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Quantitative Risk Assessment (QRA) Prenatal Mercury Exposure of Whitening Cosmetic and Infant Neurodevelopmental Risk

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ABSTRACT

Introduction: Mercury compounds are divided into elemental mercury, inorganic mercury, and organic mercury. Exposure to mercury through both direct and indirect pathways can have serious impacts on environmental and health issues, especially sensitive populations such as pregnant women, infants, and children. According to the Global Nielsen institution, 45% of women in Indonesia use whitening cosmetics. It should be noted that the content of whitening cosmetics contains mercury and its derivatives. Pregnant women are exposed to mercury through the use of cosmetics and the consumption of seafood. The impact caused if accumulated in the placenta will cause neonatal neurodevelopmental risk. This study aimed to analysed the quantitative risk assessment of prenatal mercury exposure and neurodevelopmental risk.
Methods: The study design is an observational analytic with a cross-sectional study. Statistical analysis of Hg concentration in scalp hair samples was performed using SPSS software. The correlation between Hg concentration in scalp hair and skin whitening cosmetics was determined by chi-square correlation analysis, with $p < 0.05$ considered significant. The quantitative risk assessment (QRA) method analyses hazard identification, assessment exposure, hazard characterization, and risk characterization. The sample used was 20 pregnant women and 20 babies. The mercury concentration in the scalp hair of pregnant women and their babies will be examined in the BBLK Laboratory.
Results: The results of this study indicate that hazard identifications were mercury concentrations in the scalp hair of pregnant women is average of 7.04 (range 0.18-41.70 ppm, the mercury concentration in scalp hair is average of 0.71 (range 0.24-1.68), mercury whitening cosmetic is average 17.34 (range 3.5-86.0 ppm). Hazard characteristics are divided according to HBM 3 categories: normal at 60%, alert at 15%, and high at 25% for mercury concentration in pregnant women. In comparison, the baby concentration is divided into two categories: normal 70% and alert 30%. Risk characteristics found that around nine people, or 45% of babies, experienced the risk of neurodevelopmental symptoms, and mothers exposed to mercury had an impact on their babies.
Conclusion: This study highlights the occurrence of Hg in skin-whitening cosmetics and the accumulation of Hg in the human body through their application. There is a correlation between mercury in pregnant women's scalp hair and the mercury concentration in their babies. Babies exposed to mercury with alert concentration levels have a neurodevelopmental risk. Therefore, it is better not to use whitening cosmetics during prenatal periods because mercury exposure can affect the baby.

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INTRODUCTION

Mercury (Hg) is a dangerous heavy metal because it is toxic, even in low-level concentrations. Three forms of mercury are found in the environment: elemental mercury, inorganic mercury, and organic mercury or methylmercury (1).Mercury exposure enters the body through food, cosmetic products, vaccine products, and problematic environments. Mercury will change into Methylmercury (MeHg) by environmental microorganisms, which bioaccumulates in marine organisms and is biomagnified through the food chain (2,3). Methylmercury toxicity in pregnant women accumulates in transplacental absorption, which damages the enzyme system it affects the development of the central nervous system in the fetus so that it is at risk of neurodevelopmental (4–6).

Based on the EPA (Environmental Protection Agency), mercury can cause disorders in the fetus, namely infant neurodevelopmental risks, such as impaired fetal brain development, central nervous system disorders, and impaired cognitive function. In addition, speech disorders, motor disorders, visual impairment, reduced head size, cerebral palsy, and mental retardation may also occur in the fetus (7).

Most cosmetic users are women; women of reproductive age are particularly concerned about mercury exposure because mercury is a teratogenic agent that can cross the placental wall (8–10). However, most women in their twenties use cosmetics in their daily routine and have little knowledge about cosmetic ingredients or mercury toxicity (11–13). Therefore, hazardous skin-whitening products are widely used with limited awareness of their potential health effects.

Mercury exposure in pregnant women is not only through consuming fish but also mercury-containing cosmetics (10,12–17). Pregnant women who use whitening cosmetics because of changing hormones during pregnancy cause the body to darken and cause anxiety for pregnant women, so to overcome this, pregnant women use cosmetics to keep their bodies and faces beautiful during pregnancy. Mercury in cosmetics reasonably blocks melanin, preventing the skin from causing black flakes(18,19). Long-term and repeated exposure to Hg can cause disorders of the brain, nervous system, and kidneys, disrupt immune function and microtubule formation, change the integrity of cell membranes, disrupt or inhibit enzyme systems, shift the intracellular calcium balance and membrane potential, and inhibit protein and DNA synthesis (20).

