Original Research

RMJ. 2022; 47(1): 213-216

Ecological and hygienic assessment and regulation of innovative technology of pesticide application using unmanned aerial vehicles

Andrii Borysenko, Anna Antonenko, Sergii Omelchuk, Sergii Bilous, Fedir Melnychuk.

ABSTRACT

Abstract

Objective: To carry out ecological and hygienic assessment and regulation of innovative technology of pesticide application using unmanned aerial vehicles.

Methodology: To conduct field research using the fungicide Amistar Extra 280 SC, we used an unmanned aerial vehicle (drone) for spraying fields Agras T16, DJI.

Results: The occupational risk with the use of UAVs did not exceed the allowable (<1). The formation of a significantly higher combined occupational risk for the UAV tank refueler (0.15±0.004 at $p<0.05$) is due to contamination of the skin and the inhalation effect of the pesticide.

Conclusion: The safety of the production environment for workers at all technological stages of work is reliably guaranteed when using the Amistar Extra 280 SC formulation from the air with an unmanned aerial vehicle in real conditions.

Key words: UAV application, workers' health, drift of pesticides, complex, combined occupational risk.

How to Cite this Article

Pubmed Style

Borysenko A, Antonenko A, Omelchuk S, Bilous S, Melnychuk F. Ecological and hygienic assessment and regulation of innovative technology of pesticide application using unmanned aerial vehicles. RMJ. 2022; 47(1): 213-216.

Web Style

Borysenko A, Antonenko A, Omelchuk S, Bilous S, Melnychuk F. Ecological and hygienic assessment and regulation of innovative technology of pesticide application using unmanned aerial vehicles. http://www.rmj.org.pk/?mno=126575 [Access: February 01, 2022].

AMA (American Medical Association) Style

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Vancouver/ICMJE Style

Borysenko A, Antonenko A, Omelchuk S, Bilous S, Melnychuk F. Ecological and hygienic assessment and regulation of innovative technology of pesticide application using unmanned aerial vehicles. RMJ. (2022), [cited February 01, 2022]; 47(1): 213-216.

Harvard Style

Borysenko, A., Antonenko, . A., Omelchuk, . S., Bilous, . S. & Melnychuk, . F. (2022) Ecological and hygienic assessment and regulation of innovative technology of pesticide application using unmanned aerial vehicles. *RMJ*, 47 (1), 213-216.

Turabian Style

Borysenko, Andrii, Anna Antonenko, Sergii Omelchuk, Sergii Bilous, and Fedir Melnychuk. 2022. Ecological and hygienic assessment and regulation of innovative technology of pesticide application using unmanned aerial vehicles. *Rawal Medical Journal*, 47 (1), 213-216.

Chicago Style

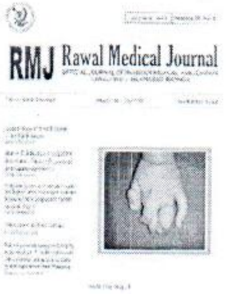
Borysenko, Andrii, Anna Antonenko, Sergii Omelchuk, Sergii Bilous, and Fedir Melnychuk. "Ecological and hygienic assessment and regulation of innovative technology of pesticide application using unmanned aerial vehicles." *Rawal Medical Journal* 47 (2022), 213-216.

MLA (The Modern Language Association) Style

Borysenko, Andrii, Anna Antonenko, Sergii Omelchuk, Sergii Bilous, and Fedir Melnychuk. "Ecological and hygienic assessment and regulation of innovative technology of pesticide application using unmanned aerial vehicles." *Rawal Medical Journal* 47.1 (2022), 213-216. Print.

APA (American Psychological Association) Style

Borysenko, A., Antonenko, . A., Omelchuk, . S., Bilous, . S. & Melnychuk, . F. (2022) Ecological and hygienic assessment and regulation of innovative technology of pesticide application using unmanned aerial vehicles. *Rawal Medical Journal*, 47 (1), 213-216.



Rawal Medical Journal

Current Issue : 2022, Vol: 47, Issue: 1

ISSN : 0303-5212

ISSUES : 4 per year

PUBLISHER : Pakistan Medical Association Rawalpindi Islamabad Branch

Rawal Medical Journal is an internationally peer reviewed journal and an official publication of Pakistan Medical Association (PMA) Rawalpindi-Islamabad Branch. It is funded by PMA and HEC Pakistan and 1000 printed copies are distributed to members of PMA and all major hospitals and teaching institutions of Pakistan. It is published every three months in March, June, September and December.

