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PERFORMANCE OF A HYDRAULIC JET AGITATION SYSTEM WITH DIFFERENT JET NOZZLE SIZES IN THE SPRAYER TANK

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Abstract

Consumption of wettable powders (WP) and water-soluble granules (WSG) have increased in last years in the pesticide market. Main problems faced with these kinds of pesticides are the requirement of continuous mixing due to sedimentation in sprayer tanks. To solve this problem, usage of hydraulic jet agitators in sprayer tanks have increased in last years. However, position of agitator in tank, mixing pressure and technical specifications of hydraulic jets are important for an effective agitation. In this study, we determined the agitation performances of a hydraulic jet in a 400 L sprayer tank by using one jet nozzle at 3 different jet nozzle sizes (orifice size: 1.0, 1.5 and 3.0 mm) and 3 different agitating pressures (3, 6 and 8 bar). Kaolin clay and Cooper oxide chloride were used as a tracer material for simulating WP and WSG solutions in the tank. And, International ISO 5682-2:1997 (E) Standard has been used for sampling method in the tank level. To measure the rate of tracer material in the tank, turbimetric and drying method were used and results were comparted with reference solution concentrations to determinate of deviation rates. As a result, deviation rates of all agitation configuration used in this research were higher than the defined acceptable limits in ISO 5682-2:1997 (E) at all measurements in the sprayer tank.

Key words*: sprayer tank agitation, turbidimeter, wettable powder, water-soluble.*

INTRODUCTION

The use of agricultural chemicals is one of the indispensable elements in decreasing crop losses caused by diseases, harmful and weeds in agricultural production. Each year, 3 million tons of pesticides are used in the world and 45 thousand tons of pesticides are used in our country. Although pesticides are classified according to their formulation types, the usage rates of especially wettable powder formulations (WP) have increased in recent years and reached 17% of the total pesticide used in Turkey. Unlike other formulations, the wettable powder (WP) is required to be mixed effectively and continuously in the tank during spray application, since it is delivered to the target with the water in the tank. If the proper agitation is not achieved during the pesticide application, the pesticide liquid componentswill fall bottom of the tank and a rate of application of a pesticide that is not in proper conditions arises. This problem is especially important for sprayers with large tank capacity (Ozkan and Ackerman, 1999). Pneumatic, hydraulic and mechanical agitators are used in the sprayer tanks, either individually or in combination with both agitators (Brusselman et al., 2010) For sprayers produced in Turkey, mostly hydraulic jet type agitators are preferred (Bolat et al., 2012). The agitators in the sprayers produced in Turkey are usually located perpendicular to the sprayer tank bottom and provide a flow towards the top of the pressurized fluid tank exiting the agitator. However, this type of sprayer tank agitators cannot provide a sufficient level of agitating within the tank. In a study conducted in Cukurova region of Adana/Turkey, where intensive chemical consumption is high in Turkey, agitation system mistakes of the existing sprayers were determined and found to be 90% in the sprayers (Bayat et. al., 1999). These locally produced sprayers with a high

level of agitator failure cause pesticide application at different concentrations on the same field surface and pesticide applications cause heterogeneous pesticide distribution. Pesticide applications with these sprayers cause very high or very low spraying activities. In recent years, some R & D studies have been conducted on pesticide tank mixing technologies in USA and EU countries and the successful results obtained from these studies have been transferred to practice. The performance of the agitators used depends on the sprayer tank shape and size, agitator design and location, mixing pressure and formulation of pesticide (Uçar et al., 2000; Zeren and Bayat, 1999). In particular, the agitator performance is directly influenced by the location of the agitator in the tank, and the hydraulic jet sprayer has been found to be more effective when placed at an inclination of 2.5-5 cm above the basin and 30° relative to the basin (Uçar, 1998). The international ISO 5682-2: 1997 (E) standard is used to determine the performances of the agitators in the sprayer tanks (Anonymus, 1997). According to this standard, in order to determine the activity of the agitator, agitatation of the wettable powder and the specified Copper oxide chloride and water should be put in the recommended concentration in the tank, and samples taken from the tank should be dried at certain temperatures (105-110°C) for evaluation. In recent years, however, measurement instruments (Turbidimeters), which are a new technology in turbidity measurements and which can produce results in a very short time, have also started to be used (Ozkan and Ackerman, 1999). These turbidimeter measurements of the samples are made according to the optical sampling method and the results can be recorded in the digital environment.

