Environmental and occupational exposure to cadmium in Iran: a systematic review

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Abstract

Introduction: Cadmium (Cd) is one of the heavy metals that have negative effects on human health. In Iran, there is no policy to regularly measure Cd in the general population. However, some studies have been performed on special groups and in different cities of Iran. This paper has reviewed these studies and human contamination levels in Iran.

Method and materials: All accessible electronic information resources such as Scientific Information Database (SID), Magiran, IranMedex, PubMed, Web of Knowledge, Google Scholar and Science Direct were searched, with relevant phrases and their Persian translations. The search included all studies conducted in Iran and listed in the databases until March 15, 2016.

Results: Eventually, 18 articles were selected from 25 retrieved articles. Cd was higher among industrial workers exposed to Cd. In the general population, Cd was higher among smokers and in people with environmental exposure from living in industrial areas.

Conclusion: Considering the high Cd contamination in the workers of industries, it seems to be necessary to do surveillance in this group through periodic regular check-ups and avoiding unnecessary exposure to Cd as much as possible. Also due to the high concentration of Cd in smokers, there should be more awareness of the damaging effects of smoking, especially among pregnant women, and more attention to local industries, especially those dealing with Cd, is necessary. These industries should be kept at a safe distance from residential areas.

Keywords: cadmium; environmental exposure; heavy metals; Iran.

Introduction

Heavy metals are toxic metals that independently or in combination with other chemicals have negative effects on human health. These metals can be hazardous in even small amounts and endanger human health (1). Cadmium (Cd) is one of these metals. It has a bluish white color, is soft and flexible and can be found naturally in the earth’s crust (2). Cd is used in nickel-cadmium batteries, pigments, stabilizers and coatings (3).

In nature, Cd enters the environment through volcanic activities on the earth or in the depths of the sea, remobilization of old sources such as groundwater pollution caused by drainage water from mines and human activities like smoking, melting and using fossil fuels (4). Cd can widely spread in the environment. For example, Cd can contaminate air through suspended particles from industries or through smoking. Cd in suspended particles can reach humans after entering soil, water, plant and animal tissues (5).

According to the International Cadmium Association (ICdA), the expected amount of Cd in suspended particles varies from 0.1 to 5 ng/m³ in rural areas, 2 to 15 ng/m³ in urban areas and 15 to 150 ng/m³ in industries. Also, the acceptable amount of Cd in an occupational environment is 2–50 ng/m³. Cd should be measured routinely in the urine and blood of workers exposed to this chemical in occupational exposure (5).

In smokers, exposure to Cd mainly occurs through smoking; there is 0.5–2 μg of Cd in every cigarette (5). There are also high amounts of Cd in plant and animal foods such as lettuce, spinach, potatoes, beans, peanuts, soybeans, sunflower seeds (30–150 ppb), fish and meat (5–40 ppb), with the exception of these animals’ livers and kidneys, where the amount of Cd reaches 1000 ppb (5).

According to the latest report in 2010 and by consensus of the International Organization of Food and Drug Administration (FAO) and the Joint Expert Committee for Food Additives (JECFA), generally, the acceptable level of Cd intake from food and other agricultural products per month is 25 μg/kg of body weight (4).

Evidence shows that Cd levels are high in people exposed directly. A study by Hallen et al. in Sweden
showed that although the total amount of Cd in blood and milk samples of mothers in the area close to the melting furnace was not significantly different from the control group, the level was significantly higher in smokers (6). The study of Grasmick et al. in France showed that not only is Cd higher in smokers, but also the use of alcohol makes the situation worse and can increase blood Cd levels in these people (7). Also in Lauwerys et al. study, in Belgium, the amount of Cd was significantly higher in blood and urine samples of people occupationally exposed (8).

As noted before, Cd and its compounds are toxic to humans and have a destructive effect on the respiratory and digestive systems, skin and especially kidneys and bones (9). Studies have shown that bone mineral density decreases and urinary protein level increases in people with higher blood Cd levels (10), also Cd increases bone resorption and probably has a direct osteotoxic effect with increased calcuiura and reactive changes in calcium hormones (11). Cd even at low environmental exposure levels may increase skeletal demineralization, enhance bone fragility and facilitate bone fractures (12).

