

**Occupational and bystander exposures to pesticide's  
during aerosol applications in horticulture and  
amenity gardening.**

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\*Photo taken of the Greenhouses in the Botanic Gardens, Ireland.

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## Abstract

The objective of this study is to investigate the potential for occupational and bystander exposure to pesticides in horticulture and amenity gardening. Professional uses of pesticides have been linked to a number of illnesses such as cancer, respiratory illnesses and fertility issues. Exposures can be via direct contact with the chemical, inhalation of the airborne aerosols and surface transfer from contact with contaminated surfaces. Occupational exposure research is available in agriculture however there is little information on occupational and bystander exposures during horticultural work. Application of pesticides in horticulture can involve a number of different chemicals e.g. Grazon®90, Roundup Bioactive which are used to control unwanted pests. Application methods usually involve producing a fine aerosol with an applicator. Exposures to pesticides can be evaluated by measuring the aerosol concentration in the worker breathing zone, by measuring dermal exposure or biological methods.

In this research workers will be grouped into similar exposure groups, by task, chemical used and the application method. Exposures will be evaluated by measuring the concentration of aerosol in the workers breathing zone, estimating the dermal exposure and total exposure using biological monitoring methods.

Exposure data will also be compared to data generated from exposure modelling tools such as the European Food Safety Authority (EFSA) risk assessment tool and the Advanced Reach Tool (ART).

The results collected in this study will help evaluate the suitability of worker controls and also will be used to determine the suitability of some of the available exposure modelling tools for evaluating pesticide exposure. Furthermore, this information will be useful to regulatory bodies involved in the registration of pesticide.

## Introduction of the Project

An aerosol is defined as suspension of solid or liquid particles suspended in air or gas. Aerosol can form several types including mist, spray and suspension. Aerosol technology is the study of properties, behaviour and physical principles of aerosols and the application of this knowledge to their measurement and control (Hinds, 1982).

The most significant aspect of aerosols, in terms of health effects, is the size of the aerosol. This determines where in the body it can penetrate. Particle sizes are measured in micrometres ( $\mu\text{m}$ ) ( $1.0 \times 10^{-6}$  metres) and the diameter ranges from 100 to  $0.001 \mu\text{m}$ .

Atmospheric aerosols can be natural or anthropogenic. Anthropogenic aerosols such as pesticides, pose a hazard to the human body due to their chemical composition i.e. chemicals that are carcinogenic.

The overall objective of using pesticides is to control unwanted pests. Pests can range from weeds, insects to rodents. There are numerous pesticides that are used to control pests including herbicides (for invasive weeds), insecticides (for insects) and rodenticides (for rodents such as mice and rats). These pests can have an adverse effect on the growth of crops, infestations of insects and spreading diseases, which is a major concern to public health as vector-borne diseases account for 17% of the estimated global burden of infectious diseases (WHO, 2006).

The chemicals that are used in the development of pesticides have active ingredients that also have health effects in humans. There are many chronic illnesses and diseases that have been linked to pesticides from long term exposure (Montano, 2014).

Previous research on the health effects of pesticide usage has indicated that chronic exposure to small, low level doses can have adverse health effects (Maroni et al., 1999, Bouvier et al., 2006, Mostafalou and Abdollahi, 2013). Chronic exposures to chemicals can be more difficult to study than acute exposure because additional information is required to determine exposure, while information on effects from acute exposures can be derived from animal studies (MacFarlane et al., 2013). Another study indicates that chronic exposure to pesticides can have more risk than acute exposures (Krieger, 1995). There is also little research on the effects of using multiply pesticides over long periods which could lead to adverse health effects (deRaaf et al., 1997). Chronic exposures to pesticides would be very common in the horticultural sector due to the nature of the work.

