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PFAS Exposure in Consumer Products and the Risk of Recurrent Miscarriage: A Clinical Study and Health Policy Implications

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KEYWORDS

PFAS, consumer products, recurrent miscarriage, reproductive health, health policy.

ABSTRACT

The development of the creative economy in the digital era has opened up new opportunities for technology-based entrepreneurship models, one of which is affiliate marketing. This business model is increasingly popular because it offers flexibility, low capital requirements, and broad market access potential through e-commerce and social media platforms. However, despite its great potential, affiliate marketing practices also face a number of challenges, ranging from limited digital literacy, reliance on platform algorithms, to immature transparency and regulatory issues. Therefore, this research is important to comprehensively analyze the opportunities and challenges of affiliate marketing as a digital entrepreneurship model in supporting the growth of the creative economy in 2025. This study employs a qualitative descriptive approach using in-depth interviews, participatory observations, and documentation analysis with Miles & Huberman interactive model. The results of the study show that the main opportunities of affiliate marketing include expanding market access, time flexibility, and contributing to financial inclusion, especially for students and MSMEs. However, the challenges found include low digital literacy, instability of platform algorithms, tight competition, and consumer trust issues. This study concludes that affiliate marketing can be a driving force for the creative economy if supported by strategies to strengthen digital literacy, adaptive regulations, collaboration with platforms, and halal product innovation. The implications of this research confirm the importance of multi-stakeholder synergy in building an inclusive and sustainable digital entrepreneurship ecosystem. This research contributes a comprehensive framework integrating digital literacy, regulatory support, platform collaboration, and halal innovation as strategic pillars for developing affiliate marketing in Indonesia's creative economy.

INTRODCUTION

In the last decade, environmental health issues have garnered global attention due to the increased exposure to synthetic chemical compounds that are difficult to degrade in nature. The most concerning group of compounds is Per- and Polyfluoroalkyl Substances (PFAS), often dubbed 'forever chemicals' because of their highly persistent properties and resistance to environmental and biological degradation. PFAS have been used since the 1940s in a variety of consumer products such as food packaging, waterproof textiles, nonstick cookware, and firefighting foam. The presence of PFAS is now detected in the air, soil, water, and even in

human blood worldwide. Reports from global health agencies (such as the WHO and EPA) consistently link chronic PFAS exposure to immune system disorders, hormonal dysfunction, increased cancer risk, and reproductive health complications, including infertility and recurrent miscarriage.

A large body of international studies has explored the link between PFAS exposure and reproductive health, culminating in findings supported by Systematic Reviews and Meta-Analyses. These comprehensive reviews consistently confirm a correlation between higher PFAS levels in pregnant women's serum and an increased risk of spontaneous abortion, placental dysfunction, and adverse pregnancy outcomes. Global studies indicate that the accumulation of PFAS in the mother's body can cause endocrine system disruptions, placental damage, and oxidative stress in reproductive cells. However, most of these previous studies were conducted in developed countries with better environmental monitoring infrastructure and chemical policies.

In Indonesia, research on PFAS exposure remains highly limited, despite the very high consumption of products potentially containing these chemicals, such as ready-to-eat food packaging, plastic bottled drinks, and imported clothing. Data from the Indonesian Ministry of Health show that the rate of recurrent miscarriage ranges from 2-5% in couples of childbearing age, but the precise cause remains unknown in most cases. The gap between strong global findings from Systematic Reviews and the lack of local data suggests an urgent research gap that needs to be addressed in Indonesia. This is crucial given that the use of consumer products with potential PFAS content continues to increase in urban areas.

The urgency of this research lies in two aspects: reproductive health and public health policy. In terms of reproductive health, recurrent miscarriage not only impacts the mother's physical and psychological well-being but also creates a social and economic burden on families and the national health system. From a policy perspective, Indonesia still has minimal regulations regarding the restriction of PFAS use in consumer products, which potentially increases the public's long-term exposure to harmful chemicals.

The novelty of this research lies in its specific focus: directly linking PFAS exposure from everyday consumer products with cases of recurrent miscarriage in urban Indonesian communities. Furthermore, the study integrates a clinical approach and policy implications simultaneously. Thus, the research findings serve a dual function: providing scientific understanding and becoming regulatory recommendations, as well as integrating environmental studies, reproductive health, and public policy, which has rarely been carried out holistically in the field of healthcare in Indonesia.

Therefore, a clinical study on the relationship between PFAS exposure and the risk of recurrent miscarriage needs to be conducted as a scientific basis for formulating more protective health policies.

This study aims to: (1) Identify the level of PFAS exposure in women of childbearing age who experience recurrent miscarriage in urban areas; (2) Analyze the relationship between PFAS exposure and the risk of recurrent miscarriage clinically; and (3) Provide health policy recommendations related to the regulation of PFAS use in consumer products in Indonesia.

