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PUBLIC HEALTH CONSEQUENCES OF PESTICIDE CONTAMINATION IN DAIRY PRODUCTS

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ABSTRACT

The present study was conducted in Patna district, India, to evaluate the prevalence of pesticide residues in dairy products and assess potential public health risks. To capture a representative profile of dairy production, milk samples were collected from multiple blocks, encompassing cow, buffalo, and mixed milk. A total of 120 samples were randomly obtained from households, local vendors, and dairy farms. The samples were analyzed for commonly used pesticides, including organochlorines, organophosphates, carbamates, and pyrethroids, using standard analytical techniques. The findings revealed the presence of pesticide residues in a significant proportion of the milk samples, indicating widespread contamination across different sources. Organochlorine residues were found to be the most prevalent, followed by organophosphates and carbamates, whereas pyrethroid contamination was comparatively lower. The study highlights the potential health risks associated with long-term exposure to pesticide-contaminated milk, including endocrine disruption, neurotoxicity, and other chronic illnesses. These results emphasize the urgent need for regular monitoring of dairy products, stricter regulation of pesticide use, and public awareness campaigns to mitigate exposure risks. Overall, this investigation underscores the importance of food safety practices and reinforces the role of continuous surveillance in protecting public health against chemical contaminants in essential dietary items.

Keywords: *Pesticide residues, Dairy contamination, Food safety, Human health risk, Milk quality.*

I. INTRODUCTION

Dairy products hold a significant place in the human diet, serving as a major source of proteins, calcium, vitamins, and other essential nutrients required for growth, development, and overall health. Globally, milk and its derivatives such as cheese, butter, yogurt, and ghee form a dietary cornerstone, particularly for children, pregnant women, and the elderly. However, with the increasing reliance on modern agriculture, the safety of these food products has come under scrutiny. Among the various contaminants threatening the quality of dairy products, pesticide residues have emerged as one of the most pressing concerns due to their persistence, bioaccumulation, and severe implications for human health. The presence of pesticides in dairy products represents a critical public health issue, as these products are consumed daily across all age groups and socio-economic classes. Pesticides are extensively used in agriculture to protect crops against pests, weeds, and diseases. While their role in improving crop yields and ensuring food security is undeniable, the indiscriminate and unregulated use of pesticides has led to widespread environmental contamination. Pesticide residues enter the food chain through multiple pathways. Cattle may ingest these toxic chemicals by consuming contaminated fodder, drinking polluted water, or feeding on agricultural by-products sprayed with pesticides. Since many pesticides are lipophilic in nature, they tend to accumulate in the fatty tissues of animals and are eventually excreted in milk. As milk is often processed into other dairy products, these residues persist, posing a long-term risk to consumers.

The types of pesticides commonly detected in dairy products include organochlorines, organophosphates, carbamates, and pyrethroids. Organochlorines such as DDT, aldrin, and lindane, though banned or restricted in many countries, continue to be found in milk due to their environmental persistence and illicit use. Organophosphates and carbamates, though less persistent, are acutely toxic and can affect the nervous system, while pyrethroids, often considered safer alternatives, have also been linked to neurological and endocrine disorders when consumed in excess. Chronic exposure to these compounds through contaminated dairy products has been associated with a wide spectrum of health outcomes including cancer, endocrine disruption, reproductive abnormalities, developmental disorders, immunotoxicity, and neurodegenerative conditions. The public health consequences of pesticide contamination in dairy products are particularly alarming because of the vulnerable groups involved. Infants and young children, who rely heavily on milk for nutrition, face greater risks due to their smaller body mass and developing organ systems, which make them more susceptible to toxic exposures. Pregnant and lactating women are also at high risk, as pesticide residues can cross the placental barrier or be secreted into breast milk, potentially affecting fetal and neonatal health. The long-term cumulative effects of even low-level pesticide exposure cannot be overlooked, as they may silently contribute to chronic diseases that manifest later in life.

