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Pesticide residues in drinking water and associated risk to consumers in Ethiopia

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HIGHLIGHTS

- Diazinon, 2,4-D, malathion and fenpropimorph were detected in drinking water sources of Jimma and Addis Ababa.
- All consumers are at chronic risk of all pesticides but acute risk was not observed.
- Pesticide residues were detected from source up to community taps from Jimma and Addis Ababa water sources.
- Wells, streams and ponds have higher concentration of all pesticides under study than the community taps.

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ABSTRACT

Access to safe and reliable drinking water is vital for a healthy population. However, surface water may be contaminated with pesticides because of the nearby agricultural areas as well as from household application. Water samples were collected from water sources in Jimma zone and Addis Ababa, Ethiopia. The extraction and clean up of the samples were undertaken using liquid-solid and liquid-liquid methods. Human exposure was assessed by calculating the estimated daily intake (EDI) of pesticides in water and compared with the acceptable daily intake (ADI) and the acute reference dose (ARfD). The mean concentrations of 2,4-D, malathion, diazinon and fenpropimorph were 1.59-13.90 μg/l and 0.11-138 μg/l in Jimma and Addis Ababa water sources, respectively. The residue level of some of the pesticides were above the European drinking water guide line values, which is an indication of an illegal use of pesticides in the study areas. Concerning human health risk estimation, there was no acute risk (EDI < ARfD). However, chronic risks to human health were observed from exposure to diazinon and fenpropimorph (EDI > ADI) for Jimma and Addis Ababa populations, respectively. A comprehensive monitoring is required to reduce the level of pesticide residues in the water and to minimize particularly the long term human health risks.

1. Introduction

Access to clean water is a fundamental human right and vital to sustain healthy life. Reports, however, indicate that residues of pesticides occur in different water sources (Sankararamakrishnan et al., 2005; Ntow, 2001; Chowdhury et al., 2012; Flores-García et al., 2011; Varca, 2012). Environmental contamination of natural water by pesticide residues during and after field applications is of a great concern. Water is an important component of public health and failure to supply safe drinking water will cause a heavy health burden to humanity (van der Kooij, 2014). The contamination of surface and ground water by pesticides is discussed by different authors (Varca, 2012; Donald et al., 2007). For example, a study done by Teklu et al. (2015), detected 2,4-D, malathion, deltamethrin, atrazin, chlorothalonil and endosulfan in surface water samples from Ethiopia.

Pesticides may enter into the aquatic system by diffusion to the surface or subsurface hydrological pathways. Pesticide transport to

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surface water, is mainly caused by spray drift, runoff water and drainage water (Ikehata and Gamal El-Din, 2005). This may happen, due to improper operations such as filling of sprayers, washing of measuring utilities, disposing of packing materials and cleaning of spraying equipment. The pesticide sprayers in Ethiopia can do mixing/loading or dilution of pesticides near to water sources, which contaminate the water as well as the irrigated crops. In turn, such practices affect the health of the communities living around these areas. Additionally, applications on lawns and runoff during rain events are prone to be flushed into the sewerage channels and end up in the receiving water bodies (Gerecke et al., 2002).

Due to the persistence of some pesticides, such as DDT and its metabolites, in the environment and their potential adverse health effects for consumers, contamination of surface and ground water has long been recognized as an important issue in many countries. In developing countries, the need to ensure local agricultural production and food security while simultaneously protecting the population against health effects from pesticide exposure, remain a major public health challenge. According to Kesavachandran et al. (2009), developing countries use only small amount of the world's agrochemicals, but they suffer from 99% of deaths from unsafe application of pesticides and poor handling due to illiteracy and poverty status of the users. Even if Ethiopia has a huge potential of surface and ground water sources, the country utilizes a small portion of these resources. About 48.9% of the population obtains unprotected drinking water (Central Statistical Agency, 2012).

Some of the water sources in the rural communities around Jimma, in southwestern Ethiopia, are springs, rivers, streams, wells and ponds. Jimma town, which is located at 353 km southwest of Addis Ababa, suffers from shortage of clean water supply due to power interruption and limited capacity of the existing treatment plant and inefficient water distribution system. Currently, new treatment plant is being operational. However, there is no continuous treated water supply to all communities of the town which forces them to fetch water from unprotected sources. The dwellers of the town use water from different sources such as tap water, springs, wells and rivers for drinking and other domestic purposes. Before 2014, the town has only one conventional water treatment plant in the town which supplies purified water (Kifle and Gadisa, 2006). Other parts of the communities in Jimma zone do not have a conventional water treatment plant but rely on the different water sources.