The main objective of this study was to compare the performance of the hydraulic jet agitator with different nozzle orifice diameters (1.0 mm, 1.5 mm and 3.0 mm) in three different agitating fluid pressures (3, 6 and 8 bars) in conjunction with ISO 5682-2: 1997 (E) standard as measured by Turbidimetric and Drying methods.

MATERIALS AND METHODS

A field sprayer with a tank capacity of 400 liters was used for the measurements made within the scope of the research. Agitating with a hydraulic jet placed perpendicular to the tank bottom was performed in the sprayer tank. The efficacy tests were carried out in 3 different jet nozzle orifices (Type A: 1.0 mm, Type B: 3.0 mm and Type C: 1.5 mm) and 3 different pressures (3, 6 and 8 bar) were determined. In determining agitating performance, the samples taken are in accordance with the international ISO 5682-2: 1997 (E) standard for Turbidimetric and Drying methods.

Samples taken according to this standard were carried out in 4 stages;

Stage 1: The Jet type tank agitator was operated for 10 minutes while the tank was in full position and samples were taken at three different elevation levels (10%, 50% and 90% full) of the tank.

Stage 2: The hydraulic jet agitator was run for 16 minutes after stopping for 10 minutes and the samples taken in the first stage were repeated.

Stage 3: At the time of unloading the filled storage by means of the nozzles, samples were taken at 8 different storage height levels (every 50 liters).

Stage 4: Sampled from the residual liquid in the bottom of the emptied tank.

An experiment was setup in order to be able to take samples at stage 1 and stage 2 from the sprayer tank and not to disturb the sprayer concentration (Figure 1). Here, a series of plastic hoses fitted at three different heights (90%, 50%, and 10% sampling levels) of the tank and other mounted glass beakers was used. The glass beaks, which is connected parallel to each other, were connected to a vacuum pump (KNF Neuberger D-79112 Freiburg) to suck the samples. Thus, samples were able to be taken from the tank simultaneously. In addition, a separate pressure gauge is fitted on the agitation line in addition to the existing system on the pump in order to be able to follow the pressure in the hydraulic agitator in the test setup.

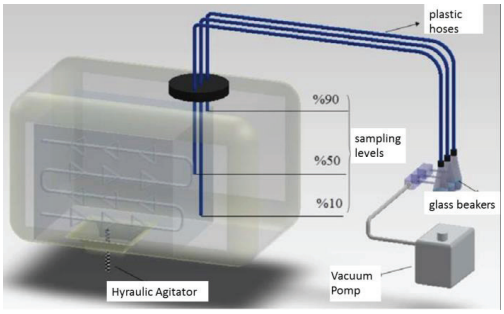

Figure 1. The experimental setup established for sampling in the tank

Turbidimetric and Drying methods were carried out separately in determining the mixing performances with the same sampling methods for the liquid concentrations taken from the tank.

Drying Test Measurements (Classical Method)

In this method, wettable powders of Copper oxychloride (Cu2 (OH) 3Cl) were used in the tank and the samples were dried in a drying cabinet (oven) for 24 hours and at a temperature of 105-110 °C (Figure 2). In the determination of the mixing tests, the samples were taken in four steps according to the international ISO 5682-2: 1997 (E) standard.
The measurements made in this method were recorded by weighing before and after drying, so that the absolute percentage deviation from the initial concentration of each sample was calculated using the formula given in Equation 1, by determining the amount of dry matter.

$$MS(\%) = \left| \frac{NK - BK}{NK} \right| x100 \qquad \text{(Eq. 1)}$$

Where:
MS - Absolute deviation rate (%);
NK - Sample Concentration;
BK - Initial Concentration.

Figure 2. Drying process of the samples

Turbidimetric Test Measurements

Measurements on the samples obtained by this method were carried out in accordance with the international ISO 5682-2: 1997 (E) standard as in the drying method. However, in this method, Kaolin clay, which is a wettable powder, is used in the tank. In this method, measurements were made with Turbidimeter (HF Micro 1000) and calibration kits were used in different measurement ranges (0.02 - 10 and 1000 NTU) (Figure 3).