The majority of research on the occupational exposure to pesticides, has focused on the agricultural sector (Ramos et al., 2010, Lebailly et al., 2009), which usually use large volumes of chemicals which are applied with large boom sprayers. Acquavella et al (2003) cited that farmers tend to use between two and four pesticides and up to half of these farmers spent less than 20 days a year on pesticide application tasks. A farmer that would apply pesticides once a year would have significantly lower exposure than an applicator of

pesticides that would spray on consecutive days or weeks throughout the season (Damalas and Eleftherohorinos, 2011).

There is little research on the use of pesticides in the horticultural sector (Ramos et al., 2010, MacFarlane et al., 2010, Garcia-Santos et al., 2011, Flores et al., 2011). This sector's use of pesticides is wide ranging and involves the maintenance of parks, outdoor gardens, arboretums and other similar gardens. This sector would use pesticides to avoid or eliminate weeds, protect plants from infestation of insects and for aesthetic properties. These gardens can also have protected and endangered species of interest to botany and need to use pesticides to ensure its survival (Damalas, 2009).

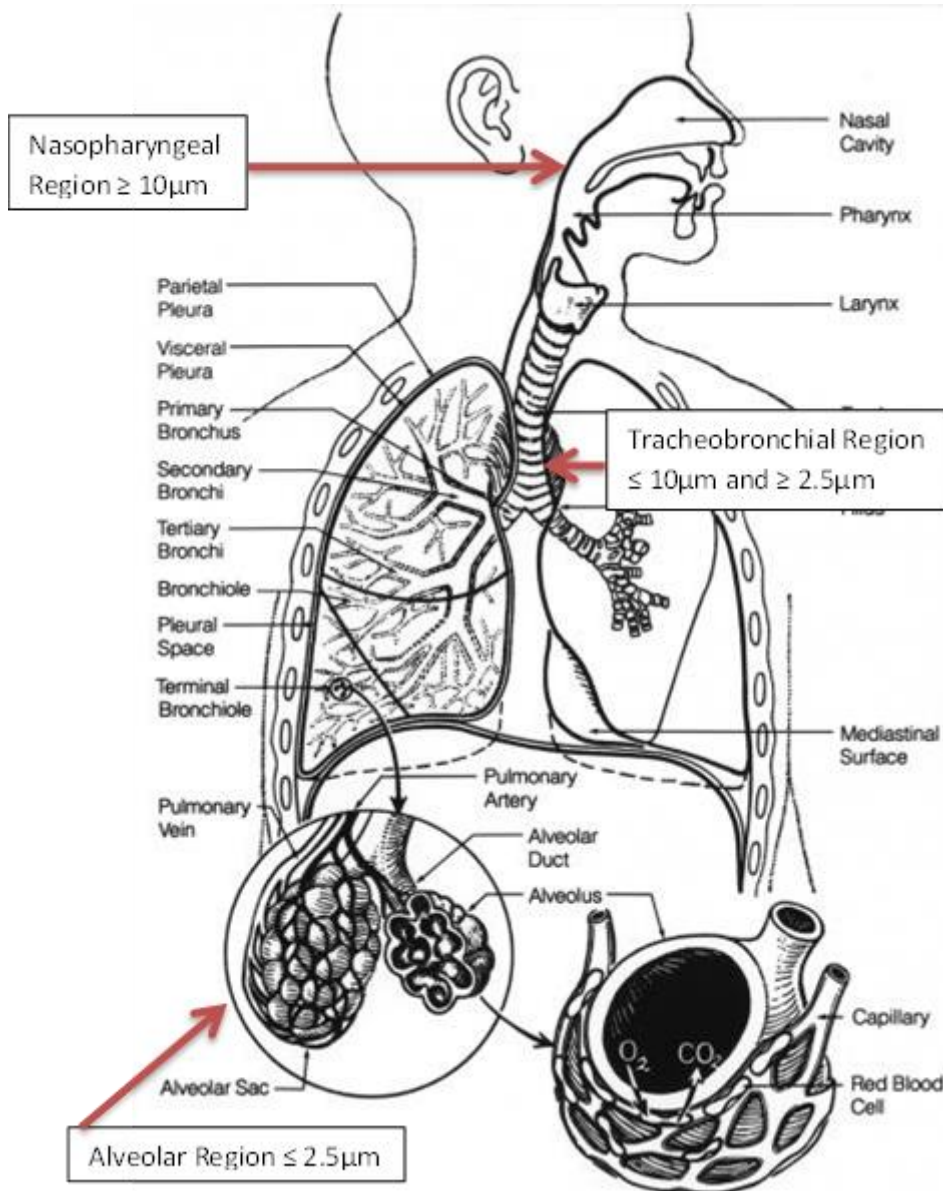
Many differences between the agricultural and horticultural sector can be defined. Typically, in the horticultural sector, a variety of chemicals are used, such as herbicides for footpaths, specialised pesticides for rose gardens and insecticides for preventing insect damage. There are a variety of application methods used including boom sprayers, manual knapsack sprayers to battery operated sprayers (MacFarlane et al., 2013). Horticultural workers normally complete the pesticide spraying task from collection of the pesticide, mixing and loading, spraying and cleaning (Ramos et al., 2010). A study in the floriculture sector found that one person completing all of these tasks could expose them to an unsafe amount of pesticides (Flores et al., 2011).

