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Pregnant Women Exposure to Heavy Metals and Hypertensive Disorders of Pregnancy: A Narrative Review

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ABSTRACT

Introduction: Pregnant women are exposed to heavy metals through the consumption of contaminated food, water, and air. Toxic heavy metals are among the most dangerous environmental pollutants and can cause hypertensive disorders during pregnancy. This study aimed to review the exposure of pregnant women and fetuses to heavy metals, their relationship with pregnancy blood pressure disorders, and strategies to reduce exposure.

Materials and Methods: In this narrative review study, PubMed, Web of Science, Scopus, Science Direct, and Google Scholar databases were used to search for scientific published papers between 2005 and 2025 with the main keywords "Pregnant women," "Maternal Exposure," "Heavy metals," "Hypertension," and "Blood pressure."

Results: The most important exposure routes for pregnant women to heavy metals are contaminated drinking water and food, cosmetics, dental practices, cigarette smoke, and indoor and ambient air pollutants. The most influential heavy metals on hypertensive disorders of pregnancy (HDP) in pregnant women are lead (Pb), cadmium (Cd), mercury (Hg), arsenic (As), chromium (Cr), and copper (Cu). Heavy metals disrupt the function of endothelial cells by producing free radicals and causing oxidative stress and increasing lipid peroxides, which can cause hypertensive disorders of pregnancy.

Conclusion: Therefore, lifestyle modification and the use of safety foods containing iron, calcium, and selenium, as well as a healthy diet containing protein, dairy products, especially milk, vegetables, and organic fruits, can play a significant role in reducing exposure to heavy metals and expelling these from the body.

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Introduction

Today, with the development of agriculture and industries and the consumption of fossil fuels, various pollutants are produced and enter to the water, soil and air resources [1]. One of the most important pollutants found in abundance in environmental sources is heavy metals [2]. Heavy metals are divided into two categories: non-toxic and toxic metals for the growth of living organisms. Essential metal elements such as Zinc (Zn), Copper (Cu), Cobalt (Co), and manganese (Mn), which have important physiological roles such as cofactor role, oxidation and reduction reactions and ligand binding [3]. Non-essential or

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toxic heavy metals include Arsenic (As), Cadmium (Cd), Chromium (Cr), Lead (Pb) and Mercury (Hg), which disrupt the physiological and metabolic processes of the body due to their high stability and accumulation in the body of living organisms [4, 5]. Heavy metals are the main constituent of the earth's crust that do not decompose through chemical and biological processes in nature. Heavy metals occur naturally in soil, water, and air (as a result of volcanic eruptions, soil erosion, and weathering) [6]. It also enters the environment through human activities and the consumption of fossil fuels in industries, vehicle fuel, agricultural activities, and mining activities [7]. Toxic heavy metals are stable, persistent and non-degradable compounds that not only reduce the quality of water and soil resources, but also pose a serious threat to the atmosphere and food products, which in turn threatens the health of living organisms and humans [8, 9]. These metals, when entering water and soil resources, are absorbed by plants, agricultural crops, and fruit trees through the roots and leaves. Then, they are stored in the leaves and fruits of agricultural products and enter the food chain of humans through the consumption of these products [10, 11]. Humans and living organisms are exposed to heavy metals, directly and indirectly, through the consumption of agricultural products, food, drinking water, breathing polluted air, and contact with contaminated materials and products such as cosmetics and personal care products [12]. Exposure through the digestive system and consumption of contaminated food and water is the most important route of exposure to heavy metals [5, 13]. Toxic metals accumulate in various body tissues such as the liver, kidneys, bladder, and bones, causing various adverse effects on various body systems such as the renal and urinary tract systems, cardiovascular systems, respiratory and lung systems, and central nervous systems, and can cause many types of cancers [14-17].

