RESEARCH ARTICLE

Estimation and human health risk assessment of organochlorine and organophosphate pesticide residues in raw milk collected in Kenya [version 1; peer review: 1 approved with reservations]

Sheridan Wanjiku Philip ^{1,2}, Vincent Madadi Odongo¹, Shem Oyoo Wandiga¹, Duke Gekonge Omayio ³, Mitchel Otieno Okumu ^{4,5}

¹Chemistry, University of Nairobi, Nairobi, Nairobi, +254, Kenya

²Analytical Chemistry and Food Safety Laboratory, Directorate of Veterinary Services, Nairobi, Nairobi, +254, Kenya

³Food Science, Nutrition, and Technology, University of Nairobi, Nairobi, Nairobi, +254, Kenya

⁴Public Health, Pharmacology, and Toxicology, University of Nairobi, Nairobi, Nairobi, +254, Kenya

⁵Pharmacy, Jaramogi Oginga Odinga Teaching and Referral Hospital, Nairobi, Nairobi, +254, Kenya

V1 First published: 07 Jan 2022, 11:14
<https://doi.org/10.12688/f1000research.74748.1>

Latest published: 07 Jan 2022, 11:14
<https://doi.org/10.12688/f1000research.74748.1>

Abstract

Background: This study determined the levels of organochlorine (OCPs) and organophosphate (OPPs) pesticide residues in cow milk from Kiambu and camel milk from Isiolo and Laikipia. The human dietary intake and the potential consumer health risks were also evaluated.

Methods: In total, 90 cow and 82 camel milk samples were collected and analyzed using gas chromatography tandem mass spectroscopy to determine the levels of OCPs and OPPs. The levels were compared to the maximum residue limits (MRLs) established by the Codex Alimentarius (CA), EU Pesticides Database (EUPD), and the United States Department of Agriculture. The estimated daily intake and chronic hazard quotient (CHQ) of the milk were also calculated.

Results: Cow milk from Kiambu was contaminated with 11/18 of the evaluated OCPs and 13/14 of the evaluated OPPs while camel milk from Isiolo was contaminated with 9/18 of the evaluated OCPs and 9/14 of the evaluated OPPs. Camel milk from Laikipia was contaminated with 11/18 of the evaluated OCPs and 11/14 of the evaluated OPPs. The mean heptachlor value in camel milk from Isiolo was above the EUPD MRLs. The mean value of heptachlor in Camel milk from Laikipia was above the CA and EUPD MRLs. The CHQs for Disulfoton, Fenamiphos, and Methacrifos in Cow milk were above 1 for adults and children. The CHQs for Fenchlorphous and Profenofos in Camel milk were above 1 for adults and children. The CHQs for α -endosulphan, β -endosulphan, dieldrin, and heptachlor in cow milk

Open Peer Review

Approval Status ?

	1
version 1	?
07 Jan 2022	view

1. **Agata Witczak**, West Pomeranian University of Technology in Szczecin, Szczecin, Poland

Any reports and responses or comments on the article can be found at the end of the article.

was above 1 for adults and children while the CHQs for heptachlor in camel milk was above 1 for adults and children.

Conclusions: The potential health risks from chronic dietary intake of cow and camel milk in Kenya cannot be excluded. The routine monitoring of organophosphate and organochlorine pesticide levels in milk is recommended to minimize risks to human health.

Keywords

Pesticide residue limits, milk, milk quality, organophosphates, organochlorines, public health, public safety

This article is included in the **Agriculture, Food and Nutrition** gateway.

Corresponding author: Sheridan Wanjiku Philip (sheridanwanjiku@yahoo.com)

Author roles: **Wanjiku Philip S:** Conceptualization, Funding Acquisition, Investigation, Methodology, Project Administration, Resources, Writing – Original Draft Preparation, Writing – Review & Editing; **Madadi Odongo V:** Conceptualization, Investigation, Methodology, Supervision, Validation, Writing – Review & Editing; **Wandiga SO:** Conceptualization, Investigation, Methodology, Supervision, Validation, Writing – Review & Editing; **Omayio DG:** Data Curation, Formal Analysis, Investigation, Visualization, Writing – Review & Editing; **Okumu MO:** Data Curation, Formal Analysis, Investigation, Methodology, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing

Competing interests: No competing interests were disclosed.

Grant information: This study was partially funded by the Ministry of Agriculture, Livestock and Fisheries through the Directorate of Veterinary Sciences-Standard Market Access Program (SMAP).

The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Copyright: © 2022 Wanjiku Philip S *et al.* This is an open access article distributed under the terms of the **Creative Commons Attribution License**, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

How to cite this article: Wanjiku Philip S, Madadi Odongo V, Wandiga SO *et al.* **Estimation and human health risk assessment of organochlorine and organophosphate pesticide residues in raw milk collected in Kenya [version 1; peer review: 1 approved with reservations]** F1000Research 2022, 11:14 <https://doi.org/10.12688/f1000research.74748.1>

First published: 07 Jan 2022, 11:14 <https://doi.org/10.12688/f1000research.74748.1>

Introduction

Rapid urbanization and population growth have increased the food requirements in Sub-Saharan Africa including Kenya¹. To meet this demand, various techniques including the use of fertilizers and pesticides have been introduced to increase food production and stave off serious livestock diseases².

Kenya's appetite for pesticides is high and is increasing exponentially³. Approximately 18,000 tonnes of pesticides were imported into the country in 2018 relative to about 7,600 tonnes in the late 90s^{1,3}. Many of these pesticides have been banned, or their use is heavily restricted, in Europe and other developed jurisdictions due to their high toxicity towards the health of animals, humans, and the environment³. Despite European restrictions and interventions to use less hazardous products, some of the withdrawn pesticides are still in use in Kenya and continue to threaten the environment and health of Kenyans³. Dichlorodiphenyltrichloroethane (DDT), Dibromochloropropane (DBCP), Chlordimeform, Chlordane, Heptachlor, Toxaphene, and Edrin are some organochlorines currently banned in Kenya¹. Moreover, the use of Lindane, Aldrin, and Dieldrin is restricted in Kenya¹.

Organophosphate and organochlorine pesticide residues have been detected in rain, rivers, groundwater, fish, soil sediment, rice, milk, tomatoes, beef, and camel meat in Kenya^{1,4–13}. The health effects of pesticide exposure among formulators, repackers, and store workers in Nairobi have also been reported¹⁴.

Milk is a food with immense nutritional importance to Kenyans as it provides proteins, calcium, iodine, phosphorous, and vitamins that promote the growth and development of infants². Kiambu County is a leader in milk production while Isiolo and Laikipia Counties have the largest number of camel farmers and are associated with high levels of production of camel milk. However, little is known of the extent of pesticide residue contamination of the milk from these areas. This study aimed to determine the extent to which cow and camel milk collected from Kiambu, Isiolo, and Laikipia Counties is contaminated with pesticides residues. The human health risk assessment of pesticide residue contamination was also evaluated.