Original Article

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Objective: To carry out ecological and hygienic assessment and regulation of innovative technology of pesticide application using unmanned aerial vehicles.
Methodology: To conduct field research using the fungicide Amistar Extra 280 SC, we used an unmanned aerial vehicle (drone) for spraying fields Agras T16, DJI.
Results: The occupational risk with the use of UAVs did not exceed the allowable (< 1). The formation of a significantly higher combined occupational risk for the UAV tank refueler (0.15 ± 0.004 at $p < 0.05$) is due to contamination of the skin and the inhalation effect of the pesticide.
Conclusion: The safety of the production environment for workers at all technological stages of work is reliably guaranteed when using the Amistar Extra 280 SC formulation from the air with an unmanned aerial vehicle in real conditions.
Keywords: Ecological and hygienic assessment, pesticide application, aerial vehicles.

INTRODUCTION

Population growth leads to an increase in demand for agricultural products. More than 60 percent of the world's population depends on agriculture.[1] The introduction of advanced innovative agricultural technologies is the decisive factor in increasing the yield of agricultural crops and productivity of farms.[2] Precision farming seeks to use new technologies to increase crop yields and profitability, while reducing the traditional costs required growing crops (land, water, fertilizers, pesticides, etc.). The introduction of systems based on the information technology in crop production usage gives positive economic results: monitoring the use of machinery and fuels and lubricants, control of fertilizers, plant protection products and seeds ensure the rational use of resources. Systems of so-called precision agriculture, which are rapidly spreading in the leading world countries, are gradually being introduced, including in Ukraine.[3]

One of the innovative rounds of precision agriculture is the unmanned aerial vehicles (UAVs, drones) use. They can be used to shoot from a height, monitor fields, create 3D maps, sow seeds, apply fertilizers and chemicals, control crops, help with irrigation, and control animals in agriculture.[4]

According to the International Association of UAV forecasting, the legalization of commercial drones could create an economic impact of more than $80 billion from 2015 to 2025, and agriculture's need for UAVs will reach 80% of the total. It is expected that the global market for agricultural drones during the forecast period 2018 – 2026 will grow by 18.5%.[5] Currently, more than 90% of agricultural UAVs in China for chemical use are multi-rotor, electric. Agricultural multi – rotor UAVs are of interest to many countries around the world and are widely used in the United States, India, South Korea, Brazil, Sri Lanka.[6] The purpose of this study was to carry out ecological and hygienic assessment and regulation of innovative technology of pesticide application using UAVs.

METHODOLOGY

Field studies were conducted in 2020 using the Amistar Extra 280 SC (active ingredients (a.i.) cyproconazole 80 g/l and azoxystrobin 200 g/l) in the maximum formulation consumption rate (0, 75 l/ha), working solution – 10 l/ha, spraying speed – 4.8 l/min.

For this, using the fungicide Amistar Extra 280 SC, we used an UAV (drone) for spraying fields Agras T16 manufactured by DJI, which is today the market leader in drones. Agras T16 is equipped with six rotating rotors that rotate in the opposite direction to each other, which allows keeping in the air a 16-liter tank. As a result, the initial weight at takeoff reaches 39.5 kg. The wingspan is up to 2.5 m, and the spraying speed is adjustable, the maximum – 4.8 l/ in, which actually allows to empty the tank in 3 minutes. In our studies, the spray rate was 4.8 l/min Agras T16 is equipped with 4 pumps and 8 XR TEEJET 11001VS nozzles, creating drops from 150 to 265 microns. Spraying width – 6.5 m, which can cover an area of 10 hectares per hour. The speed of the drone was 25 km/h.

To ensure accurate and stable field treatment, the sprayer is equipped with an electromagnetic flowmeter. The flight altitude of the drone (spray height) above the ground is 1.5m. The maximum controlled flight range is up to 5 km.[7] During the field tests, we chose to place the remote piloting point (ground control station and sprayer tank) at 30m. This distance allowed to effectively organizing all the necessary stages of the introduction of ChPPP unmanned method on the ground and in the air at visibility distance.

