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Evaluation of Manganese (Mn) and Cadmium (Cd) Heavy Metal Content in Staple Foods Based on Food Sources and Environmental Conditions in Pregnant Women in Sambas Regency, Indonesia

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ABSTRACT

Exposure to heavy metals, particularly Manganese (Mn) and Cadmium (Cd), in staple foods is a serious health issue for pregnant women in Sambas Regency, Indonesia. This study aims to evaluate the content of Mn and Cd in staple foods and environmental factors that influence exposure in pregnant women. The method used was an analytical observational design with a cross-sectional approach, involving 93 pregnant women selected by purposive sampling. Data were collected through structured interviews and laboratory analysis using atomic absorption spectrometry. The results showed that the average level of Mn in rice was 7.37 mg/kg, while the average level of Cd was 0.056 mg/kg. A total of 68.8% of respondents obtained their rice from local markets, potentially increasing the risk of heavy metal exposure. In addition, 87.1% of respondents reported using house paint, which could be an additional source of exposure. Conclusions from this study emphasise the need for closer monitoring of food quality and education on the dangers of heavy metal exposure for pregnant women, as well as the need for further research to understand the cumulative impact of multi-metal exposure in the context of pregnancy.

Keywords: Manganese (Mn), Cadmium (Cd), Pregnant women, Heavy metal contamination

INTRODUCTION

Exposure to heavy metals such as Manganese (Mn) and Cadmium (Cd) in staple foods is a serious health issue, especially for pregnant women in Sambas Regency, Indonesia. Although Mn is an essential element that the body needs in small amounts, overexposure can cause neurotoxicity that negatively affects maternal and foetal health (Sanders, Claus Henn, en Wright 2015; Takatani et al. 2024). On the other hand, Cd is a heavy metal that has no biological function and is known to be highly toxic, with long-term exposure leading to kidney, bone, and cardiovascular disorders (Nordberg en Costa 2021). Sambas Regency, which is an agricultural area, has a high potential for heavy metal contamination due to the use of pesticides and chemical fertilisers, as well as pollution from mining and industrial activities around the region. (Tóth et al. 2016). This condition raises serious concerns about the quality of staple foods consumed by the local population, especially pregnant women who are highly vulnerable to the negative effects of heavy metal exposure.

Sambas Regency is located in West Kalimantan, Indonesia, which is an agricultural area with great natural resource potential, but also faces challenges in good environmental management. Intensive agricultural activities, pesticide use, and irrigation with water that may be contaminated with heavy metals, can all increase the risk of Mn and Cd accumulation in staple foods such as rice, vegetables, and fish that make up the main diet of the population (Hadzi et al. 2019). In addition, the area is also affected by illegal gold mining activities that can contribute heavy metal contaminants to soil and water, which are then absorbed by plants and aquatic products (Fashola, Ngole-Jeme, en Babalola 2016).

Exposure to heavy metals such as Mn and Cd during pregnancy can have serious consequences for maternal health and foetal development. Research shows that excessive Mn can result in impaired neurological development in the foetus, while Cd can result in abnormalities in foetal kidneys and bones, as well as increase the risk of preterm birth and low birth weight. (Sanders et al. 2014; Takatani et al. 2024). In Sambas District, with environmental conditions at high risk of heavy metal contamination, it is important to evaluate the Mn and Cd content in staple foods to protect the health of pregnant women and foetuses.

Research on heavy metal contamination in staple foods and its impact on health has increased in recent years, with a particular focus on the impact on vulnerable populations such as pregnant women (Munir et al. 2021). In many countries, including Indonesia, studies have shown an increase in heavy metal content in staple foods such as rice and vegetables, which exceeds the safe limits set by the World Health Organisation (WHO). (Zhou et al. 2016). Research in China, for example, found that the concentrations of Mn and Cd in rice varied significantly across regions, demonstrating the influence of environmental conditions on the heavy metal content of food (Singh en Kalamdhad 2011).