Methods

Study area

Kiambu, Isiolo, and Laikipia County were selected as study areas. Kiambu County (1°10'0.01" S-36°49'59.99"E) has an area of 1679 m above sea level and is generally a dairy and tea zone area¹⁵. Sheep farming, horticulture and maize farming is also practiced. There are about 2.4 million inhabitants in Kiambu scattered over an area of 2450 km²¹⁶. The county currently leads in cow milk production in Kenya¹⁷.

Isiolo County (0°21'16.63"N-37°34'55.85"E) has a population of about 200,000 inhabitants and an area of 25,700 Km²^{16,18}. The main economic activity is livestock production and nomadic pastoralism is the major lifestyle of the inhabitants of this county¹⁸. Laikipia County (0°01'0.01"N-37°04'22.19"E)

has a population of about 520,000 people and an area of about 8700 Km². The map of the study area is shown in Figure 1.

Sample collection and preservation

The study was conducted between 2017 and 2018. Milk samples from 8 different wards of Kiambu, Isiolo and Laikipia were collected in 50 mL falcon tubes. A total of 90 cow milk and 82 camel milk samples were provided by farmers from collection centers for analysis. The samples were labelled (date, location, time), packed into ice-bags and transported to the Analytical Chemistry and Food Safety Laboratory-Directorate of Veterinary Services, Kabete for storage at -20 °C in the deep freezer before analysis.

Laboratory analysis of pesticide residues in milk

Chemicals and reagents. Acetonitrile and Isooctane of high purity (99.9%) were purchased from Merck. Organophosphate standards (methacrifos, disulfoton, terbufos, chlorpyrifosmethyl, tolclofosmethyl, fenclorophos, malathion, tetrachlorvinfos, fenamiphos, chlorthiophos, profenofos, leptophos, and coumaphos) and Organochlorine standards (Alpha- Benzene Hexachloride [BHC], beta-BHC, Hexachlorobenzene, gamma-BHC (lindane), Delta-BHC, heptachlor, cis-chlordane, trans-chlordane, p'-p-DDE, Alpha-endosulfan, dieldrin, Op'-DDD, Trans-nonachlor, chlorfenson, p,p'-DDD, Endrin, Beta-Endosulfan, p'-p-DDT, Op'-DDT, Cis-Nonachlor, and mirex) were purchased as a gas chromatography multiresidue pesticide kit (100 µg/mL each in toluene, 1mL/ampoule) from Restec company. Quick, easy, cheap, effective, rugged, and safe (QuEChERS) extraction tubes, preweighed salts (6 g magnesium Sulphate, 1.5g sodium acetate) and 15 mL fatty samples AOAC tubes with ready to use salts (400 mg PSA, 400 mg C18EC, 1200mg magnesium sulphate) were all purchased from Agilent Technologies through Nesvax Innovations Ltd Nairobi, Kenya.

Preparation of standard solution. A stock solution (1µg/mL) was prepared by weighing 200 µL of the multi residue pesticide standard into a 20 mL volumetric flask and topped up with isooctane. The standard stock solution was used to prepare various working concentrations through serial dilutions. The standard stock solution and other working solutions were stored in a refrigerator at 4°C. The standard for spiking experiment was obtained by transferring predefined volumes of family mixes from 150 µL–1500µL.

Extraction of pesticide residues in milk. Milk samples were extracted using the QuEChERS technique. Briefly, 15 mL of whole milk was weighed into a 50 mL polypropylene centrifuge^{19,20}. An appropriate amount of the pesticide spiking standard was added to the fortified blank sample and vortexed for 60 seconds, allowing 1 minute for the interaction of the matrix and the standard before extraction^{19,20}. Acetonitrile (15mL) was added to each milk sample, capped, vortexed for 1 minute and pre-weighed salts (6g magnesium sulfate, 1.5g sodium acetate) were added and immediately shaken vigorously by hand for 1 minute to prevent the agglomeration of salts. The resultant mixture was centrifuged at 5000 rpm for 10 min at 4°C^{19,20}, 6 mL of the supernatant layer were then

Figure 1. Map of the study area.

transferred into a 15 mL tube containing 400 mg PSA, 400 mg C18EC, and 1200 mg magnesium sulfate. The resultant mixture was capped and vortexed for 1 minute then centrifuged at 5000 rpm for 10 minutes^{19,20}. Following this, 1 mL of the extract was transferred into another tube, dried by nitrogen flow at 40°C, reconstituted with 1 mL of isooctane and filtered through disposable 0.45µm membrane filters into gas chromatography tandem mass spectroscopy (GC-MS/MS) auto sampler vials for GC-MS/MS analysis.

GC-MS/MS. The pesticides residues were detected using a GC-MS-TQ8040 (Shimadzu, Japan) machine equipped with Shimadzu manufactured AOC-20s auto sampler and AOC-20i auto injector. The analytical capillary column was a ZB-5ms with a thickness of 0.25 µm, a length of 30.0 m, and a diameter of 0.25 mm. The column temperature was maintained at 50 °C for 1 minute then programmed at 25 °C/minute up to 125 °C, then finally 10 °C up to 300 °C for 3.50 minutes. This was held for 20 minutes. Helium (99.999% purity) was used as the carrier gas at a flow rate of 1.69 mL/min. The injection port temperature was 250°C and 1 µL was used as the injection

volume with the spitless mode/purge flow was 5 mL/min. The ion source temperature was 200 °C, the interface temperature was 250 °C and the solvent cut was 1.5 minutes with a detector voltage 0.5 kV. Multiple reaction monitoring (MRM) was used to convert MS1 (parent ion) to MS2 (daughter ion). The retention time windows and base peak ions were designed for OCPs and OPPs. All pesticides were identified with specific ions and retention time and were quantified using the external standard method.

Quality assurance

Recovery studies were carried out using blank milk samples spiked at 10 ppb, 50 ppb and 100 ppb to determine the accuracy of the method. The amount of analyte which was recovered after complete sample extraction and processing was determined. The average recoveries of spiked OCP samples ranged from 73% to 97% and 78% to 100 % for OPPs. To determine the linearity of the method, a standard curve was constructed. Calibration curves of organophosphates and organochlorines were prepared using concentrations of 20 ppb, 30 ppb, 50 ppb, 100 ppb and 200 ppb. The calibration standards were

prepared from a 1 ppm stock solution by using serial dilutions of the mixed OCPs and OPPs. Linearity was determined by regression analysis of the peak area against the concentration of the analyte and was expressed using the linear regression coefficient (R^2). Generally, an R^2 value of >0.998 is considered as evidence of an acceptable fit of data to the regression line. In this study the linear regression range was from 0.991–0.999.