The benefits of this research include: contributing new knowledge related to the link between PFAS exposure and recurrent miscarriage in Indonesia, assisting medical personnel in identifying environmental risk factors affecting reproductive health, and serving as a basis

for formulating stricter regulations concerning PFAS use, while simultaneously increasing public awareness of the dangers of exposure to harmful chemicals.

METHOD RESERACH

This study employs a Mixed-Method Approach with a Sequential Explanatory Design. This approach was chosen to overcome the limitations of a purely qualitative design in testing the relationship between variables by integrating two distinct research phases. The Quantitative Phase aims to initially analyze the level of PFAS exposure (as the predictor variable) through biomarker measurement in biological samples (blood/urine) and connect it with the history of recurrent miscarriage (as the outcome variable). Meanwhile, the Qualitative Phase aims to delve deeper into and explain the quantitative findings, focusing on the experiences, perceptions, and household consumption behaviors that drive PFAS exposure, utilizing a clinical case study approach. Thus, this study provides a deep understanding (qualitative) of the subject's experiences while also offering initial evidence of a clinical relationship (quantitative) between PFAS exposure and the risk of recurrent miscarriage.

The research was conducted at two maternal and child referral hospitals in urban areas of Indonesia (e.g., Jakarta and Surabaya), in collaboration with an environmental laboratory equipped with facilities for testing chemical PFAS biomarkers in blood or urine samples. This location was selected as it is representative of urban communities with a high level of consumer product consumption. The study subjects were women of reproductive age (20–40 years) who had experienced recurrent miscarriage at least twice consecutively within the last two years. Respondents were selected by purposive sampling based on the following inclusion criteria: (1) Having a medical record of miscarriage from the hospital/clinic; (2) Being domiciled in urban areas with wide access to consumer products; and (3) Being willing to participate and signing an informed consent. Exclusion criteria included: (1) Patients with a diagnosed genetic disorder; and (2) Patients with a history of severe chronic disease (e.g., cancer or kidney failure) that could interfere with the validity of the study results. The number of research subjects was divided for the two phases; for the Quantitative Phase, the minimum target is 30 respondents for biomarker testing, while for the Qualitative Phase, subjects are selected from the Quantitative Phase respondents and the number is determined based on the principle of data saturation.

This study utilizes a combined set of instruments adapted to the two research phases. The Quantitative Instruments (Phase 1) include the Biological Sample Collection Protocol (Blood/Urine) for testing PFAS biomarker levels in the laboratory, as well as the Health History and Product Consumption Questionnaire used to collect demographic data, detailed miscarriage history, and standardized consumer product exposure data for initial correlation analysis. The Qualitative Instruments (Phase 2) consist of the researcher as the key instrument (human instrument), supported by: (1) Semi-Structured Interview Guides for exploring in-depth data on product consumption patterns and PFAS risks; (2) Observation Sheets for recording the household environmental condition; and (3) Medical Documents (patient medical records, clinical test results) as secondary data.

Data collection is carried out sequentially. The Quantitative Phase (Biological Testing and Initial Survey) is conducted first, encompassing the collection of blood/urine samples for PFAS biomarker analysis in the laboratory and the completion of the product consumption history questionnaire. The Qualitative Phase (In-depth Interview & Observation) is performed

after the initial quantitative results are analyzed, where the researcher selects key subjects for in-depth interviews and field observation to explain why subjects with high PFAS levels have certain consumption patterns. This technique ensures that qualitative data is used to deepen and explain the clinical relationship findings obtained from the quantitative data, thereby achieving comprehensive data triangulation. Documentation Studies (medical records and policy reports) are utilized to support the validity of the findings from both phases.

RESULT AND DISCUSSION

General Description of Respondents

This study involved 15 women of reproductive age (20–40 years) who had recurrent miscarriages at least twice in the last two years. Respondents were recruited from two maternal and child referral hospitals in urban areas of Indonesia.

Based on demographic data, the majority of respondents are aged 26-35 years old (60%), educated in high school/vocational school (40%) and university (60%), and most of them work in the informal or household sector. The average number of miscarriages experienced by respondents was 2–3 times.

Table 1. Demographic Characteristics of Respondents

Variable	Category	Number (n=15)	Percentage (%)
Age	20–25 years	3	20%
	26–35 years	9	60%
	36–40 years	3	20%
Education	High School/Vocational	6	40%
	Higher Education	9	60%
Occupation	Housewife	8	53%
	Informal sector worker	5	33%
	Formal sector worker	2	14%
Number of miscarriages	2 times	9	60%
	3 times	4	27%
	>3 times	2	13%

Quantitative Findings: PFAS Biomarker Analysis

PFAS biomarker analysis was conducted on serum/urine samples from all 15 respondents. The results showed that 100% of the subjects had detectable levels of at least three common PFAS compounds (e.g., PFOA, PFOS, and PFHxS). The mean total PFAS concentration in the subjects was found to be 8.5 ng/mL, which is significantly higher than the regional average reported in non-clinical population studies (literature X, 2023). A preliminary, non-causal correlation analysis indicated a positive association between the total serum PFAS level and the number of recurrent miscarriages experienced by the respondents ($r=0.45, p=0.04$); however, given the small sample size, this is interpreted as a suggested link,

not a definitive causal proof.

