Assessing Public Awareness on the Potential Health Risks of Phthalate exposure in Plastic Consumer Products

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Abstract

Background: Phthalates are chemical agents used to improve the plasticity of plastic products. Their ubiquitous use in various commercial products results in extensive exposure to humans. Toxicological studies have linked phthalate exposure to developmental and reproductive toxicity, presenting potential health risks. This study investigated the general population on their knowledge and hazard perception of phthalate exposure. The assessment determined if changes in policies or guidelines are needed to minimize potential health impacts from improper plastics handling.

Methods: Awareness of phthalates in the general population was measured through a self-administered online survey distributed on various subreddits and Facebook survey exchange groups. The survey was created using SurveyMonkey that consists of 14 knowledge, practice, and attitude (KAP) questions regarding phthalates in purchased plastic products. The survey was open for two weeks, and Chi-square statistical tests were conducted using NCSS to analyze the data.

Results: Among 188 participants, 55.61% were male, and 40.64% were female. Most participants were between 18-24 years of age and had post-secondary or higher education. The study found that older and more educated participants were more aware of potential health risks from phthalate exposure ($p = 0.0031$, $p = 0.0054$). Gender did not affect phthalate awareness ($p = 0.6398$). Participants with background knowledge of plastic chemicals were more concerned and aware of phthalates ($p = 0.0000$), were less likely to microwave their food in plastic containers or wraps ($p = 0.0040$), and had a higher perception of health risks regarding phthalates ($p = 0.0000$). Participants who frequently purchased plastic products were not more aware of phthalates and their risks ($p = 0.6507$, $p = 0.2033$). Many participants with knowledge of plastic chemicals did not know of phthalate health effects ($p = 0.2584$).

Conclusion: The results indicated that participants who heard of phthalates were moderately aware of its potential health risks. Many participants had a poor knowledge of phthalates as awareness did not increase with more plastic purchases. Although participants with background knowledge of plastic chemicals were more aware of phthalates, there seemed to be a lack of concern when heating food in plastic wraps or containers. The study identified the need for education and accessible information to improve consumer's plastic handling practices. Information could be incorporated by organizations, government agencies, and manufacturers to help educate the public and improve their awareness.

Keywords: Phthalates, chemical, awareness, plastic, toxicity, exposure

Introduction

Phthalates are human-made chemicals used as plasticizers to increase the flexibility and versatility of plastic consumer products. These chemicals are made of esters, a compound that is widely used in industrial applications. They are produced in large quantities and are found in everyday products such as toys, adhesives, flooring and wall coverings, cosmetics, medical devices, and personal care products (Hauser & Calafat, 2005). Advances in materials science and engineering have led to plastics' widespread usage to provide cheaper, lighter, and more cost-efficient products in our lives. As a result, there is a high risk of the public being exposed to phthalates.

Many people may not be aware of phthalates' dangers due to the lack of knowledge and how it is an invisible chemical. One concern is how susceptible populations, like children, can be affected as they are at greater risk of being exposed due to their hand-to-mouth behaviours (Kim et al., 2011). Other vulnerable populations, such as pregnant women, should also be informed of phthalates because of potential toxicity towards the baby. Since individuals can be exposed to phthalates at any given time, manufacturers need to ensure that their practices meet the required legislation to minimize potential impacts on the susceptible population. Given that phthalates can adversely affect human health, this literature review will investigate phthalates' impact in terms of exposure, toxicity, and health effects.

Literature Review

Phthalates are divided into low phthalate and high phthalate, depending on the compounds' molecular weight (Council, 2008). Low phthalates are compounds that have 1-4 carbon atoms in their chemical backbone. They include diethyl phthalate [DEP] and dibutyl phthalate [DBP], which are used mainly in personal-care products (Council, 2008). Conversely, high phthalates have five or more carbon atoms in their chemical backbone. The most common types of high phthalates comprise of diisononyl phthalate (DINP), diisodecyl phthalate (DIDP), and di-2-Ethylhexyl phthalate (DEHP), which are primarily used as plasticizers for polyvinyl chloride (PVC) products (Council, 2008).

Phthalate Exposure

People can be exposed to phthalates by ingesting food or beverages that are served or packaged with phthalate-containing products (CDC, 2009). They can also be exposed by inhaling off-gassed phthalate vapours and dust particles contaminated with these chemicals (CDC, 2009). Also, people can be exposed to the dermal route by contacting equipment like medical devices (Hauser & Calafat, 2005). Phthalate exposure cohort and case-control studies were conducted to measure human exposure and indirectly monitor its environmental impacts (Hauser & Calafat, 2005).

In our bodies, phthalates are readily metabolized and quickly excreted in urine and feces (Hauser & Calafat, 2005). At low concentrations, the exposures may not have any significant health effects. However, phthalate exposure at high concentrations can potentially adversely affect both men and women (Hauser & Calafat, 2005). According to Meeker et al. (2009), phthalate compounds can act as an endocrine-disrupting compound (EDC). In men, EDC can decline reproductive capacity and increase testicular and prostate cancer (Meeker et al., 2009). In women, EDC's presence can increase the risk of endometriosis and various endocrine-related cancers (Meeker et al., 2009).