The maintenance of the Agras T16 drone involved two persons (operators), professional users, trained and responsible for the safe conduct of the unmanned aircraft flight, which is performed by remote control equipment. The operator №1 (external pilot) was responsible for the unmanned aircraft control; the duration of the drone staying in the air was about 4 minutes before the next tank refueling. The operator №2 prepared the working solution, refueled the drone, the duration of the operation was 5 – 7 minutes, 7 consecutive operations were performed. The total cultivated area was 7 hectares. Treatment of soybean crops was carried out for 60 minutes (excluding the previous flight of the field, to determine its boundaries, size, shape, and formation of the flight map). Operator №1 and operator №2 during operations were dressed in special protective clothing: overalls made of synthetic fabric and boots. Rubber gloves, goggles and respirators were used as personal protective equipment.

Air sampling of the operators' breathing zone, the wear zone was carried out using a portable electro aspirator "Typhoon". Air samples were taken on a paper filter "blue tape" (BT), silica gel and polymer resin XAD-2. When performing each operation at three parallel points, 3 samples were taken sequentially. To assess the possible wear of the aerosol and soil contamination outside the treated areas, we also tested an experimental approach[8,9] to determine the active ingredients of pesticide formulation in sedimentation samples. The method is based on the simultaneous monitoring of the active ingredients content due to the wear of the aerosol in the air and the substance that settled on the ground on the border of the sanitary gap between the treated area and settlements, livestock complexes, places of manual work on crops, water and boom spraying should be not less than 300m (when using a fan sprayer – 500m), 2000m – during aircraft treatment, 10 – 15m – within personal farms.

Studies of the pesticides content on the workers' skin surface were performed after the operation with degreased and soaked in ethyl alcohol diluted in water in a ratio of 1: 1, gauze napkins and stripes (3 – layer stripes (outer layer – cotton fabric, middle layer – medical gauze, internal – the filter "blue tape")) on overalls. Quantitative determination of the content of active substances was performed by high – performance liquid and gas-liquid chromatography.

All work on the introduction of pesticides was carried out in the early morning (up to 10 AM) and evening hours (after 7 PM) with minimal upward air currents, with air velocity not exceeding – 3m/sec, air temperature not higher than + 22°C, relative humidity was in the range of 35 – 70%.

Occupational risk assessment was performed in accordance with the guidelines.[10] Because Amistar Extra 280 SC is a combined formulation, the simultaneous effect of two active ingredients is possible. Therefore, to assess, we calculated the magnitude of occupational risk in the combined exposure of both active substances in one formulation. The combined risk (CR) was determined by simply summing the risk values of several active substances in a complex intake.

Statistical Analysis: The data were analysed using SPSS 22.

RESULTS

It was found that the concentration of azoxystrobin and cyproconazole in the air of the working zone and zone of possible wear in all variants of experiments did not exceed the limits of quantitative determination of methods. Even established for these substances standards in the air. When preparing a working solution of the pesticide in the air of the tanker's working area, the concentration of azoxystrobin was 0.002 mg/m^3, cyproconazole – 0.06 mg/m^3, which exceeded the LOQs of the methods, but met the hygienic standards approved in Ukraine. The data obtained during the aspiration sampling of air in the possible wear zone of the Amistar Extra 280 SC formulation, were identical to the previous ones, i.e. the concentrations of active ingredients are less than the methods' LOQs. It was found that the concentration of azoxystrobin was 0.005 mg and cyproconazole – 0.003 mg in the washings from the gloves of the operator №2 (tanker of the drone sprayer tank), from the open (face, neck) and closed areas of the skin was lower than the limit of quantification of the respective methods. The content of active ingredients of the Amistar Extra 280 SC formulation in the washes and stripes on the overalls of the operator №1 (external pilot of the drone) was below the methods' LOQs (Table 1). Analysis of calculations to determine the inhalation risk

Table 1: The content of active substances of the Amistar Extra 280 SC in air samples, mg/m^3.