Addis Ababa, the capital of Ethiopia and the diplomatic center of Africa, is one of the fastest growing cities in the continent. Its population has nearly doubled every decade. The city is subdivided into 10 sub-cities with a total population of 3,048,631. The main water supply sources of Addis Ababa are generated from the three ponds (Geferesa, Legedadi, and Dire) and ground water source (Akaki). Water coverage of the city is about 94% in 2012 with a daily supply of 374,000 cubic meters (City Government of Addis Ababa, 2013).

The Legedadi pond is the largest water supply source which contributes 40% of the town water. The water treatment capacity of the plant is 150,000 cubic meters per day (UNEP/UNESCO/UN-HABITAT/ECA, 2003). The catchment area of Legedadi is about 206 square kilometers and is surrounded by farm lands. These farm lands are owned by smallholder farmers who use different crop protection products (pesticides). During application they may contaminate drinking water sources. The other possible sources of pesticide contamination in the drinking water sources may be attributed to leaks of pesticides from obsolete stockpiles near the study area ("Sireguyo pesticides store") (personal observation). Inappropriate storage, poor handing practice, inappropriate labeling (labels are in English rather than the local language), and illegal use of pesticides due to poor knowledge of farmers may aggravate the contamination of the water sources (Haylamicheal and Dalvie, 2009).

A study conducted in the rift valley region of Ethiopia indicates that, organochlorine pesticides such as endosulfan and DDTs were detected in the soils. This can pose a risk of contamination to the surrounding water bodies (Westbom et al., 2008). In Ethiopia, the health hazards associated with pesticide handling are not well understood by both the sprayers and consumers. Misuse of pesticides, lack of awareness towards the proper handling of pesticides and poor monitoring systems and the presence of high amounts of pesticides are the main contributors of water source contamination (Mekonnen and Agonafir, 2002). Consumption of water and other consumer products that are contaminated with pesticides could expose individuals to different acute and chronic illnesses, such as cancer. In Ethiopia, the prevalence of cancer is increasing. This has dictated the government to establish cancer treatment centers in selected referral hospitals. On the contrary, there is little effort to investigate the major underlying causes of such illnesses. Consequently, a study such as ours, could help in tracing major possible causes of chronic illnesses.

To date, there are no comprehensive assessments of pesticide residues from different drinking water sources upon which consumer risk could be estimated. Therefore, the present study aims at investigating pesticide residues from different drinking water sources that are used for human consumption and to undertake consumers risk assessment.

2. Materials and methods

2.1. Study area

One of the water sample source is the Addis Ababa water supply system. Addis Ababa lies 9°1′48″N latitude and 38°44′24″E longitude. The city is located at the heart of the country at an altitude of 2100 m. The city occupies a total area of 540 km^2 and has a complex mix of highland climate regions with annual average temperature of 22.2 °C. The study area encompasses the Legedadi pond which is the main water supply source for Addis Ababa. The catchment area of Legedadi pond is about 206 square kilometers, which has similar rainfall and temperature conditions compared to Addis Ababa (Fig. 1).

The other water sample source is Jimma zone in southwestern Ethiopia. The study area includes ten districts of Jimma zone (Jimma, Dedo, Seka, Kersa, Tiro Afeta, Mana, Limu kossa, Shebe, Omo-Nada and Gomma) in which water samples were collected. Jimma zone is located in Oromia region, 1744 m above sea level, at a latitude of 7°40′0.01″ and longitude of 37°0′0″ (Fig. 2).

2.2. Sampling

A total of 50 sep-pak and 45 raw water samples were collected from springs (n = 19), well water (n = 7), river water before treatment (n = 5), community taps (n= 17) and distribution reservoirs (n= 2) located in different districts and Jimma town. Most of the water sources are surrounded by agricultural fields where chemical pesticides were applied (personal observation). The water samples from Jimma zone were classified into treated (samples taken immediately after treatment, community taps and reservoir) and untreated water (samples taken from surface water, springs and wells).

The water samples were also collected from Legedadi water treatment plant which is the main water supply source to Addis Ababa city. Two small streams that pass through agricultural fields and join the pond were considered as sampling sites. Before the