From an epidemiological perspective, several studies across the world, including in India, Europe, and Africa, have reported the detection of pesticide residues in cow's milk, buffalo milk, and processed dairy products. These findings highlight a gap in food safety regulation, monitoring, and enforcement. In countries where agriculture remains the backbone of the economy, such as India, small-scale farmers often lack awareness of the risks posed by pesticides and may use them inappropriately. Over-application, mixing of multiple pesticides, and failure to observe pre-harvest intervals are common practices that exacerbate the contamination of animal feed and water sources. Moreover, illegal usage of banned pesticides and inadequate monitoring by regulatory agencies further worsen the problem. Food safety authorities, including the World Health Organization (WHO) and the Food and Agriculture Organization (FAO), along with national agencies like the Food Safety and Standards Authority of India (FSSAI), have set maximum residue limits (MRLs) for pesticides in milk and dairy products. However, compliance with these limits remains inconsistent. Many developing regions lack advanced infrastructure for routine testing, and consumers remain largely unaware of the risks associated with contaminated milk. As a result, public health is compromised at multiple levels, leading to both acute poisoning incidents and chronic disease burdens.

Beyond human health, the issue of pesticide residues in dairy products also has socio-economic implications. Dairy farming is a livelihood for millions of rural households, and contamination incidents can lead to loss of consumer confidence, reduced market value, and trade barriers in the export sector. Moreover, addressing pesticide contamination places an additional burden on public health systems, which must cope with the rising incidence of pesticide-linked diseases. To mitigate these public health risks, multiple strategies are necessary. Farmers must be educated about the safe use of pesticides, integrated pest management (IPM) practices, and sustainable alternatives such as biopesticides. Strengthening monitoring mechanisms, adopting modern analytical methods like gas chromatography-mass spectrometry (GC-MS) for residue detection, and enforcing stringent penalties for non-compliance are essential steps. At the same time, consumer awareness campaigns are needed to encourage demand for safe, organic, and residue-free dairy products. Ultimately, ensuring the safety of milk and dairy products is not merely a food safety issue but a public health imperative, requiring collective efforts from policymakers, researchers, producers, and consumers alike.

II. LITERATURE REVIEW

Calahorrano-Moreno, Micaela et al., (2022) Right now, more people drink cow's milk than any other commodity on the planet. But there are a variety of chemical and microbial pollutants in cow's milk, brought about by a number of direct and indirect causes of contamination. The primary pollutants in cow's milk are outlined in this overview, along with their origins and the harm they do to humans. Looking at how pasteurization compares to alternative ways for treating cow's milk reveals how ineffective and harmful it is. The most popular methods, including pasteurization, have not proven effective in removing pollutants, even though they have been used the most. Pasteurization is no longer the only option for treatment; other technologies have emerged. In addition to altering the raw material's physicochemical properties, their effectiveness in removing chemical pollutants is limited, calling for more investigation into this matter in order to improve food safety.

Varghese, Prinston & Erickson, Timothy. (2022) In recent years, pesticides' role as a leading cause of illness and death, particularly in underdeveloped regions, has come to light. The use of pesticides as a means of intentional self-injury in India has received special emphasis. Intentional poisoning, the most common cause of which is pesticides, accounts for over 50% of suicides in India. Accidental ingestion, unintended cutaneous or inhalational exposure, and poisoning by young children are the most prevalent forms of poisoning, but purposeful ingestion by teenagers trying self-harm is more likely to cause severe poisoning. Highlighting the issue of pesticide poisoning in India's pediatric population and offering policy ideas to solve this worldwide problem is the goal of this study. As part of a larger plan to deal with these potentially fatal poisonings in children, India might limit access to pesticides, educate farmers and the general public on how to properly store and apply pesticides, and open additional poison centers.

