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Review

Exposure to pesticides and the associated human health effects

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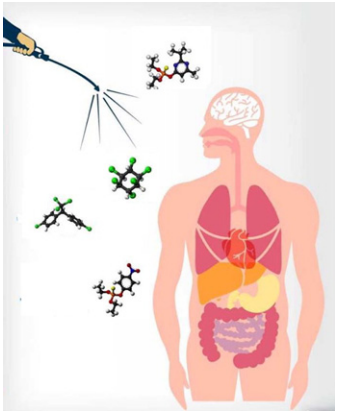
HIGHLIGHTS

- Pesticides are designed to function with reasonable certainty and minimal risk to human health.
- Pesticide exposure is however turned out to be linked with various diseases including cancer.
- In light of the significance of pesticide pollution, the general aspects of pesticides are assessed.
- The current state of knowledge regarding pesticide use and its detrimental impacts is described.

GRAPHICAL ABSTRACT



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ABSTRACT

Pesticides are used widely to control weeds and insect infestation in agricultural fields and various pests and disease carriers (e.g., mosquitoes, ticks, rats, and mice) in houses, offices, malls, and streets. As the modes of action for pesticides are not species-specific, concerns have been raised about environmental risks associated with their exposure through various routes (e.g., residues in food and drinking water). Although such hazards range from short-term (e.g., skin and eye irritation, headaches, dizziness, and nausea) to chronic impacts (e.g., cancer, asthma, and diabetes), their risks are difficult to elucidate due to the involvement of various factors (e.g., period and level of exposure, type of pesticide (regarding toxicity and persistence), and the environmental characteristics of the affected areas). There are no groups in the human population that are completely unexposed to pesticides while most diseases are multi-causal to add considerable complexity to public health assessments. Hence, development of eco-friendly pesticide alternatives (e.g., EcoSMART) and Integrated Pest Management (IPM) techniques is desirable to reduce the impacts of pesticides. This paper was hence organized to present a comprehensive review on pesticides with respect to their types, environmental distribution, routes of exposure, and health impacts.

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Contents

1. Introduction

Pesticides are one of the few toxic substances released deliberately into the environment to kill living organisms (e.g., weeds (herbicides), insects (insecticides), fungus (fungicides), and rodents (rodenticides)). Although the term pesticide is often misunderstood to refer only to insecticides, it is also applicable to herbicides, fungicides, and various other substances used to control pests' (Matthews, 2006).

Agriculture is the largest consumer (around 85% of world production) of pesticides to chemically control various pests. Moreover, pesticides are also used in public health activities to control vector-borne diseases (e.g., malaria and dengue) and unwanted plants (e.g., grass and weeds) in ornamental landscaping, parks, and gardens. They are also useful in suppressing or avoiding the proliferation of insects, pests, bacteria, fungi, and algae in electrical equipment, refrigerators, paint, carpets, paper, cardboard, and food packaging materials (Gilden et al., 2010). However, unintended exposure to pesticides can be extremely hazardous to humans and other living organisms as they are designed to be poisonous (Sarwar, 2015). They may also be harmful to people who are exposed to pesticides through occupational (or home) use, eating foods or liquids containing pesticide residue, or inhalation (or contact) of pesticide-contaminated air (Pimentel et al., 2013). Even very low levels of exposure may have adverse health effects at early development (Damalas and Eleftherohorinos, 2011). The physical makeup, behavior, and physiology of children make them more susceptible to pesticides than adults (Mascarelli, 2013).

Pesticide exposure is linked with various diseases including cancer, hormone disruption, asthma, allergies, and hypersensitivity (Van Maele-Fabry et al., 2010). A line of evidence also exists for the negative impacts of pesticide exposure leading to birth defects, reduced birth weight, fetal death, etc. (Baldi et al., 2010; Meenakshi et al., 2012; Wickerham et al., 2012). On the basis of scientific evidence, the real, predicted, and perceived risks that pesticides pose to human health (occupational and consumer exposure) and the environment are fully justified. In light of the environmental significance of pesticide pollution and its impact, this review has been organized to describe the general aspects of pesticides with respect to classification, the status of pollution, the transfer route, and the impacts on human health. The objective of this review is to conduct a systematic review of published studies (since 1999 to 2016) with respect to the use of pesticides and their detrimental impacts on human health and ecological systems.

2. Methodology

A comprehensive literature search was conducted to accurately describe the impact of pesticide exposure and its health outcome. To this end, the following data sources were utilized: Medline, EMBASE, Science direct, PubMed, psycINFO, and papers cited in those database. In light of the extensiveness of the existing literature on this topic as well as the availability of many reviews, we focused on studies published mainly from 2010 to the present. No restrictions on study type were applied while the search terms were organized by health effect and topic area. We did not restrict our search to papers written in English but also those presented in other languages (as long as English abstracts are available). After removing duplicate records, all remaining references retrieved from the literature search were screened by using only the title and abstract (when necessary and available).

After primary screening to remove records with irrelevant topics, a secondary screening was done to focus on the articles of our study interest. The results were organized according to health effect to assess the effect of exposure to cumulative or aggregate mixtures of pesticide. We also considered studies focusing not only on their impact but also on exposure route. The titles for each citation were screened and 272 articles were selected for the review of their abstracts. All abstracts were sorted to yield 121 publications for full review. After reviewing those full texts, only 87 studies were finally cited in the menu script. Overall, topics dealing with cancers associated with pesticide exposure are one of the most studied issues during the last decade. Distribution of the cited studies has been illustrated in Fig. 1.

3. Types of pesticides

Pesticides can be classified by various criteria such as chemical classes, functional groups, mode of action, and toxicity (**Garcia** et al., 2012). Table 1 provides classification of pesticides based on different criteria. The active ingredients of most pesticides are either organic (contain carbon) or inorganic (copper sulfate, ferrous sulfate, copper, lime, sulfur, etc.) (Gunnell et al., 2007). The chemicals in organic pesticides tend to be more complex and less soluble in water than those of inorganic pesticides (Debost-Legrand et al., 2016). Organic pesticides can be additionally subdivided into two groups: natural (produced from naturally occurring sources) and synthetic (artificially produced by chemical synthesis). Table 2 also displays the classification based on chemical structure. Pesticides have different modes of action or ways to control the