The results of Vincent et al.’s study in Italy indicated that there was a strong relation between exposure to Cd (especially at high levels) and prostate cancer [odds ratio (OR) = 4.7] (13). Also, the study of Nawrot et al. in Europe’s general population showed that an increase of Cd in 24 h excretion has a significant relation with the total risk of cancer (HR = 1.31), and the attributable risk for lung cancer in regions exposed to high Cd was 67% (14).

Studies have also suggested that Cd interferes with nervous system functions and exposure to Cd may cause cognitive impairment in adults (15), slowing of vasomotor functions, peripheral neuropathy, impaired equilibrium and decreased concentration ability (16).

In Iran, there is no policy for regularly measuring Cd in the general population. However, some studies have been performed on special groups and in different cities about measuring human contamination levels with Cd. The current paper attempted to review these studies.

**Methodology**

**Literature sources and searching methods**

All available electronic information resources, including SID, Magiran, IranMedex, PubMed, Web of Knowledge, Google Scholar and Science Direct, with these phrases “cadmium poisoning, cadmium toxicity, cadmium measuring, cadmium exposure, occupational exposure to cadmium, environmental exposure to cadmium, heavy metals” and their Persian translations were searched until March 15, 2016.

**Inclusion criteria**

Among them, the original studies investigating occupational or environmental exposure to Cd in Iran and which measured Cd levels in human tissues such as blood, hair, saliva, milk and urine were included in this study. Studies done outside Iran or on non-human samples were excluded.

**Data extraction**

All articles were reviewed by two people separately. Information including first author, year of data collection, population, sample size of population, mean and standard deviation of Cd levels and location were retrieved from each article.

**Statistical analysis**

The population under study in included articles was very heterogeneous. Therefore, the authors decided not to merge the data in a meta-analysis and report the levels in each of the different populations.

**Results**

Eventually, 18 articles (as seen in Table 1) were selected from 25 retrieved studies. According to the study results presented in Table 1, Cd contamination levels are high among industrial workers exposed to Cd (23, 26). Also, in the general population, Cd levels are higher among smokers (17, 32) and in people with environmental exposure to Cd living in industrial areas (28–30).

**Discussion**

**Environmental exposure to Cd**

In the general population, people are indirectly contaminated with Cd following exposure to contaminants in the air, water, soil and food or directly by smoking (5). The level of contamination is different depending on its type and severity. The results of a study by Tadayon et al. showed that the level of Cd in people living in Tehran is more than double the people living in Tekab. Tekab is a small non-industrial city in West Azarbaijan Province with a population of 81,000 in 2006, located 540 km from Tehran (30). This can be related to the greater density of the factories and industries, also more buildings and population density in Tehran. Also bigger populations use
Table 1: Summary of studies performed on human contamination with Cd in Iran.

<table>
<thead>
<tr>
<th>First author and year of data collection (reference)</th>
<th>Population</th>
<th>Sample</th>
<th>Mean±SD of Cd levels</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tadayon, 2009–2010 (27)</td>
<td>250 Women (108 diabetics type 2 and 142 healthy people)</td>
<td>Hair</td>
<td>Diabetes = 0.192 ± 1.53 µg/g, Healthy = 0.076 ± 0.6 µg/g</td>
<td>Tehran</td>
</tr>
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<td>Norouzi, 2007–2008 (28)</td>
<td>80 Mothers (63 mothers from Lenjan and 17 mothers from Konjedjan)</td>
<td>Breast milk</td>
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<td>Dahaghin, 2003–2005 (29)</td>
<td>330 Pregnant women</td>
<td>Blood and umbilical cord</td>
<td>Blood = 2.3 ± 0.51 µg/L, Umbilical cord = 0.34 ± 0.4 µg/L</td>
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<tr>
<td>Tadayon, year not reported (30)</td>
<td>212 People (172 people from Tehran and 40 people from Tekab)</td>
<td>Hair</td>
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| Farzin, year not reported (32)                       | 101 Volunteers (61 men and 40 women) | Blood | Males = 1.88 ± 0.73 μg/L  
Females = 1.72 ± 0.78 μg/L  
Total = 1.82 ± 0.67 μg/L | Tehran |
|                                                       |            |        | Males:                  |          |
|                                                       |            |        | – Smoker (n = 19) = 2.18 ± 0.89 μg/L  
– Non-smoker (n = 42) = 1.74 ± 0.66 μg/L |          |
|                                                       |            |        | Females:                |          |
|                                                       |            |        | – Smoker (n = 10) = 2.05 ± 0.84 μg/L  
– Non-smoker (n = 10) = 1.61 ± 0.62 μg/L |          |
| Mohajeri, 2005–2006 (33)                             | 80 People (40 patients with kidney disease and 40 healthy people) | Blood | Patients = 2.6 μg/L  
Healthy people = 1.18 μg/L | Tehran |
| Vigeh, 2003–2004 (34)                                | 396 Pregnant women (31 pre-eclampsia and 365 healthy pregnant women) | Blood | Pre-eclampsia = 0.54 ± 0.31 μg/L  
Healthy pregnant women = 0.5 ± 0.3 μg/L | Tehran |