Pregnancy is a period when women are more vulnerable and sensitive to exposure to environmental pollutants, especially toxic heavy metals [18]. Pregnancy is a time when significant hormonal and physiological changes occur in pregnant women, which can lead to increased nutritional needs and subsequent nutrient deficiencies. These deficiencies alter the absorption and metabolism of toxic heavy metals in the pregnant woman's body, causing the release of heavy metals stored in the body and their transfer to the placenta [13]. The most important consequences of exposure to heavy metals during pregnancy include spontaneous abortion, premature birth, infertility, and hormonal disorders in pregnant women [11, 19]. As a result, exposure to toxic heavy metals during pregnancy can have negative effects on fetal development and dangerous consequences such as miscarriage, stillbirth, and low birth weight [20, 21]. Long-term exposure to toxic heavy metals is one of the most important risk factors for blood pressure in humans [22]. Hypertension is one of the chronic diseases, is considered one of the main causes of death in societies with high prevalent due to dysfunction of vital organs such as the brain, heart, and other organs [23]. Hypertensive disorders of pregnancy (HDP) is one of the most common diseases among pregnant women, which pose a high risk of adverse outcomes for pregnant women and fetuses, such as miscarriage and premature birth [24]. HDP is a major cause of maternal and perinatal morbidity and mortality [25]. In the latest classification, HDP comprises four subgroups based on symptoms and time of onset: gestational hypertension (GH), preeclampsia (PE), superimposed preeclampsia, and eclampsia [26]. Based on epidemiological studies, the global prevalence rates of HDP, gestational hypertension, and preeclampsia are 5.2–8.2%, 1.8–4.4%, and 0.2–9.2%, respectively [26, 27]. The most important risk factors associated with HDP are include body mass index, anemia, education level, tobacco and alcohol use, advanced maternal age, family and genetic history, and exposure to environmental pollutants and toxins [26, 28, 29]. Toxic heavy metals are among the most significant environmental pollutants, and exposure to them may be associated with HDP [29]. Studies show that heavy metals such as Pb and Cd have a high risk for blood pressure during pregnancy [30].

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Therefore, considering the serious risks of exposure to toxic heavy metals and their effects on health, and considering the sensitivity during pregnancy and the risks that exposure to these metals through drinking water, food, and air can have for the mother and fetus, and on the other hand, there is a need to categorize existing information and studies in the field of pregnancy blood pressure due to heavy metals exposure, this study aimed to review studies related to pregnant women's exposure to heavy metals and its effect on pregnancy blood pressure and HDP, and to determine the mechanism of influence, as well as to provide control strategies to reduce exposure.

Materials and Methods

PubMed, Web of Science, Scopus, Science Direct, and Google Scholar databases were used to search for published paper between 2005 to 2025. The search strategy in this study was based on the use of the main keywords includes "Pregnant women", "Pregnant People", Maternal Exposure", "Metals, Heavy", "hypertensive disorders of pregnancy", "Hypertension", "Blood pressure" and "Arterial Pressure" were performed. Then, out of the 64 articles found, after reviewing the articles, finally 15 relevant papers were selected and reviewed based on their similarity and proximity to the subject of study, which was specifically in the field of HDP and heavy metals. The main heavy metals reviewed in this study were include: Pb, Cd, Hg, As, Cr, and Cu.

Toxic heavy metals health risks

The term heavy metals refers to metals and metalloids with a specific gravity greater than 5 grams per cubic centimeter, with the potential to bioaccumulate along the food chain [8]. With the increasing development of industry and agriculture, the problems of environmental pollution caused by toxic metals have taken on serious dimensions, and today, environmental pollution, especially toxic heavy metals, has become a serious problem worldwide [1].