Active Ingredients	Air in Breathing Zone of (n = 6):		Air in Zone of (n = 6)				
			10 m from Field Edge	100 m from Field Edge	Possible Wear After		
	Operator №1 (External Pilot)	Operator №2 (Refueler)	Application Moment	Application Moment	1 Hour.	3 Days	7 Days
Azoxystrobin	< 0.001*	0.002	< 0.001*	< 0.001*	< 0.001*	< 0.001*	< 0.001*
Cyproconazole	< 0.05*	0.06	< 0.008*	< 0.008*	< 0.008*	< 0.008*	< 0.008*

Table 2: Values of potential risk of dangerous influence of the Amistar Extra 280 SC on the tanker and the external pilot of the UAV.

Active Ingredients	Risk Values						Inhalation Risk Share, %		Percutaneous Risk Share, %		Combined Risk	
	Inhalation, $\times 10^{-2}$		Percutaneous $\times 10^{-2}$		Complex, $\times 10^{-2}$							
	R	TD	R	TD	R	TD	R	TD	R	TD	R	TD
Azoxystrobin	0,04*	0,02	0,18	0,17	0,22*	0,19	17	11	83	89	0.15*	0.09
Cyproconazole	12,4*	7,08	2,73*	2,51	15,13*	9,59	82	74	18	26		

showed that it is higher for azoxystrobin and cyproconazole for the operator №2, and the difference between the tank refueler and the UAV external pilot in the field studies is significant according to Student's criterion ($p > 0.05$). The calculated percutaneous risk of a worker engaged in refueling a drone tank is also significantly higher for cyproconazole. Significantly higher levels of inhalation and percutaneous risks of the tanker of the UAV sprayer tank caused a significant difference between the complex (azoxystrobin and cyproconazole) and combined risks (Table 2).

The combined risk values of the UAV refueler (0.15 ± 0.004) significantly exceeded the data obtained for the external pilot (0.009 ± 0.003).The share of percutaneous risk for the tanker by azoxystrobin and cyproconazole was 83% and 18%, respectively. For the UAV external pilot, the share of percutaneous risk was 89% and 26%, respectively. The share of inhalation risk for the external pilot of the UAV by azoxystrobin – 11% and cyproconazole – 74%, for the tanker of the UAV by azoxystrobin – 17% and cyproconazole – 82%.

DISCUSSION

Comparing the working conditions of the UAV tanker and the knapsack sprayer tanker, we can state the absence of significant differences, i.e. there is no increased or decreased risk of this operation. The advantage of using a UAV is that this technology separates the person who applies ChPPP from direct contact with the spray, and as a result exponentially reduces the risks to a level no more than an outside observer, about 2-3 orders of magnitude less.[11,12]

The obtained results of analysis of air of the wear zone, selected by aspiration and sedimentation methods, indicate that the drift of the pesticide did not exceed 10 m under the studied conditions of formulation application (speed, drone movement, flow rate, nozzle type) and meteorological parameters. This correlates with as it was found that the wear zone of CHPPP to the level of 1% of the total pesticide when using UAVs decreased from the edge of the field by a distance of 7.5 m in the wind and to 0.1% of the total the amount of pesticide at a distance of 32m.[4,13,14] On average, 0.28 – 0.54% of the total amount of introduced material settled in the observation area in the wind, the vast majority (about 82%) settled during the first 7.5m in the wind.

According to, a tractor operator working on a tractor aggregated with a boom sprayer has a higher risk of harmful effects than a sprayer tank refueler that does not correlate with the data obtained in our study.[16,17] It is also obvious that the pesticide wear potential is much higher during rod and fan treatments compared to knapsack application, according to it can reach more than 25m.[18] Therefore, we can assume that the wear zone of ChPPP in the use of UAVs is smaller than in tractor treatment.

Of course, this assumption requires a more detailed study with different combinations of input parameters for field research (technical, meteorological conditions, etc.). When comparing the technology of introducing ChPPP from the air using a UAV with the classical aviation method it should be noted a number of advantages of the UAVs, as the aviation method often requires the involvement of a third party – a signalman that indicates the pilot's direction of flight.[9]

CONCLUSION

The safety of the production environment for workers at all technological stages of work is reliably guaranteed when using the Amistar Extra 280 SC formulation from the air with an unmanned aerial vehicle in real conditions. The occupational risk with the use of UAVs did not exceed the allowable (< 1).

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Conflict of Interest: None declared.
Rec. Date: Sep24, 2021 Revision Rec. Date: Dec13, 2021 Accept Date: Dec 3, 2021.

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