Recent research has shown increased attention to the heavy metal content of staple foods and their impact on human health. In Indonesia, several studies have shown that concentrations of Mn and Cd in staple foods, such as rice and vegetables, often exceed the safe limits set by the World Health Organisation (WHO), highlighting the need for stricter monitoring (Munir et al. 2021). For example, research in agricultural areas in Central Java found that Cd concentrations in rice reached 0.4 mg/kg, well above the safe limit of 0.2 mg/kg set by FAO/WHO (Pandiangan en Audah 2022; Sukarjo et al. 2021; Suzuki et al. 1980). In addition, a study in West Sumatra showed that soil and water used for agriculture contain high levels of Mn, potentially increasing the Mn content of staple foods consumed by the community (Lanas, Amrin, en Rizal 2013; Nengsih en Afkar 2013).

Studies in other countries have also shown a significant link between human activities and elevated concentrations of heavy metals in staple foods. For example, a study in China showed that areas close to industrialised areas had higher concentrations of heavy metals in rice, which directly impacted the health of local residents (Sheng et al. 2020). Research in India has also shown that irrigation with Cd-contaminated water increases the accumulation of this heavy metal in food crops, which are then consumed by the local population (Zhou et al. 2016).

Although there have been studies examining heavy metal content in staple foods and their impact on health, there is still a need for further research as most previous studies have focused on specific heavy metals, such as Cd, without exploring the interaction and cumulative impact of exposure to multi-metals, such as Mn and Cd, in a specific context such as Sambas Regency (Akash et al. 2023). Whereas, combined exposure to multiple heavy metals can have synergistic or antagonistic effects that are not well understood. Whilst there are some studies on the health effects of heavy metal exposure in children and adults, studies focusing on the effects of heavy metal exposure during pregnancy are limited, especially those related to the combination of Mn and Cd (Liu et al. 2020). Furthermore, existing studies are mostly conducted in areas with high levels of contamination, while studies in areas with moderate or low levels of contamination, such as Sambas Regency, are often neglected.

This study aims to evaluate the Mn and Cd content in staple foods of pregnant women in Sambas District, Indonesia, by considering food sources and environmental conditions. Thus, the results of this study are expected to provide more in-depth information on the risk of heavy metal exposure during pregnancy and support prevention efforts to protect the health of pregnant women and foetuses in the area.

METHODS

Research Design

This study used an analytical observational research design with a cross-sectional approach. This approach was chosen to evaluate the heavy metal content of Manganese (Mn) and Cadmium (Cd) in staple foods consumed by pregnant women in Sambas Regency, Indonesia. The cross-sectional design allows data collection at a single point in time to evaluate the prevalence of heavy metal content in staple foods and the relationship between heavy metal exposure and environmental factors (Brand en Brand 2014; Jardim 2014). This study will identify the relationship between Mn and Cd exposure based on food sources and environmental conditions with the health of pregnant women.

Study Population and Sample

The population in this study were pregnant women in Sambas Regency, Indonesia. The research sample was taken using purposive sampling method, in which the research subjects were selected based on certain predetermined criteria. The inclusion criteria in this study were pregnant women in the first trimester to the second trimester, totalling 93 respondents. Exclusion criteria included pregnant women with a history of chronic diseases that could affect the results of the study, such as kidney disease or heavy metal metabolism disorders. (Patimah, Susilawati, en Sundari 2021; Putri et al. 2023)..

A sample size of 93 respondents was selected to ensure representativeness and accuracy of data in estimating the prevalence of heavy metal content in staple foods and heavy metal exposure in pregnant women. (Etikan, Musa, en Alkassim 2016).. Sampling will be conducted at several health centres in Sambas District, which geographically represent the population distribution of pregnant women in the region.

Data Collection

Data were collected through structured interviews using a questionnaire that had been tested for validity and reliability. The questionnaire included questions related to demographic characteristics (age, education, occupation), pregnancy status (gestational age, pregnancy history), food consumption patterns (frequency and types of staple foods consumed), and living environment conditions (sources of drinking water, use of pesticides) (Char en Serre 2020; Galletta en Cross 2013). In addition, additional data on environmental factors that may influence heavy metal content in staple foods were collected, including agricultural land use, water sources, and farming practices around the study area.

Staple Food Sampling and Laboratory Analysis

Samples of staple foods often consumed by pregnant women, namely rice, were taken from respondent households. Staple food samples were taken randomly and representatively from each household participating in the study. Food samples will be collected in sterile containers and stored at cool temperature to prevent further contamination prior to laboratory analysis.