Research involving human health outcomes is often challenging to assess as single exposures to phthalates do not consider the long-term exposure level (Johns et al., 2015). For the general population, DEHP and DBP were predominant exposures caused by the ingestion of food and dust particles containing these compounds (Wang et al., 2019). In the study, the tolerable daily intake (TDI) of DEHP and DBP estimated to be safe for humans is in the range of 0.05mg/kg and 0.01 mg/kg of body weight per day, respectively. However, Hines et al.'s (2011) study has found that the TDI for DEHP and DBP were many folds higher for workers exposed in an occupational setting. These values may not reflect the general population's exposure level; however, workers may include pregnant women, which are sensitive populations (Hines et al., 2011).

To analyze the outcome of phthalates exposure, Meeker et al. (2009) conducted a study that evaluates the effects of DBP and DEHP phthalates on fetal exposure in rodents. In this study, Meeker et al. (2009) has found that exposure to these compounds induced reproductive and developmental problems. A similar study conducted by Fréry et al. (2020) has shown that some male offspring of rats were born with reproductive abnormalities. DEHP and DBP were the two most potent types of phthalates that cause toxicity in animals (Fréry et al., 2020). Conversely, Kamrin's (2009) study states that while DEHP had the highest potency among all the phthalates based on animal data, the dose of phthalates used in animals is many times higher than human exposure. Thus, it is unlikely that humans will be exposed to high amounts of these phthalates that can significantly impact human health (Kamrin, 2009).

Cantonwine et al. (2014) did a human study to evaluate the relationship between plastics use and urinary concentrations of phthalate metabolites in pregnant women from Puerto Rico. He concluded that all the urine samples contained phthalate esters, and the majority of the samples had higher concentrations than the average reproductive age of women in the mainland United States population (Cantonwine et al., 2014). He found that participants who used bottled water for cooking and plastic cisterns for water storage had significantly higher concentrations of phthalate esters in their urine (Cantonwine et al., 2014). Furthermore, participants who use personal care products and cosmetics presented noticeable differences in phthalate concentrations than those who did not use them (Cantonwine et al., 2014).

Bucci et al. (2010) surveyed the general population to assess their risk perception of phthalate-containing plastic products. She concluded that while most participants were aware of adverse effects from exposure to chemicals, the majority had a lower risk perception of the unsafe use of plastics in the microwave (Bucci et al., 2010). Also, she found that participants with only a high school background had significantly lower knowledge of health risks associated with phthalates than those with college degrees (Bucci et al., 2010). Thus, this shows us that people with higher education may be more aware of plastic products' chemical hazards.

Another survey conducted by Hartmann & Klaschka (2017) assessed consumer's awareness of harmful chemicals in everyday products. They found that while most of the respondents were familiar with potentially harmful chemicals in products, their knowledge of chemistry did not increase their awareness (Hartmann & Klaschka, 2017). Many respondents assumed products to be safe if the packaging was not labeled with hazardous pictograms (Hartmann & Klaschka, 2017). The study also found that respondents' education levels did not provide them with additional knowledge of harmful chemicals in products (Hartmann & Klaschka, 2017). This survey's findings demonstrated that chemical awareness could only be improved when exposed to visual details, such as information provided by consumer organizations, hazard pictograms, and labeling of ingredients (Hartmann & Klaschka, 2017).

Phthalate-Related Toxicity

The toxicity of phthalates varies depending on the form of the phthalate compound (Shea, 2003). Mature laboratory animals were tested in the liver, kidneys, thyroid, and testes for toxicity from ingestion. The toxicity of phthalates is separated into two major categories: Reproductive and Developmental.

Shea (2003) observed reproductive toxicity in laboratory animals after a high DEHP and DINP exposure dose. The phenotypic changes detected in male rats after DEHP exposure had similarities with common human reproductive disorders such as low sperm counts. In this study, Shea (2003) found that only high doses of phthalates can adversely affect adult and developing female rats. Similarly, Ambe et al. (2019) found that DBP and DEHP cause adverse effects on reproductive organs at high doses. Toxicity included a delay in spermatocyte formation and testicular malfunction due to the anti-androgenic effects of these phthalates.

A study conducted by Chen et al. (2014) on zebrafish embryos found a connection between enhanced estrogenic activity and developmental toxicity from BBP and DBP phthalates. The mechanism was linked with endocrine-disrupting potency that resulted in embryo mortality even at low concentrations. Similarly, Ema (2002) did a different study on the adverse effects of DBP on pregnant rats. The fetuses developed developmental deformities, including malformations of the thoracic and cervical vertebrae. Although the research methods were different, the two studies presented similar findings in the embryo's developmental toxicity.

The studies above suggest that phthalates cause reproductive and developmental toxicity that can be detected in animal experiments. However, since animals and humans are different, it is unclear whether the data on phthalates toxicity can be translated into human health outcomes.

Effects of Phthalates in Susceptible Populations

Based on the existing animal data, phthalates exposure can cause toxicity in reproduction and development. This may imply that there are potential health effects to humans, especially susceptible individuals, when exposed at high concentrations or chronically. The human health effects of phthalates are still being investigated by various government agencies, including Health Canada (Health Canada, 2017). Most research involving human health effects from phthalates are small and only include urine measurements (Hauser & Calafat, 2005). Therefore, focusing studies on susceptible populations is more valuable and practical.

