

The Correlation Between Increased Plastic Exposure and the Hormonal Imbalance in Teenage Girls in Indonesia

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Abstract

Bisphenol A, an endocrine-disrupting chemical found in microplastics, has presented various health disorders due to its ability to mimic estrogen, a hormone extremely vital for the reproductive health of females. As a result of the increased exposure to plastic in Indonesia, teenage girls could experience hormonal imbalances that disrupt their menstrual cycle. In this study, we aim to prove the correlation between increased plastic exposure and irregularities in menstrual cycles in teenage girls in Indonesia. To do this, we conducted a survey that we sent out to girls ages 12 to 18 years old living in Indonesia and analyzed the frequency of their exposure to plastic and their menstrual cycles. From our survey, we discovered that there was a trend that presents the relationship between the independent variable (plastic exposure) and the dependent variable (menstrual cycle). Moreover, we found that the increased plastic exposure resulted from the participants' usage of plastic utensils or containers when they ate or drank. We assume that the plastic exposure increased the risk of bisphenol A entering into the girls' endocrine system and affecting their hormonal balance, causing menstrual irregularities. Therefore, although an increase in plastic exposure might not be the only explanation for hormonal imbalances, it is a possible cause. This is because a correlation can be found between the plastic exposure and the length or regularity of menstrual cycles.

Keywords: Bisphenol A, Estrogen, Endocrine-Disrupting Chemicals, Menarche, Microplastics

1. Introduction

In the past 3 years, COVID-19 has encouraged single-use plastic, causing a drastic increase in the global consumption of plastic [11]. Approximately 7 to 9.8 million tons of plastic have been used by 193 countries during the pandemic alone [11]. In fact, 14% of Indonesia's solid waste is plastic [6]. According to ten studies that were conducted over 5 regions in Indonesia (Java, East Nusa Tenggara, East Kalimantan, South Sulawesi, and North and Southwest Sumatera) regarding plastic pollution, Jakarta is most abundant in microplastics with 37,440 to 38,790 particles/kg dry weight sediment [6].

A common chemical found in microplastics is bisphenol A, also widely known as BPA [9]. According to a study on the development of embryos in vitro, humans are exposed to bisphenol A, whether it is through direct or indirect contact [10]. It is estimated that the global intake of bisphenol A is 30.76 ng/kg per body weight/day [10]. Bisphenol A is an industrial chemical that is overly used to create synthetic polymers and is frequently found in plastic bottles and epoxy resins that coat metal food cans and bottle caps [1,3]. Although bisphenol A is found in the plastic containers used to store food and drinks, it can travel to the food or drink itself when it is exposed to heat or even when it is under its normal condition [6]. Based on Scott Becher's experiment in using polycarbonate plastic bottles in cold and hot water, bisphenol A in hot water was released at a much

faster rate than it was in cold water [13]. Prior to hot water exposure, 0.2 to 0.8 nanograms of bisphenol A were released per hour; however, after hot water exposure, 8 to 32 nanograms were released per hour [13]. Our body can be exposed to bisphenol A through the digestive tract, respiratory tract, and dermal tract [8]. However, it is believed that 90% of bisphenol A enters the body through ingestion [10].

Bisphenol A, along with many other chemicals found in microplastics are known as endocrine-disrupting chemicals [1]. This particular chemical can pose a threat to the human body because it can disrupt the endocrine system by mimicking the shape of estrogen and binding to estrogen receptors [1]. In other words, bisphenol A's phenolic structure allows it to interact with estrogen receptors in the body, which potentially causes pathogenesis, the development of diseases, in the endocrine system [4, 16]. Not only that, but its similar structure to estrogen results in bisphenol A's ability to bind onto nuclear hormone receptors and interfere with hormonal signals [5, 6]. Bisphenol A has a higher binding affinity with ER α rather than with ER β ; however, it binds the strongest with ERR γ [10, 17, 18].