The bioaccumulation of heavy metals absorbed in plant in concentrations exceeding the standard levels, in addition to reducing the growth and yield of agricultural products, leads to contamination of the food chain and endangering the health of human communities [6]. Human activities such as industrial and energy production activities, vehicle exhaust emissions, chemical fertilizer discharges, and fuel and coal combustion are all potential sources of heavy metals discharge to agricultural soils. The main sources of heavy metals are the atmosphere, mining, industries, fossil fuel combustion, ash residue deposition from coal combustion, traffic and vehicles, or the use of pesticides and chemical fertilizers in agriculture [10]. In addition, toxic heavy metals can also enter the food products during the production and packaging process. For example, heavy metals including Pb and Cd may be released from polyethylene packaging. Polyethylene terephthalate (PET) is transferred to food during long-term storage and heating, and there is even the potential for heavy metals to be transferred to food packaging [31]. The following are the most important toxic heavy metals that affect the reproductive system and the effects of exposure to them, especially during pregnancy.

Lead (Pb)

The bioavailability of Pb depends on its structure (organic or inorganic), the amount it enters the body, the age and diet of the individual. Pb has the potential to cause cancer in humans [32]. In adults, the cessation of hemoglobin synthesis is also associated with low levels of Pb in the blood. At higher levels of Pb in the blood, signs of neurotoxicity such as decreased central nervous system conduction velocity, as well as nephrotoxicity, are observed. In children, toxic effects of Pb, such as growth retardation, balance problems, and other neurobehavioral signs, have been associated with blood Pb levels (10 µg/dL) [33]. Pregnant women are at high risk for exposure to Pb metal due to Pb mobility during this period, because bones are catabolized during pregnancy to help form the fetal skeleton [34]. Chemical biosynthesis disorders and anemia, increased blood pressure, kidney damage, miscarriage and premature birth, nervous system disorders, brain

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damage, and male infertility are some of the complications of Pb exposure, especially during pregnancy [35].

Cadmium (Cd)

Cd, with a concentration of 0.06 to 1.1 mg/kg of soil, is considered one of the most important and mobile heavy metals in soil. Poisoning with this metal causes serious damage to the kidneys, bones, and nervous system [36]. Cd is classified as carcinogenic by IARC in Group 1, and by OSHA in it is also known as a carcinogen [37]. The primary route of exposure to Cd is inhalation. Depending on its structure, 15-35% of inhaled Cd is absorbed into the blood. When Cd is absorbed into the blood, it forms a bond with albumin and is transported to the liver and causes liver damage and increases in liver enzymes [38]. Studies show that the female reproductive system is very vulnerable to Cd. Consuming water, food, and breathing air contaminated with Cd, It can affect the functioning of the reproductive system in women, especially the uterus, and Cd inhibits and alters important biochemical processes in the reproductive system [39]. Cd disrupts the function of the ovaries and placenta by causing changes in steroidogenesis. Cd can also cause delayed puberty, loss of reproductive hormones during pregnancy, menstrual cycle disruption, premature birth, and low birth weight in pregnant women [40].

Chromium (Cr)

Cr compounds are mainly present in the environment in two main forms, trivalent and hexavalent. Hexavalent Cr is widely used in various industries. Hexavalent Cr compounds are highly toxic to biological systems. In terms of carcinogenicity, hexavalent Cr compounds are classified by IARC as Group 1, and are considered carcinogenic to humans [41]. Some studies show that hexavalent Cr, after entering the body through the consumption of water, food or contaminated air, is extremely harmful and toxic to human tissues due to its high solubility in water. Its solubility increases the active transport of chromate across biological membranes, which, as soon as it enters the cell, causes its mutagenic and carcinogenic effects [42, 43]. Cr toxicity to pregnant women is related to adverse effects on fetal development and pregnancy. Cr, especially in its hexavalent form, can Pb to various reproductive problems. Cr exposure during pregnancy has been associated with reduced fetal growth, low birth weight, premature birth, and other complications. These effects are often through mechanisms such as oxidative stress and placental dysfunction [44].

