrogen, similar to that of estrogen in rates of concern that were leading to prevalent reproductive and behavioral problems in the fish populations such as the feminization of the fish (Barber et al., 2012). This group of compounds was less studied as it was initially believed to not be as much of an issue at the time because they were believed to be removed in wastewater treatment plants. The estrogen contamination within the Great Lakes is one example of detected levels in water, but there is far more potential for estrogen exposure elsewhere.

Global Estrogen Levels

A rise in the use of steroid estrogens has created a global concern that some researchers feel the need to address head on such as Du et al. (2020), who worked on a five-year global review study compiling together research from January 2015 to March 2020 on levels of environmental estrogens and water compiling together older studies and newer studies to summarize the findings. Of specific interest is the Ethinylestradiol, EE2, a synthetic estrogen and its prevalence in the water supply as this becomes a rising concern as more studies are indicating the elevated levels found within the environment.

Although there are many naturally occurring estrogenic compounds, the focus of this research was to look at synthetically derived compounds such as 17α-Ethinyl estradiol (EE2) prevalent in many pharmaceutical drugs like the contraceptive pill and household products (Du et al., 2020). The levels present in the water supply are often not removed by comprehensive

filtering systems for wastewater due to low concentrations, yet over time the long-term accumulation of these levels may have serious implications. The study summarizes the existing published research, including the concentration range of estrogenic compounds found within various environmental samples (e.g., lake water, wastewater effluent, etc.) in various regions around the globe including Europe, North America, and many other continents (Du et al., 2020). Du. et al. (2020) reviewed over 37 studies of over 20 compounds in various media from 1996 to 2020 to indicate the presence and range levels of EE2. Most studies were able to discern that the detected concentrations of estrogenic compounds, such as EE2, were elevated in various water samples to which were at maximum concentration of previously reported thresholds (Du et al., 2020). Some ranges of a mixture of estrogenic compounds found in North America amassed up to 4000 ng/L which exceeds the acceptable daily intake of 2.6 ng/L (Du et al., 2020). In turn, indicating that through various means, the estrogen levels as a whole are elevated above the acceptable daily intake and found at a higher frequency than expected. Therefore, there is a higher amount of estrogen contamination in the environment than what the researchers expected to see as the efficiency of filtration and removal of EE2 and other estrogenic compounds were between 64-79.56% (Du et al., 2020).

Although the combined research, over 37 studies and other additional articles, shows the presence of estrogenic compounds in water supply, the amount of data collected on only drinking and tap water is minimal compared to above normal thresholds. Much more research is needed that includes specific data collected on the drinking water supply rather than other forms of water because there is not comprehensive data that can give conclusive results from the minimal data present. With further statistical analysis, Du et al. (2020) recaps the presence of specific estrogenic compounds within natural water bodies as well as wastewater treatment plants

(WWTP) and their associated health risk level by country. EE2 represents the synthetic estrogen, and is represented in relatively high numbers in most countries such as North America which means that its presence in the environment is strong and at higher doses than expected (Du et al., 2020). The prevalence of high-risk levels for specific types of estrogenic compounds establishes that the current levels found can pose risk to health. North America, Africa, South America, and every other region evaluated were defined as a high risk for EE2, meaning that calculations were performed to discern the potential persistence and accumulation of EE2 in the environmental samples (Du et al., 2020). The higher the risk level, the more likely a higher concentration of that compound is found in the water, and those levels exceed the previously established "normal" level. The greater frequency of these estrogenic compounds found in the water are associated with an increased risk of potential harmful effects over time as they are not degrading on their own as they are retained in the environment. Various other compounds were evaluated as well, such as 17β-E2 and E3, which were also found above health screening levels since they are persisting in the environment too (Du et al., 2020). Therefore, this research validates that there is a global issue with the rise in synthetic estrogen according to years' worth of compiling data from various researchers. This study combined with various others helps to create a better foundation of establishing that there is a problem with elevated estrogen found in the water supply. Although it is important to establish that the problem exists, it is equally important to understand the implications of this increase in estrogen found in the water supply.

Health Implications of Estrogen in the Water Supply

Even at relatively low doses, it is possible for estrogenic compounds to still harm the human body and its regular functions if these levels accumulate over time (Lecomte, 2017). Any presence of estrogenic-mimicking chemicals that can cause endocrine disruption may be too

much because they negatively impact normal processing (Lecomte, 2017). Hormones, endocrine disrupting chemicals, and estrogen compounds can become problematic at extremely tiny doses that may go unnoticed but pose a toxicity risk within the body (Demasi & Collins, 2015). Current literature lacks a definitive answer to whether or not the detected levels are harmful. These individual tiny doses may not be hazardous, but their cumulative impact in combination with other chemicals may pose a risk (Lecomte, 2017). There are health risks associated with reproduction, cancer, and normal functioning.

