Drying Kinetics of Pesticide Droplets

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Abstract— Pesticides are widely used in the agricultural industry to control pests and prevent losses of crops. The objective of this paper is to investigate of the drying kinetics of pesticide droplets. The pesticide samples were applied on the target surface and placed into a drying chamber. The evaporation profile was plotted from the data obtained. It was found that the droplet exhibited a linear drop in drying rate at very low concentrations. Further investigation revealed that the pesticide used in the experiment is a surface active compound and alters the drying kinetics of the droplet with low concentrations.

Keywords— Drying Kinetics, Pesticide, Surface Active, Surface Tension, Droplet

1. Introduction

Pesticides have been widely and extensively used for various purposes in agricultural activities. It is classified based on two main criteria: structural basis and mode of action. Discovered since 1945, pesticides in use today are labeled as organic synthetic pesticides, a label which includes pesticide families such as organophosphorus, carbamated and organochlorided insecticides [1]. Among the few families listed above, neonicontinoids are the latest and most rapidly-growing class of pesticides, representing almost 24% of the global market in 2008 [2]. Neonicotinoids are systemic pesticides that act on the central nervous systems of insects, a selectivity trait that makes it a potent hazard towards insects, without presenting threat towards mammals. This mode of action has resulted in a pesticide that is target specific, and has almost no cross-resistance towards older pesticides that have been stated above. Hence, neonicotinoids have been replacing older variants of pesticide on the field [3, 4].

In view of the low solid concentration in typical pesticides (10mL in 3000mL, roughly 0.33% v/v), the pesticide droplet is expected to have a drying profile that is similar to a pure water droplet. Many authors have done research on pesticide droplets, most of which used pesticides of the organophosphorus family, or were otherwise not stated. The variables that were frequently tested and studied were the effects of droplet size, addition of adjuvants and target surface morphology on the drying times, wettability, and deposition efficiency [5, 6, 7]. However, research on the drying kinetics is rather scarce. The purpose of this study is to study the drying kinetics of pesticide droplets. This will provide evidence if the drying of pesticide resembles water droplets or otherwise.

2. Methodology

A schematic of the apparatus used for measuring drying kinetics is shown in Fig. 1. The apparatus consists of a digital flow meter, a dehumidifier, a water bath, a coil and a drying chamber. The gas flow is regulated by the digital flow meter, which introduces the gas into a dehumidifier which removes any humidity present in the gas. The coil is immersed in the water bath, which serves to heat up the gas and regulate gas temperature into the drying chamber.

The variables controlled in the experiment are based on real-time environmental data. Weather data of the target area was collected from the Malaysian Meteorological Department. Data such as wind speed and temperature were collected and tabulated for the month of March, and the average values were selected to be the environmental variables of the investigation. Tomatoes were obtained from local market. The pesticide (15g/L Imidacloprid) was obtained from Hortico, a company which produces garden care products. The concentrations studied were the recommended concentration by the manufacturer, with ±5mL samples.

Glass slides that were used to hold the samples were weighed and labeled. The target surface was prepared by removing a section of 1.5 cm x 1.5 cm skin off a tomato and placing it onto the glass slide. The tomato skin was washed gently to avoid abrasion to the surface and to ensure that there is no residue from previous pesticide applications. The pesticide was prepared in sample vials using tap water, and was mixed by shaking to simulate the procedure done in the field. Using a syringe, nine 1µL droplets were placed onto the sample. The prepared slide with tomato skin was weighted, before and after applying the pesticide droplet. A control set (tomato skin only) was also prepared, to be run side-by-side with the experiment set. The drying chamber was set according to the collected variables. The drying chamber was set according to the collected variables. The samples were put into the chamber and weighed at 30 second intervals.

For each set of the experiment, the data collected was then compared between the sample set and the control set that were run concurrently. By running the control set in parallel with the sample set, both skins were exposed to similar drying conditions, which can be used to determine drying kinetics of pesticide droplets. All experiments were done in triplicates to avoid any error introduced.

In addition to that, further investigation was carried out to determine the surface tension of the samples, by using the capillary rise method. A petri dish was filled with water, and a capillary filled with water was inserted. The water is allowed to recede till it reaches a constant level, where the water level is noted. The same procedure is carried out in triplicates for each sample, and the surface tension is then derived from the data collected.

Fig. 1: Schematic of drying apparatus used in this study.
3. Results and Discussion

Fig. 2 shows drying rate of a sample studied at 24°C. Notice that the drying profile shows a linear progressive reduction in reduction rate. This profile contradicts with literature hypothesis. It is widely accepted that at low initial solid concentration, the activation energy for evaporation is very low, and should produce a profile that resembles pure water droplet drying, where a constant rate period would be observed followed by a drop at the end. A question then arises: Why is there a progressive reduction in evaporation rate even at such low solute condition at 0.167 %v/v concentration? In addition, within the resolution of the experiments, the initial constant rate period was also not observed. These observations suggest that significant solute already accumulated on the surface of the droplet even at the initial stage of drying.

The pesticide solute could have transported onto the droplet surface due to its surface activity. Fig. 3 shows a schematic diagram of this phenomenon. The molecules take up space on the surface of the droplet, reducing the available area for evaporation to take place. This effect is intensified as the droplet becomes smaller, since the pesticide molecules do not evaporate, making the surface of the droplet more saturated.

Therefore, to verify this claim, the surface tension of water and the samples are measured using the capillary rise method [8]. Fig. 4 shows the height liquid travels due to adhesion forces between the liquid and solid interface. It compares the relative effect of lactose and the pesticide towards surface tension of water. Surface tension of pesticide droplets relatively low compared to lactose. Lactose reduces the height travelled by water from 24.9 mm to an average of 23.7 mm for all concentrations tested. The pesticide used, however, reduced the height travelled by the water from 24.9 cm to an average of 13.8 mm. Even at concentrations as low as 0.167% v/v, the height travelled was reduced from 24.9 mm to 17.8 mm. This indicated that the pesticide is very surface active, even at very low concentrations which supports the explanation given above on the retardation of evaporation rate observed.

![Fig. 2: Drying rate of sample A at 24°C](image)

4. Conclusions

Imidacloprid is a surface active compound, which affects the drying rate of a pesticide formulation at extremely low concentration which is 0.167 %v/v. The progressive retardation of the drying rate even at very low concentration is due to the accumulation of dissolved pesticides on the air-droplet interface via the surface activity mechanism. This provides an interesting insight into understanding the drying kinetics of pesticides, which may contribute into the development of newer and more efficient formulations and delivery of active ingredients for crop protection.

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References