Arsenic (As)

Long-term exposure to As, as a dangerous toxic heavy metal, can cause numerous health problems and complications for humans, the most important of which include the development of various cancers, especially skin, liver, bladder, and lung cancer, blood pressure, diabetes, cardiovascular diseases, reproductive system toxicity, and skin lesions [14, 45]. As is one of the most important toxic metals for the reproductive system in female and male. Studies show that exposure of pregnant women to As through consumption of contaminated water, food or air can cause oxidative stress, spontaneous abortion, disruption of the reproductive cycle, HDP, decreased progesterone and testosterone levels and impaired fertility [11].

Mercury (Hg)

Hg, one Neurotoxin It is present in the environment through various natural and human sources. The most important effects related to exposure to Hg include cellular toxicity, adverse effects on the cardiovascular, hematopoietic, pulmonary, renal, and nervous, endocrine, reproductive and embryonic systems [46]. The toxic Hg poses significant risks to pregnant women and their fetuses due to its ability to bioaccumulate and cross the placenta. Hg exposure is mainly through the consumption of seafood, especially fish. Toxic effects of Hg can Pb to various adverse health consequences, including developmental problems in infants and high blood pressure disorders in pregnant women [47].

Hypertensive disorders of pregnancy (HDP)

Fertility is one of the most important aspects of human life and its goal is to have healthy children.

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Fertility is affected by a variety of factors, and environmental hazards can make it difficult to have a successful pregnancy, healthy baby, and successful birth [18]. Hypertensive disorders of pregnancy (HDP) are among the most common health problems during pregnancy and in pregnant women, which can increase the risk of fetal and maternal mortality [47]. These disorders are seen in two forms: gestational hypertension and preeclampsia (PE) [48]. Gestational hypertension is defined as a systolic blood pressure greater than or equal to 140 mmHg or a diastolic blood pressure greater than or equal to 90 mmHg [49]. Preeclampsia is associated with adverse pregnancy outcomes for the mother and fetus and increased maternal blood pressure, and the risk of mortality in mothers with a history of preeclampsia is 7 to 8 times higher than others [50]. The main risk factors related to HDP are included family history of high blood pressure, high body mass index (BMI), inactivity, being over 35 years old at the time of pregnancy, gestational diabetes, pre-pregnancy diabetes, psychological stress during pregnancy, diet and environmental exposures [51].

The relationship between heavy metal exposure and HDP

Environmental risk factors, especially heavy metals, can affect both individual fertility and pregnancy, as well as childbirth, fetal and child health. Studies show that exposure to heavy metals such as Pb, Cd, Hg, and As can have adverse effects on pregnant women and the fetus [28, 52]. The most important heavy metals exposure routes in pregnant women are through the drinking water, food, cosmetics, cigarette smoke, and indoor and outdoor air pollutants [5]. Nowadays, environmental exposures, especially exposure to heavy metals, have been considered as one of the risk factors for HDP [24]. Table 1, shows various studies related to heavy metals exposure and HDP in pregnant women. Studies show that the most important heavy metals affecting on HDP are include Pb, Cd, Hg, As, Cr, and Cu (Table 1).

According to a study by Morimoto et al., in Japan, which was conducted on 88,670 pregnant women with an average age of 31, to determine the relationship between exposure to heavy metals Pb, Cd , and Hg in the blood during the second and third trimesters of pregnancy and HDP, the results showed that the HDP was positively and significantly associated with the concentration of Pb (with an odds ratio (OR) of 1.58), Cd (odds ratio of 1.3), and Hg (odds ratio of 1.15) in the blood [53]. Pb can cross the placenta during pregnancy and is associated with intrauterine fetal death, preterm delivery, and low birth weight [24]. Cd also targets tissues of the heart and blood vessels, kidneys, lungs, and brain, causing cardiovascular disease, high blood pressure, liver damage, and a weakened immune system [23]. According to previous studies, there is a positive and significant relationship between exposure to Cd and high blood pressure [23]. In a study conducted by Mahmood and Al-Helaly in Iraq on 153 pregnant women In two groups of pregnant women with hypertension (75 people) and healthy pregnant women (78 people) and by measuring the heavy metals Pb, Cd and Cr in the amniotic fluid, the results showed that with increasing heavy metal concentrations in pregnant women with hypertension, blood pressure increased significantly compared to the control group [54].