One of the biomarkers for assessing mercury exposure is hair. Hair has been recognized as a potential storage place for all elements entering the body for the past 50 years. Hair mineral analysis indicates the mineral composition of hair accumulated over a long period, corresponding to the body's levels of elements. Hair records filaments that can reflect metabolic changes of many elements over a long period. The advantage of hair tissue analysis over other diagnostic samples is that its concentration is not affected by rapid fluctuations due to diet, air, and water, so there is long-term stability in nutritional status (21–23).

Considerable epidemiologic research studies have examined the potential adverse health effects of prenatal low-level Hg exposure. In the U.S., typical Hg levels at delivery in the hair and maternal or cord blood were found to be deficits in infant development(10,24,25). Given the potential implication of these results for public health, it is imperative to examine further the possible association between prenatal low-level Hg exposure and fetal growth. Over the past several decades, concerted public health interventions to reduce Hg emissions and pollution in South Sulawesi have been implemented, such as an official ban and restriction on Hg mining activities and improved management for the production of cosmetics and disposal of mercury(26)(27). According to research by abbas et al., 70% of pregnant women use whitening cream cosmetics. The results of the study found that pregnant women are potentially at risk of anemia at 55%, the fetus is not actively moving at 15%, and the weight of the fetus does not increase by 30%. Based on these facts, this study aims to quantify the risk assessment of prenatal mercury exposure by whitening cosmetic use and the potential risk of infant neurodevelopmental risk.

METHOD

The study design is an observational analytic with a cross-sectional study. Statistical analysis of Hg concentration in scalp hair samples was performed using SPSS software. The correlation between Hg concentration in scalp hair and skin whitening cosmetics was determined by chi-square correlation analysis, with $p < 0.05$ considered significant. The quantitative risk assessment (QRA) method analyses hazard identification, assessment exposure, hazard characterization, and risk characterization. The cross-sectional cohort study, randomized controlled trial, or another design. Provide a rationale for choosing the specific design and how it aligns with the research objectives. Clearly describe the characteristics of the study population, including inclusion and exclusion criteria.

Mention any sampling methods employed and justify why these methods were chosen. Include relevant demographic information and any special considerations related to the population.

Sample collection was conducted in August 2024 in the Hospital of RSIA Sitti Khadijah 1 Makassar. The biomarker sample is scalp hair. The number of samples for the pregnant women is 20, and for the baby, there are 20 samples. To examine the concentration of mercury exposure in pregnant women and their babies. All participant's hair samples were taken to analysed mercury concentrations. The scalp hair was cut close to the skin from the occipital region on the right back side of the head around 50-100 mg. They were then labelled and sealed in a plastic sample bag before being sent to the laboratory for analysis.

Analyzing scalp hair samples using an atomic absorption spectrophotometer (AAS) in Balai Besar Laboratorium Indonesia (BBLK) Makassar, Indonesia. Scalp Hair samples were washed with Milli-Q water. The scalp hair sample was cut into pieces and then put into a 100 mL Erlenmeyer flask, and 10 mL of HNO3 and HClO4 were with a ratio of (1:1). Then the Erlenmeyer was heated on a hotplate until the solution became clear and white smoke came out. The scalp hair solution that had been dissolved and sputtered was then filtered. The filtered solution was added with distilled water in a 50 ml measuring flask. The blank was made by doing the same treatment without the hair sample. After making the blank, a sample was taken, put into a tube, and analysed using an analyzer. The Hg parent standard solution was created using a 1000 ppm Hg (NO3) 2 solution. The 1000 ppm Hg parent solution was diluted gradually from ppm units. Then, it shakes until it is homogeneous. The standard solutions were measured individually and recorded and read for each absorbance. Whitening cosmetic products used by pregnant women were taken as samples. Small amounts of cosmetic cream were placed in a compact powder case and delivered to the laboratory for analysis—presentation of research results in the form of tables and narratives.

Ethical Approval

This study was approved by the Health Research Ethics Committee of Sekolah Tinggi Maluku Husada (Approval Number: RK.175/KEPK/STIK/VIII/2024). All participants, including parents or guardians of participants under 18, provided informed consent before participating in the study. The confidentiality of all participants was strictly maintained throughout the research process.

