Science of the Total Environment 639 (2018) 438–456

Contents lists available at ScienceDirect

Science of the Total Environment

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

Review

The use of a disability-adjusted life-year (DALY) metric to measure human health damage resulting from pesticide maximum legal exposures

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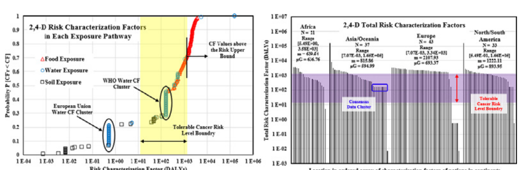
HIGHLIGHTS

- The DALY approach was used to measure health damage from maximum pesticide legal exposure.
- Theoretical health risks of pesticides with different modes of action were compared.
- Legal health damage measured from soil exposure to pesticides is much lower than other routes.
- European nations adopted the uniform and strict pesticide standard values presenting in the consensus data cluster.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 24 February 2018
Received in revised form 26 April 2018
Accepted 12 May 2018
Available online xxxx

Editor: Yolanda Picó

Keywords:
Pesticides
DALYs
Human health risks

ABSTRACT

Most agencies around the world have developed a separate regulation frameworks for pesticides with different modes of action, likely because of the lack of a uniform quantification for health damage, which may underestimate pesticides' impact on human health and disease burden. In this study, the disability-adjusted life-year, a uniform metric used to express the human health impact and damage, was used to measure theoretical health damage resulting from maximum exposure as permitted by law to the most widely used pesticides. The total human risk characterization factors computed from chlorpyrifos and diazinon standard values through main exposure routes are generally larger than that of other widely used pesticides, and most factors of chlorpyrifos exceed the upper bounds of health risk. In addition, the damages to human health quantified from soil legal exposure to these widely used pesticides are much lower than that from exposure to drinking water or foods, which could help derive exposure allocation factors for different exposure routes. A total of 412 (28.3% of the total) computed total risk characterization factors of the 13 pesticides exceed the upper bound of tolerable risk uncertainty. Some nations, such as those in Europe, have adopted uniform and strict pesticide standard values as well as some computed risk characterization factors presented in the consensus data cluster. In addition, the results of an analysis on the geographical distribution of health risk characterization factors indicated that European nations have provided more conservative pesticide standard values in general. It is hoped that regulatory agencies can apply this uniform metric to compare and formulate legal limits for pesticides that have different modes of action.

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https://doi.org/10.1016/j.scitotenv.2018.05.148

Contents

1. Introduction

Pesticides are deliberately applied to control pests. More than three billion kilograms of pesticides are used around the world each year (Pan-UK, 2003). After application, pesticides can be transported into residential soil, air, drinking water sources, and biomass. Specifically, agricultural crops uptake pesticides after their application, which is the most important aspect of pesticide bioaccumulation in biomass (Jacobsen et al., 2015). Pesticides can be found in the food people eat, the air people breathe, the water people drink, and residential soil (Giannouli and Antonopoulos, 2015; Yan et al., 2018; Lai, 2017; Jennings and Li, 2014). Human exposure to pesticides could happen via inhalation, ingestion, and dermal contact, and ingestion of pesticides is predominantly via crop residues (Fantke et al., 2012a, 2012b). Short-term exposure at high doses to pesticides could cause some symptoms, such as skin and eye irritation (Penn State College of Agricultural Sciences, 2017), vomiting (Canadian Centre for Occupational Health and Safety, 2017), headache, and dizziness. Long-term exposure to pesticides could cause various forms of health damage, such as nerve system abnormalities (Rani et al., 2017; Hu et al., 2015), damage to the reproductive system (Ullah et al., 2018; Hesperian Health Guides, 2017), genetic damage (Cycoń et al., 2013; Bist et al., 2017; Jiang et al., 2017), indicative liver cell changes (Lodovici et al., 1997; Lorenz, 1985), sensitivity or allergic reaction (Chatzi et al., 2007; Schulze et al., 1997), and cancer (Blair et al., 1983; Dich et al., 1997).

Promulgated by worldwide regulatory jurisdictions in major human exposure routes, pesticide standard values, including pesticide soil regulatory guidance values (RGVs), drinking water maximum concentration levels (MCLs), residential air MCLs, and agricultural foods maximum residue limits (MRLs), specify the maximum amount of pesticides that can exist in the environment without prompting regulatory responses that aim to avoid adverse human health effects in most cases. Pesticide soil RGV aims to protect human health from soil ingestion, soil dust inhalation, and soil dermal contact of the pesticide. Pesticide drinking water MCL and agricultural foods MRL aim to protect human health from ingestion of pesticide-contaminated drinking water and foods. To help control human health risks, worldwide regulatory jurisdictions have legislated standard values for pesticide concentrations in major routes of human exposure, such as residential soil, air, drinking water, and agricultural foods. Regulating pesticide standard values is a very complicated process because there are many variables and uncertainties, such as pesticide toxicity, exposure scenarios, human metabolism, and so forth.

Previous studies have made efforts to evaluate pesticide standard values. Harrison et al. (2000), Hornstein (1993), and Li and Jennings (2018) analyzed and discussed drinking water regulations and MCLs among international nations and organizations, including the U.S. Environmental Protection Agency (USEPA), European Union (EU), and World Health Organization (WHO). Winter and Jara (2015) developed pesticide food safety standards and compared them with current standards. Geng et al. (2015) conducted a quality risk analysis of pesticide food standards in China. Li and Jennings (2017) catalogued and created a database for global pesticide standard values. Studies have also focused on a cumulative risk assessment for chemicals that have a common mode of action and that pose a risk for additive effects, which helped agencies developed pesticide standard values for mixtures (USEPA, 2002a; USEPA, 2017). However, current studies have analyzed and derived chemical regulatory standard values only for the same pesticide or a group of pesticides that have a common mechanism of action. Health risks of pesticides with different toxicity modes of action are always assessed separately, and regulation frameworks are developed independently, which results in underestimating human health impacts and disease burdens caused by different pesticides. For example, atrazine is an endocrine disruptor that causes hormone imbalance (Jing et al., 2017; Sagarkar et al., 2014), and aldicarb acts as a cholinesterase inhibitor, which damages the nerve system (Jaeger et al., 1999; Burgess et al., 1994). The risk assessment and regulatory process of these two pesticides are usually conducted separately, although humans are always exposed to them concurrently. Regulatory agencies have applied toxicological information such as acute and chronic reference doses from animal tests of each pesticide to derive standard values for atrazine and aldicarb independently; however, when exposed to