Science of the Total Environment 635 (2018) 308–314

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Lead and cadmium levels in raw bovine milk and dietary risk assessment in areas near petroleum extraction industries

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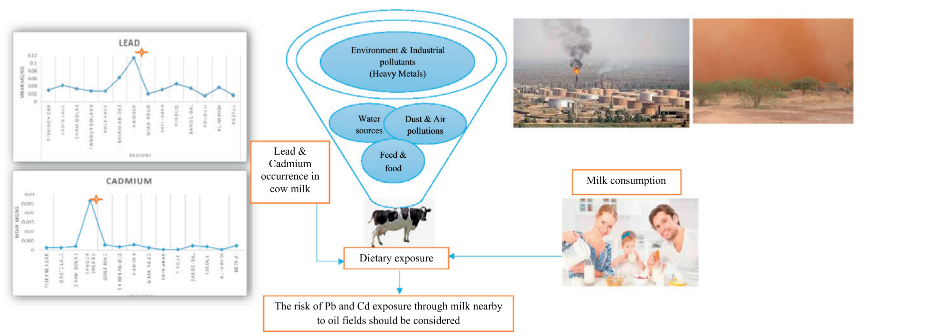
HIGHLIGHTS

- Oil fields are a source of pollution by heavy metals.
- Pb and Cd have been measured in cow milk, fodder and water in SW of Iran.
- Most samples for Pb (82%) were above the permissible limits.
- Mean exposure to Pb and Cd are below tolerable weekly intake for all age groups.
- A continuous monitoring of these contaminants in milk is recommended.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 18 February 2018
Received in revised form 8 April 2018
Accepted 9 April 2018
Available online xxxx

ABSTRACT

Oil fields are a source of heavy metal pollution, but few studies have evaluated its impact on the intake of these contaminants through milk, an important food especially for children. From February 2015 to 2016, 118 samples of raw cow's milk, 14 of fodder and 8 of water in Southwest Iran were collected from farms close to oil fields or related industries. Lead (Pb) and cadmium (Cd) levels were evaluated by graphite furnace atomic absorption spectrometry. Mean ± SE in milk and fodder were 47.0 ± 3.9 and 54.0 ± 6.9 μg/kg for Pb, and 4.7 ± 1.0 and 3.5 ± 1.3 μg/kg for Cd. No Pb or Cd was detected in water. Most milk samples (82.2%) for Pb were above the

Abbreviations: CONTAM, Panel on Contaminants in the Food Chain; EFSA, European Food Safety Authority; EPA, Environmental Protection Agency; IARC, International Agency for Research on Cancer; JECFA, Joint FAO/WHO Expert Committee on Food Additives; MI, monthly intake; PTMI, provisional tolerable monthly intake; TWI, tolerable weekly intake; WI, weekly intake.

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https://doi.org/10.1016/j.scitotenv.2018.04.138
0048-9697/

Editor: F.M. Tack

Keywords:
Raw cow milk
Lead
Cadmium
Heavy metals
Exposure assessment

permissible limits (20 μg/kg). Exposure to Pb and Cd from milk consumption was calculated in two scenarios: mean and maximum exposure for the age range of 2–90 years. The intake of an average Iranian adult (25 years, 60 kg b. w., 0.14 kg milk/day) would be 6.6 μg Pb and 0.66 μg Cd/day (WI of 46.2 and 4.6 μg, respectively), well below the risk values proposed by some international organizations, even in the maximum exposure scenario. However, Pb exposure for infants and toddlers may be closer to the risk values, since milk and milk products could be the main contributor to Cd and Pb, and small children consume 2–3 times more food than adults relative to their body weight. The risk of Pb and Cd exposure through milk close to oil fields should be considered and a monitoring plan for these contaminants is strongly recommended.

1. Introduction

Milk is an important nutritious food, especially for children, in many parts of the world. The risk of milk contamination increases in the vicinity of highly polluted areas. Oxidants, nitrates, agricultural pesticides, industrial chemicals, and heavy metals could be potential contaminants of milk (Swarup et al., 2005; Patra et al., 2008).

Sources of heavy metal contamination include combustion of fuels, the proximity of roads, mining and industrial areas, and specifically, iron and steel plants (Swarup et al., 2005; Singh et al., 2011; Tunegová et al., 2016). Plants from land irrigated with contaminated water allow heavy metals to pass into the atmosphere, land, water and then to animal feed. Through this route it enters the trophic chain and is finally ingested by animals and people (Patra et al., 2008; Singh et al., 2010; Perween, 2015).

Heavy metals such as lead (Pb) and cadmium (Cd) have negative effects on livestock health (Rahimi, 2013; Lane et al., 2015), as well as harmful effects on human health (Perween, 2015). This problem is more important for children, who consume large amounts of milk, and are the most vulnerable population.