Figure 3. Turbidimeter Device (HF Micro 1000) and calibration kits

Turbidimetric measurements are obtained in the Nephelometric Turbidimeter Unit (NTU). The turbidity measurements made by this method are used to determine the initial concentration value in the tank and to determine the turbidity reading ranges. The measured turbidity values of the existing calibration kits of the device are shown in as shown in Table 1, turbidity measurements with calibration kits (0.02 - 10 and 1000 NTU) were determined to be measurable at a concentration range of 0.02 - 0.6 g/l solution concentration.

Table 1. Average turbidity value for different solution concentration (NTU)

Solution concentration (g/l)	Average turbidity value (NTU)
0.02	64.325
0.06	72.725
0.1	146
0.2	293
0.3	424.5
0.4	573.5
0.5	779.75
0.6	1086.75

The measurements for each selected concentration were made in 4 replicates and the average turbidity values measurable in the turbidity measurements were calculated as: 64.3 to 1086.7 NTU.

The regression equation determined by solution concentrations and the corresponding graph are given in Figure 4.

RESULTS AND DISCUSSIONS

In the scope of the study, the percentages of deviations of each of the first and second stage agitators at the agitator pressures of 3, 6 and 8 bar are given in Table 2 and Table 3.

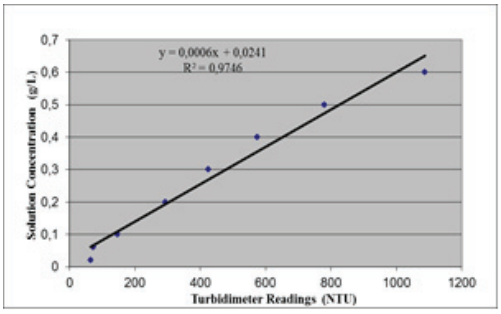

Figure 4. Regression graph and equation for solution concentrations

Equation (2) given below is used to determine the mixing performance (%) in the turbidimetric method.

$$KP = \frac{SBD - \ddot{O}BD}{SBD} \times 100 \qquad \text{(Eq.2)}$$

Where:
KP - Mixer performance (%);
SBD - The initial turbidity value (NTU);
ÖBD - Measured turbidity value.

When Table 2, the results of the first stage evaluating the agitator efficacy tests, is examined, it is seen that the type A mixer produces the lowest percentage of deviation (18.4%) to the first concentration value similarly in both methods at 6 bar pressure.
ISO 5682-2: 1997 (E) specifies that an effective mixing should be in the range of 0.95-1.05% acceptable for the first concentration (Anonymous, 1997).
Accordingly, it can be said that, in terms of the results of the first stage, the deviation rates obtained in the three types of mixers and their associated pressure levels are considerably higher than the initial concentration and form an inefficient mixing process.
According to the results of the second stage, the lowest measured deviation rate was measured with a Type A mixer and a pressure of 8 bar with 18.8% (Table 3).
Similar to the first step here, the difference with respect to the initial concentration in all three types of mixers is well above the acceptable limits.
The third stage (reduced storage levels) where the mixer performances were determined consisted of samples taken every 50 liters during discharge of the liquid from the reservoir through the nozzles.
Figure 5 shows the drying rate and Figure 6 shows the deviation rates calculated by Turbidimetric method.

Table 2. First Stage (after initial operation) Deviation Rates (%)

Agitator types	Deviation rates from initial concentration (%)					
	Drying Method			Turbidimetric Method		
	3 bar	6 bar	8 bar	3 bar	6 bar	8 bar
A	24.2	18.4	19.4	28.5	16.1	22.1
B	21.6	22.8	23.6	24.2	20.3	21.9
C	24.6	20.1	19.2	27.5	19.2	24.5

Table 3. Deviation Rates in the Second Stage (after 16 hours of operation)

Agitator types	Deviation rates from initial concentration (%)					
	Drying Method			Turbidimetric Method		
	3 bar	6 bar	8 bar	3 bar	6 bar	8 bar
A	29.3	22.0	18.8	28.3	23.2	23.6
B	26.4	26.6	24.8	28.2	21.7	21.8
C	28.1	24.7	24.1	26.6	22.0	23.3