Occupational exposure to Cd

Cd is one of the main heavy metals used in industries. Workers may be exposed to Cd during metal smelting or purifying, making batteries, plastics, coating and solar panels. Occupations including electroplating, metal machining, welding, painting, landfilling, waste collection and recycling or electronic parts or plastics may be exposed to Cd. Exposure of workers to Cd can also occur in manufacturing, wholesale trade and transportation (44).

Regular measurement of Cd levels in workers' urine and blood has been recommended in industrial settings. Cd can also be released into the environment and eventually have a greater exposure to it. More material containing Cd and release it into the environment, occupational and blood samples have been collected in Tehran and other cities in Iran. Cd levels in the blood of a group of volunteers in Tehran and showed that Cd increases significantly in elderly people and smokers (32). These results are similar to the results of Elinder et al. in America, Ellis et al. in Canada and Zenzes et al. in Sweden that showed Cd levels in smokers are generally higher than non-smokers (35–37). Mannino et al.'s study showed that higher levels of Cd in blood and Cd may be an independent risk factor in causing high blood pressure (38). Also, a study from the USA indicated that Cd even at levels below the current safety standards may cause peripheral arterial disease (39). The results of a study from pregnant women in Tehran showed that Cd levels were significantly lower in pregnant smokers (26%) than the non-smokers (28%) (32). Also, a study from the USA showed that higher levels of Cd in blood and Cd may be an independent risk factor in causing high blood pressure (38). The current safety standards may cause peripheral arterial disease (39). The results of a study from Pregnant women in Tehran showed that Cd levels were significantly lower in pregnant smokers (26%) than the non-smokers (28%) (32). Also, a study from the USA showed that higher levels of Cd in blood and Cd may be an independent risk factor in causing high blood pressure (38). The current safety standards may cause peripheral arterial disease (39). The results of a study from Pregnant women in Tehran showed that Cd levels were significantly lower in pregnant smokers (26%) than the non-smokers (28%) (32). Also, a study from the USA showed that higher levels of Cd in blood and Cd may be an independent risk factor in causing high blood pressure (38). The current safety standards may cause peripheral arterial disease (39).
(5) as Cd levels have been reported to be higher in industrial workers than the general population. Kargar et al. in Yazd investigated Cd levels in the urine of the glazers and showed that urine levels were significantly higher after working hours, and this amount increased more than three times compared to the amount taken before working hours and people working in administrative units in the same company (23). Thun et al. investigated the effect of Cd exposure on nephropathy in workers who recovered Cd from industrial waste. Their study indicated that cumulative exposure to Cd (exceeding 300 mg/m³ days) increased the probability of multiple tubular abnormalities and raised serum creatinine concentration (45).

The results of Golbabaei et al.’s study in Brojen showed that Cd in urine of natural gas pipe welders was higher than the people working in other units (26). Jarup et al. in Sweden showed that the occupational exposure of workers to Cd even at low levels can increase urine protein and damage kidneys (46). Also, the results of Alfven et al.’s study in Sweden are similar to the results of Jarup et al. ’s study and showed that the subgroup with the highest Cd blood level had a four-fold risk of tubular proteinuria compared to the subgroup with the lowest level. Also in the age group above 60 years, the risk of low bone mineral density for the group with the highest blood Cd levels was almost three-fold in comparison to the group with the lowest levels. Their study supports previous evidence that Cd exposure may affect both bone mineral density and kidney function (10). Palus et al. showed that Cd can induce clastogenic and aneugenic effects in peripheral lymphocytes and suggested that significant exposure to Cd is a potential health risk to working populations (47). These results show the importance of monitoring occupational groups exposed to Cd.