RESULTS

This study was conducted at RSIA Khadijah 1. The samples taken in the study were pregnant women in their third trimester who used facial whitening cosmetics and their babies. The biomarkers taken were scalp hair. The samples were taken: 20 for pregnant women and 20 for babies. To analysed the concentration of mercury in scalp hair using the Atomic Absorption Spectrophotometer (AAS) test. The results of the analysis are presented in tables and narratives. The analysis of the research variables was univariate and bivariate.

Identification Hazard

The demographic characteristics of the pregnant women who used whitening cosmetics are shown in Table 1. The Pregnant women's cosmetics usage (frequency, duration, and cosmetics application) is presented in Table 1. Most pregnant women (60%) applied cosmetics to their faces more than two times per day. The duration of more than 12 months of cosmetics use by pregnant women is 55%. Therefore, applying cosmetics to pregnant women was based on the weight of the cosmetic cream per container used. Cosmetics application was classified into two groups, namely low (≤ 10 g/month) and high (> 10g/month), with an even distribution of pregnant women across the groups. Most pregnant women (58.3%) applied more variation cosmetic use.

Table 1. Demographic characteristics of the Pregnant women

No.	Demographic Variable	Frequency =20	%
1.	Age (year)		
	< 35	15	75
	≥ 35	5	25
2.	Frequency of use		
	≤ 2 times per day	8	40
	> 2 times per day	12	60

No.	Demographic Variable	Frequency =20	%
3.	Duration of use (month)		
	≤ 12	9	45
	> 12	11	55
4.	The volume of use (gram)		
	≤ 10	10	50
	> 10	10	50
5.	Variation of cosmetic use		
	Not Variation	7	58.3
	Variation	5	41.7

Assessment of Mercury Exposure in Scalp Hair of Pregnant Women

Table 2 shows mercury concentrations in the scalp hair of cosmetics-using pregnant women were in the range of 0.18–41.70 ppm (mean 7.04 ppm), whereas the mean concentration in the babies whose mothers use cosmetics was 0.71 ppm, the range of 0.24-1.68 ppm. The mercury concentration in the cosmetics was in the range of 3.5-86.0 ppm.

The Human Biomonitoring Commission (HBMC) of the German Federal Environmental Agency (28) has released threshold limits for Hg (Table 3). By the HBMC classification, our results indicate that 25% of cosmetics-using pregnant women had 'high' levels of Hg in scalp hair, with 15% at the 'alert' level. Still, mercury concentration was almost expected to be 60%.

Table 2. Mercury Concentration in Scalp Hair

Scalp Hair	Mercury Concentration (ppm)		
	Mean	Standard deviation	Range (min-max)
Pregnant women	7.04	12.54	0.18-41.70
Baby	0.71	0.57	0.24-1.68
Cosmetic	17.34	18.65	3.5-86.0

Table 3. Threshold limit by the Human Biomonitoring (HBM) Commission of the German Federal Environment Agency.

1HBM	Pregnant women	Baby
Normal (< 1 ppm)	13 (60.0%)	14 (70.0%)
Aler (1-5 ppm)	2 (15.0%)	6 (30%)
High (> 5 ppm)	5 (25.0%)	-
Total	**20**	**100**

Hazard Characteristics

Table 4. Correlation Demographic Variabel Between Mercury Concentration in Scalp Hair

No.	Demographic Variable	Hg Concentration in scalp hair			P-value < 0.05
		Normal (< 1 ppm)	Alert (1-5 ppm)	Hight (> 5 ppm)	
1.	Age of Pregnant women (year)				0.277
	< 35	9	1	5	
	≥ 35	4	1	0	
2.	Frequency of use				0.028
	≤ 2 times per day	8	0	0	
	> 2 times per day	5	2	5	
3.	Duration of use (month)				0.005
	≤ 12	10	0	0	
	> 12	3	2	5	
4.	The volume of use (gram)				

	≤ 10	8	0	0	0.028
	> 10	5	2	5	
5.	Variation of cosmetic use				
	Not Variation	13	2	0	0.000
	Variation	0	0	5	

Table 4 shows pregnant women exposed to mercury in cosmetics; the significant correlations between frequency use, duration use, volume use, and the variation of cosmetic use were p values 0.028, 0.005, 0.,28, and 0.000, respectively < 0.05. The more often whitening cosmetics are used, the higher the mercury exposure in the body; the longer whitening cosmetics are used, the more mercury accumulates. As for the volume of use, the more use it, the faster it is absorbed in your body, so that mercury exposure is increasingly toxic.

