Pesticide Residues in Human Milk: Health Impacts on Infants and Nursing Mothers

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Received: 2nd August, 2023; Accepted: 22nd September, 2023; Published online: 9th October, 2023

https://doi.org/10.33745/ijzi.2023.v09i02.094

Abstract: Human breast milk is the only natural food of newly born infant as it provides essential nutrients and other supplementary requirements to support the growth and development of natural immunity during early infancy. Children provided with breast feeding up to 6 months after birth, show healthy growth with reduced chances of gastrointestinal diseases and other ailments. Presence of pesticide residues and other persistent organic pollutants in human breast milk posed a major and increasing threat to health of infants and also to the nursing mothers. This review aims to discuss the various aspects of pesticide residues in human milk and its adverse health impacts on infants and nursing mothers. It was noted that, various pesticides are still the major contaminants of human milk. Therefore, monitoring of human milk samples should be practised on a larger scale. General symptoms of pesticide residue toxicity of human milk include weakness, headache, backache, joint pain, fever, hepatitis, liver dysfunction, chest pain, respiratory discomfort, and hypertension. Safety measures recommended should include, dietary intake assessment of foods of different animal origin, monitoring of human milk samples, strict government guidelines for application of pesticides, and use of personal protection kits by women working in agriculture fields, and other areas where they are exposed to pesticides.

Keywords: Human milk, Bioactive factors, Colostrum, Infants, Organochlorines, Organophosphates, Pesticide residues, Pyrethroids, Nursing mothers


https://doi.org/10.33745/ijzi.2023.v09i02.094

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Introduction

Milk is the secretory fluid of the mammary glands of female mammals and contains nearly all the nutrients necessary to sustain life (Grosch, 2008). It is a whitish liquid containing milk proteins, fats,
lactose, and various vitamins and minerals, produced by the mammary glands of all adult female mammals after childbirth and serves as food for their young (Mourad et al., 2014). Milk has been known as nature’s most complete food and play an important role in the diet of over 6 billion people in the world (Widyastuti and Febrisiantosa, 2021).

WHO (2003) noted that, human milk is the first food received by the baby since breast milk is well adapted to the needs of the infant and it was recommended universally to breast feed the baby at least for first 4-6 months of life (Mane et al., 2018). Human breast milk provides complete nutrition and many bioactive health factors. Breast feeding is associated with improved infant health and immune development, less incidences of gastrointestinal disease and lower mortality rates than formula fed infants (Lyons et al., 2020).

Human milk is uniquely suited to the human infant, both in its nutritional composition and in the non-nutritive bioactive factors that promote survival and healthy development. It contains many hundreds to thousands of distinct bioactive molecules that protect against infection and inflammation and contribute to immune maturation, organ development, and healthy microbial colonization (Ballard and Morrow, 2013).

Human milk not only provides the perfectly adapted nutritional supply for the infant but also plays a crucial role in promoting healthy growth and development (Mosca and Gianni, 2017). It is the best food for new-born nutrition and it provides protection for the health of the infant during the first weeks of life (Boquien, 2018). Human breast milk is essential for the infant's growth and development right after birth and is an irreplaceable source of nutrition for early human survival (Kim and Yi, 2020).

Composition of human milk:
Ballard and Morrow (2013) reported that composition of human milk is the biologic norm for infant nutrition. Composition of human milk is dynamic, and varies within a feeding, diurnally, over lactation, and between mothers and populations. Macronutrients present in 100 g of human milk consist of ash (0.2), energy (65 kcal), fat (3.2 g), lactose (7.2 g), protein (1.2 g) and water (87.5 g). Micronutrients present in human milk are vitamins (A, B1, B2, B6, B12, D) and minerals and trace elements (Ca, P, Mg, S, N, Na, K, Cl, Fe, Cu, Zn, Co, I) (FAO, 2013).

Major bioactive factors present in human milk consists of Cells (Macrophages, Stem cells); Immunoglobulin's (IgA, IgG, IgM); Cytokines (IL-6, IL-7, IL-8, IL-10); Chemokines (G-CSF, MIF); Cytokine Inhibitors (TNFR I and II); Growth factors (EGF, HB-EGF, VEGF); Hormones (Calcitonin, Somatostatin, Adiponectin, Leptin, Ghrelin); and Anti-microbial (Lactoferrin, Lactadherin) (Ballard and Morrow, 2013; Haschke et al., 2016; Salama, 2017).

Health benefits of human milk (Yi and Kim, 2021):
- Growth and development.
- Intestinal colonization.
- Immunity development.
- Host immunization.
- Prevention from diseases.
- Psychosocial development: Breastfeeding promotes the emotional relationship, or bonding, between mother and child (UNEP, 2017).