Associated Reproductive Problems

The rise in estrogen levels within the drinking water has created a shift in reproductive and hormonal levels in individuals which has altered some basic biological functions (Adeel et al., 2017). Due to an increase in endocrine disrupting hormones in the water supply, they mimic estrogen once within the bodies and therefore cause early onset of puberty (Demasi & Collins, 2015). Young adults are experiencing puberty and development at a younger age due to the estrogen levels within the water supply and the age is decreasing progressively more each year (Ozen & Darcan, 2011). Although this may not in itself seem to be extremely harmful, it creates further implications for populations such as younger women being of reproductive age younger than before as well as health implications for all. The estrogenic chemicals have shown to alter endocrine functions too. As there is an increase in estrogen levels in the water supply, men can also be affected which in turn causes their hormones to be imbalanced which could lead to issues such as decreased sexual and reproductive functioning (Vilela et al., 2018). Estrogenic compounds are known to increase infertility rates too (Vilela et al., 2018). Reproductive issues may be thought to be one of the major concerns, but there are many other direct associations with other diseases as well.

Connection to Diseases and Cancer

Environmental estrogen and endocrine disruptor exposure are directly associated with an increased risk for the development of cancer (Lecomte, 2017). Various substances that are chemically similar to natural estrogen become the most problematic due to their ability to mimic normally occurring estrogens that bind to target cells in order to cause destruction at various levels (Vilela et al., 2018). Any type of exposure to these chemical substances generates worry for the serious implications it can lead to. Many people are unaware of the issue of endocrine disrupting chemicals and their prevalence in the water, and therefore less mitigation occurs (Vilela et al., 2018).

Just one example of this problem deals with the rise in the use of BPA and its effects such as its association with an increased risk of endocrine disorders, infertility, and cancer (Demasi & Collins, 2015). Many studies focus on the harmful impact of chemicals such as BPA on the function and quality of life for aquatic life such as less reproductive capacity and increased birth defects that is more discernible and easily studied but actually connecting if these levels are problematic to human health becomes more complex (Demasi & Collins, 2015). Researchers were able to connect the elevated levels of estrogenic compounds to health implications for fish, which therefore supports the idea to encourage others to perform more research on water sources and water treatment plan controls (Barber et al., 2012). Blazer et al. (2018) also researched the Great Lakes region to assess the exposure to estrogenic EDC such as estrogen receptor α and β2 that indicated adverse effects on the fish also including reproductive disruption and carcinogenic problems associated with increased disease states. They determined the threshold level to be 10 μg/ml for the fish and found in most instances that the levels found exceeded that threshold justifying that there is an increase in estrogenic contamination found within the environment

(Blazer et al., 2018). Overtime, the chemicals can either build up in the body reaching more toxic levels with time and/or be excreted in the environment that can lead to a downhill effect and spread its influence into the water supply (Lecomte, 2017). Research tends to focus on animal subjects such as aquatic life due to relative ease of studying aquatic animals, but lacks a definitive correlation between the effect of a combination of many chemicals such as endocrine disrupting hormones on human health.

Many bioassay techniques such as chromatography and mass spectrometry can detect the presence of endocrine disrupting chemicals, which many have detected out of normal ranges within the environment with concentrations ranging drastically from ng to μg per liter of water (Lecomte, 2017). The tiny doses present may not seem extremely alarming but the wastewater treatment facilities do not eliminate all of these substances and with time will accumulate causing risk for life. The problem with this type of research is that it is minimal and the biological effects are not well understood in humans. Yet, research suggests a correlation between this direct increase and the rise of disease states.

As estrogen pollution is on the rise, understanding the connection between this increase and disease trends are important. Studies have shown the connection between an increase in estrogen disrupting chemicals with negative side effects such as an increase in breast and prostate cancer (Lee, Kang, Su, Okubo, & Nagahama, 2012). Lee and his researchers used bioassay technique to study the effect of endocrine disrupting chemicals to embryos and concluded that the chemicals can cause decreased neuronal activity and slower normal activity, amongst other negative conclusions (Lee et al., 2012). Because an increase in adipose estrogens suppresses normal functioning of estrogen in the female body, increased estrogen levels are

linked to obesity and to an increased risk in breast cancer (Hilakivi-Clarke, Assis, & Warri, 2013).