The ability of the method to detect and separate OCPs and OPPs in the mixture without interference from other components in the mixture was determined. The selectivity of the method was determined when chromatographic peaks obtained from the mixture of the pesticide standard analysis showed the absence of interfering peaks. The lowest concentration at which OCPs and OPPs could be detected and also quantified was determined using the formula $S_{LOD}=S_{RB}+3\sigma_{RB}$, $S_{LOQ}=S_{RB}+10\sigma_{RB}$, where S_{LOD} is the signal at the limit of detection (LOD), S_{LOQ} signal at the limit of quantification (LOQ), S_{RB} signal of the reagent blank, and σ_{RB} standard deviation of the reagent blank. According to the directives of the International Union of Pure and Applied Chemistry (IUPAC) and the American Chemical Society's Committee on Environmental Analytical Chemistry the LOD for OCPs range from 0.1–0.3 ng/mL, the LOQ for OCPs range from 0.1–0.4 ng/mL, the LOD for OPPs range from 0.02–0.3 ng/mL, and the LOQ for OPPs range from 0.03–0.4 ng/mL. The relative standard deviation (RSD) was less than 3%.

Human health risk assessment. Dietary exposure, in the form of estimated daily intake (EDI), and the chronic/long-term hazard quotient (cHQ) are a measure of the health risk due to ingestion of milk contaminated with OCPs and OPPs. These were calculated for adults (aged above 18 years) and children (3–10 years) using the formula described by John *et al.*²¹.

$$\text{i.e.} \quad \text{EDI} = \frac{C * F_i}{\text{Bwt}}$$

A body weight of 70 kg was used for adults (aged above 18 years) and 23 kg was used for children (aged 3–10 years) as recommended by the European Food Safety Authority²². C represented the average concentration of the chemical contaminants (ng g⁻¹) in the milk, F_i was the average daily intake and was based on the information retrieved from United States Agency for International Development-Kenya Agricultural Value Chain Enterprises (USAID-KAVES) dairy value chain analysis for adults (380 g) and Ogenche *et al.* for children (250 g)^{23,24}. EDIs were compared with the acceptable daily intake (ADI) values^{25,26}. The cHQ was calculated by the formula $\text{cHQ}=\text{EDI}/\text{ADI}$ ²⁷.

Results

The mean, median, range and percentage of samples contaminated with organochlorines (OCs) in raw cow and camel milk collected from Kiambu, Isiolo, and Laikipia counties²⁸ are summarized in Table 1.

In general, the values of OCs ranged from below the detection limit to 22.38 ppb (Table 1). The mean values ranged from 0.00 to 12.38 ppb, and the percentage of contaminated samples ranged from 0.00 to 93.85% (Table 1). The mean levels of heptachlor in cow milk collected from Kiambu County were above the maximum residue levels set by the Codex Alimentarius, and the European Union (EU) Pesticides Database (Table 1). The mean levels of heptachlor in camel milk collected from Isiolo and Laikipia Counties were above the maximum residue limits set by the Codex Alimentarius and the EU Pesticides Database (Table 1), 12/18 of the OCs evaluated are unregulated by the Codex Alimentarius, 10/18 are unregulated by the European Pesticides Database, and 15/18 are unregulated by the United States Department of Agriculture (USDA) (Table 1).

The estimated adult daily intake of OCPs in milk from Kiambu and Isiolo ranged from 0.00–0.08, while the estimated adult daily intake of OCPs in milk from Laikipia ranged from 0.00–0.10 (Table 2). The estimated pediatric daily intake of OCPs in milk from Kiambu ranged from 0.00–0.10 while the estimated pediatric daily intake of OCPs in milk from Isiolo and Laikipia ranged from 0.00–0.11 (Table 2). The adult cHQ of OCPs in milk from Kiambu and Laikipia ranged from 0.00–1000 while the cHQ of OCPs in milk from Isiolo ranged from 0.00–300.00 (Table 2). The pediatric cHQ of OCPs in milk from Kiambu ranged from 0.00–1000, the pediatric cHQ of OCPs in milk from Isiolo ranged from 0.00–400.00 while the pediatric cHQ of OCPs in milk from Laikipia ranged from 0.00–1100 (Table 2).

The mean, median, range and percentage of samples contaminated with OPPs in cow and camel milk collected from Kiambu, Isiolo, and Laikipia counties are summarized in Table 3. In general, the values of OPs ranged from below the detection limit to 387.47 ppb (Table 3). The mean values ranged from 0.00 to 46.07 ppb, and the percentage of contaminated samples ranged from 0.00 to 93.18% (Table 3). 10/14 of the OPPs evaluated are unregulated by the Codex Alimentarius, 6/14 are unregulated by the European Pesticides Database, and 10/14 are unregulated by the USDA (Table 3).

The estimated adult daily intake of OPPs in milk from Kiambu ranged from 0.00–0.29, the estimated adult daily intake of OPs in milk from Isiolo ranged from 0.00–0.07 while the estimated adult daily intake of OPPs in Laikipia ranged from 0.00–0.09 (Table 4). The estimated pediatric daily intake of OPPs in milk from Kiambu ranged from 0.00–0.38, the estimated pediatric daily intake of OPPs in milk from Isiolo ranged from 0.00–0.46 while the estimated pediatric daily intake of OPPs in milk from Laikipia ranged from 0.00–0.12 (Table 4). The adult cHQ of OPPs in milk from Kiambu ranged from 0.00–33.33, the adult cHQ of OPPs in milk from Isiolo ranged from 0.00–3.00, and the adult cHQ of OPPs in milk from Laikipia ranged from 0.00–66.67 (Table 4). The pediatric cHQ of OPPs in milk from Kiambu ranged from 0.00–66.67, the pediatric cHQ of OPPs in milk from Isiolo ranged from

Table 1. Comparison of the mean, median, range, and percentage of milk samples contaminated with organochlorines in the study area.