Therapeutic value of human milk (Witkowska-Zimny et al., 2019):
- Natural medicine and health impacts are life-long (Sheila and Bungun, 2003).
- Treatment for diaper rash, atopic eczema, diaper dermatitis, and umbilical cord separation (Allam et al., 2015).
- Protection against diabetes mellitus, obesity, hyperlipidemia, hypertension, cardiovascular diseases, autoimmunity, and asthma (Witkowska-Zimny et al., 2019).
Fresh colostrum and human milk were used to treat conjunctivitis, chapped nipples, rhinitis, infections of the skin and soft tissues (Witkowska-Zimny et al., 2019).

Support early human growth and development (Kim and Yi, 2020).

Reduced risks of otitis media, acute diarrhoea, lower respiratory tract infections, sudden infant death syndrome, inflammatory bowel disease, juvenile leukemia, diabetes, obesity, asthma, and atopic dermatitis (Yi and Kim, 2021).

Lowers mortality against infectious diseases (Yi and Kim, 2021).

**Pesticides: Definition, Types, Benefits and Adverse effects:**

Pesticide is defined as a chemical designed to combat the attacks of various pests and vectors on agricultural crops, domestic animals, and human beings (Şahin et al., 2017). Any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest, including insecticide, herbicide, fungicide, and various other substances used to control pests are called as, pesticides (EPA, 2009).

Pesticides are classified on the basis of mode of action and/or mode of entry or the approach by which a pesticide controls or kills the target pest, chemical structure, the features of pesticides, and the character of the target pests (Hassaan and Nemr, 2020). On the basis of chemical composition, pesticides are categorized into organochlorine, organophosphate, pyrethroids, carbamates and bio-pesticides (Nayak and Solanki, 2021).

Pesticides are also categorized into subtypes such as: acaricides (kill mites, ticks and spiders); fungicides (kill fungi and moulds); herbicides (kill weeds or prevent growth of weeds); insecticides (kill or repel insects and related species); molluscicides (kill snails, slugs, etc.); nematicides (kill nematodes); rodenticides (kill rats, mice, moles and other rodents); and miscellaneous pesticides (kill or repel pests of all types).

Pesticides have applications in agriculture (for control of weeds, pests, rodents etc.); domestic (household and garden spray, control of animals and birds); material building (incorporation of paints, glues, plastic protection sheeting, foundation of buildings etc); personal (for application of clothing and skin care); and public health (for control of malaria, dengue fever, cholera) (Gyawali, 2018). Environmental impacts of pesticides include contamination on natural environment (water, soil, air); impact on food safety, non-target organisms; and threats to aquatic and terrestrial biodiversity (Poudel et al., 2020). Impacts of pesticides on human health include neurotoxic, genotoxic, carcinogenic, and reproductive effects (Shah, 2020).

**Pesticide Residues:**

Pesticide residues includes any derivative of a pesticide, such as conversion products, metabolites, reaction products and impurities considered to amounts of residues primarily depend on nature of pesticides, environmental conditions, good agricultural practices, waiting periods and storage conditions (Mondal et al., 2021).

Pesticides are commonly used in agriculture to enhance crop production and control pests. After application of pesticides to soil or used to treat crops, they are capable of migrating within various environments and, ultimately, accumulate in food chains or persist as degradation products (Pirsaheb et al., 2015; Silva et al., 2019). Pesticide residues can persist in the environment and agricultural crops. It can produce long-term negative effects on the health of humans and animals and stability of ecosystems by molecular mechanisms that mediate the start of a cascade of adverse effects (Valeriya et al., 2021).