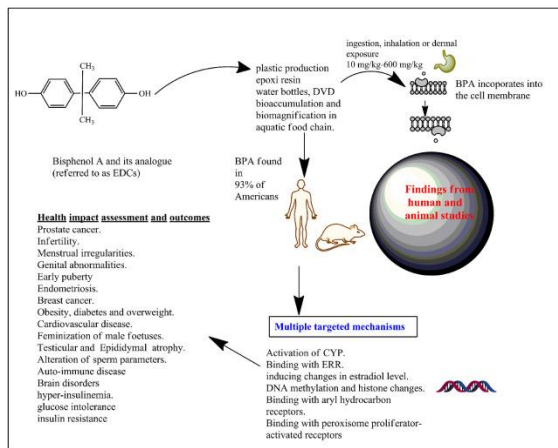


Figure 1 The Mechanism of Bisphenol A in Relation to the Endocrine System [10]

Some disorders that can arise from the disruption of the endocrine system are: infertility in both male and female, early puberty, hormone-dependent tumors, and polycystic ovary syndrome (PCOS) [4]. Based on the findings of high serum concentration of bisphenol A (1.53 to 2.22 $\mu\text{g/L}$) in females, bisphenol A causes alterations in estradiol E_2 , which has been found to result in hormonal imbalances and metabolic abnormalities that lead to early puberty, including menstrual inconsistency [10].

The endocrine system is made out of glands that are responsible for the secretion of hormones [2]. These hormones are critical for the functions that our body performs as it initiates functions through sending signals to parts of the body [2]. If the endocrine system is disrupted, homeostasis can be interrupted and can lead to disorders [2]. Since it is known that bisphenol A can mimic the hormone estrogen and disrupt the endocrine system, it is acceptable to infer that increased plastic exposure can increase the risk of developing endocrine disorders [2, 12].

Further research on the effect of bisphenol A has indicated that it can promote weight gain [1]. The most feasible explanation as to why girls obtain menarche at an earlier age compared to girls in the past is due to girls having a higher body mass than girls in the past [12]. Menarche refers to the first menstrual cycle experienced by girls [15]. A higher body fat percentage results in prematurity of the pituitary glands, which are responsible for generating hormones for puberty [12]. In addition, based on Biro's study, it was discovered that a higher body mass index (BMI) causes puberty to occur earlier in girls mainly because of the exposure to endocrine-disrupting chemicals (EDCs) [12]. In fact, girls in Indonesia have obtained menarche at a much younger age in comparison to girls in 2010, decreasing from 14.43 years to 13.63 years [14].

Therefore, the objective of this research is to determine the correlation between the increased use of plastic and hormonal imbalance in teenage girls in Indonesia; specifically, to establish whether the increased use of plastic and higher exposure to bisphenol A could potentially lead to hormonal imbalance in teenage girls.

2. Method and Experiment Details

To investigate the correlation between increased plastic exposure and hormonal imbalances in teenage girls in Indonesia, an anonymous Google Forms survey was shared via Gmail and Instagram. The audience of this survey was limited to 12 to 18 year old girls who live in Indonesia. All of our survey questions were required to be answered by the participants. Prior to asking the participants questions that were directly related to their menstrual cycles and exposure to plastic, we collected their personal information. For their personal information, we asked the participants to state the full name of the school they currently attend, whether they are homeschooled, their race, the city they currently live in, and their current grade level. This was done so that: first, we would know the diversity of the participants partaking in the survey and enable us to compare the different experiences of menstrual cycles each teenage girl goes through, and second, the results of the survey would come from our desired audience, who are teenage girls in Indonesia.

The questions asked in the survey were related to the participants' menarche, the length of their menstrual cycle, how regular they would receive their menstrual cycle, and their exposure to plastic through the products they purchased. Specifically, the questions regarding the details of the occurrences of menstruation and plastic exposure were designed to yield a result that can show the correlation between how the amount of exposure to plastic takes part in affecting hormonal imbalances in the participants [15].

Our study focused on gathering data through an online survey because we wanted to find data that could show the correlation between plastic exposure and hormonal imbalance among a larger number of people throughout different areas in Indonesia. Online surveys also help gather responses at a much faster rate than conducting an experiment on a single person or a small group of teenage girls, which would yield a sample that is too small for us to generalize for the whole population of teenage girls living in Indonesia. Since every individual may be exposed to different environmental conditions, they may experience various factors that affect their hormonal stability. Thus, if we were to collect data from a small

number of people living in the same area, the result would not provide us with an accurate and precise answer as to how plastic exposure and hormonal imbalance correlate to one another.