Analysis of the heavy metal content of Mn and Cd in the staple food samples will be conducted in an accredited laboratory using atomic absorption spectrometry (AAS) technique, which is a standard method for detecting heavy metal concentrations in food samples (Ackah et al. 2014; Soylak en Aydin 2011). Prior to analysis, the food samples will be pretreated using the acidification method to separate the metals from the food matrix. The analytical results will be measured in mg/kg wet weight to determine the concentration of Mn and Cd.

Data Processing and Analysis

Data obtained from questionnaires and laboratory analysis will be statistically analysed. Descriptive analyses will be conducted to describe the demographic characteristics of respondents, frequency of staple food consumption. Heavy metal content data will be presented as mean, standard deviation and concentration range. To evaluate the association between Mn and Cd exposure with environmental factors and food consumption, bivariate analyses using the chi-square test and Pearson or Spearman correlations will be performed, depending on the distribution of the data.

Research Ethics

This study will follow the principles of research ethics, including obtaining ethical approval from the health research ethics committee of the Poltekkes Kemenkes Pontianak. Informed consent is obtained from each respondent prior to participation in the study. Information regarding the purpose of the study, the procedures to be performed, and the rights of participants will be clearly explained, and respondents will be given the freedom to withdraw from the study at any time without any negative consequences (Association 2013; Shrestha en Dunn 2019).. All data collected will be kept confidential and used only for research purposes.

RESULTS AND DISCUSSION

In this study, we evaluated the demographic and environmental characteristics of pregnant women in Sambas Regency, Indonesia, that could potentially influence their exposure to heavy metals, particularly Manganese (Mn) and Cadmium (Cd), in the staple foods they consume. Table 1 presents key information on respondents' profiles, including age, education, history of miscarriage, source of clean water, and food consumption patterns, such as sources of rice and fish. These data are highly relevant for understanding the social and economic context of the population under study, as well as for identifying factors that may contribute to the health risks faced by pregnant women. Thus, analysis of these characteristics is expected to provide a clearer picture of conditions that may affect maternal and foetal health, and support prevention efforts against harmful heavy metal exposure. The following are the results obtained from analysing the characteristics of the respondents involved in this study.

Table 1 presents the characteristics of the respondents consisting of 93 pregnant women in Sambas District, reflecting various relevant demographic and environmental aspects. In terms of age, the most dominant age group was 20-29 years old, with a percentage of 49.5% or 46 respondents. This shows that the majority of pregnant women are within the general productive age range for pregnancy. The 30-39 years age group was also quite significant, accounting for 39.8% or 37 respondents, while only 4.3% (4 respondents) were under 20 years old and 6.5% (6 respondents) were between 40-49 years old, signalling that pregnancies at younger and older ages are less common.

In terms of education, the majority of respondents had a high school educational background, which reached 43.0% (40 respondents), indicating good access to secondary education among pregnant women. Meanwhile, 20.4% (19 respondents) had primary school education, and 6.5% (6 respondents) had junior high school education, with only 30.1% (28 respondents) having tertiary education, indicating a variation in education levels.

Regarding miscarriage history, 20.4% (19 respondents) reported having had a miscarriage, while 79.6% (74 respondents) had no such history, indicating that most pregnant women in this area had no previous miscarriage problems. In terms of clean water sources, the majority of respondents used rainwater as the main source, reaching 49.5% (46 respondents), followed by sources from rivers (24.7% or 23 respondents), wells (5.4% or 5 respondents), and Regional Water Utility (20.4% or 19 respondents), indicating a reliance on water sources that may be affected by environmental conditions.

Table 1. Characteristics of respondents (n=93)

Respondent characteristics	All n (%) or mean ± SD
Age	
< 20 years	4 (4.3)
20-29 years old	46 (49.5)
30-39 years old	37 (39.8)
40-49 years old	6 (6.5)
Education	
Primary education	19 (20.4)
Lower secondary education	6 (6.5)
Upper secondary education	40 (43.0)
Tertiary (higher) education	28 (30.1)
Miscarriage History	
Yes	19 (20.4)
No	74 (79.6)

Source of Clean Water	
Well	5 (5.4)
River	23 (24.7)
Rainwater	46 (49.5)
Regional Water Utility	19 (20.4)
Rice Source	
Local Market	64 (68.8)
Supermarket	16 (17.2)
Farmers	8 (8.6)
Others	5 (5.4)
Fish Source	
Local Market	78 (83.9)
Supermarket	2 (2.20
Fisherman	3 (3.2)
Others	10 (10.8)
Use of house paint	
Yes	81 (87.1)
No	12 (12.9)
Rice Mn content	7.37 (2.44)
Rice Cd content	0.056 (0.023)