	Cow milk				Camel milk										
	Kiambu				Isiolo				Laikipia				MRL (ppb)		
Organochlorine	Mean	Median	Range	CS (%)	Mean	Median	Range	CS (%)	Mean	Median	Range	CS (%)	Codex Alimentarius	EU pesticides database	USDA
α-BHC	0.00	0.00	< dl	0.00	0.00	0.00	< dl	0.00	0.00	0.00	< dl	0.00	nr	nr	nr
β-BHC	0.00	0.00	< dl	0.00	0.00	0.00	< dl	0.00	0.00	0.00	< dl	0.00	nr	nr	nr
γ-BHC	0.00	0.00	< dl	0.00	0.08	0.09	< dl-0.20	74.62	0.00	0.00	< dl	0.00	1	10	300
δ-BHC	0.12	0.14	0.17	85.47	2.35	2.61	< dl-2.94	89.23	0.10	0.13	< dl-0.15	75.00	nr	nr	nr
α-endosulphan	2.41	2.50	3.41	93.85	0.36	0.26	< dl-1.43	79.23	1.57	2.20	< dl-2.67	68.75	nr	nr	nr
β-endosulphan	2.69	2.87	3.91	92.18	2.74	2.75	< dl-4.66	96.15	1.89	2.63	< dl-3.21	68.75	nr	nr	nr
α+β endosulphan	5.10	5.37	< dl-7.14	93.02	3.11	3.13	< dl-5.57	87.69	3.46	3.69	< dl-5.52	68.75	10	50	nr
cis-Chlordane	0.01	0.00	0.96	1.12	0.00	0.00	< dl	0.00	0.00	0.00	< dl	0.00	nr	nr	nr
trans-Chlordane	0.00	0.00	0.00	0.00	0.00	0.00	< dl	0.00	0.00	0.00	< dl	0.00	nr	nr	nr
cis+trans Chlordane	0.01	0.00	< dl-0.96	0.56	0.00	0.00	< dl	0.00	0.00	0.00	< dl	0.00	2	2	nr
Chlorfenson	1.03	1.29	< dl-1.36	78.77	0.00	0.00	< dl	0.00	0.81	1.28	< dl-1.34	62.50	nr	50	nr
Dieldrin	1.72	1.94	< dl-2.90	85.47	0.00	0.00	< dl	0.00	1.51	1.92	< dl-2.26	75.00	6	6	300
Endrin	0.00	0.00	< dl	0.00	0.00	0.00	< dl	0.00	0.00	0.00	< dl	0.00	nr	0.8	nr
Heptachlor	12.38	13.39	< dl-22.50	87.71	4.62	5.11	< dl-5.89	90.00	13.42	14.36	< dl-19.68	87.50	6	4	nr
Hexachlor Benzene	0.00	0.00	< dl	0.00	0.00	0.00	< dl	0.00	0.00	0.00	< dl	0.00	nr	nr	nr
Mirex	0.72	0.83	0.85	86.59	0.00	0.00	< dl	0.00	0.80	0.84	< dl-1.01	93.75	nr	nr	nr
cis-Nonachlor	1.42	0.00	4.78	41.34	4.09	0.00	< dl-9.93	48.46	1.86	3.06	< dl-3.64	56.25	nr	nr	nr
trans-Nonachlor	1.30	1.56	2.84	83.24	1.26	1.43	< dl-2.90	80.00	1.08	1.49	< dl-1.90	68.75	nr	nr	nr
cis+trans nonachlor	2.72	1.81	< dl-6.33	61.17	5.35	2.28	< dl-11.53	64.23	2.94	3.64	< dl-4.94	62.50	nr	nr	nr
o,p-DDD	8.97	9.58	16.87	91.62	0.10	0.00	< dl-1.61	13.85	8.91	9.58	< dl-10.51	87.50	nr	nr	nr
DDT	3.27	3.49	< dl-4.12	47.35	12.95	13.35	< dl-13.78	30.00	2.98	3.48	< dl-3.51	43.75	20	40	1250

MRL: Maximum residue limit; ppb: parts per billion; CS%: percentage of contaminated samples; EU: European Union; USDA: United States Department of Agriculture; BHC: Benzene Hexachloride; <dl: below detection limit; nr: not regulated; DDD: Dichlorodiphenyldichloroethane; DDT: Dichlorodiphenyltrichloroethane

Table 2. Acceptable daily intake, estimated daily intake, and chronic/long-term hazard quotient of organochlorines in cow and camel milk consumed in Kiambu, Isiolo, and Laikipia counties in Kenya.

Organochlorine compounds	ADI	EDI (adult)			EDI (child)			cHQ (adult)			cHQ (child)		
		Kiambu	Isiolo	Laikipia	Kiambu	Isiolo	Laikipia	Kiambu	Isiolo	Laikipia	Kiambu	Isiolo	Laikipia
α-BHC	nr	0.00	0.00	0.00	0.00	0.00	0.00	-	-	-	-	-	-
β-BHC	nr	0.00	0.00	0.00	0.00	0.00	0.00	-	-	-	-	-	-
γ-BHC	0.008	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
δ-BHC	nr	0.00	0.01	0.00	0.00	0.01	0.00	-	-	-	-	-	-
α-endosulphan	0.006	0.01	0.00	0.01	0.03	0.00	0.02	1.67	0.00	1.67	5.00	0.00	3.33
β-endosulphan	0.006	0.01	0.01	0.01	0.03	0.01	0.02	1.67	1.67	1.67	5.00	1.67	3.33
α+β-endosulphan	0.006	0.03	0.02	0.02	0.06	0.02	0.04	5.00	3.33	3.33	10.00	3.33	6.67
cis-Chlordane	nr	0.00	0.00	0.00	0.00	0.00	0.00	-	-	-	-	-	-
trans-Chlordane	nr	0.00	0.00	0.00	0.00	0.00	0.00	-	-	-	-	-	-
cis+trans Chlordane	nr	0.00	0.00	0.00	0.00	0.00	0.00	-	-	-	-	-	-
Chlorfeson	0.01	0.01	0.00	0.00	0.01	0.00	0.01	1.00	1.00	0.00	1.00	0.00	1.00
Dieldrin	0.0001	0.01	0.00	0.01	0.02	0.00	0.02	100.00	100.00	100.00	200.00	0.00	200.00
Endrin	0.0003	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heptachlor	0.0001	0.07	0.03	0.07	0.13	0.03	0.15	700.00	700.00	700.00	1300.00	300.00	1500.00
Hexachlorbenzene	nr	0.00	0.00	0.00	0.00	0.00	0.00	-	-	-	-	-	-
Mirex	nr	0.00	0.00	0.00	0.01	0.00	0.01	-	-	-	-	-	-
cis-Nonachlor	nr	0.01	0.02	0.01	0.02	0.02	0.02	-	-	-	-	-	-
trans-Nonachlor	nr	0.01	0.01	0.01	0.01	0.01	0.01	-	-	-	-	-	-
cis+trans-Nonachlor	nr	0.02	0.03	0.02	0.03	0.03	0.03	-	-	-	-	-	-
o,p-DDD	nr	0.05	0.00	0.05	0.10	0.00	0.10	-	-	-	-	-	-
DDT	0.0005	0.02	0.07	0.02	0.04	0.14	0.03	40.00	-	-	-	-	-

ADI: Acceptable daily intake; EDI: estimated daily intake; cHQ: chronic hazard quotient; BHC: Benzene Hexachloride; DDD: Dichlorodiphenylchloroethane; DDT: Dichlorodiphenyltrichloroethane; nr: not regulated

Table 3. Comparison of the mean, median, range, and percentage of milk samples contaminated with organophosphates in the study area.