Risk characterization

Table 5 shows a significant correlation between pregnant women exposed to mercury in cosmetics and mercury concentration in baby scalp hair. According to the Human Biomonitoring Commission (HBMC), pregnant women exposed to mercury are almost category normal, and their children are. Even though pregnant women are exposed to mercury in the alert and high category, their children are in the alert category.

Table 5. Correlation of Mercury Concentration in Scalp Hair of Pregnant Women Between Baby Scalp Hair

Scalp Hair of Pregnant Women	**HBM Scalp Hair Baby**				**Total**		**P value < 0.05**
	Normal (< 1 ppm)		**Alert (1-5 ppm)**				
	n	%	n	%	n	%	
Normal (< 1 ppm)	11	78.6	2	33.3	13	65	0.04
alert (1-5 pm)	0	0	2	33.3	2	10	
High (>5 ppm)	3	21.4	2	33.4	5	25	
Total	14	100	6	100	20	100	

Babies exposed to mercury are at risk of neurodevelopmental disorder at 45%, with a normal category on scalp hair of 33.3% and an alert category of 66.7%. at the same time, the normal category of Mercury concentration does not show neurodevelopmental symptoms.

Table 6. The Correlation of Mercury Concentration in Baby Scalp Hair Between Neurodevelopmental Risk

Mercury Concentration in Baby Scalp Hair	**Neurodevelopmental**				**Total**		**P value < 0.05**	**OR Lower-Upper limit**
	No Risk		**Risk**					
	n	%	n	%	n	%		
Normal (< 1 ppm)	11	100	3	33.3	14	70	0.002	1.191-7.558
Sedang (1-5 ppm)	0	0	6	66.7	6	30		
Total	11	100	9	100	20	100		

DISCUSSION

According to BPOM RI, the rules for mercury content in food and cosmetic products are regulated in No. 23 of 2019, namely mixing mercury and derivatives with oxidizing materials of less than 1-1.5% (29).

Prenatal Mercury low-dose exposure adversely affects neurodevelopment. Although it is still unclear, contemporary science and public health scientists are paying close attention to this problem. Many global countries have supported and encouraged the in-depth study of the health impact of low-level prenatal mercury exposure through maternal fish consumption.

In animal experiments, prenatal methylmercury exposure's most frequently evident effects are related to learning and memory deficits. Behavioral and spatial learning deficits have been observed in animal models of methylmercury exposure in utero and through lactation. Based on a study by Collucia et al. The postnatal brain growth spurt in mice exposed to methylmercury caused induced subtle and persistent motor and learning deficits (30). A Danish longitudinal survey distributed in the Faroe Islands showed a correlation between prenatal exposure to methylmercury through maternal seafood consumption and adverse neuropsychological outcomes such as language, attention, and memory deficits in school-aged children (31).

Mercury poisoning requires seriousness, especially for pregnant women, because it will affect the fetus they are carrying. Therefore, a health promotion program is needed with sensitive target groups such as children and pregnant women first and then for all.

Regulatory bodies must be identified and responsible for effectively monitoring imports, production, sales, distribution, promotion, processes, and markets. Standards must be set to limit mercury content in cosmetics. Laws and Regulations must be implemented along with effective compliance monitoring mechanisms.

Harmonize laws, standards, and chemicals in products worldwide, continents, and regions, even within the country. Product packaging must have clear labels about heavy metals such as lead, mercury, etc. so that the general public can make the right choice to choose safe products.

Manufacturers must provide warnings about the level of toxicity of the ingredients used in their cosmetic products. Consumers must look at the label and ask whether the products they are going to use are really safe for them or not. It is necessary to form an independent monitoring agency tasked with conducting testing and monitoring the content of heavy metals and other toxic materials in cosmetic products and conducting periodic socialization of monitoring results.