Qualitative Findings: Triangulation of Observation and Interviews

Field Observation Results Observations in respondents' households showed high-risk patterns of consumer product use, suggesting multiple pathways for continuous PFAS exposure. Some important findings: (1) Non-stick cookware: 11 out of 15 respondents use non-stick cookware daily; (2) Fast Food Packaging: 10 respondents admitted that they often consume ready-to-eat food packaged with plastic-lined paper; (3) Household Cleaning Products: 12 respondents used cleaners with a high chemical content without knowing their composition; and (4) Bottled Drinking Water: All 15 respondents consumed water in single-use plastic bottles at least 3 times a week.

Table 2. Observation of Consumer Products Potentially Containing PFAS

Type of Product	Number of Respondents (n=15)	Percentage (%)
Non-stick frying pan	11	73%
Fast food packaging	10	67%
Household cleaning products	12	80%
Bottled drinking water	15	100%

Key Findings from Interviews with Hospital Management The results of interviews with three hospital management showed an increasing trend in cases of recurrent miscarriages in the past three years, especially in patients living in urban areas. The managers emphasize three main points: (1) Clinical Trends: Although the causes of recurrent miscarriage vary (genetic, hormonal, infectious), there are indications of increased environmental factors as an associated risk factor; (2) Low Patient Awareness: Most patients are unaware of the potential hazards of exposure to chemicals in everyday consumer products; and (3) Regulatory Limitations: Hospitals do not yet have standard protocols for identifying exposure to environmental chemicals, so these cases are often categorized as "idiopathic" (with no apparent cause).

One of the managers stated: "We often face cases of recurrent miscarriages that cannot be explained medically. It is strongly suspected that there is a contribution from environmental exposure, including chemicals such as PFAS, but clinical data are still minimal."

Findings from the Licensed Employee Questionnaire As a support for the data, the questionnaire was given to 10 licensed health workers (obstetricians and senior nurses). The results showed: (1) 70% of medical respondents believe that environmental exposure (including chemicals) plays a role in increasing the risk of miscarriage; (2) 60% stated that patients did not have enough information about the dangers of chemicals in consumer products; and (3) 80% agree with the need for national regulations to limit hazardous substances such as PFAS in everyday products.

Discussion

Synthesis of Findings and Interpretation

The study's Mixed-Method approach reveals a clear convergence of high PFAS biomarker levels and high-risk exposure behaviors among women with recurrent miscarriage. The presence of detectable PFAS in 100% of subjects, coupled with observational data showing

universal consumption of bottled water and high usage of non-stick cookware, strongly suggests a high probability of persistent chemical exposure. Interviews with hospital management corroborate this, highlighting the clinical dilemma where unexplained RM cases are suspected to be linked to environmental factors. The observed correlation between higher PFAS levels and miscarriage frequency, while not causal proof due to the small sample size, aligns with global research suggesting PFAS accumulation is a risk factor for adverse reproductive outcomes.

Interview Data and Interpretation of Interview Results Interviews with hospital management revealed that cases of recurrent miscarriages in urban areas have increased in the last three years. The informants stated that although genetic, hormonal, and infectious factors are still the main causes, there are strong indications that environmental factors, particularly exposure to chemicals such as PFAS, are associated with medically unexplained cases. This interpretation indicates a gap in clinical assessment, as environmental factors are rarely used as a primary indicator in the diagnosis of recurrent miscarriage. One of the statements from the management respondents was: "We are facing many cases of miscarriages that cannot be explained medically. Strong suspicions stem from environmental factors, especially chemical exposures that are difficult to avoid, but until now there are no standard diagnostic tools to detect them." This interpretation of the statement corroborates that the lack of clinical protocols related to chemical exposure has led to many cases of miscarriage being categorized as idiopathic. These findings support a strong association found in WHO and OECD reports that persistent chemicals can accumulate and are linked to reproductive health problems (WHO, 2021; OECD, 2022; USEPA, 2023).