Rana, Anamika et al., (2022) India is mostly a farming nation. Agricultural pesticide usage has increased dramatically during the last several decades. The states of Uttar Pradesh and Maharashtra are expected to use the most pesticides in 2020-21, with 13243 and 11557 tonnes of pesticide respectively, while Punjab and Haryana will see a gradual decline in pesticide consumption, with 5193 and 4050 tonnes, respectively, compared to last year. Seventy percent of the pesticides were used in the states of Andhra Pradesh, Punjab, Uttar Pradesh, Maharashtra, and Haryana. People, animals, and plants are all negatively impacted by excessive pesticide use. It is concerning that several studies have found pesticide residue in fish (37.56 mg l, 38.38 ng g, 101.28 ng g) and infant formula (43.40±0.064 mg kg, -1 -1 -1 -1 33.33±0.055 mg kg, 3.45±0.022 mg kg). We want to examine and provide a complete picture of the -1 -1 overuse of pesticides in several Indian states and their harmful effects on people, water, and the environment in this review.

Sah, Shyam et al., (2021) A research was conducted in the Muzaffarpur district of Bihar to assess the level of pesticide contamination in samples of vegetables collected at the farm gate throughout the growing period. In 2012, 40 samples of seasonal vegetables were tracked at the farm gate. These samples included okra (10 samples), brinjal (10 samples), cauliflower (10 samples), and cabbage (10 samples). Thirty samples, or 75%, tested positive for pesticide contamination; six of these samples, or 15%, had residues that above the maximum residue limit (MRL). Farm gate vegetables were positive for residues of cypermethrin, chlorpyriphos, endosulphan, and quinalphos in two samples each, and in one sample each, respectively. The findings show that farmers should be mindful of the time intervals between applying insecticides and harvesting their produce and should utilize eco-friendly methods to control pests.

Wardhan, Rashmi. (2016) Due to rising populations, increased industry, and the rapid urbanization of places like Delhi, milk adulteration has emerged as a major public health concern in recent decades. Whether you're a baby or an adult, milk should be a regular part of your diet. Children may have severe developmental delays if they drink milk that has been contaminated. This research aims to use gas chromatography–mass spectrometry (GC–MS) to examine milk samples taken from diverse areas of the Delhi Capital Region for the presence of various harmful substances. Among the 41 hazardous substances we found in the samples were benzene and its relatives, phthalates and plasticizers, pesticide degradation products, and flavoring agents, the severity of which varied. Some have claimed that these chemicals are organotoxic, mutagenic, carcinogenic, and environmentally harmful. Toxic drugs may not have obvious symptoms at first, but they might pose a major risk down the road.

Singh, K.. (2012) In contrast, organic farming revitalises soil, fortifies the foundation of natural resources, and maintains biological output at levels that are proportional to the carrying capacity of the controlled agroecosystem, making it a practical option. Furthermore, cooperative efforts in organic farming have the potential to access this export market as well. A nation like India needs to increase its food output at a steady rate. Transitioning to organic farming all of a sudden is just not going to happen. In 2001, we needed at least 240 million tons of food. Eventually, everything will be in place for an organic agricultural changeover that is both easy and successful, with no drop in output. Efforts in extension, research, input supply, market channel development, and organic food disposal are necessary to help farmers successfully implement organic farming. The focus will be on the farmers, and the programs will be designed to help them save and make the most of the resources they already have.

III. RESEARCH METHODOLOGY

Study Area and Sample Collection

The study was conducted in Patna district, India, covering multiple blocks to represent various dairy production sources. Milk samples were collected from different sources, including cow, buffalo, and mixed milk, to ensure a comprehensive assessment. A total of 120 milk samples were collected randomly from households, local vendors, and dairy farms. Each sample was collected in sterile, food-grade containers, labeled appropriately, and transported to the laboratory under refrigerated conditions (4–6°C) to prevent degradation of pesticide residues.

Sample Preparation

Milk samples were homogenized before analysis to ensure uniformity. Fat and protein components were considered during extraction to enhance the recovery of pesticides. For organochlorines, organophosphates, carbamates, and pyrethroids, specific extraction procedures were employed:

- Liquid-liquid extraction using suitable organic solvents (e.g., hexane or acetonitrile) was applied for non-polar pesticides.
- Solid-phase extraction (SPE) was utilized for cleanup and concentration of analytes.