Regarding the characteristics of respondents focusing on the source of fish and the use of house paint among pregnant women in Sambas District. In terms of fish source, the majority of respondents, 83.9% (78 out of 93 respondents), obtained fish from the local market. This indicates a high reliance on local markets as a source of animal protein, which may reflect local consumption habits as well as the availability of fish in the area. This source of fish from local markets may also have implications for potential exposure to heavy metals, given the possible contamination that could occur due to industrial or mining activities around the area. In addition, the use of house paint among respondents was also significant, with 87.1% (81 respondents) reporting that they used paint for their homes. This high percentage indicates that the majority of pregnant women live in an environment that may be exposed to chemicals from paint, which could potentially contain heavy metals. This is an important concern, as exposure to hazardous chemicals during pregnancy can negatively impact maternal health and foetal development. Thus, both the dominant source of fish from local markets and the high use of house paint provide important insights into environmental factors that may affect the health of pregnant women in Sambas District.

The most common source of rice is the local market, with 68.8% (64 respondents) relying on rice from there, while 17.2% (16 respondents) buy from supermarkets, and 8.6% (8 respondents) directly from farmers. The source of fish is also dominated by the local market, with 83.9% (78 respondents) getting fish from there, indicating that the local community relies heavily on the market for their food needs. In addition, the use of house paint is also quite high, with 87.1% (81 respondents) using paint, which could potentially affect heavy metal exposure.

Finally, heavy metal levels in rice showed that the average Manganese (Mn) level was 7.37 mg/kg with a standard deviation of 2.44, while the average Cadmium (Cd) level was 0.056 mg/kg with a standard deviation of 0.023. These figures indicate the presence of heavy metals in the staple foods consumed by pregnant women, which is important to note given their potential impact on maternal and foetal health. Overall, these characteristics provide a comprehensive picture of the demographic and environmental conditions that may affect the health of pregnant women in Sambas District.

Table 2: Differences in Mn and Cd levels in rice by source

Group	Mn (ppm)		P Value*
	Min±Max	Mean±SD	
Local Market	0.00 ± 14.61	7.40 ± 2.60	0.126
Supermarket	3.29 ± 10.68	7.08 ± 2.07	
Direct Farmers	4.65 ± 12.01	5.93 ± 2.39	
Others	4.28 ± 8.84	7.03 ± 1.68	
	Cd (ppm)		
Local Market	0.00 ± 0.10	0.05 ± 0.02	0.866
Supermarket	0.02 ± 0.10	0.06 ± 0.03	
Direct Farmer	0.02 ± 0.10	0.07 ± 0.02	
Others	0.03 ± 0.08	0.07 ± 0.02	

*Oneway Anova Test; Significant ≤ 0.05

Table 2 presents the differences in the levels of heavy metals Manganese (Mn) and Cadmium (Cd) in rice based on their sources. The average level of Mn in rice obtained from local markets was 7.40 ppm with a range of 0.00 to 14.61 ppm, while rice from supermarkets showed an average level of 7.08 ppm with a range of 3.29 to 10.68 ppm. Rice obtained directly from farmers had the lowest average level of 5.93 ppm with a range of 4.65 to 12.01 ppm. Although no significant difference was found (P Value 0.126), this data shows that rice from local markets and supermarkets have relatively high levels of Mn. For Cd levels, rice from local markets had an average level of 0.05 ppm with a range of 0.00 to 0.10 ppm, while rice from supermarkets and direct farmers showed average levels of 0.06 ppm and 0.07 ppm, respectively. Cd levels in all rice sources showed values that were still below the safe limit set by WHO, with a P Value of 0.866 indicating no significant difference between rice sources. Overall, these results highlight the importance of monitoring heavy metal content in staple foods consumed by pregnant women to safeguard their health and that of the foetus.

Exposure to heavy metals such as manganese (Mn) and cadmium (Cd) in staple foods, especially rice, has become a serious concern due to its impact on human health, especially for pregnant women. Based on the results of this study, it was found that the content of Mn and Cd in rice consumed by pregnant women in Sambas Regency showed significant variations, although there were no statistically significant differences among the various sources of rice. This condition is in line with the results of other studies that show that exposure to heavy metals through food can be strongly influenced by environmental conditions, agricultural practices, and water

sources. (Sanders, Claus Henn, en Wright 2015; Takatani et al. 2024)..