Cow milk				Camel milk				Quality assurance				Implication						
Kiambu				Isiolo				Laikipia				MRL (ng/mL)						
Organophosphate	Mean	Median	Range	CS (%)	Mean	Median	Range	CS (%)	Mean	Median	Range	CS (%)	LOD	LOQ	RSD%	Codex Alimentarius	EU pesticides database	USDA
Chlorthiophos-1	46.07	0.00	< dl-387.47	34.66	10.77	0.00	< dl-91.76	39.84	14.30	0.00	< dl-118.94	12.50	0.20	0.30	2.4	nr	nr	nr
Chlorthiophos-2	0.05	0.05	< dl-0.18	86.36	1.53	1.53	< dl-1.78	99.22	0.05	0.05	< dl	81.25	0.02	0.03	0.6	nr	nr	nr
Chlorthiophos-3	2.17	2.32	< dl-2.39	93.18	0.04	0.00	< dl-5.06	0.78	2.25	2.31	< dl	100.00	0.20	0.30	0.9	nr	nr	nr
Coumaphos	4.53	5.47	< dl-5.80	82.39	5.74	5.90	< dl-6.23	96.88	3.34	5.05	< dl-5.78	68.75	0.20	0.30	2.8	nr	nr	1250
Disulfoton	2.19	0.00	< dl-5.08	46.02	0.00	0.00	< dl	0.00	2.67	4.15	< dl-5.92	56.25	0.20	0.30	1.3	10	10	nr
Fenamiphos	1.24	1.52	< dl-1.65	80.68	0.16	0.18	< dl-0.35	77.34	1.29	1.53	< dl-1.93	81.25	0.20	0.20	0.1	5	5	nr
Fenchlorphous	0.00	0.00	< dl-0.00	0.00	2.52	2.54	< dl-2.61	99.22	0.00	0.00	< dl	0.00	0.30	0.40	3.1	nr	5	nr
Leptophos	3.17	3.46	< dl-3.52	91.48	5.35	5.42	< dl-5.76	98.44	3.12	0.00	< dl	93.75	0.20	0.20	0.3	nr	nr	nr
Malathion	0.15	0.00	< dl-3.95	15.34	1.34	1.71	< dl-2.80	70.31	0.17	0.00	< dl-0.46	43.75	0.20	0.30	3.1	nr	20	500
Methacrifos	0.88	1.21	< dl-1.30	72.73	0.00	0.00	< dl	0.00	1.07	1.23	< dl	81.25	0.30	0.40	2.7	nr	10	nr
Profenofos	1.10	1.22	< dl-5.29	85.23	4.91	4.95	< dl-5.14	99.22	1.24	1.25	< dl	0.00	0.10	0.20	1.3	10	10	10
Terbufos	0.82	0.00	< dl-3.30	25.57	0.00	0.00	< dl	0.00	0.01	0.00	< dl-3.94	31.25	0.20	0.30	0.2	10	10	nr
Tetrachlorvinphos	0.77	1.35	< dl-1.42	55.31	9.93	11.08	< dl-11.89	89.06	0.47	0.00	< dl-1.39	37.50	0.30	0.40	5.8	nr	nr	10
Tolclofos-methyl	0.00	0.00	< dl-0.17	22.73	0.00	0.00	< dl	0.00	0.01	0.01	< dl	37.50	0.20	0.30	1.5	nr	10	nr

MRL: Maximum residue limit; ng/mL: nanogram per mL; CS%: percentage of contaminated samples; LOD: limit of detection; LOQ: limit of quantitation; RSD: Relative Standard Deviation; EU: European Union; USDA: United States Department of Agriculture; <dl: Below detection limit; *nr*: not regulated

Table 4. Acceptable daily intake, estimated daily intake, and chronic/long-term hazard quotient of organophosphates in cow and camel milk consumed in Kiambu, Isiolo, and Laikipia counties in Kenya.

Organophosphate compounds	ADI	EDI (adults)			EDI (child)			cHQ (adult)			cHQ (child)		
		Kiambu	Isiolo	Laikipia	Kiambu	Isiolo	Laikipia	Kiambu	Isiolo	Laikipia	Kiambu	Isiolo	Laikipia
Chlorthiophos-1	nr	0.25	0.06	0.08	0.50	0.12	0.16	-	-	-	-	-	-
Chlorthiophos-2	nr	0.00	0.01	0.00	0.00	0.02	0.00	-	-	-	-	-	-
Chlorthiophos-3	nr	0.01	0.00	0.01	0.02	0.00	0.02	-	-	-	-	-	-
Coumaphos	nr	0.02	0.03	0.02	0.0	0.06	0.04	-	-	-	-	-	-
Disulfoton	0.0003	0.01	0.00	0.01	0.02	0.00	0.03	33.33	0.00	33.33	66.67	0.00	100.00
Fenamiphos	0.005	0.01	0.00	0.01	0.01	0.00	0.01	2.00	0.00	2.00	2.00	0.00	2.00
Fenchlorphos	0.01	0.00	0.01	0.00	0.00	0.03	0.00	0.00	1.00	0.00	0.00	3.00	0.00
Leptophos	nr	0.02	0.03	0.02	0.03	0.06	0.03	-	-	-	-	-	-
Malathion	nr	0.00	0.01	0.00	0.00	0.01	0.00	-	-	-	-	-	-
Methacrifos	0.006	0.01	0.00	0.01	0.01	0.00	0.01	1.67	0.00	1.67	1.67	0.00	1.67
Profenofos	0.01	0.01	0.03	0.01	0.01	0.05	0.01	1.00	3.00	1.00	1.00	1.00	1.00
Terbufos	0.002	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	5.00	0.00	0.00
Tetrachlorvinphos	nr	0.00	0.05	0.00	0.0	0.11	0.01	-	-	-	-	-	-
Toldofos-methyl	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

ADI: Acceptable Daily Intake; EDI: Estimated Daily Intake; cHQ: Chronic Hazard Quotient; nr: Not regulated

0.00-4.00, and the adult cHQ of OPPs in milk from Laikipia ranged from 0.00-66.67 (Table 4).

Discussion

Milk may arguably be one of the most consumed food commodities in the world. The residual concentrations of OCPs and OPPs in two kinds of raw milk (cow and camel) available in Kenya were estimated in the present study.