Infants and children are especially vulnerable to phthalate exposure through ingestion and dermal absorption (Kim et al., 2011). They play with plastic toys and often put their hands or objects into their mouths. Infants and children can also ingest foods containing phthalates unknowingly (Kim et al., 2011). Furthermore, kids like to crawl around make them more susceptible to phthalates exposure by inhaling dust or fumes in products containing vinyl (Kim et al., 2011). Pregnant women are also vulnerable to phthalates because they have a weakened immune system. Thus, susceptible individuals should be precautious that phthalates-containing plastic may cause unpredicted health outcomes.

Qian et al. (2019) conducted a prenatal cohort study to examine the relationship between phthalates exposure and neurodevelopment in children at two years of age. They found that all children exposed to low molecular weight phthalates had decreased psychomotor developmental index (PDI) scores. Children exposed to high molecular weight phthalates were observed to associate with girls' PDI scores negatively. In contrast, boys' PDI scores were positively associated with high molecular weight phthalates such as DEHP. Thus, this shows that the hazards of high molecular weight phthalates exposure in neurodevelopment are still unclear.

Colón et al. (2000) case-control study examined the developmental effects of DEHP and other phthalates esters in 41 Puerto Rico girls between the age of six months to eight years with early breast development (thelarche) and 35 female control patients between the age of six months to 10 years. Significant levels of phthalate esters were detected in the serum of the 28 thelarche patients, with only one control patient showing any significant levels of phthalates. Similarly, BCPP (2019) has found that premature breast developed children from DEHP exposure can increase the likelihood of developing breast cancer later in life. The studies suggest that there may be a possible link between DEHP exposure and abnormal cell growth, which indicates the potential for an increased risk of developing breast cancer.

Given the information from the studies above, it can be concluded that those who often contact plastic products are more likely to be exposed to phthalates (Cantonwine et al., 2014). Although these studies were unable to correlate exposure and toxicity to human health directly, some evidence suggests that exposure to high molecular weight phthalates like DEHP may increase breast cancer risk (BCPP, 2020).Furthermore, most pregnant women with college degrees are aware of the potential health effects of chemicals in plastics, as seen in Bucci et al. (2010) study. This implies that education plays a significant role in an individual's awareness, which may help minimize the person's exposure to phthalates when plastics are better handled.

Scope

This research aims to determine consumers' awareness of phthalate chemicals' potential health risks in plastic products. This will help health agencies communicate environmental health information to the public, which raises knowledge of health concerns associated with phthalates. Furthermore, health agencies can use it as an educational tool to provide precautionary steps in minimizing exposure for the general population. As a result, it will reduce potential health effects on susceptible people, such as pregnant women exposed to phthalate chemicals by microwaving plastic food containers.

Materials and Methodology

Materials

This study's material included a desktop computer that was used for survey distribution and statistical analyses. The survey was posted online using SurveyMonkey, an online tool that can be used to create online surveys (http://www.surveymonkey.com). Statistical analyses were done using NCSS, and Excel was used to organize the data. NCSS (2021) is a statistical software used to run a Chi-square test on the raw data to determine if an association exists between two variables. A $100 gift card from BCIT inventory was also available for participants who entered their email into the draw at the end of the survey.

Standard Methods

The data for this study was collected in Canada via an online self-administered survey using the platform SurveyMonkey. The survey was open for two weeks, from January 21, 2021, to February 4, 2021. It was posted publicly on subreddits and Facebook groups, including r/samplesize, r/BCIT, r/takemysurvey, and survey exchange. This ensured anyone could reach the survey with or without an account. The survey consisted of demographic, knowledge, attitude, and practice (KAP) questions regarding phthalates awareness in plastic products.

Questions in the survey were all closed answers. The first part of the survey was demographic questions, and the second part of the survey was KAP questions. The questions had "Prefer not to answer" or "I don't know" options to avoid any random guessing of the answers, resulting in an inaccurate categorization for data analysis (Dobronte, 2016). The questions were also designed in layman's terms so that the general public could easily understand them.

Inclusion and Exclusion Criteria

Any Canadian resident over 18 was eligible to participate in this study. This excluded any participants under 18 and from outside Canada. The exclusion criterion was addressed in the first question of the survey, where data from participants who answer "No" was excluded. Friends, family, and classmates of the investigators were also excluded from the study.

Ethical Considerations

The consent form, cover letter, and survey questions were sent to and approved by the BCIT Research Ethics Board before disseminating the survey. Survey results were kept confidential in a secured password-protected desktop computer. A consent form and cover letter included the study's purpose. The BCIT Research and Ethics Board approved the survey questions before posting on Reddit and Facebook.

Results

Description of Data

Data collected for this study was both nominal and ordinal. A total of 14 questions were asked. The first section consisted of demographic questions, including age, gender, education, and geographical region. The second section included knowledge, attitude, and practice (KAP) questions regarding plastic use and awareness of phthalates in plastic products. For the analysis, the 'prefer not to answer' options were omitted due to the potential outlier effect. However, the 'prefer not to answer' choices have been included in the descriptive data to show that those results were collected in the survey.