We analyzed our data by looking at both the plastic exposure through how frequent their recent purchases contained plastic packaging and how frequently they use plastic utensils and/or containers to consume their food and drinks. From doing so, we can take into account the irregularities of their menstrual cycle in alignment with their plastic exposure; we can test our hypothesis to determine whether there exists a correlation between plastic usage and hormonal imbalance.

3. Result and Discussion

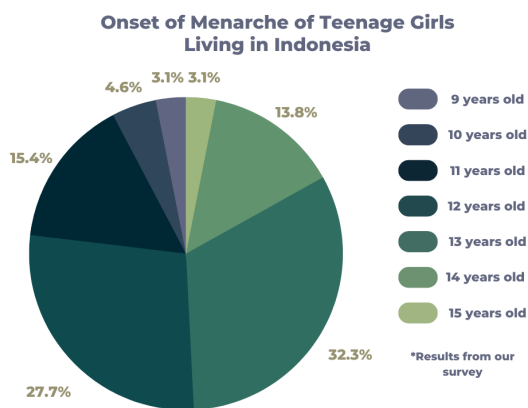


Figure 2 Onset of Menarche from Survey Results

Exposure to Plastic	Regularity of Menstrual Cycle	Number of Participants
N/A	Less than 2 weeks	1
	Every 1 month	12
	More than 1 month	2
Once a week	Every 2 weeks	1
	Every 1 month	9
	More than 1 month	6
2-3 times a week	Less than 2 weeks	1
	Every 2 weeks	1
	Every 3 weeks	3

	Every 1 month	10
	More than 2 month	2
Once everyday	Every 2 weeks	1
	Every 3 weeks	2
	Every 1 month	7
	More than 1 month	2
Several times a day	Every 3 weeks	2
	Every 1 month	2
	More than 1 month	1

Table 1 Correlation Between Plastic Exposure and Menstrual Cycle Regularity

Exposure to Plastic	Average Length of Menstrual Cycle	Number of Participants
N/A	3-5 days	6
	5-7 days	8
	More than a week	1
Once a week	3-5 days	3
	5-7 days	9
	More than a week	4
2-3 times a week	3-5 days	4
	5-7 days	12
	More than a week	1
Once everyday	3-5 days	3
	5-7 days	7
	More than a week	2
Several times a day	3-5 days	2
	5-7 days	1

	More than a week	2
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Table 2 Correlation Between Plastic Exposure and Menstrual Cycle Length

The data that we obtained from the survey is from girls who are 12 to 18 years old. The participants are from various places in Indonesia, such as Solo, Semarang, Jakarta, Salatiga, Bandar Lampung, Bandung, Pekanbaru, Ungaran, and Jayapura. In other words, the girls who participated came from 19 different schools in Indonesia. Those schools include ACS Jakarta, Al Azhar Pekanbaru, Bandung Independent School, Bina Bangsa School Semarang, Hillcrest International School, IPEKA Integrated Christian School, Jakarta Taipei School, Krista Mitra Semarang, Lazuardi Haura, Maria Regina School, Mountainview Christian School, Sekolah Pelita Bangsa Lampung, Semarang Multinational school, Singapore Intercultural School Kelapa Gading, Singapore Intercultural School Semarang, SMA Kolese Loyola, SMAN 2 Bandar Lampung, SMAN 9 Bandar Lampung, and Tunas Muda. Overall, our survey received 65 responses, which we have summarized in the figure and tables above.

Most of the respondents experienced their menarche when they were 12 or 13 years old. Meanwhile, there were 2 girls who had their menarche at the age of 9 and 2 girls who had it at the age of 15. Our survey reported that the average age of the respondents who experienced menarche was 12.5 years old. This number is lower than the one reported in the *International Journal of Adolescent Medicine and Health*, which was 13.63 years old [14]. Moreover, the data from **Table 1** and **Table 2** demonstrate that those who were exposed to more plastic tend to have more abnormal menstrual cycles and menstrual lengths. For example, 2 girls who were exposed to plastic several times a day had menstrual cycles that lasted for more than a week.