The toxic metal Hg is found in pesticides, fungicides, fish, dental fillings, and other industrial processes. Women who are dental assistants or female dentists who handle Hg for dental fillings have higher exposures to Hg than the general population [55]. In a study by de Oliveira et al., on the association between Hg exposure during pregnancy and blood pressure in pregnant women, the results showed that pregnant women's exposure to Hg and the presence of Hg in their urine and blood were positively and significantly associated with high blood pressure in the exposed groups compared to the control groups [47]. In a study conducted by Ma et al., in China, 146 women with HDP and 292 normal pregnant women at 10 and 19 weeks of pregnancy were investigated in the context of the relationship between HDP and exposure to heavy metals Cu, Pb, Hg, aluminum (Al), nickel (Ni), and vanadium (V). The results

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showed that there was a positive and significant relationship between exposure to heavy metals Hg, Al, Ni, and V. There is an association with HDP, and the highest odds were observed in exposure to Hg [29].

Exposure to Cu is through the water pipes, contraceptives, swimming pools and jewelry. Studies have confirmed a positive association between Cu exposure and HDP in women and during pregnancy [56]. In a study conducted by Lewandowska et al., in Poland on 121 pregnant women with high blood pressure and 363 pregnant women with normal blood pressure at 10 and 14 weeks of pregnancy on the relationship between exposure to Cu and Zn metals and pregnancy blood pressure, the results showed that low Cu concentration in the blood in early pregnancy in pregnant women was significantly associated with an increased risk of pregnancy blood pressure [56].

Studies show that exposure to As, a dangerous toxic and carcinogenic metal, can also increase the risk of blood pressure and cardiovascular diseases in pregnant women. In a study conducted by Wang et al. on 1038 pregnant women, it was shown that there is a positive and significant association between increased As concentration and increased systolic and diastolic blood pressure in pregnant women [57].

The main mechanisms of pregnancy-induced hypertension due to heavy metals exposure in pregnant women include the changes and dysfunction in endothelial function, activation of inflammatory reactions and oxidative stress [58, 59]. In fact, increased exposure to heavy metals increases lipid peroxides and oxygen free radicals, causing disruption or damage to endothelial cells and can play a role in the development or exacerbation of HDP [60]. Exposure to heavy metals can reduce the activity of Myosin ATPase, increased arterial wall tension due to calcium overload in vascular smooth muscle, may increase blood pressure in pregnant women [61].

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Table 1. Different studies related to heavy metals exposure and the hypertensive disorders of pregnancy.

Region/year	Study type	Sample size	Exposure routes	Measurement technique	Heavy metals	Results	References
Iraq, 2019	A case-control study	153 pregnant women in two groups: pregnant women with hypertension (75 sample) and healthy pregnant women (78 sample)	Amniotic fluid sampling from pregnant women via the vagina with a sterile syringe	Atomic absorption spectrometry (AAS)	Pb, Cd and Cr	-With increasing heavy metal concentrations, blood pressure significantly increased in pregnant women with hypertension compared to that in the control group. Heavy metal concentrations were higher in pregnant women who smoked than in non-smokers.	54
Canada, 2023	Pregnancy cohort	1560 pregnant women	Blood samples from the first and third trimesters of pregnancy	Inductively coupled plasma mass spectrometry (ICP-MS)	Pb, Cd, As and Hg	- Increased concentrations of Pb and As in the blood increase the risk of preeclampsia and gestational hypertension.	52
Japan, 2025	Pregnancy cohort	88670 pregnant women	Blood samples from the second and third trimesters of pregnancy with blood pressure ≥ 140/90	ICP-MS	Pb, Cd, and Hg	- A positive and significant association was observed between exposure to heavy metals Pb, Cd, and Hg with hypertensive disorders of pregnancy	53
China, 2022	A case-control study	146 women with gestational hypertension and 292 normal pregnant women in the control group	Blood sample at 10 and 16 weeks of pregnancy with blood pressure ≥ 140/90	ICP-MS	Pb, Hg, Cu, Al, Ni, and V	- Positive and significant association was observed between exposure to heavy metals Hg, Al, Ni and V with hypertensive disorders of pregnancy The highest odds ratio was observed for exposure to Hg.	29
Poland, 2019	A case-control study	121 pregnant women with high blood pressure and 363 pregnant women with normal blood pressure	Blood samples of Pregnant women with blood pressure ≥ 140/90	ICP-MS	Cu and Zn	- Low blood Cu levels in early pregnancy were significantly associated with an increased risk of gestational hypertension in pregnant women	56

