

## Sprayer tank agitation check: A proposal for a simple instrumental evaluation

**Balsari, P.; Tamagnone, M.; Allochis, D.; Marucco, P.; Bozzer, C.**

Dipartimento di Economia e Ingegneria Agraria Forestale e Ambientale – Sezione di Meccanica, Università degli Studi di Torino, 10095 Grugliasco, Italy

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### Abstract

The performance of the sprayer agitation system has an important effect on both pesticide distribution quality and environmental contamination. The visual inspection of sprayer tank agitation systems during inspections of sprayers in use could not give enough precise and repeatable information also due to the human factor.

With the aim to provide more reliable and objective results for the equipment already in use, experiments were carried out for individuating instruments and methods enabling to make a simple and quick evaluation of sprayer tank agitation systems efficiency. Use of a solid inert tracer (glass microspheres) characterized by high sedimentation velocity, to be inserted with the water in the main tank, was found suitable to provide useful information about the efficiency of tank agitation systems in a quick and reproducible way. Further tests are in course in order to confirm the reliability of results obtained using this tracer and to define the details of a test methodology to propose for inspections of sprayers in use.

### Introduction

Inspections of sprayers in use, that are now mandatory according to the prescriptions of EU Directive 128/2009/EC, foresee several checks on main sprayer components in order to verify their proper functioning.

Among the assessments to carry out, the check of sprayer tank agitation system is very important. Several studies (He *et al.*, 1999; Ucar *et al.*, 1999; Ucar *et al.*, 2001), have pointed out that only with a correct agitation of the spray mixture in the tank it is possible to achieve a good efficacy of the spray application and it is possible to minimize pesticide losses. Due to this fact, the assessment of the tank agitation system during inspections of sprayers in use is mandatory and must result positive in order to pass the inspection.

Actually, two different procedures are adopted to evaluate the tank agitation systems for new sprayers and for sprayers in use. For brand new sprayers the ISO standard 5682-2 is applied: it requires to use a copper oxychloride (1% w/w) suspension as test material. Samples of spray mixture are taken after 10 minutes agitation at three levels of the tank in order to establish a reference copper concentration and then the spray mixture is left in the tank without any agitation for 16 hours before making a second sampling that is carried out after 10 minutes agitation. Comparing the reference copper concentration assessed in the samples taken just after the introduction of the test material in the tank and the one of samples taken after 16 hours it is possible to make an evaluation of the efficiency of the tank agitation system. This method, however, is long and is not suitable for inspections of sprayers in use. In this latter case, actually, according to ISO DIS 16122, just a visual assessment is carried out, but this is not an objective measurement of the tank agitation functioning.

In order to get a quick, objective and reproducible evaluation of the efficiency of the tank agitation system a study was therefore carried out at DEIAFA – University of Torino, aimed at defining an ad hoc test methodology also applicable in the inspections of sprayers in use.

Two different approaches were considered:

- a) The assessment of the liquid turbulence inside the sprayer tank using specific instruments able to register the liquid movements in different parts of the tank;
- b) The measurement in different parts of the tank of the concentration of a solid tracer mixed in the water, featured by a high sedimentation velocity.

### Materials and methods

#### 2.1. Devices to measure liquid turbulence in the tank

First phase of tests was addressed to evaluate the use of three different types of sensors, featured by the same principle of functioning (magnetic sensor or phonic wheel) but having different shapes and made of different materials.

The first instrument tested was realised using three flow meters “Wolf” model manufactured by Arag company. They are made of polypropylene and polyamide and consist of an electronic sensor able to measure the movement of a wheel equipped with small blades having its rotation axis transverse with respect to the liquid flux direction. Sensors have the capacity to measure in both directions and are featured by a measurement range of 10÷200 l/min (Fig. 1).

The three flow meters were mounted in series on a metal telescopic support 150 cm long, at 15 cm spacing, therefore enabling the simultaneous detection of the liquid movement at three tank levels and allowing the measurement of the liquid flow from different directions, thanks to the possibility to rotate sensors and their support along the vertical axis (Fig. 2).