Levels of OCPs

The recorded results revealed that the percentage of cow milk samples contaminated with OCPs ranged from 0.00 to 93.85% while the percentage of camel milk samples contaminated with OCPs ranged from 0.00-96.15%. These ranges were higher than those detected in goat (75%), buffalo (75%), and cow milk (50%) samples by Raslan and colleagues in Zagazig city in Egypt²⁹. However, the percentage of positive samples in cow milk reported in the current study were lower than the percentage of positive samples in buffalo and sheep milk marketed in Brazil (100%)³⁰. In general, the values of OCPs ranged from below the detection limit to 22.38 ppb and the mean values ranged from 0.00 to 12.38 ppb. These values were lower than what was reported in human milk from Tanzania, cow, buffalo, and goat milk from Egypt, and goat milk and cheese marketed in Ethiopia and Ghana^{29,31-33}. The results also showed that the detected concentrations of the OCPs were low when compared with the established maximum residue levels (MRLs) established by the Codex Alimentarius, the EU Pesticide Database and the USDA^{34,35}. However, the mean levels of heptachlor evaluated in cow and camel milk collected in the study area were above the maximum residue limits set by the Codex Alimentarius and the EU Pesticides Database. These findings are in agreement with those of Omwenga and colleagues who reported high levels of heptachlor in farmed fish collected in the Kiambu and Machakos counties¹⁵. Heptachlor is a persistent organic pollutant (POP) which has been reported to be present in soil for up to 14 years after its initial application³⁶. Like other POPs, it is lipophilic and poorly soluble in water and tends to accumulate in the body fat of humans and animals³⁶. This organochlorine was banned in the US in the 1980s and is considered a potential carcinogen by the International Agency for Research on Cancer and the Environmental Protection Agency (EPA)³⁶. Animals exposed to heptachlor during gestation and infancy were reported to have altered immune function, decreased body weight and some died³⁷.

BHC isomers and DDT were detected in some of the milk samples in the study area. The use of these pesticides was banned in Kenya on account of their persistence in the environment and toxicity to untargeted organisms¹⁵. Some of the isomers of BHC were initially used for seed dressing to protect crops against termites and for use in cattle dips. *pp'*-DDT was detected in 47.35% (Kiambu) of cow milk samples, and 30% (Isiolo) or 43.75% (Laikipia) of camel milk samples. These values were lower than the 50%, 75%, and 75% in cow, buffalo and goat milk samples in Egypt²⁹. The presence of these OCPs in milk samples suggest previous use of these pesticides in agricultural activities in Kenya similar to what was

observed in previous studies in Egypt (milk), Ghana (milk, yoghurt, and cheese), and Ethiopia (milk)^{29,31,32}. Could farmers in the study area be using these pesticides illegally? Could their detection be related to previous application? These are pertinent queries that require further inquiry.

Human dietary intake of OCPs and health risk assessment

Humans may be exposed to OCPs in a number of ways including polluted air, dermal ingestion, or via contaminated food and/or water²⁹. The main source of human exposure to pesticides include foods such as milk and dairy products^{29,38}. In the current study, the human dietary intake, EDI and risk assessment (cHQ) of pesticides were calculated using ADI values previously summarized by Dourson and Lu^{25,26}. On the basis of this summary, the estimated daily intake and chronic/long-term hazard quotient values of only 11 out of 18 OCPs could be estimated. When cHQ values exceed 1, a health risk cannot be excluded³⁷. The results of cHQ suggest that the consumption of cow's milk by adults and children is alarming for endosulphans, dieldrin, heptachlor and DDT and the consumption of camel's milk by adults and children is alarming for endosulphans, dieldrin, and heptachlor. A similar trend was observed in the case of heptachlor and dieldrin in Egypt and DDT in Arusha, Tanzania^{29,33}.

Levels of OPPs

It was established that the mean levels of all the 14 organophosphates tested were below the maximum residue limits set by the Codex Alimentarius, EU pesticides database, and the USDA. It may therefore be plausible that i) farmers in the study area may be adequately educated on the use of these pesticides, ii) the use of these pesticides may be generally low in the study area, or iii) proper handling of milk is practiced in the study area which minimizes contamination of the milk with the pesticides. However, the observation that cow milk registered higher mean levels of some organophosphate pesticides, including Chlorthiophos-2, Coumaphos, Fenchlorphos, Leptophos, Malathion, Profenfos, and Tetrachlorvinphos, relative to camel milk may have something to do with the fact that Kiambu county (where the cow milk was collected) is an agriculture intensive area and there may be a possibility of prior use of these pesticides relative to Isiolo and Laikipia counties (where camel milk was collected) which are mainly inhabited by pastoralists who may not be practicing large scale agriculture. Leaching and surface run-off could be another potential reason for the high levels of these organophosphates³⁹.

In total, 15.34% of cow milk samples from Kiambu, 70.31% of camel milk samples from Isiolo and 43.75% of camel milk samples from Laikipia were contaminated with Malathion. This is in contrast to the 44% reported in raw buffalo milk collected in Assuit Egypt⁴⁰. In general, the values of OPPs ranged from below the detection limit to 387.47 ppb. The mean values ranged from 0.00 to 46.07 ppb, and the percentage of contaminated samples ranged from 0.00 to 93.18%. A previous study on the levels of selected organophosphates in human

colostrum and mature milk samples in Uttar Pradesh reported high ethion contamination in colostrum (23.1% or 6/26) and high levels of chlorpyrifos contamination in mature milk samples (50% or 4/8)⁴¹. The study further reported that the percentage chlorpyrifos contamination was 19.2% (5/26), dimethoate contamination was 3.8% (1/26) while 25.0% (2/8) of mature samples were contaminated with dimethoate, and 12.5% (1/8) of mature milk samples was contaminated with ethion⁴¹. Another study in Pakistan evaluated the dietary transfer of pesticides to dairy milk and its effect on human health. The study reported that about 40% and 20% of cow milk samples recorded residue levels of cypermethrin+chlorpyrifos and profenofos that was higher than their maximum residue limit as suggested by the World Health Organization⁴².

The primary objective of organizations such as the World Health Organization, the United States EPA, the Codex Alimentarius, and the EU Pesticides Database is to develop MRLs that are aimed at protecting the health of consumers while facilitating trade⁴³. The MRLs are set at values which are not higher than those resulting from pesticide use in line with good agricultural practices (GAP)⁴³. Most developing countries have not developed their own internal regulatory mechanisms for pesticides choosing instead to rely on the aforementioned organizations for guidance. In this context, it was worrying to observe that 10/14 of the studied OPPs did not have MRLs as per the Codex Alimentarius, 6/14 of the studied OPPs did not have MRLs as per the European Pesticides Database, and 10/14 of the studied OPPs did not have MRLs as per the USDA. This lack of regulation may be a huge pitfall as far as monitoring the levels of these chemicals is concerned.

Human dietary intake of OPPs and health risk assessment

Organophosphates have a high acute toxicity to target organisms⁴. However, they are not as persistent in the environment as organochlorines because they decompose into non-toxic products⁴. Notwithstanding, on the strength of the analyzed data, it may be inferred that the health of children in the study area may be at a higher risk from organophosphates than

adults. Data from Africa on this phenomenon is scant but a similar finding was observed in a study in India on the pesticide residues in peri-urban milk from Bhubaneswar, Guwahati, Ludhiana, and Udaipur in India⁴⁴.