Descriptive Statistics

A total of 188 Canadian participants consented. Descriptive statistics were exported using the export function on SurveyMonkey. Circle graphs and horizontal bar graphs were used to indicate the distribution of responses by group. The descriptive results from the "demographics" section are shown below.

Participants' ages ranged from younger than 18 to 64 years (Figure 1). Most of the participants were between 18-24 years of age (42.02%), while 34.57% were between 25 and 34, and 15.96% were between 35 and 44.

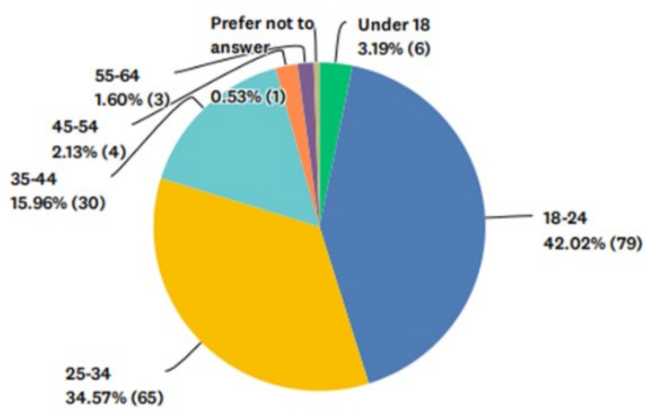

Figure 1. Age Distribution of Participants

Among the participants, 55.61% were male, 40.64% were female, 2.14% indicated as others, and 1.60% did not disclose their gender (Figure 2).

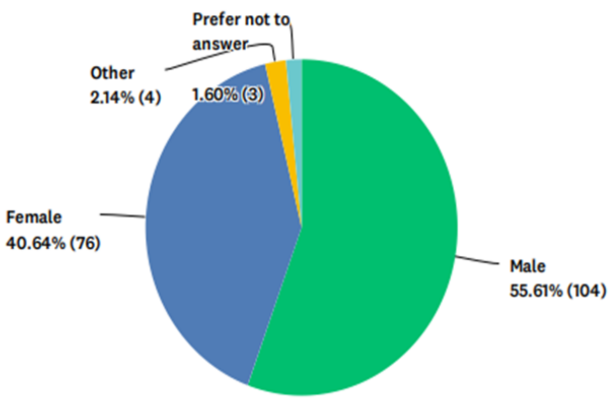

Figure 2. Gender Distribution of Participants

Most participants completed post-secondary or higher education in terms of education (Figure 3). Of the majority, 45.74% had some post-secondary education, while 28.19% had a bachelor's degree, and 6.91% had a Postgraduate degree. About 12.77% were high school graduates, and 5.32% had some high school or less education. 1.06% of the participants did not disclose their answers.

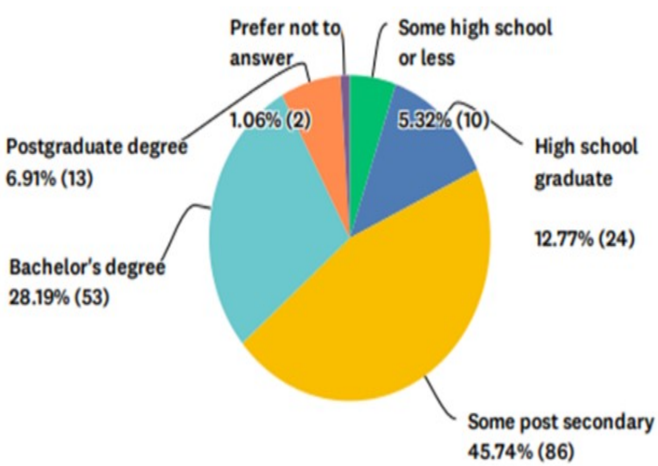

Figure 3. Education Distribution of Participants

Most participants purchase plastics at least once per week (Figure 4). About 11.92% purchase daily, 54.40% purchase often, 28.50% purchase sometimes, and 5.18% purchase rarely. None of the respondents answered "never" to purchasing plastic products.

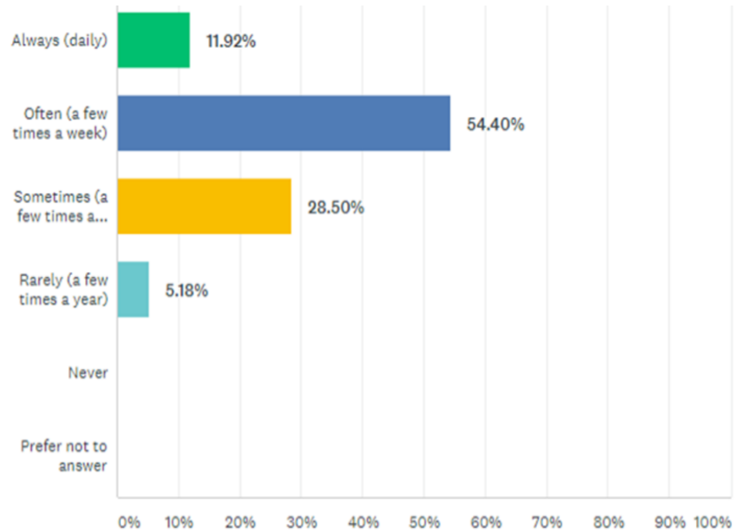

Figure 4. Participants' Frequency of Purchasing Plastic Products

<u>Inferential Statistics</u>

Statistical tests on the data were performed using NCSS (2021), and inferential statistics were done using the Chi-square test. The following table summarizes the inferential statistics.