Pb and Cd are not essential for animals and plants. These metals are potentially toxic, causing hematologic, neurotoxic, and nephrotoxic effects even at low concentrations. Human exposure to these heavy metals has a negative effect on specific organs that may lead to metabolic disorders, fatigue, heart failure, and cancer. Furthermore, both chronic and acute exposure to Pb can result in encephalopathy (vomiting, depressed consciousness and lethargy), and it also decreases the learning ability in childhood (EFSA, 2010; JECFA, 2011; EFSA, 2012). Thus, Pb and Cd monitoring in milk must be considered as a fundamental part of public health and product quality (Rahimi, 2013; Tunegová et al., 2016).

The concentration of heavy metals in milk produced in some areas varies greatly, due to the differences in the contamination source (Swarup et al., 2005; Ataro et al., 2008). To the best of our knowledge, no studies have been carried out on the concentration of heavy metals in milk from livestock living close or exposed to contamination from oil extraction activities, not only pumping but also transport and processing, perhaps a consequence of dominant winds. Because oil fields are a source of Pb, Cd and other heavy metal contamination, our objective was to estimate the level of Pb and Cd contamination in cow's milk, as well as water and fodder, by studying an area of Southwest Iran exposed to contamination not only from nearby oil fields, but also to contaminated areas because of the Iran-Iraq war, and oil-related facilities (pipelines, and refineries). By studying that area, we aimed at testing the hypothesis that Pb and Cd levels are elevated in the water and fodder produced locally, as well as elevating heavy metal pollution in milk. In addition, we estimated the population's exposure to these two heavy metals from milk consumption, in order to assess the risk level in these areas.

2. Materials and methods

2.1. Characteristics of the studied area

Southwest Iran has differential characteristics from the rest of the country. Oil and gas extraction, transport, processing and distribution of their derivatives are sources of contamination (Lane et al., 2015). Moreover, the fine dust entering from Iraq and Saudi Arabia transfers many contaminants to these areas, with war and political-military conflicts making things worse (Ashrafi et al., 2014). Dez river, which flows through eight provinces of Southwest Iran moves contaminants downstream, significantly increasing the risk of contamination in some areas.

2.2. Sampling design

Convenient sampling was performed on 15 dairy farms located in 14 different regions of Southwest Iran (Khuzestan province), including industrial or traditional farms. Samples of milk, food and water were obtained based on the existing most representative livestock in the investigated area. Most farms were located in the Dezful area, except for two farms in the Shirin Ab-Dez region (Fig. 1, farms A and B). Fig. 1 shows farms are North or North-East relative to many oil fields and their facilities, and to current or former war areas (Iraq/Saudi Arabia). Therefore, these areas are exposed to contaminants not only by proximity to contamination sources but also because of the predominant South/Southwest winds.

Immediately after milking, 200 ml raw cow milk was collected in pre-acid wash sterile screw-topped bottles. Before sampling, all the dishes were kept in 10% nitric acid for 24 h, then washed with deionized water for 48 h and dried in an incubator. The same method was used to collect water samples and fodder samples. All samples were kept at −80 °C until the time of measurement. This study included 118 milk samples distributed as shown in Tables 1 and 2, eight water samples, and 14 fodder samples.

2.3. Pb and Cd analyses

All reagents were purchased from Merck KGaA Laboratories (Darmstadt, Germany). According to Iranian National Standard Determination of Food Pb and Cd Content (INS method No. 9266 and AOAC official method 999.11 standards), the samples were dried and then ashed at 450 °C under a gradual increase in temperature. 6 M HCl (1 + 1) was added, and the solution was evaporated to dryness. The residue was dissolved in 0.1 M HNO_3, and Pb and Cd were measured with a graphite furnace atomic absorption spectrometer (Varian-SpectrAA 600), equipped with a platform graphite tube and a deuterium background corrector. A blank digestion solution was made for comparison.

To check the accuracy of the analytical method, a multi-element standard solution (Merck) with different concentrations of Cd and Pb (0.2, 1, 10, 50 and 100 μg/kg) was used for calibration. The standard curve was performed with a concentration range of 5, 10, and 30 μg/kg for Pb and 0.5, 1.0, and 1.5 μg/kg for Cd.

The precision of the method was expressed as recoveries close to 100% (95–110% for Pb and 80–97% for Cd), with a standard deviation (SD) of the recoveries lower than 0.010, and with a relative standard deviation (RSD) lower than 10% for both metals. Limit of detection (LoD) and limit of quantification (LoQ) was 3 and 9 μg/kg, respectively for Pb measurement and 0.4 and 1.2 μg/kg, respectively for Cd measurement. Duplicate analysis was performed for all samples.