For each sensor, measured liquid flow rate values (l/min) detected in the measuring points were read on a “Digiblock 2” display manufactured by Arag (Fig. 3).

The second instrument tested consists of a cylindrical axial fan flow meter equipped with a magnetic sensor which is attached to a speed measuring system (having a range of 0-11 m/s). The sensor axial fan is 98 mm diameter and is provided with 12 small blades, it can rotate in both directions (clockwise or anticlockwise) and it is mounted in correspondence of the centre of a cylindrical structure 150 mm long and featured by a 130 mm external diameter (Fig. 4).

The cylinder was fixed at the edge of a metallic pole 150 cm long, in order to allow its positioning in different parts of the tank.

The third device used in the tests was realized with a cup sensor like the ones used for anemometers, linked to a speed measuring system, similar to the one applied to the second instrument, having a range 0-11 m/s (Fig. 5). Tests were carried out with two different cup sensor sizes: the first one had an overall diameter of 150 mm while cup diameter was 43 mm and cup depth was 22 mm; the second one was featured by an overall diameter of 120 mm, cup diameter of 28 mm and cup depth of 15 mm. All the three instruments were employed to make measurements inside two tanks: a) a 200 l capacity tank of a mounted sprayer; b) a 2000 l capacity tank of a trailed sprayer (Tab. 1)

Tab. 1. Main features of the tanks used for the determination of the liquid turbulence.

Volume (l)	Tank depth (cm)	Kind of agitation system	Pump capacity (l/min)	Pump model	N° of agitation points
200	75,5	Backflow	max 70	Comet APS71	1
2000	111	Venturi system (1) and backflow	max 140	Comet IDS1400	2



Fig. 1. Flow meters “Wolf” model manufactured by Arag company and example of a paddlewheel sensor.



Fig. 2. Telescopic support for the flow meters enabling to measure liquid flows at different levels and from different directions.



Fig. 3. Displays "Digiblock 2" manufactured by Arag company for visualization and registration of flowrate measurements.



Fig. 4. Second type of sensor instrument equipped with an axial fan flow meter in a cylindrical body.



Fig. 5. Third type of sensor instrument, equipped with cup anemometer sensors.

Tests carried out using the three different instruments were made filling the tanks up to half of their nominal capacity (100 l and 1000 l respectively) with clean water, then activating the agitation system at a pump working pressure of 15 bar and a PTO revolution speed of 540 rev/min. Sensors were positioned in predetermined positions inside each tank following a reference measurement grid as shown in Fig. 6.

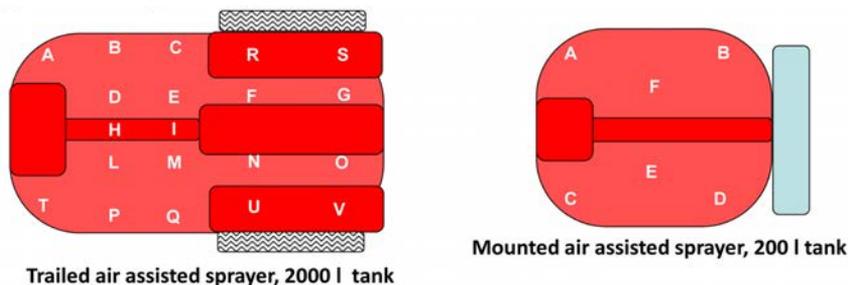


Fig. 6. Measuring positions used as reference in the two tanks examined.

For each point of the grid, measurements were taken at three different liquid levels: 1) close to the tank bottom; 2) in correspondence of the surface liquid level; 3) at an intermediate level between 1) and 2).

## 2.2. Use of an inert solid material as tracer inside the tank

Preliminary tests were made to individuate the most suitable inert material to employ in the tank agitation assessments: three different tanks were examined, two having a 200 litres capacity and applied on mounted vineyard air-assisted sprayers, one having a 600 litres capacity and applied on a mounted field crop sprayer (Table 3). The following requirements and characteristics were searched for the test material:

**Reduced or null abrasiveness:** the material shall not damage sprayer components during its agitation in the tank.

**Inertia:** the material shall not be subjected to any physical or chemical reaction, it has to be not harmful for users and the environment.