Mn is an essential trace element required by the body in small amounts. However, overexposure, especially in pregnant women, can cause neurotoxicity disorders that impact the neurological development of the foetus (Sanders, Claus Henn, en Wright 2015). A study showed that high levels of Mn in the blood of pregnant women were associated with reduced cognitive function in children (Takatani et al. 2024). Other research supports these findings by showing that excessive exposure to Mn can increase the risk of neurological and brain development abnormalities in infants (Sanders, Claus Henn, en Wright 2015).

Meanwhile, Cd is a highly toxic heavy metal that has no biological function in the human body. Exposure of pregnant women to Cd is associated with various health risks, including impaired kidney function, bone damage, and cardiovascular disorders. (Nordberg en Costa 2021). Cd has also been identified as a contributing factor to preterm birth and low birth weight, both of which are important indicators of foetal health (Fujita et al. 2019; Nkwunonwo, Odika, en Onyia 2020).. In the context of Sambas District, the overuse of chemical fertilisers and pesticides as well as mining activities around the region may increase the risk of Cd exposure through staple foods. (Fashola, Ngole-Jeme, en Babalola 2016)..

Sambas Regency, an agricultural region, faces serious challenges related to its environmental quality. Contamination of soil and water with heavy metals due to the use of pesticides and fertilisers containing Mn and Cd has been documented in several studies (Hadzi et al. 2019; Sheng et al. 2020).. The use of river water and rainwater as water sources for irrigation can also be a pathway for heavy metals to enter the food chain, increasing the levels of Mn and Cd in rice and vegetables consumed by the population (Al-Huqail et al. 2022; Limmer en Seyfferth 2024).

A study in China showed that the concentration of heavy metals in rice varied significantly depending on the distance from industrial areas, with areas closer to industries showing higher levels of heavy metals (Sheng et al. 2020). Similar conditions may occur in Sambas District, especially in areas close to mining or industrial activities. Another study in India found that irrigation using Cd-contaminated water increased the accumulation of this heavy metal in food crops, suggesting that clean water sources are a key factor in preventing foodborne heavy metal exposure (Zhou et al. 2016)

The results of this study indicate the importance of ongoing monitoring of heavy metal content in staple foods consumed by pregnant women in Sambas District. Measures to reduce heavy metal exposure, such as strict monitoring of fertiliser and pesticide use, and better management of water sources, should be a priority. (Gao et al. 2022; Limmer en Seyfferth 2024).. The local government may also consider conducting regular quality tests on agricultural products from local markets and supermarkets to ensure that the food sold meets the safety standards set by WHO and FAO.

While this study has provided valuable insights into the Mn and Cd content of staple foods in Sambas District, there is still much to understand about the long-term health impacts of heavy metal exposure during pregnancy. Further research exploring the interactions between different heavy metals and the cumulative impact of multi-metal exposure is urgently needed (Chen et al. 2023; Zhao et al. 2023). In addition, longitudinal studies that track the effects of heavy metal exposure from pregnancy to child development may provide more comprehensive data on the health effects of heavy metal exposure.

CONCLUSION

This study aims to evaluate the heavy metal content of Manganese (Mn) and Cadmium (Cd) in staple foods consumed by pregnant women in Sambas District, and to understand the environmental factors that influence such exposure. The main findings showed that Mn and Cd were present in rice consumed by pregnant women, indicating potential health risks. Food sources obtained from local markets contribute to heavy metal accumulation, and the use of house paint by most respondents may also be an additional source of exposure. The results of this study emphasise the importance of stricter monitoring of food quality and the need for education on the dangers of heavy metal exposure to protect the health of pregnant women and fetuses.

RECOMMENDATIONS

Based on the results of the study on the content of heavy metals Manganese (Mn) and Cadmium (Cd) in the staple foods of pregnant women in Sambas Regency, it is recommended that the government and related parties increase supervision of food quality, especially rice and fish consumed by pregnant women. Education on the dangers of heavy metal exposure and safe agricultural practices should also be conducted. In addition, further research is needed to explore the interactions and cumulative effects of multi-metal exposure in the context of pregnancy, to more effectively protect maternal and foetal health.

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