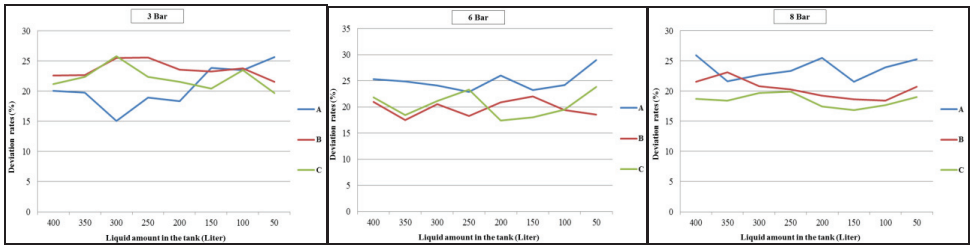

Figure 5. Deviation rates (%) occurring in the third stage of the drying process (reduced storage levels)

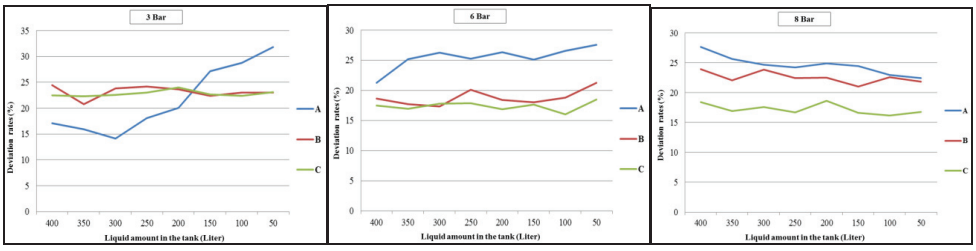

Figure 6. Turbidimetric method deviations in the third stage (reduced storage levels) (%)

As can be seen from Figure 5 and Figure 6, high rates of deviations above the predicted deviations of the entire liquid levels of the depot are obtained by both the drying method and, if necessary, by the turbidimetric method.

This results in the fact that no mixer is effective at the desired level throughout the spraying in the sprayer storage. Drug applications with mixers with such high deviation rates have reached heterogeneous and inadequate biological activity values overall field surface and lead to unsuccessful results in the formulation. In particular, the low level of mixer mistakes during application is very important in terms of spraying success. The sedimentation of the medicine in the warehouse takes place mostly while the medication is in progress.

Therefore, the reduction of mixer mistakes and their problems will increase the success of spraying, thus providing human and environmental health and country economy (Bolat et al., 2013).

The deviation rates of the samples taken from the bottom of the tank the fourth stage in which the mixing performances are tested, are given in Figure 7.

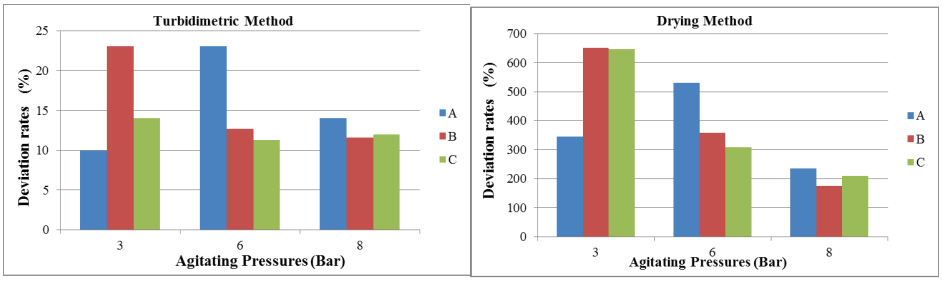

Figure 7. Deviation rates in the fourth stage (tank bottom region) (%)

In Figure 7, when the calculated deviation rates of the samples taken from the bottom of the tank are examined, it is seen that the deviation rates calculated by both methods are at high levels. As can be seen from this, the wettable powder substance was found to collapse to the bottom of the tank due to insufficient agitating.

In terms of the results obtained from the mixing test measurements made, the results of

both measurement methods used were close to each other. This shows that both evaluation methods can be used safely in mixing performance. Although the International ISO 5682-2: 1997 (E) standard used in mixing tests does not recommend a drying method, the Turbidimetric method has proven to be a more preferable method in terms of ease of measurement, instantaneous results and high sensitivity. Furthermore, the performance of the mixer at different pressures and jet nozzle bore diameters in terms of the results obtained in the mixing tests performed did not reach the expected levels of mixing performance. For this reason, it has been determined that mixer designs which enable more effective mixing should be done by performing R & D studies in the domestic production of sprayer tanks.

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