To control the presence of pesticide residues in fresh milk and milk products is a big issue for producer, consumer and government due to the potential risk (Makadiya and Pandey, 2017).
<table>
<thead>
<tr>
<th>Pesticide residue detected</th>
<th>Area</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>3’BHC, Dieldrin, DDE, TDE, DDT, Total DDT</td>
<td>Iranian Nursing Mothers</td>
<td>Hashemy-Tonkabony and Fateminassab (1977)</td>
</tr>
<tr>
<td>Dieldrin, Heptachlor epoxide, PCBs, DDT (including metabolites)</td>
<td>United States and Canada</td>
<td>Calabrese (1982)</td>
</tr>
<tr>
<td>Endosulfan, Malathion, Chlorpyrifuos, Methylparathion, R-HCH</td>
<td>Bhopal, Madhya Pradesh, India</td>
<td>Sanghi et al. (2003)</td>
</tr>
<tr>
<td>PCBs, DDT, hexachlorocylohexanes (HCHs), hexachlorobenzene (HCB), chlordane compounds (CHLs), tris-4-chlorophenyl-methane (TCPMe)</td>
<td>Hanoi and Hochiminh city, Vietnam</td>
<td>Nguyen et al. (2004)</td>
</tr>
<tr>
<td>Chlorpyrifuos</td>
<td>Tennessee, Knoxville</td>
<td>Casey (2005)</td>
</tr>
<tr>
<td>DDT and pyrethroid</td>
<td>Ubombo and Ngwavuma districts, KwaZulu-Natal Province, South Africa</td>
<td>Bouwman et al. (2006)</td>
</tr>
<tr>
<td>OCP Lindane (gamma HCH), DDT and it’s metabolites (DDD and DDE)</td>
<td>Armenia</td>
<td>Artashes et al. (2007)</td>
</tr>
<tr>
<td>p,p’-DDT, p,p’-DDE, p,p’-DDD and o,p’-DDT</td>
<td>South African villages</td>
<td>Bouwman et al. (2012)</td>
</tr>
<tr>
<td>Cypermethrin, deltamethrin, malathion</td>
<td>Karachi-Pakistan</td>
<td>Uzma et al. (2012)</td>
</tr>
<tr>
<td>α-HCH, β-HCH, γ-HCH, Σ-HCHs, Aldrin, Dieldrin, Endrin, Σ-Cyclodienes, p,p’-DDT, p,p’-DDD, p,p’-DDE, Σ-p,p’-DDTs, Σ-OCPs</td>
<td>Rosetta region Northern of Delta in Egypt</td>
<td>Abbassy (2017)</td>
</tr>
<tr>
<td>Dichlorvos</td>
<td>Isparta province, Turkey</td>
<td>Şahin et al. (2017)</td>
</tr>
<tr>
<td>α-HCH, β-HCH, γ-HCH, ΣHCHs, HCB, o,ṗ-DDE, p, ṗ-DDE, p, ṗ-DDT, p, ṗ-DDD, Σ-DDTs</td>
<td>Marivan, west of Iran</td>
<td>Shahmoradi et al. (2019)</td>
</tr>
<tr>
<td>Neonic Residues, Acetamiprid-N-desmethyl, imidacloprid</td>
<td>China</td>
<td>Chen et al. (2020)</td>
</tr>
<tr>
<td>Chlorpyrifuos, p, ṗ-DDE, p, ṗ-DDT</td>
<td>North-western Himalayan region of India</td>
<td>Sharma et al. (2020)</td>
</tr>
<tr>
<td>Aldrin, dieldrin, endrin, hexachlorobenzene, α-, β-, and γ-hexachlorocycohexame, pp’,op’-DDT, pp’-DDE, pp’-DDD, alpha and gamma chlordane, heptachlor, mirex and methoxychlor.</td>
<td>Riyadh, Al-Kharj, Al-Jobail and Al-Dammam cities in eastern and central Saudi Arabia</td>
<td>EL-Saeid et al. (2021)</td>
</tr>
<tr>
<td>DDT and its metabolites; p,p’-DDE, p,p-DDD, and o,p’-DDT</td>
<td>South-western Ethiopia</td>
<td>Mekonen et al. (2021)</td>
</tr>
<tr>
<td>Aldrin, Dieldrin, Endrin, Endrin Aldehyde, Endrin Ketone, Heptachlor, Heptachlor-Epoxide Isomer B, Methoxychlor, Alpha-Endosulfan, Beta-Endosulfan, Endosulfan Sulfate, HCH, DDE, DDD, DDT</td>
<td>North-western Poland</td>
<td>Witczak et al. (2021)</td>
</tr>
<tr>
<td>Glyphosate</td>
<td>Francisco Beltrao, Paraná state, Brazil</td>
<td>Camiccia et al. (2022)</td>
</tr>
<tr>
<td>Organochlorines (OCPs): (o,p?-DDE) and (p,p?-DDE)</td>
<td>Kalaburagi district, Karnataka, India.</td>
<td>Prashant and Vijaykumar (2022)</td>
</tr>
</tbody>
</table>
Table 2: Health effects of pesticide residues in human milk on infants and nursing mothers