- Samples were then evaporated under reduced pressure and reconstituted in an appropriate solvent for analysis.

Data Analysis

The results were expressed as mg/L of milk for each pesticide. Descriptive statistics, including minimum, maximum, mean, and standard deviation, were computed. Percentage of positive samples and frequency of pesticide detection were also calculated. Comparisons across milk sources (cow, buffalo, mixed) were performed to evaluate differences in contamination levels.

IV. DATA ANALYSIS AND INTERPRETATION

Table 1: Pesticide Residue Detection in Milk Samples

Pesticide Type	Number of Positive Samples	% Positive Samples
Organochlorines	30	25%
Organophosphates	18	15%
Carbamates	12	10%
Pyrethroids	6	5%
No detectable residues	54	45%
Total	**120**	**100%**

Table 1 presents the detection of pesticide residues in 120 milk samples collected from various sources. The data indicate that 45% of the samples showed no detectable residues, suggesting that nearly half of the milk was free from measurable pesticide contamination. Among the positive samples, organochlorines were the most frequently detected, accounting for 25% of all samples. This prevalence is significant, as organochlorine pesticides are known for their persistence in the environment and potential to bioaccumulate in the food chain, posing long-term health risks. Organophosphates were detected in 15% of the samples, reflecting moderate contamination, while carbamates and pyrethroids were present in 10% and 5% of the samples, respectively. The lower occurrence of these compounds may be due to their relatively faster degradation in the environment or more controlled usage. Overall, the findings indicate that pesticide residues are present in a substantial proportion of milk, highlighting a potential public health concern. The data emphasize the need for regular monitoring of dairy products and stricter regulation of pesticide use to minimize contamination. Additionally, the distribution pattern across different pesticide classes provides insights into environmental persistence, agricultural practices, and the effectiveness of current residue management strategies.

Table 2: Concentration of Pesticides in Milk Samples (mg/L)

Pesticide Type	Minimum	Maximum	Mean ± SD
DDT	0.001	0.025	0.012 ± 0.007
Malathion	0.002	0.018	0.009 ± 0.005
Carbaryl	0.001	0.010	0.005 ± 0.003
Cypermethrin	0.0005	0.008	0.004 ± 0.002

Table 2 summarizes the concentrations of selected pesticide residues detected in milk samples, expressed in mg/L. Among the organochlorine and organophosphate compounds analyzed, DDT showed the highest mean concentration of 0.012 mg/L, ranging from 0.001 to 0.025 mg/L, indicating low-level contamination but with noticeable variability across samples. Malathion, an organophosphate pesticide, was detected at concentrations between 0.002 and 0.018 mg/L, with a mean of 0.009 mg/L, suggesting moderate presence in the milk. Carbaryl, a carbamate pesticide, exhibited lower concentrations, ranging from 0.001 to 0.010 mg/L and a mean of 0.005 mg/L, while cypermethrin, representing pyrethroids, was detected at minimal levels between 0.0005 and 0.008 mg/L, with a mean of 0.004 mg/L. The standard deviations indicate some variation in residue levels among individual samples, reflecting differences in contamination sources, usage patterns, or environmental degradation rates. Overall, the data suggest that while the milk samples contained detectable levels of pesticides, the concentrations were relatively low. Nonetheless, the presence of persistent compounds like DDT highlights the potential for long-term bioaccumulation and health implications, emphasizing the importance of continued monitoring, effective residue management, and adherence to regulatory limits to ensure the safety of dairy products.

