Computer Science in Environmental Safety Research

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Abstract. The today’s state-of-the-art chemical plant protection method is cost-effective. However, the environmental safety of this process is questionable. Aerosol pesticides are not targeted; only 5% to 30% of the sprayed dosage is actually deposited on plants, whereas the rest ends up in the soil. Although high-stability pesticides are no longer in use, low- and medium-stability agents have been recorded to render soil toxic to plants. When spraying, large drops exceeding 200 µm roll down to the soil and contaminate it. Smaller droplets (< 100 µm) are gone with the wind. It is imperative to systematically monitor the process of spraying chemical protective agents from the environmental standpoint. As a tool for monitoring and forecasting, this paper proposes a software package that can monitor the spraying process online. The package comprises a data module, a pesticide spraying test module, and a data visualization/storage module. The proposed system provides real-time monitoring of the spraying process and records the concentration of pesticides, whether plant- or soil-deposited; if necessary, the user can make changes in the agent and toolkit database. Field tests have been carried out using this software to identify the environmentally safest spraying system; it generates droplets sized 120 µm, which is necessary for chemical treatment of crops. Other sprayers involved in the experiment either had a drop size >200 µm, which would quickly reach the soil; or <100 µm, which would be quickly dispersed by the wind. Field test data can be further used to optimize the pesticide spraying process.

1. Introduction
Analysis of the state-of-the-art in the environmental safety of pesticides reveals that in 2017–2022, according to Business Stat, pesticide usage will grow by 6.2% every year onm average due to the increasing shortage of arable land coupled with the world’s growing population [Gorbatov 2016; Zybalov 2017]. Experience has shown that chemicals are the only cost-effective protection. The problem is that chemical treatment is pre-requisite for better yield, yet it may compromise the environment.

2. Research methods and technology
This paper dwells upon the pesticide aerosol spraying process. Research was carried out in real time on a plot of arable land using the software package by [Udartseva 2014].

Pesticides are applied by agricultural machinery equipped with various sprayers. Two parameters were adopted to indicate environmental safety: the uniformity of pesticide spraying across the treated surface; and the quantity of pesticides that ended up outside the area (“carryover”). To evaluate
pesticide distribution uniformity and carryover, researchers have developed a method for testing the spraying process in the field [Kireyev et al., 2011; Guidelines, 2011]. This method defines the pattern of sprayer travel across the field as well as the location of instruments (sensors), see Figure 1. Instruments, or sensors, are mounted in such way as to read the concentrations of pesticides on plant leaves as well as in the soil, see Figure 2.

![Figure 1. Sprayer travel pattern and sensor layout (B₁ to Bₙ).](image1)

![Figure 2. Sensor 1 is located in the soil; Sensor 2 is located on the leaves.](image2)

All the data is written in a special template-based file, which further helps decide how to optimize spraying. Data can be analyzed either by pesticide application data or by the treated site number. Aside from pesticide concentrations, it is imperative to consider the microclimate, as windy or rainy weather is inappropriate for spraying [Rogozin & Beketova, 2011]. Repeated testing helps evaluate the environmental safety and efficiency of a sprayer. If the process is environmentally safe, pesticides are distributed uniformly across the field, a sign of efficient spraying. Research data are visualized in summary tables. These tables present data on sprayer types, weather, and the weight of pesticides deposited on soil and on leaves, see Table 1.

**Table 1.** Tabular data on the concentrations of pesticides deposited on plants and in the soil; data is based on sensor readings with breakdown by sprayer type, temperature, humidity, and air speed.

| Date       | Time, AM | Site | Agent     | Wt. on plants | Wt. in soil | Temperature | Humidity | Air speed | Sprayer      |
|------------|----------|------|-----------|---------------|-------------|-------------|----------|-----------|--------------|
| May 10, 2017 | 7:15     | 1    | Zellek Super | 12            | 45          | 17          | 75       | 3         | GRD          |
| May 11, 2017 | 7:25     | 2    | Furex     | 12            | 24          | 19          | 75       | 3         | KR-0295      |
| May         | 6:15     | 3    | Biathlon  | 12            | 45          | 17          | 75       | 4         | Antey        |
3. Research results

Field tests used five types of sprayers. Each sprayer was tested at least 10 times. Experimental data are summarized in Table 2.