H_o and H_A	**Test Used**	**Result**	**Conclusion**
H_o: There is no association between level of education and phthalate awareness **H_A**: There is an association between level of education and phthalate awareness	Chi-square test	p-value = 0.0054	The p-value is <0.05; therefore, reject the H_o and conclude that there is a statistically significant association between the level of education and phthalate awareness. The potential is low for a type I error (away from cut-off). To minimize type I error, acceptable alpha can be lowered from 0.05 to 0.01.
H_o: There is no association between the frequency of purchasing plastic products and phthalate awareness **H_A**: There is an association between the frequency of purchasing plastic products and phthalate awareness	Chi-square test	p-value = 0.6507	The p-value is >0.05; therefore, do not reject H_o and conclude that there is not a statistically significant association between the frequency of purchasing plastic products and phthalate awareness.
H_o: There is no association between knowledge of plastic chemicals and risk concern of phthalates exposure **H_A**: There is an association between knowledge of plastic chemicals and risk concern of phthalates exposure	Chi-square test	p-value = 0.0000	The p-value is <0.05; therefore, reject H_o and conclude that there is a statistically significant association between knowledge of plastic chemicals and risk concern of phthalates exposure. The potential is low for a type I error (away from cut-off). To minimize type I error, acceptable alpha can be lowered from 0.05 to 0.01.
H_o: There is no association between age and phthalate awareness **H_A**: There is an association between age and phthalate awareness	Chi-square test	p-value = 0.0031	The p-value is <0.05; therefore, reject the H_o and conclude that there is a statistically significant association between age groups and phthalate awareness. The potential is low for a type I error (away from cut-off). To minimize type I error, acceptable alpha can be lowered from 0.05 to 0.01.
H_o: There is no association between gender and phthalate awareness **H_A**: There is an association between gender and phthalate awareness	Chi-square test	p-value = 0.6398	The p-value is >0.05; therefore, do not reject H_o and conclude that there is not a statistically significant association between gender and phthalate awareness.

H_o: There is no association between frequency of heating food in plastic and phthalate awareness **H_A**: There is an association between frequency of heating food in plastic and phthalate awareness	Chi-square test	p-value = 0.0040	The p-value is <0.05; therefore, reject the H_o and conclude that there is a statistically significant association between frequency of heating food in plastic and phthalate awareness. The potential is low for a type I error (away from cut-off). To minimize type I error, acceptable alpha can be lowered from 0.05 to 0.01.
H_o: There is no association between perceived health effects of phthalates exposure and phthalate awareness **H_A**: There is an association between perceived health effects of phthalates exposure and phthalate awareness	Chi-square test	p-value = 0.0000	The p-value is <0.05; therefore, reject the H_o and conclude that there is a statistically significant association between perceived health effects of phthalates exposure and phthalate awareness. The potential is low for a type I error (away from cut-off). To minimize type I error, acceptable alpha can be lowered from 0.05 to 0.01.
H_o: There is no association between knowledge of plastic chemicals and perceived health effects of phthalates exposure **H_A**: There is an association between knowledge of plastic chemicals and perceived health effects of phthalates exposure	Chi-square test	p-value = 0.2584	The p-value is >0.05; therefore, do not reject H_o and conclude that there is not a statistically significant association between knowledge of plastic chemicals and perceived health effects of phthalates exposure.
H_o: There is no association between knowledge of plastic chemicals and phthalate awareness **H_A**: There is an association between knowledge of plastic chemicals and phthalate awareness	Chi-square test	p-value = 0.0000	The p-value is <0.05; therefore, reject the H_o and conclude that there is a statistically significant association between knowledge of plastic chemicals and phthalate awareness. The potential is low for a type I error (away from cut-off). To minimize type I error, acceptable alpha can be lowered from 0.05 to 0.01.
H_o: There is no association between risk concern of phthalates exposure and frequency of heating food in plastic **H_A**: There is an association between risk concern of phthalates exposure and frequency of heating food in plastic	Chi-square test	p-value = 0.2033	The p-value is >0.05; therefore, do not reject H_o and conclude that there is not a statistically significant association between risk concern of phthalates exposure and frequency of heating food in plastic.

Discussion

The results showed that most participants were aware of phthalates exposure with an increased education level from the statistical analyses. The study found that those with post-secondary or higher education were more aware of phthalates and perceived exposures to phthalate-containing plastic products to be riskier. In contrast, participants with high school education or less were excessively unaware of phthalates and their risks. These results support Bucci et al. (2010) study, which found that people with college graduate degrees had more knowledge of health risks associated with phthalates than those with a high school education only. Education plays an important role where one comes to know various facts and ideas. In case of plastic chemicals, the general population could become more aware of its risks when they are equipped with plastic knowledge. People who are poorly educated are less aware of phthalates and proper plastic handling techniques, as highlighted in Cantonwine et al.'s (2014) study.