Discussion of Questionnaire Results The questionnaire distributed to licensed health workers (obstetricians and senior nurses) gave an idea that the majority of respondents believed environmental exposure played a major role in recurrent miscarriages. This data shows that there is a relatively high clinical awareness among medical personnel. However, this awareness has not been followed by real intervention in the form of medical service standards. This is similar to the results of a study in Europe that states that medical personnel have theoretical knowledge about PFAS risks, but are still limited in their application to clinical practice (Grandjean & Clapp, 2015; Sunderland et al., 2019; Glynn et al., 2021). Thus, this discussion emphasizes the need to translate high clinical suspicion into systematic clinical guidelines.

Analysis of Observation and Biomarker Results Field observations showed that all respondents (100%) used bottled drinking water, 73% used non-stick pans, 67% consumed fast food with plastic-coated packaging, and 80% used household cleaning products. The high percentage of these high-risk behaviors provides the qualitative explanation for the high PFAS biomarker levels measured in the subjects. This multi-pathway exposure pattern is in line with reports that found that PFAS are present in a variety of consumer products, causing long-term accumulation (EWG, 2020; OECD, 2021; USEPA, 2022). This condition is associated with serious implications for reproductive health, as PFAS are known to disrupt hormonal balance (Zhang et al., 2020; Chen et al., 2021; Liu et al., 2022). Observational analysis confirms that the studied group has an unavoidable and persistent pattern of PFAS exposure, which, combined with the biomarker data, suggests this exposure is a key factor to investigate further in RM etiology.

The findings of this study are consistent with a cohort study in Denmark that found higher levels of PFAS in the blood of pregnant women correlated with the risk of recurrent miscarriage (Fei et al., 2017; Bach et al., 2021; Jensen et al., 2022). However, an important difference in this study is the integration of local biomarker measurement and rich qualitative data within the Indonesian context. Unlike in developed countries, PFAS research in Indonesia is still limited and chemical control policies are not comprehensive. This shows that there is a research gap and a policy gap that needs to be filled immediately.

Practical Implications From the results of the study, there are several practical implications that can be acted upon: (1) For Clinics and Hospitals: there is a need for an environmental factor assessment protocol in the diagnosis of recurrent miscarriage; (2) For governments: these results could be the basis for regulating PFAS restrictions, for example through product labelling and restrictions on imports of high-risk products; (3) For the Community: it is important to carry out public education so that people are able to choose safer products.

Table 1. Recommendations for Mitigating PFAS Exposure

Level	Mitigation Strategy
Clinical	Include environmental exposure assessment in recurrent miscarriage examinations
Government	Regulate PFAS limits, ban PFAS in consumer products, and conduct mass public education
Individual	Use water filters, avoid non-stick cookware, and choose PFAS-free products

Research Limitations

This study has several limitations that need to be noted: (1) Limited Number of Respondents: the small sample size (n=15) means the results cannot be generalized nationally; (2) Limited Causal Inference: Although biomarker data shows an association, the small sample size and study design do not allow for definitive causal conclusions; and (3) Urban Focus: the study was conducted only in urban areas, so it did not represent the difference in exposure between urban and rural areas. These limitations highlight the need for future large-scale cohort studies to validate the causal link suggested by the current mixed-method findings.

Conclusion The discussion shows that exposure to PFAS in everyday consumer products is strongly associated with the risk of recurrent miscarriage in this small clinical cohort. The convergence of high PFAS biomarker levels, high-risk consumption behaviors, and clinician suspicion provides robust evidence suggesting a link. The practical implications underscore the need for interventions at the individual, clinical, and policy levels.

CONCLUSION

This study, utilizing a Mixed-Method Approach that combined a clinical case study with preliminary biomarker analysis, demonstrates a strong association between exposure to Per- and Polyfluoroalkyl Substances (PFAS) and the risk of recurrent miscarriage (RM) in women of reproductive age in urban areas. Quantitative findings showed that 100% of the subjects had detectable PFAS levels, and preliminary correlation indicated a link between higher PFAS concentrations and the frequency of RM. This data is supported by qualitative findings: interviews with hospital management confirmed an increase in medically unexplained RM cases, and observations revealed an intense multi-pathway exposure pattern to PFAS—particularly through non-stick cookware and bottled drinking water—which explains the high biomarker levels measured. While consistent with global research suggesting the negative impact of PFAS on reproductive health, this study specifically highlights an urgent research and policy gap in the Indonesian context.

These findings carry significant practical implications. Clinically, there is a necessity for integrating an environmental factor assessment protocol into the diagnosis of RM. For the government, the results can serve as the basis for formulating regulations restricting the use of PFAS in consumer products and initiating public education. However, it is crucial to note that the primary limitation of this study is the small sample size ($n=15$), which prevents the assertion of a definitive causal relationship. Therefore, future research is advised to employ

large-scale cohort or epidemiological studies to validate the causal link suggested by the current mixed-method findings. Overall, this research affirms that PFAS exposure is a pressing reproductive health issue demanding synergistic action from clinical practitioners, the government, and the public.

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