Correlation between Mercury exposure in the scalp hair of pregnant women to the scalp hair of their babies

BPOM RI found 112 billion illegal cosmetics and/or containing prohibited substances or hazardous substances in 2018. The cosmetic findings were dominated by mercury, hydroquinone, and retinoic acid products. BPOM also found six types of cosmetics that had been notified as containing prohibited or hazardous substances: prohibited dyes (Red K3) and heavy metals (lead). In general, these materials can cause cancer (carcinogenic), fetal abnormalities (teratogenic), and skin irritation (32).

The study results in pregnant women and babies born at RSIA Khadijah 1 Makassar found that the concentration of Hg in pregnant women was 25% in the high category, 15% in the alert category, and 60% in the normal category. It can be concluded that around 40% of pregnant women are exposed to Hg through the whitening cosmetics used. After it was known that the mother was exposed to Hg, the Hg concentration in the baby's hair biomarker was also analysed. The laboratory analysis found that 30% of babies exposed to Hg were in the alert category, while 70% were in the normal category, with the baby's age taken from 3 days to 28 days.

The statistical test results found an effect of exposure of pregnant women to Hg or mercury on the baby in their womb, where the p-value was 0.04 <p value 0.05. This study's results align with the research of Putri et al. and Besse Rafiqah et al. Fitriani et al. stated that mothers who use whitening cosmetics would absorb through the skin, enter the skin tissue system, and then accumulate in the blood, which continues to the brain system, so the use of cosmetics for years will impact the fetus.

According to the research of Maharani et al., students who use whitening cosmetics are exposed to mercury because the results of the hair biomarker test found a moderate/alert category of 15% and a high category of 85%. The results of this study have an impact on health, namely skin health on the face, such as acne, pimples, black spots, itching, and reddish appearance.

According to research by Nurfadillah et al., students who use whitening cosmetics are exposed to mercury, with the average mercury content in the hair of UMI nursing interns who use whitening cream cosmetics is 0.33ppm. One of the health effects that arises is often experiencing menstrual irregularities (33).

Babies born with high mercury concentrations will affect the development and growth of several baby organs that are still developing in the early stages of life, damage the baby's nervous system and brain development so that it can affect their intelligence, cause babies to be late to talk, inhibit the growth of fine motor skills in babies, affect the immune system so that the older they are, the more susceptible they are to heavy metals in the surrounding environment if the immune system is lacking (8,10,34).

According to research by Ayu Lestari et al., pregnant women who are exposed to mercury will have an impact on neurodevelopmental symptoms, namely the occurrence of Autism spectrum Disorder(35). The results of the study found that the average Hg concentrations in the hair of ASD children were significantly higher than non-ASD children (p-value = 0.004). The toxicity caused by mercury can impact health, be it elemental, inorganic, or organic mercury. There are ways to enter the human body through absorption, inhalation, and ingestion. Therefore, understanding the mercury content in cosmetics, fish, and other foods must be improved so women can avoid mercury exposure.

Correlation Between the Frequency Use Cosmetics to Mercury Exposure in Scalp Hair pregnant women and their babies

The use of whitening cosmetics that are too frequently causes the absorption of mercury in the body of pregnant women, which can affect the intake of the fetus obtained through the placenta. The baby will be further exposed by consuming contaminated breast milk. Mercury can also be found in breast milk; this means that breastfeeding women and their bodies are exposed to mercury will be very likely to be exposed to mercury in breastfed babies. The risk of mercury exposure to foetuses, infants, and children is hazardous to cause neurodevelopmental disorders.

Mercury exposure due to the use of whitening cosmetics by each pregnant woman is different. This is influenced by the frequency pattern of using whitening cosmetics. Some pregnant women use whitening cosmetics routinely and frequently, while some only use them a few times a day, with different durations for each individual.

Mercury in whitening cosmetics can cause poisoning and hurt health if used for an extended period. The more often an individual uses whitening cosmetics in a day/week, the more mercury concentration in the body will be affected.

The results of this study indicate that there is an impact of the frequency of use of whitening cosmetics with the concentration of mercury in the scalp hair of pregnant women, where the p-value is 0.028 $<$ p value 0.05, namely the higher the frequency of use, the higher the concentration of Hg in the body. The research results on the concentration of mercury (Hg) in baby hair show that the frequency of use of cosmetics by pregnant women affects the concentration of Hg in baby hair where the p-value is 0.042 $<$ p value 0.05. This concludes that the higher the frequency of use of cosmetics during pregnancy, the higher the concentration of Hg in the baby's body. This study is in line with Putri Handayani et al., Besse Rafiqah et al., Anugrah Maharani et al., Fitriani et al., and Nurfaddillah et al., who said that there is a relationship between the frequency of use of cosmetics and high levels of mercury concentration in the body(33,36–39). The toxic nature of mercury is to accumulate so that continuous use so that mercury will accumulate in the body in the long term can impact health.