Table 2. Comparison of environmental safety indices for different pesticide sprayer types.

| Sprayer                  | Median mass deposited droplets, $d_{m}$, µm | Process fluid distribution non-uniformity, % | Pesticide particle carryover, % |
|--------------------------|--------------------------------------------|---------------------------------------------|---------------------------------|
| GRD aerosol generator based on a ZIL 131 car | Non-uniform > 15                           | >30                                         |
| Kerkitox sprayer based in an MTZ-82 tractor | Non-uniform > 13                           | > 15                                        |
| Hose sprayers OP 200M    | Non-uniform >10                            | None                                        |
| SUMO-24 based on a UAZ-452 car, GPS-enabled   | Non-uniform > 20                           | None                                        |
| KR-0295 universal sprayer based on a Nissan Atlas | Uniform                                    | None                                        |

For practitioners, it is important to get all the information based on the process research results with breakdown by sprayer type, chemical, plant-deposited amounts (which reflects the efficiency of spraying) and soil-deposited amounts (which corresponds to the contamination rate). Pesticides that do not reach the target are either gone with the wind or roll down off the plant towards the soil. This means that for this process, the two basic safety parameters are the uniformity of spraying in the treated area, and the precise droplet size of 120 µm, as larger droplets (>150 µm) will fall onto the soil while smaller droplets will be carried away by the wind.
Data has been visualized with breakdown by field sites and pesticide types, see Figure 3.

As can be seen in the Figure, sites 1 and 4 had the greatest soil concentration of pesticides (45 mg/m²), making the environmental safety of such spraying questionable. Pesticides are specified to suggest how phytotoxic they can be when in the soil.

![Figure 3](image.png)

**Figure 3.** Visualization of pesticide concentration testing in the field by the proposed software package.

The proposed option for monitoring the pesticide spraying process helps systematize the results already available in the database, add more readings for newer pesticides or spraying methods, and report the necessary information. Visualizing the problematic sites is necessary for a more detailed analysis of soil phytotoxicity.

4. Conclusions

Field tests have revealed that KR-0295 based on a Nissan Atlas car is the best sprayer in terms of environmental safety. The median mass diameter of droplets $d_{\text{m}}=120 \, \mu\text{m}$, which is suitable for pesticide treatment of crops. GPS helps improve the maneuvering. No pesticide carryover detected.

SUMO-24 based on a ZIL-131 car is the second best option. GPS prevents pesticide carryover; however, the sprayer lacks a process fluid flow control system, thus being unable to provide uniform coverage. Altering the sprayer travel speed may result in a $>20\%$ variance in the uniformity. The size of generated droplets is critical in this application.

GRD (adjustable dispersity generator) based on a ZIL-131 car is the third best option. Its droplet size is $d_{\text{m}}=300 \, \mu\text{m}$. Spraying becoming exponentially less uniform over a distance of about 400 meters. Particle carryover exceeds 30%.

OP 200M and Kerkitox based on an MTZ-82 tractor are the worst. They generate very large droplets ($d_{\text{m}}= 200:540 \, \mu\text{m}$), forcing them to flow down to the soil; the application is not uniform even within the sprayer rod, with a variance of $>15\%$. The environmental safety of the spraying process has been found to correlate with the size of generated droplets. Larger droplets ($d_{\text{m}}= 200 -600 \, \mu\text{m}$) flow down to the soil, while smaller droplets ($d_{\text{m}}=70 -100 \, \mu\text{m}$) are wind-carried away. Of all the tested sprayers, KR-0295 with its automatic fluid flow control system and GPS is clearly advantageous in terms of environmental safety.
Computer science methods for agricultural process studies help monitor the environmental safety remotely without direct human intervention. Such monitoring is necessary for timely decision-making in relation to the toolkit, chemicals, and climate.

5. References

[1] Gorbatov V S 2016 Structure of Environmental Data on Pesticides Zashchita i karantin rasteniy 3
[2] Zybalov V S 2017 Environmental Issues of Pesticide Usages in Chelyabinsk Oblast’s Agriculture Proceedings of the Conference on Solutions to Environmental Problems of the Urals’ Agriculture (Yekaterinburg) 106–114
[3] Kireyev I M 2011 Technology and Requirements to Advanced Agricultural Machinery (Moscow: Rosinformagrotekh) 248
[4] 2011 Guidelines on Evaluating the Hazard of Chemical Contamination of Soil Decree of the Russian Government 37
[5] Rogozin M Yu Environmental Consequences of Pesticide Application in Agriculture Young Scientist 25(211) 39–47
[6] Udartseva O V 2014 Evaluating the Environmental Safety of Pesticide Spraying Certificate of Computer Program Registration No 2014619532