The study has also found that participants with a better perception of phthalates are less likely to heat their food in the microwave with plastic containers or wraps. Participants who are aware of phthalates would rarely or sometimes microwave their food in plastic containers or wraps. There seems to be a tendency of microwaving plastics despite being aware of risks associated with phthalate exposure. This may be because plastic products are commonly found, so that individuals may perceive them as non-hazardous. Results follow Bucci et al. (2010) study where the participants who knew that microwaving plastics are potentially hazardous would still do so at least once per week. This is concerning because studies have shown that exposure to phthalates can cause reproductive and developmental anomalies, especially in pregnant women and young children (Ambe et al., 2019 & BCPP, 2020). According to survey results, parents with children under the age of 8 did not seem to be more aware of phthalates or their health risks.

There were no statistically significant associations between awareness of phthalates and perceived health effects, as indicated by the p-value of 0.2584. Most of the participants were slightly or not knowledgeable about chemicals in plastic, let alone phthalates. Similarly, most participants who are somewhat knowledgeable of phthalates did not necessarily know if they should be concerned. The results indicate that there seems to be a deficit in the public's knowledge of phthalates, as characterized by a lack of risk concern from microwaving plastics. This agrees with Hartmann & Klaschka's (2010) study where the general public is aware of chemicals present in everyday products but is not concerned whether they are harmful unless shown on the packaging or labels.

When the frequency of purchasing plastics was compared to phthalate awareness, statistical analyses revealed no association between the two categories. The study found that participants who frequently purchase plastic products were not any more aware than others. This result may suggest that the public assumes all plastic products to be considered safe for use. With a non statistically significant p-value of 0.6507, there seems to be no correlation between the consumer's knowledge of harmful chemicals and the frequency of purchasing plastic products. It does not necessarily agree with Hartmann & Klaschka's (2010) study such that consumers are aware of toxic chemicals in everyday products the more they purchase. It shows that the general public has a poor perception of potentially harmful substances present in plastics. Many participants with knowledge of plastic chemicals also did not know of phthalate health effects, likely because many other types of chemicals are present in plastics.

Results also reveal that there is a statistically significant association between age and phthalate awareness. With increasing age, participants are better equipped with the knowledge of phthalates, likely due to more experience. Older people have more life experiences and undergo a longer learning process. For participants under 18 years old, they often do not make the purchasing decisions in a household. However, suppose an entire family has poor plastic awareness. In that case, it can be concerning since studies have found a correlation between decreased psychomotor development and increase risk of breast cancer in young children exposed to phthalates (Colón et al., 2000 & Qian et al., 2019). Additionally, the awareness of phthalates did not differ between males and females. This could mean that even susceptible groups such as pregnant women or mothers of young children also have inadequate phthalate awareness.

In terms of the study's validity, survey questions were modified after the pilot study to ensure that everyone answered them as truthfully as possible. However, this study's limitation was that some participants might have guessed the answers to specific questions, which lowers reliability. Since some categories had small responses (<30), it may have reduced the power in some categories, such as showing a non-significant association when there is a significance. Also, it is not easy to recognize whether responses are truthful in online surveys. Outliers could have potentially affected some questions. The survey results could be extrapolated to BC residents of both male and female gender and of ages over 18 since 87.23% of the participants were BC residents in the distribution of demographics.

Limitations

The study was limited for time as the survey only had a 2-week duration to gather responses. Time was limited since it took a while for REB to approve the survey questions before its dissemination. Future research should include a more extended collection period to distribute the survey on more platforms while allowing more time to collect responses. Validity would improve as the sample size increases. The participation rate could also increase if more incentives were provided to motivate people to do the surveys. Subsequent research can consider making prizes more valuable.

Another limitation with online surveys is the potential of outliers and untruthful responses impacting the study's power. Considering how online surveys are done at people's own pace and setting, they could easily search off the internet for answers or randomly guess them. As the survey took about 2 minutes to complete and questions were designed to be understood by everyone, the potential for untruthful responses is low (Rolstad et al., 2011). However, even if all the questions were answered truthfully, another limitation was that some questions had minimal responses. For example, the age distribution was very low for participants under 18 and over 44. This would affect the power of statistical analyses (Richter, 2019). One way to improve validity is to ensure all survey responses are >30 in each category. As mentioned above, this can be accomplished by doing a short survey with an adequate sampling time. In terms of untruthful responses, that would always be a flaw in survey designs. Monitoring participants could improve it in a supervised setting; however, time and money may be a constraint.

Knowledge Translation

The results of this research could prompt various stakeholders, such as schools, public health organizations, manufacturing companies, or agencies, to put in place a health promotion initiative regarding plastic products. The initiative should target the general population to ensure that everyone receives the exact and accurate information on minimizing exposures and handling plastics properly. Education can be incorporated as a form of risk communication, especially towards pregnant women or mothers of young children. For example, plastic products should be appropriately labeled with pictograms or a list of ingredients that indicates whether harmful phthalates are present. Messages should highlight precautions such as “do not heat” or “keep out of children’s reach.” Education must be easily accessible and understandable to ensure the success of the initiative.