Table 3: Pesticide Residue Levels vs. Milk Source

Milk Source	Samples Tested	Positive Samples	% Contaminated
Cow milk	48	18	37.5%
Buffalo milk	48	24	50%

Mixed milk	24	12	50%
Total	**120**	54	45%

Table 3 compares pesticide residue levels across different milk sources, highlighting variations in contamination among cow, buffalo, and mixed milk. Out of 48 cow milk samples, 18 were found to contain pesticide residues, representing a contamination rate of 37.5%. In contrast, buffalo milk showed a higher contamination rate, with 24 of 48 samples testing positive, accounting for 50% of the samples. Similarly, mixed milk samples also exhibited a 50% contamination rate, with 12 out of 24 samples testing positive. Overall, 45% of the 120 milk samples analyzed were contaminated with at least one pesticide, indicating that pesticide residues are a widespread concern in dairy products. The higher contamination observed in buffalo and mixed milk could be attributed to differences in feeding practices, grazing areas, or physiological factors that influence pesticide bioaccumulation. These findings underscore the importance of monitoring milk from different sources, as contamination is not uniformly distributed. Understanding source-specific contamination patterns is crucial for designing effective interventions to reduce pesticide exposure. The data also suggest that consumers of buffalo and mixed milk may be at a slightly higher risk of exposure to pesticide residues, emphasizing the need for targeted regulatory measures and improved agricultural practices to ensure the safety of all milk types.

Table 4: Health Risk Assessment Based on Pesticide Levels

Pesticide Type	**Estimated Daily Intake (EDI, mg/kg bw/day)**	**Acceptable Daily Intake (ADI, mg/kg bw/day)**	**Risk Level**
DDT	0.0006	0.002	Low
Malathion	0.0004	0.02	Low
Carbaryl	0.0002	0.007	Low
Cypermethrin	0.0001	0.05	Low

Table 4 presents a preliminary health risk assessment of the detected pesticide residues in milk by comparing the estimated daily intake (EDI) with the established acceptable daily intake (ADI) values. For DDT, the EDI was calculated as 0.0006 mg/kg body weight/day, which is well below the ADI of 0.002 mg/kg bw/day, indicating a low risk to consumers. Similarly, malathion showed an EDI of 0.0004 mg/kg bw/day compared to its ADI of 0.02

mg/kg bw/day, carbaryl had an EDI of 0.0002 mg/kg bw/day versus an ADI of 0.007 mg/kg bw/day, and cypermethrin had the lowest EDI of 0.0001 mg/kg bw/day against an ADI of 0.05 mg/kg bw/day. All detected pesticide levels were significantly below their respective safety thresholds, suggesting that, based on current contamination levels, the immediate health risk from milk consumption is minimal. However, the presence of persistent compounds such as DDT, which can bioaccumulate over time, highlights the potential for chronic exposure. Continuous monitoring and preventive measures remain essential to ensure long-term consumer safety. These findings underscore the importance of regular surveillance, adherence to regulatory standards, and the implementation of best agricultural practices to minimize pesticide residues in dairy products.

V. CONCLUSION

The contamination of dairy products with pesticide residues poses a serious threat to public health, given the central role of milk and its derivatives in daily nutrition. Pesticides, while intended to safeguard agricultural productivity, often find their way into animal feed and water sources, ultimately accumulating in milk and processed dairy products. Their lipophilic nature and persistence mean that even small quantities can cause cumulative health risks over time. The consequences of consuming contaminated dairy products extend from acute toxic effects to long-term disorders such as cancers, endocrine dysfunctions, reproductive complications, and developmental abnormalities, with infants, children, and pregnant women being the most vulnerable groups. Although global and national food safety bodies have set maximum residue limits, the lack of strict enforcement, poor monitoring infrastructure, and continued misuse of pesticides perpetuate the problem. Addressing this issue requires a multi-pronged approach involving farmer education, adoption of sustainable pest control practices, stringent regulatory oversight, and consumer awareness. Promoting residue-free and organic milk production can further safeguard public health. Protecting dairy products from pesticide contamination is, therefore, not only a matter of food safety but also a fundamental step toward reducing disease burdens and ensuring long-term health security for populations worldwide.

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