The exposure of children and mothers to Cd

Although the amount of Cd transferred through the umbilical cord to the fetus is low, but evidence suggests that it has short- and long-term effects on the fetus. Studies have mentioned low growth, low birthweight, small head circumference, short height and small for gestational age as the short term effects (48–53). Other researchers have even mentioned fetus death due to reduced oxygen and nutrient transfer (54).

The results of a study by Dahaghin et al. in Tehran showed that despite elevated maternal blood Cd levels, Cd was trivial in the umbilical cord. It was also reported that maternal blood Cd concentration was related to low birthweight but it did not show a significant relation with Cd levels in the umbilical blood (29). This can be related to the indirect effects of maternal blood Cd and the disturbance it causes in transferring oxygen and nutrients to the fetus which leads to low birthweight. However, Nejadchehrzazin and Moghadam Banaem measured Cd in maternal umbilical cord blood of 75 pregnant women and reported a significant relationship between the amount of Cd in maternal and umbilical cord blood (r = 0.734) (25). In another study performed by Savabieasfahani et al. in Tehran, Cd levels in the hair of newborns were twice the Cd levels in the hair of mothers and these values were significantly lower than those in England (mother = 490 μg/kg and newborn = 570 μg/kg) and higher than those in Iraq (mother = 75 μg/kg and newborn = 57 μg/kg) (22).

Pashmi and Pourkhabbaz in Birjand measured Cd levels in 5- to 12-year-old children’s deciduous teeth and reported that the concentrations were higher in sectorial teeth and in boys (21). Also, Kelishadi et al. measured Cd levels in the blood of students aged 10–18 years in Isfahan. They reported no significant difference between Cd levels in children with metabolic syndrome and healthy people, but Cd concentrations were high in both the groups (18).

Mothers are among the sensitive groups, and Cd transfer from the mother to the fetus has been investigated in some studies. The results of a study by Ebrahim and Ashtarinejad in 2015 on 341 pregnant women in Tehran showed that Cd concentrations in the amniotic fluid were significantly related to the mothers’ smoking habit (measured by thiocyanate levels in the mother’s plasma) (r = 0.882). Also the prevalence of preeclampsia among smokers (26%) was significantly higher than non-smokers (10.5%) (p < 0.05) (17), which might be related to higher Cd levels or other factors. Nazarpour et al. in Varamin in 2013 measured Cd levels in the breast milk of mothers visiting health centers and found that the Cd concentration in the milk of mothers living near industrial regions was significantly higher than others. This amount was even higher than the international standard (19). The results of Norouzi et al. in 2010 in the industrial area of Lenjan in Isfahan which is close to the Mobarakhe steel melting furnaces showed that Cd in the milk of mothers in Lenjan was significantly higher than the mothers in the control group who were from Konjedjan, a non-industrial rural area in Golpayegan (28).

Nishijo et al. in Japan showed that transmission of Cd from mothers to children not only happens during the prenatal period, but also after birth and through breastfeeding (51). Considering the undesirable effects of Cd on the fetus and newborn, women should be informed about the hazardous consequences of smoking not only during pregnancy but also after delivery.
Also, Abdolsamad et al. in Hamadan showed that the amount of Cd in the saliva of pregnant mothers with gestational diabetes was higher than healthy pregnant women (24). Finally, in a study by Vige et al. in Tehran, Cd levels were measured in the blood and umbilical cord blood of 396 pregnant women, but the results showed no relation between preeclampsia and Cd levels (34).

Conclusion

Considering the high Cd contamination levels in industrial workers, these workers have to be checked regularly and should avoid unnecessary exposure to Cd as much as possible. Also, due to the high concentration of Cd in smokers, more awareness about the damaging effects of smoking, especially in mothers, is needed. Meanwhile, the location of industries, especially those dealing with Cd, should be kept at a safe distance from human residence.

References