Regulatory government agencies can also use the results to develop policies and legislation to minimize potential health risks with phthalates exposure. Health Canada (2017) is currently still investigating the human health effects of various phthalate-containing commercial products. Due to the potential health hazards of chronic phthalate exposures, plastic consumers need to raise their awareness. For example, awareness campaigns or Ads that depict the harmful effects of plastic chemicals could be led by Health Canada to increase public perception. Therefore, plastic manufacturers and regulatory bodies should inform consumers that plastics can contain toxic chemicals and that susceptible populations should be cautious when handling them. Lastly, government agencies can also regulate and monitor plastic phthalate levels to ensure exposure risks are minimal.

Future Research

Some examples of future research projects:

- Study of the estimated daily intake of phthalates in pregnant women and children
- Using the same research, survey the knowledge of plastic consumers regarding phthalate chemicals in everyday products.
- Analysis of the accuracy of proper labelling and packaging in products containing phthalates or other chemicals.
- Study of the effects of poor plastic handling practices on how it contributes to increased phthalate concentrations in the body.

Conclusion

The survey results reveal that while most of the participants were aware of phthalates or other chemicals present in plastics, they were only slightly knowledgeable of the substances. Additionally, participants who are aware did not seem to be more concerned with exposure risks. The study found that people are more aware and knowledgeable of phthalates with increasing age and education level in terms of demographics. Gender did not have an association in awareness, which signals concern since vulnerable populations such as pregnant women are likely to experience the most harmful health impacts. The study also provides evidence suggesting that products may have inadequate labelling or packaging as participants who frequently purchase plastics had similar awareness than those who rarely buy. This research will serve as a practical document for stakeholders to implement future health initiatives to improve cognition by education and proper labelling.

Acknowledgements

I want to thank my research supervisor, Dale Chen, for his continued support and constructive feedback throughout this study and for everyone who participated.

Competing Interest

The authors declare that they have no competing interests.

References

Ambe, K., Sakakibara, Y., Sakabe, A., Makino, H., Ochibe, T., & Tohkin, M. (2019). Comparison of the developmental/reproductive toxicity and hepatotoxicity of phthalate esters in rats using an open toxicity data source. Journal of Toxicological Sciences, 44(4), 245–255. https://doi.org/10.2131/jts.44.245

BCPP. (2020). Phthalates. https://www.bcpp.org/resource/phthalates/

Bucci, M., Casas, K., Colgate, E., Gunyan, H., & Heath, L. (2010). Bisphenol A and Phthalates: Public Knowledge and Risk Perception. 42. http://scholarworks.uvm.edu/comphp_galleryhttp://scholarworks.uvm.edu/comphp_gallery/42http://scholarworks.uvm.edu/comphp_gallery/42

Cantonwine, D. E., Cordero, J. F., Rivera-González, L. O., Anzalota Del Toro, L. V., Ferguson, K. K., Mukherjee, B., Calafat, A. M., Crespo, N., Jiménez-Vélez, B., Padilla, I. Y., Alshawabkeh, A. N., & Meeker, J. D. (2014). Urinary phthalate metabolite concentrations among pregnant women in Northern Puerto Rico: Distribution, temporal variability, and predictors. Environment International, 62, 1–11. https://doi.org/10.1016/j.envint.2013.09.014

CDC. (2009). Public Health Statement for Di(2-ethylhexyl) phthalate (DEHP) Public Health Statement for Diethyl Phthalate Public Health Statement for Di-n-octyl phthalate (DNOP) ToxFAQs for Di(2-ethylhexyl) phthalate (DEHP). https://www.cdc.gov/biomonitoring/pdf/Pthalates_FactSheet.pdf

Chen, X., Xu, S., Tan, T., Lee, S. T., Cheng, S. H., Lee, F. W. F., Xu, S. J. L., & Ho, K. C. (2014). Toxicity and estrogenic endocrine disrupting activity of phthalates and their mixtures. International Journal of Environmental Research and Public Health, 11(3), 3156–3168. https://doi.org/10.3390/ijerph110303156

Christodoulou, E., Kalokairinou, A., Koukia, E., Intas, G., Apostolara, P., Daglas, A., & Zyga, S. (2015). The Test-Retest Reliability and Pilot Testing of the “New Technology and Nursing Students’ Learning Styles” Questionnaire. International Journal of Caring Sciences, 8(3), 567–576.

Colón, I., Caro, D., Bourdony, C. J., & Rosario, O. (2000). Identification of phthalate esters in the serum of young Puerto Rican girls with premature breast development. Environmental Health Perspectives, 108(9), 895–900. https://doi.org/10.1289/ehp.00108895

Council, N. R. (2008). Phthalates and Cumulative Risk Assessment. In Phthalates and Cumulative Risk Assessment. https://doi.org/10.17226/12528

Dobronte, A. (2016, December 08). Pitfalls of "don't know/no opinion" answer options in surveys. https://www.checkmarket.com/blog/dont-know-no-opinion-answer-option/

Ema, M. (2002). Antiandrogenic effects of dibutyl phthalate and its metabolite, monobutyl phthalate, in rats. Congenital Anomalies, 42(4), 297–308. https://doi.org/10.1111/j.1741-4520.2002.tb00896.x

Fréry, N., Santonen, T., Porras, S. P., Fucic, A., Leso, V., Bousoumah, R., Duca, R. C., El Yamani, M., Kolossa-Gehring, M., Ndaw, S., Viegas, S., & Iavicoli, I. (2020). Biomonitoring of occupational exposure to phthalates: A systematic review. International Journal of Hygiene and Environmental Health, 229(July), 113548. https://doi.org/10.1016/j.ijheh.2020.113548