Conclusions

These findings suggest that OPP residue levels in cow and camel milk collected from Kiambu, Isiolo, and Laikipia counties are within acceptable limits. However, the levels of heptachlor in both Cow and Camel milk collected from these areas are above acceptable limits. The potential health risks with respect to chronic dietary intake of cow and camel milk in the study area cannot be excluded. The routine monitoring of OPP and OCP levels in milk is recommended to minimize risks to human health.

Data availability

Underlying data

Figshare: Data for estimation and human health risk assessment. <https://doi.org/10.6084/m9.figshare.16823788.v1>²⁸

This project contains the following underlying data:

- Data_Sheridan_F1000.xlsx (documentation of the levels of organophosphates and organochlorines in Kiambu, Isiolo, and Laikipia Counties)

Data are available under the terms of the [Creative Commons Attribution 4.0 International license](#) (CC-BY 4.0).

Acknowledgments

The authors would like to acknowledge the contribution of members of staff including Dr. Kenneth Orengo, Shadrack Karanja, Yvonne, Catherine and Wesley stationed at the Analytical Chemistry and Food Safety laboratory at the Directorate of Veterinary Services for their technical assistance. Special gratitude to the Ministry of Agriculture, Livestock and Fisheries through the Directorate of Veterinary Services for partially funding the project (transport and logistics).

References

1. Lalah JO, Yugi PO, Jumba IO, *et al.*: **Organochlorine pesticide residues in Tana and Sabaki Rivers in Kenya.** *Bull Environ Contam Toxicol.* 2003; **71**(2): 298–307. [PubMed Abstract](#) | [Publisher Full Text](#)
2. Maitho T: **Pesticides residues in animal products in Kenya: organochlorine and organophosphorous insecticides in milk and body fat.** 1978; [cited 2014 Aug 5]. [Reference Source](#)
3. Kaigwara P, Wandiga S, Lalah J: **Pesticides in Kenya. Pesticide Residues in Coastal Tropical Ecosystems.** 2002.
4. Gitahi SM, Harper DM, Muchiri SM, *et al.*: **Organochlorine and organophosphorus pesticide concentrations in water, sediment, and selected organisms in Lake Naivasha (Kenya).** *Hydrobiologia.* 2002; **488**(1–3): 123–8. [Publisher Full Text](#)
5. Musa S, Gichuki JW, Raburu PO, *et al.*: **Organochlorine and organophosphorus pesticide residues in water and sediment from Yala/Nzoia River within Lake Victoria Basin, Kenya.** *J Ecol Nat Environ.* 2011; **3**(12): 392–9. [Reference Source](#)
6. Werimo K, Bergwerff AA, Seinen W: **Residue levels of organochlorines and organophosphates in water, fish and sediments from Lake Victoria-Kenyan portion.** *Aquat Ecosyst Health Manag.* 2009; **12**(3): 337–41. [Publisher Full Text](#)
7. Akenga PC: **Method optimization and determination of selected organophosphate and carbamate pesticide residues in the rice (oryza sativa) growing region of mwea, Kirinyaga county, kenya.** 2015; [cited 2014 Aug 5]. [Reference Source](#)
8. Mbaria JM, Ogara WO, Gitau FK: **Pesticide Residues in Beef and Camel Meat**