Correlation Between the Duration of Cosmetics to Mercury Exposure in Scalp Hair pregnant women and their babies

Whitening cosmetics containing mercury that are used for an extended period can cause mercury to accumulate in the body so that absorption and the levels will also be higher. Anything that enters the mother's body during pregnancy will be absorbed into the mother's bloodstream through the small intestine, and this molecule will flow to the placenta and then be absorbed by the fetus, resulting in a higher risk of mercury exposure to the fetus.

The mercury (Hg) concentration in scalp hair is an early indicator of Hg exposure in the body. Mercury exposure that continues for an extended period will decrease kidney function. Years of use of Whitening cosmetics containing mercury will affect the concentration of mercury in the body, so the use of whitening cosmetics should be avoided during pregnancy because it can cause disorders in the fetus and pregnancy.

Direct contact between the skin and whitening cosmetics will result in absorption through the skin surface. Cosmetics containing mercury will cause mercury content to enter through the skin. Mercury penetrates the skin layer and enters the bloodstream; if this continues for an extended period, it will settle in the skin. Use for months or years will cause blackish-blue skin, trigger skin cancer, and be dangerous to health.

The results of this study indicate that there is an effect of the duration of use of whitening cosmetics with Hg concentration levels on pregnant women's hair biomarkers, where the p-value is 0.005 $<$p value 0.05, namely the higher the frequency of use, the higher the mercury concentration levels in the body. Meanwhile, research results on mercury (Hg) concentration levels in baby hair biomarkers show that the duration of use of pregnant women's cosmetics affects the Hg concentration levels in baby hair where the p-value is 0.011 $<$p value 0.05. This concludes that the higher the duration of use of cosmetics during pregnancy, the higher the Hg concentration levels in the baby's body.

Research conducted by Hasriwiani et al. concluded that there is a significant relationship between the duration of use of whitening cream and the concentration of mercury in the scalp hair of students who use cosmetics (21,40). Research conducted by Fanni Marzela with the title of Research on the correlation between mercury levels of whitening cream and mercury levels in the urine of users of facial whitening cream at FKM UNAIR states that there is a positive correlation between mercury levels in urine and the duration of use of whitening cream(41).

This research aligns with a study that found a woman had high urine mercury levels after a health check. The woman was a 39-year-old woman. Her mercury levels reached 482 µg/g creatinine. The woman used whitening cosmetics for three years to fade the dark spots on her face. Based on the results of the examination of whitening cosmetics used by the group of women, the levels of cosmetic mercury were 20,000 ppm to 57,000 ppm(41).

Correlation Between the Volume of Cosmetics to Mercury Exposure in Scalp Hair pregnant women and their babies

The high mercury absorption in pregnant women into the body causes mercury accumulation, affecting the foetus's absorption through the placental barrier. Continuous use of whitening cosmetics containing mercury, in the long term, with the increasing weight/volume used, will cause mercury to accumulate more quickly in the bloodstream, thus posing a risk to the development of the fetus carried by the pregnant woman. The fetus in the womb of a pregnant woman is the most at risk of experiencing neurodevelopmental health disorders due to high exposure to mercury in the womb.

The use of mercury in whitening cosmetics that exceed normal limits can be dangerous for users. Mercury is not allowed at any concentration in whitening cosmetics. Still, mercury is found in percentage levels ranging from 0.6-3.1% in cosmetics made by medical personnel, salons, beauty clinics, and online cosmetic stores.

The volume of whitening cosmetics varies in each package, and the substances contained therein are different, so the volume of whitening cosmetics will affect the effects on the skin and mercury levels in the body. Some pregnant women will choose to reduce or even stop routine skin care because they are worried that the ingredients in the cosmetics will be absorbed by the body and passed on to the fetus through the placenta (42).