Our survey reported that our participants have almost daily exposure to plastic, especially when they are consuming food or drinks. We discovered that 41.5% bought food or drinks 2 to 3 times a week, 20% bought food or drinks once a week, 18.5% bought food or drinks once everyday, 12.3% bought food or drinks several times a day, and 7.7% provided us with no answer, meaning that they did not get exposed to plastic as frequently as the other participants.

Based on the respondents' last 10 purchases, 35.4% reported that 4 to 6 of their items used plastic or paper packaging, 33.8% had 7 to 10 items that used plastic or paper packaging, 26.2% had 1 to 3 items

that used plastic or paper packaging, and 4.6% claimed that their recent purchases included no plastic or paper packaging. In total, 95.4% of our participants were exposed to plastic or paper packaging. Furthermore, when the respondents eat or drink, 55.4% said that they sometimes use plastic utensils or containers, 26.6% said they regularly use plastic utensils or containers, and 18.5% said they do not use plastic utensils or containers. Our survey also collected that 26.2% of the respondents used plastic utensils or containers at least 2 to 3 times a week, 24.6% used plastic utensils or containers at least once a week, 23.1% could not give an account of how much plastic utensils or containers they use, 18.5% used plastic utensils or containers everyday, and 7.7% used plastic utensils or containers several times a day. These results show that our sample population who were exposed to plastic would most likely be affected by the side effects of bisphenol A, one being hormonal imbalance.

Based on our findings, those who have more exposure to plastic tend to have more irregularities in their menstrual cycle. There is a correlation between the girls' menstrual cycle length and cycle based on their exposure to plastic. We, therefore, can assume that the respondents' exposure to plastic resulted in increased exposure to bisphenol A and could have been one of the contributing factors that may have influenced a girl's menstrual cycle. Again, bisphenol A is an endocrine-disrupting chemical and can cause hormonal imbalances by binding to estrogen receptors, which could affect a woman's menstrual cycle, specifically its length and regularity.

4. Conclusion

Increased exposure to bisphenol A through the use of products containing plastic, which may have entered our body through ingestion, is one out of many factors that contribute to the irregularities of menstrual cycles in teenage girls. Menstruation irregularities can occur in numerous ways. Some may experience their menstrual cycle in a shorter period of time, while others may experience their menstrual cycle in a longer period of time; some may have a shorter monthly cycle, while others may experience a longer monthly cycle. In many cases, the more frequent one is exposed to bisphenol A, the more irregular their menstrual cycle becomes. This proves that exposure to bisphenol A can cause a disruption in the endocrine system, leading to hormonal imbalances in the body. Furthermore, these hormonal imbalances affect menstrual cycles in teenage girls because an important part of menstruation is the involvement of hormones. The presence of either too much or too little hormones leads to a disturbance in a girl's monthly cycle. However, the exposure to bisphenol A is not the

only contributor to the hormonal imbalances faced by teenage girls in Indonesia.