The majority of research that has been completed in the horticultural sector has mainly focused on work in greenhouses, pesticide use in developing countries and research where the lack of resources which mean poor hygiene practices are common (Ramos et al., 2010, Garcia-Santos et al., 2011, Flores et al., 2011, Rubino et al., 2012, Baharuddin et al., 2011, Blanco et al., 2005, Lauria et al., 2006, Illing, 1997).

## Routes of Exposure

Due to horticultural workers completing the entire spraying task, there are a number of exposure routes that have to be considered when assessing the occupational exposure and to determine the sampling method. (Vanhemmen and Brouwer, 1995)

Occupational exposure and the resultant health effects are largely dependent on how aerosols are transported and their deposition in the respiratory system.



Aerosol transport explains how the aerosol is transported in the atmosphere and deposited in the respiratory system and is greatly influenced by the aerosol size. Once the size of aerosols is determined, a deposition assessment can be completed, to determine where in the body they reside/deposit. Figure 1 shows the different regions of penetration. The head airways region: nose, mouth, pharynx and larynx are collectively the nasopharyngeal region. Larger particles are in this region when inhaled due to settling and impaction. The tracheobronchial region is where smaller

**Figure 1- Human Respiratory System and Aerosol Deposition**

(Parker, 2014)

particles are removed due to impaction and settling. The alveolar region, where gaseous exchange occurs and is the most vulnerable region, where the smallest particles are inhaled to

due to settling and diffusion (Washington-University-&-University-Florida, 2015). The deposition of aerosols in the body is directly linked to the health effects that can occur. The smaller the aerosol, the further it can penetrate and cause adverse health effects, in the respiratory system. Once in the alveolar region, particles can even get into the blood stream and be circulated around the body. (United-States-Environmental-Protection-Agency, 2013).

The route of occupational exposure to aerosol can be through emission and deposition of the pesticide. Chemical exposure through aerosol emission, which is direct contact with the pesticide, could occur during mixing and loading stage of this process. This could be due to spills and aerosols generated during the mixing/loading. This stage can be the highest exposure due to the handling of concentrated pesticides.

Aerosol deposition occurs when spraying the diluted chemical on the target area, which can result in direct inhalation of the aerosol or deposition on skin and dermal absorption. Aerosol drift can result in inhalation and absorption of aerosols to both the worker and bystander. Any pesticide product that does not reach the intended target is considered unintended or accidental exposure. (Krieger, 1995)

Once the target area has been treated, exposures can occur via surface transfer of the chemical onto the body and absorption through the skin. This can be contaminated equipment, personal protective equipment and the areas sprayed through re-entry or spraying while walking forwards, causing the worker to walk through the just sprayed area. (MacFarlane et al., 2013) Once the route of exposure is determined another important issue is the duration of exposure and magnitude (deRaaf et al., 1997).