**High sedimentation velocity:** the material shall not remain suspended in water for a long time without liquid agitation. This parameter is related to its density and particle size.

**Particle size:** size of particles constituting the material shall be smaller than mesh size of filters usually mounted on agricultural sprayers so to avoid eventual filter blockages.

**Easy commercial availability:** the material shall be available at low cost, in order to be used on a wide scale by test stations charged of inspections of sprayers in use.

Taking into account these characteristics, three different materials were selected for preliminary tests: clay dust (kaolin); vegetal residues (corn cob and nutshell powder); microspheres of sodium calcic glass (Table 2).

Kaolin is a type of clay that was already used in the past for assessing performance of sprayer agitation systems (Ucar *et al.*, 1999), as it is also employed as a carrier in several plant protection products formulated as wettable powders.

Tests were carried out using two kaolin based products, featured by the same bulk density (2.6 g/cm<sup>3</sup>) but with different particle sizes (1-2 μm and 4-6 μm respectively).

Vegetal residues were featured by higher particle size, that was 180÷400 μm for nutshells and 100÷200 μm for corn cob, while their density ranged from 0.9 to 1 g/cm<sup>3</sup>.

Glass microspheres had a particle size of 90÷150 μm and were featured by a density (2.5 g/cm<sup>3</sup>) very close to the kaolin one.

After the selection of test materials, the measurement method for assessing the amount of inert material collected in the tank samples was defined. A comparison between different graduated containers filled with the same amount of material was carried out in order to verify their precision and practicality in reading measures.

Results indicated that volumetric glass flasks 500 ml capacity were most suitable in providing accurate measurements of solid sediments, when they were used upturned in order to concentrate the sediment in the flask neck.

Tracer		Bulk density (g cm <sup>-3</sup> )	Nominal particle size (µm)	Composition	Concentration	Sedimentation time (s)	
Clay dust	Inert kaolin	2,6	1-2	Kaolin (Fe and Al mixed silicates)	1,0%	600	
	Commercial kaolin	2,6	2-4	Kaolin (95%) and colloids (5%)	0,6%	1200	
Chopped vegetal residues	Nutshell powder	1,1	180-400	nutshell	0,7%	600	
	Corn cob powder	0,9	100-200	corn cob	0,6%	900	
Glass microspheres		2,5	90-150	soda-lime glass	5,0%	120	

Tab. 2. Materials tested as tracer for assessing efficiency of sprayer tank agitation systems

A further step to set up the test methodology using inert solid materials was to determine the tracer concentration to be used in the tank, enabling to detect sediments in the graduated flasks. For each test material examined, the concentration value was individuated introducing in the flasks a known amount of tracer, in order to have a set of samples featured by known and increasing concentrations. Sedimentation level was then observed upturning the flasks and leaving the tracer sediment for a certain time interval (Fig. 7).

Through these analysis, for each tracer, it was therefore possible to determine:

- The optimal concentration related to the sedimentation levels that can be easily observed;
- The sedimentation time intervals needed to read the sediment level in the samples.



Fig. 7. Sedimentation tests made to determine the tracer concentration and the reference sedimentation time for each tracer examined.

The test methodology set up to evaluate the performance of sprayer agitation systems by means of solid material was therefore subdivided in three phases:

#### **Phase A): Tracer preparation and introduction in the sprayer tank**

In order to avoid lumps during their introduction in the sprayer tank, tracer amounts used in the tests were first mixed with some water. Before adding the tracer, the sprayer tank was filled with clean water up to half of its nominal capacity. Tracer was introduced in the tank after that the agitation system was activated adopting a pump working pressure of 15 bar and a PTO revolution speed of 540 rev/min.

