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# Development of estimation methods for movement of applied pesticide in farmlands*

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In recent years, the outflow of pesticide from farmland to public water has been a concern. Three major routes of movement and diffusion of applied pesticides in farmland, such as drift at spraying, surface runoff by rainfall after spraying and leaching into groundwater have been investigated. As a result, several test methods have been developed for the assessment of the predicted environmental concentration (PEC) of pesticide. Among them, an indoor runoff test system was introduced under the test guidelines for PEC calculation in the Standard for Withholding of Registration. © Pesticide Science Society of Japan

*Keywords*: spray drift, runoff, indoor runoff test system, levee infiltration, leaching.

## Introduction

Among the movement and path diffusion of pesticides from farmlands to the environment, spray drift at pesticide spraying and runoff by rainfall after pesticide spraying are considered as major routes to the river system. Furthermore, leaching, or the vertical infiltration of pesticides by rain water, has been an environmental concern as a route to groundwater exposure.

This paper outlines the test methods, which were developed assuming the outflow of pesticides from applied fields through these major routes.

## Spray Drift

The drift generated by spraying pesticides diffuses outside the field by air currents (wind force) and by the kinetic energy of atomization. Kinetic energy at atomization greatly depends on the sprayers. Three typical spraying methods, such as hand spraying with a power sprayer, boom sprayer and speed sprayer, were tested. Real fields at least 20 m or more in length were used for the field trials. Glass Petri dishes and/or water-sensitive papers were used as samplers to trap drifting pesticides or atomized water. Leeward of the predominant wind direction, samplers were set up from the edge of the field at suitable intervals (1, 3, 5, 7.5, 10, 15, 20, 30, and 50 m). The results showed that drift values (%) of the sprayers ranged almost within the frame of the BBA's drift value table in Germany.

## Runoff

### 1. *Runoff in non-paddy field*

#### 1.1. *Field trial by natural rainfall*

A basic concept of the runoff trial in the field was to set up ridges in the slope field along the inclination, to cultivate crops and to spray the pesticide one day immediately before heavy rainfall is expected. However, runoff did not occur in an andosol field (tilt angle: 5–6°) with natural rainfall during the rainy season, and runoff was observed only with a rainfall of around 30 mm/hr from a passing typhoon. During this time, approximately 1.7 l/m$^2$ surface water was obtained, and the runoff percentage of three pesticides against the applied amount was about 0.01–0.05% (two days after spraying). When there was consecutive rainfall with rainfall intensity 20 mm/hr or more in andosol field (5–6°), and the amount of integrated rainfall reached 30–60 mm, surface water was easily generated.

#### 1.2. *Field trial with artificial rainfall*

As for runoff in the field trial by natural rainfall, long-term waiting may be required for large amounts of water since rainfall cannot be controlled. Thus, maintaining the field and crops are serious tasks. Therefore, an artificial rainfall trial is preferable to a natural rainfall trial. The artificial rainfall trial

* See Part II for the full Japanese article.

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provided water by setting up the sprinkler, which covered an area of 460 $m^2$ in the andosol slope field (tilt angle: 6°) of cultivated cabbages. The runoff percentage of each pesticide against the applied amount was about 0.1–0.6%. The field scale trial with artificial rainfall required a large amount of water on sloping land where there was no or a poor water supply. Thus, a field scale trial with artificial rainfall was not considered practical.

*1.3. Indoor small-scale trial*

A new indoor runoff test system with controlled rain conditions was developed to clearly understand field runoff. Containers (0.7 $m^2$: 0.76 m in width, 0.93 m in length, and 0.20 m in depth) packed with soil from the plow layer were used as test plots and placed under a rainmaking machine (10–80 mm/hr available) on a slope with a 5° tilt angle. When natural rainfall conditions were artificially simulated by the rainmaking machine, the runoff test system reproduced not only the amounts of runoff water (l/$m^2$) but also the concentrations of pesticides in the runoff water, thereby successfully simulating a runoff event. The test system was adopted as a second tier test method for PEC calculation in the non-paddy field.

*2. Outflow from paddy field*

Because of the close proximity of the river system, and the direct connection of the paddy fields by drainage, there is a high probability of the river system being affected. The amount of outflow water from the paddy field was measured through the rice-cultivating period. Based on the results, the daily mean drain percentage from the paddy water in five paddy fields was approximately 6.4%.

*3. Levee infiltration from paddy field*

Levee infiltration to drainage is thought to be one of the routes for the outflow of pesticide from paddy fields. The amount of seepage water caused by levee infiltration was measured in actual paddy fields. Two paddy fields of different levels with a long levee in between (0.7 m in height, 2 m in width, and 100 m in length) were used in the test. The mass balance of paddy water in both fields and pesticide concentrations in paddy water in the fields were investigated after pesticides were applied to the upper paddy field. The outflow of the seepage water from the upper paddy field was provisionally calculated as 0.15–0.2 $m^3$/day/m (levee length). Furthermore, the maximum concentration of pesticides in the seepage water to the lower field was about 1/200 of the pesticide treated water in the upper field.

## Leaching

*1. Leaching in non-paddy field*

A soil core (5 cm in diameter and 0.5–1 m in depth) was sampled and cut to approximately 10-cm depth layers. The soil of each depth layer was analyzed to understand the movement and underground diffusion of pesticides. Furthermore, a method of investigating pesticide concentration in soil water obtained by centrifugal separation from each soil depth layer was developed as a field leaching trial. In the soil core trial of a sandy soil field, the mobility of the pesticides was higher than in the andosol. The mobility and diffusion of pesticides in the soil core were almost the same levels as in the sandy soil field when granule and liquid pesticide formulations were compared. When the trials in two seasons were compared for the same field, almost identical mobility and diffusion were observed between the summer trial, which included the rainy season, and the winter trial, with a little rainfall. Furthermore, it was observed that in sandy soil certain pesticides disappear with little movement from the surface.

*2. Leaching in paddy field*

The plow sole layer is present in paddy fields. However, it was thought that some of the paddy water should infiltrate from the plow sole layer to a deeper layer when long-term submersion was maintained. The paddy soil core trial, which used a real field to understand the level of the pesticide that infiltrated perpendicularly with paddy water, was developed. However, the results from paddy soil core trials were unable to detect the diffusion of five pesticides before their disappearance was detected in soil and the soil water of the lower layer of the plow sole layer. This indicated that there was extremely little movement of pesticides into the lower layer through the plow sole layer in a standard paddy field where the plow sole layer was stable.