- From Slaughterhouses in 13 Districts in Kenya.** *Kenya Veterinarian*. 2009; 33(1).
[Publisher Full Text](#)
9. Nyaundi JK, Getabu A, Onchieku J, *et al.*: **Occurrence and distribution of Organochlorine Pesticide Residues in Water and Sediments of Earthen Fish Ponds in South Western Kenya.** *Uganda Journal of Agricultural Sciences*. 2021; 19(2): 47–60.
[Publisher Full Text](#)
 10. Wandiga SO, Yugi PO, Barasa MW, *et al.*: **The distribution of organochlorine pesticides in marine samples along the Indian Ocean coast of Kenya.** *Environ Technol*. 2002; 23(11): 1235–46.
[PubMed Abstract](#) | [Publisher Full Text](#)
 11. Olaka L: **Organochlorine pesticides in rain, rivers and groundwater in the Lake Naivasha basin and implications for their management.** *Africa Journal of Physical Sciences*. 2020; [cited 2014 Aug 5].
[Reference Source](#)
 12. Omwenga I: **Assessment of pesticide and heavy metal residues in tilapia fish from Machakos and Kiambu counties, Kenya.** 2013; [cited 2014 Aug 5].
[Reference Source](#)
 13. Violet Nakhungu M, Margaret NK, Deborah AA, *et al.*: **Types and Classification of Pesticides Used on Tomatoes Grown in Mwea Irrigation Scheme, Kirinyaga County, Kenya.** *Eur J Nutr & Food Safety*. 2019; 11(2): 83–97.
[Publisher Full Text](#)
 14. Ongachi FO, Wambugu W, Mbakaya C, *et al.*: **Health Effects of Pesticide Exposure among Formulators, Repackers and Store Workers in Nairobi, Kenya.** *J Nat Sci Res*. 2017; 7: 2017.
[Reference Source](#)
 15. Omwenga I, Kanja L, Nguta J, *et al.*: **Organochlorine pesticide residues in farmed fish in Machakos and Kiambu counties, Kenya.** *Cogent Environ Sci*. 2016; 2(1): 1153215.
[Publisher Full Text](#)
 16. KNBS: **2019 Kenya Population and Housing Census Volume 1: Population by County and Sub-County.** 2019 Kenya Population and Housing Census. 2019; I: 49.
[Reference Source](#)
 17. **Kiambu leads in milk production over the last 5 years – Kenya News Agency.** [cited 2014 Aug 6].
[Reference Source](#)
 18. Republic of Kenya: **Isiolo County Integrated Development Plan (CDP).** 2018; (March).
[Reference Source](#)
 19. Anastassiades M, Lehotay SJ, Štajnbaher D, *et al.*: **Fast and easy multiresidue method employing acetonitrile extraction/partitioning and “dispersive solid-phase extraction” for the determination of pesticide residues in produce.** *J AOAC Int*. 2003; 86(2): 412–31.
[PubMed Abstract](#)
 20. Lehotay SJ: **Determination of pesticide residues in foods by acetonitrile extraction and partitioning with magnesium sulfate: collaborative study.** *J AOAC Int*. 2007; 90(2): 485–520.
[PubMed Abstract](#) | [Publisher Full Text](#)
 21. John PJ, Bakore N, Bhatnagar P: **Assessment of organochlorine pesticide residue levels in dairy milk and buffalo milk from Jaipur City, Rajasthan, India.** *Environ Int*. 2001; 26(4): 231–6.
[PubMed Abstract](#) | [Publisher Full Text](#)
 22. Committee ES: **Guidance on selected default values to be used by the EFSA Scientific Committee, Scientific Panels and Units in the absence of actual measured data.** *EFSA journal*. 2012; 10(3): 2579.
[Publisher Full Text](#)
 23. USAID-KAVES: **USAID-KAVES Dairy Value Chain Analysis.** Fintrac Inc, by the United States Agency for International Development, 2015.
[Reference Source](#)
 24. Ogenche CS: **Milk Consumption Patterns and Nutritional Status of Children (24-59 Months) from Dairy and Non-Dairy Households in Nakuru County, Kenya.** Egerton University; 2019.
[Reference Source](#)
 25. Dourson ML, Lu FC: **Safety/risk assessment of chemicals compared for different expert groups.** *Biomed Environ Sci*. 1995; 8(1): 1–13.
[PubMed Abstract](#)
 26. Lu FC: **A Review of the acceptable daily intakes of pesticides assessed by WHO.** *Regul Toxicol Pharmacol*. 1995; 21(3): 352–64.
[PubMed Abstract](#) | [Publisher Full Text](#)
 27. Omwenga I, Kanja L, Zomer P, *et al.*: **Organophosphate and carbamate pesticide residues and accompanying risks in commonly consumed vegetables in Kenya.** *Food Addit Contam Part B Surveill*. 2021; 14(1): 48–58.
[PubMed Abstract](#) | [Publisher Full Text](#)
 28. Okumu M: **Data for estimation and human health risk assessment.** *figshare*. Dataset. 2021.
<http://www.doi.org/10.6084/m9.figshare.16823788.v1>
 29. Raslan AA, Elbadry S, Darwish WS: **Estimation and human health risk assessment of organochlorine pesticides in raw milk marketed in Zagazig City, Egypt.** *J Toxicol*. 2018; 2018: 3821797.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 30. Heck MC, dos Santos JS, Junior SB, *et al.*: **Estimation of children exposure to organochlorine compounds through milk in Rio Grande do Sul, Brazil.** *Food Chemistry*. 2007; 102(1): 288–94.
[Publisher Full Text](#)
 31. Darko G, Acquah SO: **Levels of organochlorine pesticides residues in dairy products in Kumasi, Ghana.** *Chemosphere*. 2008; 71(2): 294–8.
[PubMed Abstract](#) | [Publisher Full Text](#)
 32. Deti H, Hymete A, Bekhit AA, *et al.*: **Persistent organochlorine pesticides residues in cow and goat milks collected from different regions of Ethiopia.** *Chemosphere*. 2014; 106: 70–4.
[PubMed Abstract](#) | [Publisher Full Text](#)
 33. Müller MHB, Polder A, Brynildsrud OB, *et al.*: **Organochlorine pesticides (OCPs) and polychlorinated biphenyls (PCBs) in human breast milk and associated health risks to nursing infants in Northern Tanzania.** *Environ Res*. 2017; 154: 425–34.
[PubMed Abstract](#) | [Publisher Full Text](#)
 34. **EU Pesticides database - European Commission.** [cited 2014 Jun 17].
[Reference Source](#)
 35. **Pesticides | Codex Alimentarius FAO-WHO.** [cited 2014 Jun 18].
[Reference Source](#)
 36. Agency for Toxic Substances and Disease Registry: **Heptachlor and Heptachlor epoxide.** Division of Toxicology and Environmental Medicine. ToxFAQs - for Heptachlor and Heptachlor Epoxide. CAS # 76-44-8 and 1024-57-3.
[Reference Source](#)
 37. Agency CEPfan AM, Alexeeff GV: **Public Health Goal for Heptachlor and Heptachlor Epoxide In Drinking Water.** 1999; 1–57.
 38. Hassall KA: **Biochemistry and uses of pesticides.** Macmillan Press Ltd; 1990.
 39. Srivastava S, Narvi SS, Prasad SC: **Organochlorines and organophosphates in bovine milk samples in Allahabad region.** 2008.
[Reference Source](#)
 40. Shaker EM, Elsharkawy EE: **Organochlorine and organophosphorus pesticide residues in raw buffalo milk from agroindustrial areas in Assiut, Egypt.** *Environ Toxicol Pharmacol*. 2015; 39(1): 433–40.
[PubMed Abstract](#) | [Publisher Full Text](#)
 41. Srivastava S, Narvi SS, Prasad SC: **Levels of select organophosphates in human colostrum and mature milk samples in rural region of Faizabad district, Uttar Pradesh, India.** *Hum Exp Toxicol*. 2011; 30(10): 1458–63.
[PubMed Abstract](#) | [Publisher Full Text](#)
 42. Iftikhar B, Siddiqui S, Rehman S: **Assessment of the dietary transfer of pesticides to dairy milk and its effect on human health.** *Afr J Biotechnol*. 2015; 13(3): 476–85.
[Publisher Full Text](#)
 43. **Guidelines for predicting dietary intake of pesticide residues (revised) Prepared by the Global Environment Monitoring System-Food Contamination Monitoring and Assessment Programme (GEMS/Food) in collaboration with Codex Committee on Pesticide Residues.** 1997.
 44. Gill JPS, Bedi JS, Singh R, *et al.*: **pesticide Residues in peri-Urban Bovine Milk from India and Risk Assessment: A Multicenter Study.** *Sci Rep*. 2020; 10(1): 8054.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)

Open Peer Review

Current Peer Review Status: ?

Version 1

Reviewer Report 04 March 2022

<https://doi.org/10.5256/f1000research.78532.r119332>

© 2022 Witczak A. This is an open access peer review report distributed under the terms of the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Agata Witczak

Department of Toxicology, Dairy Technology and Food Storage, Faculty of Food Science and Fisheries, West Pomeranian University of Technology in Szczecin, Szczecin, Poland

The article submitted for review concerns the levels of organochlorine (OCPs) and organophosphate (OPPs) pesticide residues in cow milk from Kiambu and camel milk from Isiolo and Laikipia. The human dietary intake and the potential consumer health risks were also evaluated in Kenya.

The results obtained are disturbing, because the levels of heptachlor in both Cow and Camel milk collected from these areas are above acceptable limits. The potential health risks with respect to chronic dietary intake of cow and camel milk in the study area cannot be excluded.

I consider the results obtained at work as valuable and needed to correctly assess the health risk of consumers in Kenya.

The literature citation should be in accordance with the requirements of the publisher. Check the whole manuscript, please. Authors should carefully check for grammar, punctuation and sentence structure before submitting the revised paper.

It is recommended that this manuscript can be accepted for approval after minor revision.

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Yes

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Food toxicology, Environmental toxicology

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

The benefits of publishing with F1000Research:

- Your article is published within days, with no editorial bias
- You can publish traditional articles, null/negative results, case reports, data notes and more
- The peer review process is transparent and collaborative
- Your article is indexed in PubMed after passing peer review
- Dedicated customer support at every stage

For pre-submission enquiries, contact research@f1000.com

F1000Research