This research is in line with the research results, signifying that there is an effect of the cosmetics application of whitening cosmetics with the concentration of Hg in the scalp hair of pregnant women, where the p-value is 0.028 <p value 0.05, namely the higher the volume of use, the higher the concentration of Hg in the body. Meanwhile, the research results on the concentration of mercury in the scalp hair of babies show that the volume of use of cosmetics by pregnant women affects the concentration of Hg in the scalp hair of babies where the p-value is 0.014 <p value 0.05. This concludes that the heavier the volume of cosmetic use during pregnancy, the higher the concentration of Hg in the baby's body.

This study is in line with the results of research conducted by Putri Handayani et al., Anugerah Maharani et al., Besse Rafiqah et al., Fitriani et al., and Nurfadillah et al., that there is an effect of volume with the concentration of Hg in the body. The more weight used, the higher the Hg concentration in pregnant women's scalp hair(33,36,37,39).

Mercury absorption occurs due to long-term use and low knowledge of pregnant women about the dangers of using cosmetics containing mercury. Mercury exposure in pregnant women, in addition to the use of cosmetics, is also through seafood consumption, which is not prevented as early as possible and can have dangerous effects on pregnant women and their babies. The dangerous effects experienced by babies due to mercury exposure are infant neurodevelopmental, for example, autism spectrum disorder, less memory, and less cognitive and psychomotor (43).

Correlation Between Mercury Exposure in Scalp Hair Baby to Risk Neurodevelopmental

Mercury exposure in mothers during pregnancy can cause autoimmune activation, oxidative stress, neuroinflammation, nerve damage, and loss of nerve connectivity that affect fetal brain development. Risk factors for prenatal mercury exposure include exposure to cigarette smoke, maternal consumption of seafood during pregnancy, pesticide-containing foods, and use of mercury-containing cosmetics during pregnancy.

Methylmercury is known to be neurotoxic to humans. During early prenatal development, the susceptibility of the central nervous system to mercury is increased. Ingested methylmercury is almost completely absorbed and can cross the placenta and the blood-brain barrier. Long-term prenatal mercury exposure has effects on brain function.

The results of a Faroese cohort study showed an association between prenatal mercury exposure and effects on motor speed, psychomotor skills, and language at ages 7 and 14 years.

The results of the study obtained are shown in Table 6, showing that the results of statistical analysis using correlation tests show that there is an influence that mercury concentrations in baby scalp hair with a moderate category have a risk of neurodevelopmental events with several cases of 6, with a p-value of 0.024 <from p-value 0.05.

Other birth cohort studies conducted in Canada(44,45), England (46), Brazil(47), China (48), and the United States (49) found no significant relationship between prenatal mercury exposure and delayed cognitive development in children under three years of age.

However, in Four other longitudinal studies, a significant relationship was found between prenatal mercury exposure and adverse effects on cognitive development in children under three years of age. Birth cohort studies conducted in the Faroe Islands (50), the United States (51), Japan (52), and Poland (43) found that infant neurobehavioral function was affected by prenatal mercury exposure.

Mercury toxicity can pose a risk to neurodevelopmental symptoms, in this case, cognitive, psychomotor, language development, and, more specifically, autism spectrum disorder. This is because mercury can damage genetic development so that DNA mutates. This mutation can cause chromosomal growth abnormalities that result in impaired brain development in the fetus, and it can cause neurodevelopmental risks in infants.

Recommendations for Future Research

Further research needs to examine supplements and vitamins for children who show symptoms of neurodevelopmental risk so that more severe neurodevelopmental symptoms, such as autism symptoms, can be prevented as early as possible.

CONCLUSION

This study highlights the occurrence of Hg in skin-lightening cosmetics and the accumulation of Hg in the human body through their application. There is a correlation between mercury in pregnant women's scalp hair and the mercury concentration in their babies. Babies exposed to mercury with alert concentration levels have a neurodevelopmental risk. Therefore, pregnant women with mercury levels should not use whitening cosmetics and consume seafood.

The local government should collaborate with the Indonesian National Agency of Drug and Food Control to extend interventions by controlling the online marketing of cosmetic products containing hazardous ingredients.

AUTHOR’S CONTRIBUTION STATEMENT

The first author wrote the manuscript and analysed the research data in this study. The second author was tasked with preparing scalp hair and cosmetic samples and sending samples to a health laboratory to assess mercury concentration in the scalp hair. As an enumerator, the third author collected data and interviewed respondents in depth.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

While writing the manuscript, I did not use the Declaration of Generative AI and AI-Assisted Technologies in the Writing Process. All the results of this article are purely from the author's mind without using AI applications.

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