Dermal absorption studies have been completed in a number of studies (Galea et al., 2014, Soutar et al., 2000) and identify dermal absorption as the most prominent and higher risk to exposure to pesticides, with the highest occurrence during the mixing and loading tasks (Rubino et al., 2012, Flores et al., 2011). Due to the longer duration of the spraying task, exposure during spraying is an important factor, especially if there is any drift. Wolf et al, 1999, stated that the generation of aerosols during spraying would be much more significant than when mixing and loading. That even the additional background levels of aerosols can contribute to the potential exposure of the worker. It has also been demonstrated that cleaning of the equipment can contribute to the cumulative daily exposure and has caused variations among individual workers (Wolf et al., 1999, MacFarlane et al., 2013, Baldi et al., 2006).

To estimate the exposure of workers to aerosols an occupational exposure study can be conducted including personal sampling in the worker breathing zone to determine the potential aerosol inhalation.

## Health Effects of Aerosol Exposure

Inhalation of aerosols can cause acute respiratory infections, obstructive pulmonary disease and lung cancer. Worldwide, indoor and outdoor aerosols air pollution contributes to 1.6 million premature deaths annually (Smith, 2002).

Health effects arising from the use of pesticides is becoming a growing concern, which is reflected the increasing amount of literature in this area (Damalas and Eleftherohorinos, 2011).

Chronic diseases which are usually long term, progressing illnesses, such as cancer, have been associated with the use of pesticides (Montano, 2014, Acquavella et al., 2003). There have been studies on the connection of respiratory diseases and pesticide usage (Ye et al., 2013) and studies linking pesticide exposure to mental illnesses and neurological diseases. MacFarlane has completed studies linking worker exposure to pesticide and suicide but his studies only confirmed a causal linkage (MacFarlane et al., 2010, MacFarlane et al., 2011).

Research into reproductive problems have also indicated that workers exposed to pesticides can cause the time to pregnancy to be prolonged among pesticides users, both female and male workers (Lauria et al., 2006, Bretveld et al., 2008). Another study found an increased risk of cryptorchidism among sons of female gardeners. (Weidner et al., 1998)

Mostafalou & Abdollahi (2013) reviewed a huge body of work around the different health issues that can occur with the use of pesticides: Cancer, birth defects, Parkinson's disease, Alzheimer's disease, genetic damages and chronic respiratory diseases were among them. The International Agency for Research on Cancer (IARC) has conducted a number of studies on the incidence of cancer of people who are exposed to pesticides in their lifetime including breast cancer and non-Hodgkin lymphoma. This study stated that there seem to be a higher prevalence of Parkinson's disease and Alzheimer's disease when exposed to pesticides.

## Development of the Project

The project commenced in July 2014 with field visit to parks and gardens in Dublin city, for example, the Phoenix Park, The National Botanic Gardens, St. Stephens Green, The War Memorial Gardens and The Iveagh Gardens. Worker tasks were observed and recorded by the researcher and desktop risk assessments have been completed. Worker tasks vary from site to site, for example, many sites operate different work practices, different pesticides applicators, task durations varies and the number and type of chemicals used varies. Also, weather conditions vary during each spraying event. Some of the factors to consider when completing a health risk assessments include; the toxicity, chemical and physical properties of the chemical, obtained from the safety data sheets; the conditions and levels of exposures, quantity and duration of this exposure. (deRaaf et al., 1997) The risk assessment must be revised and updated regularly as changes can also occur over time, due to pest's resistance to chemicals, changes of pesticide composition, different applicators and necessity of usage (Damalas and Eleftherohorinos, 2011).