Hauser, R., & Calafat, A. M. (2005). Phthalates and human health. Occupational and Environmental Medicine, 62(11), 806–818. https://doi.org/10.1136/oem.2004.017590

Hartmann, S., Klaschka, U. Interested consumers' awareness of harmful chemicals in everyday products. Environ Sci Eur 29, 29 (2017). https://doi.org/10.1186/s12302-017-0127-8

Health Canada. (2017). Draft Screening Assessment Phthalate Substance Grouping Environment and Climate Change Canada Health Canada. October. http://www.ec.gc.ca/ese-ees/516A504A-0A21-4AF5-8310-ADD2FE5C0C76/DSAR Phthalates -EN.pdf

Hines, C. J., Hopf, N. B. N., Deddens, J. A., Silva, M. J., & Calafat, A. M. (2011). Estimated daily intake of phthalates in occupationally exposed groups. Journal of Exposure Science and Environmental Epidemiology, 21(2), 133–141. https://doi.org/10.1038/jes.2009.62

Hu, A., Chen, D. (2021). Assessing Public Awareness on the Potential Health Risks of Phthalate exposure in Plastic Consumer Products. BCIT, Environmental Health Journal.

Johns, L. E., Cooper, G. S., Galizia, A., & Meeker, J. D. (2015). Exposure assessment issues in epidemiology studies of phthalates. Environment International, 85, 27–39. https://doi.org/10.1016/j.envint.2015.08.005

Jones, T. L., Baxter, M., & Khanduja, V. (2013). A quick guide to survey research. Annals of the Royal College of Surgeons of England, 95(1), 5–7. https://doi.org/10. 1308/003588413X13511609956372

Kamrin, M. A. (2009). Phthalate risks, phthalate regulation, and public health: A review. Journal of Toxicology and Environmental Health - Part B: Critical Reviews, 12(2), 157–174. https://doi.org/10.1080/10937400902729226

Kim, H.-H., Yang, J.-Y., Kim, S.-D., Yang, S.-H., Lee, C.-S., Shin, D.-C., & Lim, Y.-W. (2011). Health Risks Assessment in Children for Phthalate Exposure Associated with Childcare Facilities and Indoor Playgrounds. Environmental Health and Toxicology, 26, e2011008. https://doi.org/10.5620/eht.2011.26.e2011008

McHugh, M. L. (2013). The Chi-square test of independence Lessons in biostatistics. Biochemia Medica, 23(2), 143–149. http://dx.doi.org/10.11613/BM.2013.018

McPherson, L. (2019, April 26). Survey Maker Showdown: Google Forms vs. Survey Monkey. https://zapier.com/blog/google-forms-vs-surveymonkey/

Meeker, J. D., Sathyanarayana, S., & Swan, S. H. (2009). Phthalates and other additives in plastics: human exposure and associated health outcomes. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1526), 2097–2113. https://doi.org/10.1098/rstb.2008.0268

NCSS 2021 Statistical Software (2021). NCSS, LLC. Kaysville, Utah, USA, ncss.com/software/ncss

Qian, X., Li, J., Xu, S., Wan, Y., Li, Y., Jiang, Y., Zhao, H., Zhou, Y., Liao, J., Liu, H., Sun, X., Liu, W., Peng, Y., Hu, C., Zhang, B., Lu, S., Cai, Z., & Xia, W. (2019). Prenatal exposure to phthalates and neurocognitive development in children at two years of age. Environment International, 131(July), 105023. https://doi.org/10.1016/j.envint.2019.105023

Regmi, P. R., Waithaka, E., Paudyal, A., Simkhada, P., & van Teijlingen, E. (2016). Nepal Journal of Epidemiology Guide to the design and application of online questionnaire surveys. Nepal J Epidemiol, 6(4), 640–644.

Richter, S. J. (2019). Power and sample size for research studies. https://cran.r-project.org/web/packages/PowerTOST/PowerTOST.pdf

Rolstad, S., Adler, J., & Rydén, A. (2011). Response burden and questionnaire length: Is shorter better? A review and meta-analysis. Value in Health, 14(8), 1101–1108. https://doi.org/10.1016/j.jval.2011.06.003

Sattelberg, W. (2020). The Demographics of Reddit: Who Uses the Site? https://social.techjunkie.com/demographics-reddit

Shea, K. M. (2003). Pediatric exposure and potential toxicity of phthalate plasticizers. Pediatrics, 111(6 I), 1467–1474. https://doi.org/10.1542/peds.111.6.1467

Yu, S., Alper, H. E., Nguyen, A. M., Brackbill, R. M., Turner, L., Walker, D. J., Maslow, C. B., & Zweig, K. C. (2017). The effectiveness of a monetary incentive offers on survey response rates and response completeness in a longitudinal study. BMC Medical Research Methodology, 17(1), 1–9. https://doi.org/10.1186/s12874-017-0353-1

Wang, Y., Zhu, H., & Kannan, K. (2019). A review of biomonitoring of phthalate exposures. Toxics, 7(2), 1–28. https://doi.org/10.3390/TOXICS7020021