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Strategies to reduce heavy metals exposure in pregnant women

Given the health risks of toxic heavy metals exposure and the vulnerability of pregnant women and fetuses during pregnancy, it is essential to pay attention to strategies for preventing and reducing exposure to heavy metals. Studies show that strategies for reducing exposure to toxic heavy metals for pregnant women, fetuses, and children in early life can include the production and use of organic agricultural products and foods that are free of heavy metals, especially rice and wheat (bread) as commonly consumed foods. Also, the use of home air purifiers, especially in industrial areas during pregnancy and early life, can be an effective strategy to reduce exposure to particulate matter (PM) containing toxic heavy metals [62, 63].

Lifestyle changes, especially in the nutrition and diet, are also effective in reducing blood pressure during pregnancy. It is recommended to use diets containing essential nutrients that can reduce the bioaccumulation of heavy metals and increase their excretion. For example, foods rich in iron and calcium can reduce the bioaccumulation of Pb in the body, or selenium, which is effective in reducing the bioaccumulation of Hg [64]. A healthy diet containing protein, dairy products, especially milk, vegetables and fruits prepared organically can also play a significant role in the excretion and reduction of heavy metal concentrations from the body [65]. The results of studies also show that diet can also play a role in pregnancy-induced hypertension. Potential positive effects of certain nutrients such as magnesium, omega-3 fatty acids and vitamins with antioxidant properties in HDP prevention confirmed in several studies [52].

Increasing public awareness, especially among pregnant women, about the dangers and risks associated to toxic heavy metals exposure in order to increase the perceived sensitivity and practice of this group of people to reduce consumption of food or water contaminated with heavy metals can be effective in reducing potential impacts [66]. The use of advanced methods for treatment of contaminated water and soil resources, such as phytoremediation, as well as the use of membranes processes for advanced purification of drinking water can also contribute to reducing exposure to heavy metals [67]. Sustainable development, monitoring and surveillance of agricultural products, food and drinking water distributed in different areas are also long-term solutions to reduce exposure to heavy metals [68].

Conclusion

In this study, a review of studies related to pregnant women's exposure to heavy metals and their effects on HDP was conducted. Studies show that the most important heavy metals affecting HDP are include Pb, Cd, Hg, As, and Cu at high concentrations. The mechanism of HDP caused by heavy metals exposure in pregnant women includes an increase in lipid peroxides and oxygenated free radicals and the creation of disorders or damage to endothelial cells. Prevention and reduction strategies to reduce pregnant women's exposure to heavy metals are include the use of organic food products free of heavy metals, the use of home air purifiers. Consequently, the use of organic food products, the use of home water or air purifiers, the use of foods rich in iron, calcium and selenium and a healthy diet containing antioxidants such as dairy products and organic vegetables and fruits can be strategies to reduce the exposure of pregnant women to heavy metals.

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Conflict of Interest

The authors declare no relevant financial or non-financial interests.

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Ethical Considerations

Not applicable

Code of Ethics

Not applicable

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Authors' Contributions

All authors contributed to the study conception and design. Studies search and review were performed by H. E. and F.D.B.. The first draft written and revision of the manuscript were performed by H.E, F.D.B, and M.A. All authors approved the final manuscript.

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