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In the tasks observed, there was potential for dermal exposure to pesticides and this was further evaluated using the Gulf DREAM dermal assessment tool (the Gulf Long-term Follow-up DeRmal Exposure Assessment Method). GulfDream is a dermal exposure assessment model which was an adaptation of the DREAM model (Van-Wendel-De-Joode et al., 2003). It is a Microsoft excel spreadsheet based tool for assessing dermal exposure.

Assessments also have to be completed on different parts of the body including body parts: Head (the entire head including the face) Upper Arms (both arms) Forearms (both arms) Hands (both hands), Torso front, Torso back, Lower body, Lower leg (both legs), Feet (both feet) (Institute-of-Occupational-Medicine, 2014).

From initial assessments on worker tasks involving pesticides, there is a tendency for higher exposure on the forearms and lower legs which compares well with another study. (Ramos et al., 2010)

This project will also involve total exposure assessment. To determine the inhalation of aerosols an occupational exposure strategy will be developed for the collection of aerosol inhalation samples taken via a personal sampler in the breathing zone (Baldi et al., 2006). Biological monitoring will be used to determine the total exposure and body burden of the chemical (Galea et al., 2011, Curwin et al., 2007, van der Merwe, 1999). In terms of biological monitoring, urine biological samples are preferred over blood, as it is less invasive. This will determine the actual exposure rather than the potential exposure. Urine measurements will give an indicator to the occupational exposure of workers in the horticultural sector and compared the observation risk assessment, Gulf DREAM assessment and inhalation samples. (Maroni et al., 1999)

The risk assessment, Gulf DREAM assessment and inhalation samples will also give a good indicator of the route of exposure, which is important for determining the exposure dose transfer of the chemical. These will complement each other and are hoped to reinforce the results that will be achieved.

## Conclusions

Research into the occupational exposures to pesticides during aerosol applications in horticultural amenity areas is limited.

This research is relevant to a number of industries, such as private industry, government property or maintenance of footpaths and roadside. This type of work is occurs in most countries, whether in an ornamental gardens, footpaths or personal gardening. This research will be completed in national parks, historic monuments, rose gardens and it will evaluate the level of occupational exposure to the worker and bystanders. Information acquired from this research will determine the level of inhalation and absorption of aerosols and can be used to evaluate the existing exposure controls such as personal protective equipment, to ensure it

provides adequate protection to the worker. The project will identify the potential exposure to aerosols during tasks and ensures good working practices with this type of pesticide usage.

The Irish Department of Agriculture, Food and the Marine are the government body for authorisation of pesticides and are responsible for the development and the implementation of the National Action Plan for the sustainable use of pesticides in Ireland. Pesticides cannot be authorized for use unless it can be used ‘...without causing unacceptable harmful effects to human or animal health or to the environment’. When a new or adapted pesticide is introduced, the pesticide division researches the hazardous properties of the active ingredient. This process involves using data mostly derived from exposure modelling studies to evaluating the toxicology of pesticide and determine if the pesticide has at ‘..least one use with acceptable risk..’ that can be identified. Once the hazardous nature of the chemical is determine the level of risk is established for the worker, bystander and/or non-target organisms. Obtaining actual exposure data could be used in the registration process for more accuracy. The data from this study can be used to evaluate pesticides and to ensure that they are safe for use. (Department of Agriculture, 2013)

This information could also be used to evaluate modelling tools, to ensure that the results compare with actual exposure measurements. Contextual data collected during the task could be used with modelling tools, to obtain an estimate from modelled data and compare it to actual exposure data. Tools such as the European Food Safety Authority (EFSA) risk assessment tool and the Advanced Reach Tool (ART), to estimate its accuracy.

To the author’s knowledge, in Ireland, research into exposure to pesticides of workers and bystanders, during aerosol applications, has not been carried out to date and there is limited information of this type of research internationally.

Research into pesticides in horticultural amenities is relevant for the scientific community, nationally and internationally. Once completed, it is hoped this research will be able to identify the exposure to workers in horticulture, assist in the registration process of pesticides in Ireland, used to evaluate modelling tools and fill the relevant scientific knowledge gap.

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