**Phase B): Tank sampling.**

Samples were taken out from the tank at least 5 minutes after the tracer introduction, keeping the agitation system activated, at three tank levels: close to the bottom, at middle liquid level and close to the liquid level surface. Sampling of liquid was made through a sucking device combined with a 12 V pump; for each sampling point three samples were picked up and introduced in the graduated flasks.

**Phase C): Analysis of tank samples.**

Just after the sampling, graduated flasks were upturned and placed in ad hoc supports provided with a graduated scale enabling to assess the amount of tracer deposit (Fig. 8).



Fig. 8. Graduated flasks containing the tracer suspensions upturned and positioned in supports provided with a graduated scale to read the amount of sediment deposited in the flask neck.

After the time necessary for the tracer to sediment in the flask neck, the amount of sediment was measured for each sample and it was compared with the reference one corresponding to the tracer concentration originally introduced in the sprayer tank.

Tests using the two types of kaolin were carried out comparing the samples taken from a tank with a nominal capacity of 600 l, filled with 300 l of water, either activating or not the tank agitation system (in the latter case the agitation of spray liquid was obtained just through the backflow). Two different tracer concentrations were used: 1% (w/w) for the first type of kaolin, 0.6% (w/w) for the second type. When vegetal residues were used as tracer (nutshell or corn cob reduced in powder), tests were made in the same tank employed for trials with kaolin. Tracer concentration was 0.7% (w/w) for nutshell and 0.6% (w/w) for corn cob.

Tests made employing glass microspheres as tracer were carried out in three different tanks: a 600 l tank (the same used in the previous tests with the other tracers), a 200 l tank equipped with the agitation system and a 200 l tank without any agitation system.

Tracer concentration was 0.5% (w/w).

Tab. 3. Main features of the tanks employed for the evaluation of the tracers

Volume (l)	Tank depth (cm)	Kind of agitation system	Pump capacity (l/min)	Pump model	N° of sampling levels
200	75.5	Backflow	max 70	Comet APS71	3
200	100	Venturi system (1), flat fan nozzles, backflow	max 50	Comet APS51	3
600	114	Venturi system (3) and backflow	max 150	Comet BP151	3

### 3. Results and discussion

#### 3.1. Devices to measure liquid turbulence in the tank

All the three types of sensors used to measure liquid turbulence in the tank resulted not able to provide acceptable and reliable results as the flow rate values registered were not constant and therefore it was not possible to evaluate the efficiency of the tank agitation system. Problems during measurements were mainly related to the difficulties in getting repeatable flow rate values: in the same point of the measuring grid in the tank (see Fig. 6) flow rates registered showed a very high variability over time. In some positions in the tank it was even not registered any flow rate (display value on the instrument was zero) despite liquid turbulence in those positions was visually evident. Turbulence of liquid in the tank was therefore not adequately described through the use of sensors. Moreover, the shape and size of tanks, especially of that with a reduced capacity (200 l), generated problems to operate with these sensors as their precise positioning resulted difficult, in particular in the measuring points located farther from the tank opening.

#### 3.2. Use of an inert solid material as tracer inside the tank

Sedimentation tests made with the two different types of kaolin based materials showed not significant differences between the two tracers: for both material sedimentation time ranged between 600 and 1200 seconds.

Concerning the analysis of samples taken at different levels in the tank, no big differences were observed, but it was noticed that, increasing the time between the introduction of the tracer in the tank and sampling, the level of tracer sedimentation decreased.

An analogue decreasing trend was observed in the tests made with the tank agitation system disconnected as it is shown in the graph reported in Fig. 9.

In order to evaluate the causes of such phenomenon all samples were weighed and then dried in a heater at 110°C so to determine the amount of dried residue and to check the effective tracer concentration. Results pointed out that the concentration of kaolin was constant in the samples, so the decreasing of sedimentation level was due to the variation of the tracer particle size after its pass in the hydraulic circuit of the sprayer (Fig. 10).

As the test results obtained using the kaolin based tracers pointed out poor accuracy and repeatability due to the modification of the physical properties of the material, trials were suspended.