There are other studies that address this issue amongst animal subjects over periods of time, but there is a limit in knowledge in the associated effects on human health given ethical concerns. Yet the idea here is promising as researchers discover this scientific technique to utilize in order to gain a better understanding of the effects that these chemical compounds have on normal functioning. Knowing that a problem exists suggests that the research is currently lacking in its full potential. As a whole, we must gain a better understanding of the current assessment of estrogenic compounds in the drinking water supply to establish that the problem exists. One of the biggest issues with the increased presence of these compounds is due to the lack of complete understanding of their presence and their effects on humans and the environment. Once the problem is established, proposing measures that could create further incentive for change are vital in the next steps of progression.

Discussion

The Importance of Further Research

Estrogen within the environment is a growing concern for researchers because as elevated levels are detected, a growing concern is created to try and understand its impact on the environment and human health. Some research seems to address methods to detect the estrogen levels and others discern ways to detect the endocrine disrupting hormones. Although some researchers are trying to understand the implications of the increase in the water supply and its effects on aquatic life, far too little research is being completed to try and discern how this impacts human health. There is a strong association between this increase and problems in humans such as an increase in prevalence of breast cancer for women, or prostate cancer for

men, or higher infertility rates, and lower reproductive ages (Lecomte, 2017). Yet, the research is lacking a definitive connection to estrogen and estrogenic compounds and its direct effect on human health. The best way to accomplish a goal is to try and establish that a problem exists, making the number one priority to establish whether estrogen levels in the water are increasing with time through targeted environmental monitoring programs. This is necessary to increase our understanding and to create incentives for future changes.

The presence of estrogenic compounds in drinking water poses concern for human health. The development of birth control containing estrogenic compounds was a significant step in the pharmaceutical industry as well as the use of steroids in farming and cattle, and other various industrial uses of estrogen containing compounds. Issues may arise because there are both positives and negatives to the use of the pill and other estrogen containing products so we must be mindful of the issue. The problem arose when a significant increase in the human-made, synthetic chemicals became part of the drinking water supply as a result. Most studies often mention one chemical that is studied over time in populations and its effects on health because of the complexity and difficulty to study the cumulative exposures and effects of chemicals on human health. The tiny doses present of one endocrine disrupting chemical in the drinking water may in itself not seem to be problematic, but this one in combination with the others may push the limit over the normal limit and cause hormonal imbalances or long-term health problems. More monitoring and research must occur to get a better understanding of the present levels of various compounds and compile the data together for analysis.

Elevated estrogen levels detected by various methods such as bioassay techniques have demonstrated adverse effects including increasing the risk of cancer in humans (Lecomte et al., 2017). Understanding more about the sources and uses of estrogenic compounds, ambient levels,

and health implications is key to changing the current practices used today. Trace levels of estrogenic compounds may not seem to be a significant concern at this moment in time due to lack of definitive research and understanding, but could pose potential concern if changes are not implemented as accumulations can lead to widespread health problems throughout the world. It is speculated that adjustments to current protocols and standards may need to change in order to increase the safety of drinking water.

There are limitations on the research and relative knowns about the direct implication of elevated estrogen levels in drinking water and the environment. Yet, we must address these instances before it becomes unfixable. There is clearly a reason why estrogen containing products are used which is why it becomes problematic to research this topic. In order to fully understand the implication of such, much more research must be done. The only way to expand knowledge is to learn more about how this impacts health and where we as a society should go from here.

Bridging together the different aims of this suggests that research may be lacking in demonstrating the exact cause and effect relationship of the estrogen levels in drinking water with the health of humans. It is beneficial to develop widespread use of an efficient and affordable filtering system that takes into account these estrogenic compounds that may not be a part of the current formulary. Some studies have shown using reverse osmosis and/or activated carbon systems to filter out the estrogenic compounds in water samples (Berkey Water, 2016). Stricter regulation standards may need to be implemented to allow for the widespread use of filtering mechanisms. In addition, an increase in awareness about this developing issue becomes vital in allowing the public to make changes on the instances they have control over as well. Ensuring doctors are prescribing these medications when needed is necessary for control of the

issue. Increasing compliance allows for patients to take their medication effectively. The use of estrogenic medication cannot be completely stopped because the reasoning behind this development is substantial, but developing a proper disposal protocol can help in reducing the waste of unused, improperly disposed medications that can breach into drinking water. Each individual step combined can have tremendous positive impact on the future of human health.

In order to combat the improper disposal of medications, I propose that kiosk drop off stations can be implemented nationally for convenience purposes. Personally, I believe that hormones found in the drinking water is a topic that is disregarded as being significant due to the lack of research and relative unknowns about the levels in drinking water and its effects on the environment and humans. Since I am pursuing a pharmaceutical career, I find it necessary to explore other topics in addition to the widely studied antibiotic resistance including an increased focus on estrogenic compounds in drinking water. Evidently, the goal of this research is to increase awareness of the impact of estrogenic compounds in order to take further steps to reduce its effects. This gap in research must be addressed sooner rather than later or else it might be too late.

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