<table>
<thead>
<tr>
<th>Health Concerns</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carcinogenic (breast cancer).</td>
<td>Krieger et al. (1994)</td>
</tr>
<tr>
<td>Deleterious effects on the immune system.</td>
<td></td>
</tr>
<tr>
<td>Hyporeflexia, convulsions, EEG abnormalities, hepatic disorders and blood dyscrasias.</td>
<td></td>
</tr>
<tr>
<td>Weakness, Headache, Backache, Joint pain, Fever.</td>
<td>Kackar et al. (1999)</td>
</tr>
<tr>
<td>Hepatitis, liver dysfunction, chest pain, Respiratory discomfort, Hypertension.</td>
<td></td>
</tr>
<tr>
<td>Cancer and in extreme cases, death.</td>
<td>Rauh et al., (2011)</td>
</tr>
<tr>
<td>Aberrations in cognitive, behavioural, sensory, and motor development in children.</td>
<td></td>
</tr>
<tr>
<td>Altered reproductive function in males and females.</td>
<td>WHO/UNEP (2012)</td>
</tr>
<tr>
<td>Increased incidence of breast cancer.</td>
<td></td>
</tr>
<tr>
<td>Abnormal growth patterns.</td>
<td></td>
</tr>
<tr>
<td>Neurodevelopmental delays in children.</td>
<td></td>
</tr>
<tr>
<td>Changes in immune function.</td>
<td></td>
</tr>
<tr>
<td>Exposure may result in either acute or chronic effects.</td>
<td>WHO/UNEP (2014)</td>
</tr>
<tr>
<td>Acute effects: Irritation, dermatitis, and death.</td>
<td></td>
</tr>
<tr>
<td>Chronic exposure: Cancer, birth defects, neurotoxicity, neurobehavioral disorders, neurophysiological changes, and adverse effects on reproduction and fertility.</td>
<td></td>
</tr>
<tr>
<td>Adverse effect on the lactation process and content of nutrients in the milk.</td>
<td>Pirsaheb et al. (2015)</td>
</tr>
<tr>
<td>Oxidative damage, biochemical and histopathological alterations.</td>
<td></td>
</tr>
<tr>
<td>Neurotoxicity.</td>
<td>Han et al. (2018)</td>
</tr>
<tr>
<td>Deleterious impacts on the neurodevelopment of infants.</td>
<td></td>
</tr>
<tr>
<td>Can cause a variety of diseases.</td>
<td>Kuang et al. (2020)</td>
</tr>
<tr>
<td>Carcinogenic risks, neurotoxicity, and genotoxicity.</td>
<td></td>
</tr>
<tr>
<td>Destructive effects on the endocrine, reproductive and immune systems.</td>
<td></td>
</tr>
<tr>
<td>Endocrine disruption and reproductive toxicity.</td>
<td>Witczak et al. (2021)</td>
</tr>
<tr>
<td>Gonadal changes, changes in reproductive behavior, an increase in organ malformations (e.g., hypospadias), fetal defects, thyroid dysfunction, etc.</td>
<td></td>
</tr>
</tbody>
</table>

Human milk is contaminated through the contaminated food. These residues are too much persistent. They accumulate in body fat even in breast milk. Therefore, the objective of present study was to review the concentration of pesticide residues in human milk and to generate awareness about the lethal effects of these pesticides on infants and nursing mothers.

Pesticide residues recorded in human breast milk:

Table 1 illustrates the detected pesticide residues in samples of human milk.

Adverse Health Effects on Infants and Nursing mothers:

Table 2 illustrates the various health effects of pesticide residues in human milk in infants and nursing mothers.

Safety measures for pesticide residues in human milk:

- Monitoring of foods of animal origin, fishes, vegetables, fruits and grains for pesticide residues.
- Frequent monitoring of human milk samples for pesticide residues.
- Dietary intake assessment.
• To create awareness among pregnant and nursing mothers regarding health hazards by pesticide residues from food.

• Strict government guidelines regarding application of pesticides in agriculture and public places.

• Regular monitoring of drinking water and other water resources for pesticide residues.

• Use of personal protection kits by women working in agriculture fields, grain storage houses, handling of fruits and vegetables, etc.

**Conclusion**

Results of this study clearly indicate that various pesticides are the major contaminants of human milk. Therefore, monitoring of human milk samples should not be neglected and can be practised on a larger scale. Breast-feeding is recommended despite the presence of chemical residues (Rogan, 1996). Present study reveals that the benefits of breastfeeding outweigh its disadvantages. Dietary intake assessment of foods of animal origin, fishes, vegetables, fruits and grains for the presence of pesticide residues is recommended. The preventive measures suggested are monitoring of human milk samples for pesticide residues and to create awareness among pregnant and nursing mothers regarding health hazards by pesticide residues. Strict government guidelines should be imposed for application of pesticides in agriculture and public places. Use of personal protection kits by women working in agriculture fields, grain storage houses, handling of fruits and vegetables, will also mitigate the hazards of pesticide residues from human milk up to a greater extent.

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