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6. References

- [1] Almeida, S., Raposo, A., Almeida-González, M., & Carrascosa, C. (2018). *Bisphenol A: Food Exposure and Impact on Human Health*. Institute of Food Technologists. <https://ift.onlinelibrary.wiley.com/doi/10.1111/1541-4337.12388#:~:text=BPA%20is%20considered%20an%20endocrine,%2C%20and%20obesity%2C%20among%20others>
- [2] Cleveland Clinic. (2020). *Endocrine System*. Cleveland Clinic. <https://my.clevelandclinic.org/health/articles/21201-endocrine-system>
- [3] Fadillah, G., Triana, S., Chasanah, U., & Saleh, A. T. (2020). *Titania-nanorods modified carbon paste electrode for the sensitive voltammetric determination of BPA in exposed bottled water*. ScienceDirect. <https://www.sciencedirect.com/science/article/pii/S2214180420302166#bb0015>
- [4] Konieczna, A., Rutkowska, A., & Rachoń, D. (2015). *Health risk of exposure to Bisphenol A (BPA)*. *Roczniki Panstwowego Zakladu Higieny*, 66 (1), 5–11. <https://pubmed.ncbi.nlm.nih.gov/25813067/>
- [5] Laurretta, R., Sansone, A., Sansone, M., Romanelli, F., & Appetecchia, M. (2019). *Endocrine Disrupting Chemicals: Effects on Endocrine Glands*. *Frontiers in Endocrinology*, 10. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6448049/>
- [6] Lestari, P., & Trihadiningrum Y. (2019). *The impact of improper solid waste management to plastic pollution in Indonesian coast and marine environment*. ScienceDirect. <https://www.sciencedirect.com/science/article/abs/pii/S0025326X19306435>
- [7] Li, L., Wang, Q., Zhang, Y., Niu, Y., Yao, X., & Liu, H. (2015). *The Molecular Mechanism of Bisphenol A (BPA) as an Endocrine Disruptor by Interacting with Nuclear Receptors: Insights from Molecular Dynamics (MD) Simulations*. *PLOS ONE*. <https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0120330#:~:text=BPA%20has%20a%20symmetrical%20chemical,polycarbonate%20plastics%20and%20epoxy%20resins>
- [8] Ma, Y., Liu, H., Wu, J., Yuan L., Wang, Y., Du, X., Wang, R., Marwa, W. P., Petlulu, P., Chen, X., & Zhang, H. (2019). *The adverse health effects of bisphenol A and related toxicity mechanisms*.

ScienceDirect.

<https://www.sciencedirect.com/science/article/abs/pii/S001393511930372X>

- [9] National Institute of Environmental Health Sciences. (2021). *Bisphenol A (BPA)*. National Institute of Environmental Health Sciences. <https://www.niehs.nih.gov/health/topics/agents/syabpa/index.cfm>
- [10] Ohore, E. O., & Zhang, S. (2019). *Endocrine disrupting effects of bisphenol A exposure and recent advances on its removal by water treatment systems. A review*. ScienceDirect. <https://www.sciencedirect.com/science/article/pii/S2468227619306969>
- [11] Peng, Y., Wu, P., Schartup, T. A., & Zhang, Y. (2021). *Plastic waste release caused by COVID-19 and its fate in the global ocean*. *PNAS*. <https://www.pnas.org/doi/10.1073/pnas.2111530118>
- [12] Sole-Smith, V. (2019). *Why Are Girls Getting Their Periods So Young?* Scientific American. <https://www.scientificamerican.com/article/why-are-girls-getting-their-periods-so-young/>
- [13] University of Cincinnati. (2008). *Plastic Bottles Release Potentially Harmful Chemicals (Bisphenol A) After Contact With Hot Liquids*. ScienceDaily. <https://www.sciencedaily.com/releases/2008/01/080130092108.htm>
- [14] Wahab, A., Wilopo, A. S., Hakimi, M., & Ismail, D. (2018). *Declining age at menarche in Indonesia: a systematic review and meta-analysis*. De Gruyter. <https://www.degruyter.com/document/doi/10.1515/ijamh-2018-0021/html?lang=e>
- [15] Leonardi, A., Cofini, M., Rigante, D., Lucchetti, L., Cipolla, C., Penta, L., & Esposito, S. (2017). *The Effect of Bisphenol A on Puberty: A Critical Review of the Medical Literature*. MDPI. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5615581/>
- [16] Merriam-Webster. (n.d.). *Pathogenesis*. Merriam-Webster.com dictionary. <https://www.merriam-webster.com/dictionary/pathogenesis>
- [17] Iwamoto, M., Masuya, T., Hosose, M., Tagawa, K., Ishibashi, T., Suyama, K., Nose, T., Yoshihara, E., Downes, M., Evans, R. M., & Matsushima, A. (2021). *Bisphenol A derivatives act as novel coactivator-binding inhibitors for estrogen receptor β* . *The Journal of biological chemistry*, 297(5), 101173. <https://doi.org/10.1016/j.jbc.2021.101173>
- [18] Okada, H., Tokunaga, T., Liu, X., Takayanagi, S., Matsushima, A., & Shimohigashi, Y. (2008). *Direct evidence revealing structural elements essential for the high binding ability of bisphenol A to human estrogen-related receptor-gamma*. *Environmental health perspectives*, 116(1), 32–38. <https://doi.org/10.1289/ehp.10587>