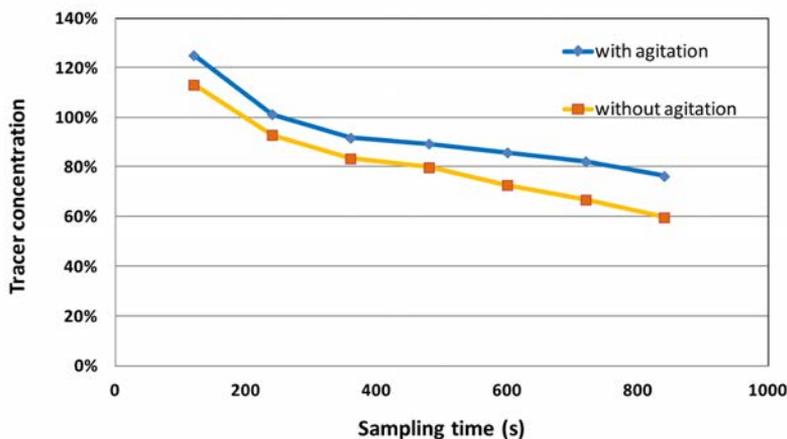


Fig. 9. Comparison between tracer concentrations measured in the tank samples after different sampling times, with and without the agitation system activated (600 l tank capacity).

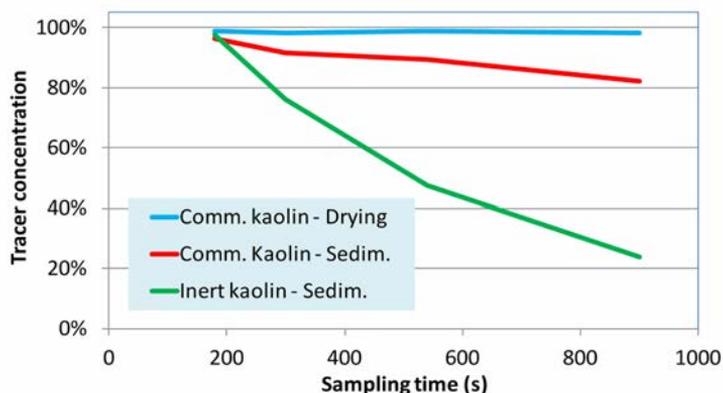


Fig. 10. Comparison between tracer concentrations measured in the tank samples after different sampling times, assessing the sedimentation levels in the flask necks or drying the samples in the heater.

The two tracers based on vegetal residues (nutshells and corn cobs) that were tested, even if they showed a good sedimentation velocity, were not suitable to be used inside a sprayer tank as they caused blockages of filters and interfered with the regular functioning of the sprayer agitation system (Fig. 11).



Fig. 11. Example of filters obstructed with nutshell powder.

Tests made employing the glass microspheres showed a different tracer behaviour with respect to the previous tests, especially regarding the trials carried out with the sprayer agitation system activated (see Figs 12, 13, 14, 15 and 16). In comparison with the experiments done using kaolin based materials, values of tracer concentration measured during the test did not vary significantly but they resulted pretty constant as the physical characteristics of the material, particularly the particle size, were not influenced by the action of sprayer hydraulic circuit. Main problems encountered during the tests made with glass microspheres were related to the low tracer concentration detected in the samples taken in the upper part of the tank, close to the liquid surface, that sometimes resulted below 3% of the original reference value even if a proper agitation of the liquid was visible in that point.

This fact was due to the high sedimentation velocity of glass microspheres that just after 2 minutes from their introduction in the tank settle down towards the tank bottom.

At the intermediate level and at the bottom level of tank sampling the trend of results was different. In the tanks equipped with the agitation system activated the tracer concentration measured in the samples taken close to the bottom of the tank resulted very high, sometimes over 100% vs. the reference concentration (Fig. 12), while at the tank intermediate level the tracer concentration resulted about 80-90% of the reference value (Fig. 14). These results showed a good efficiency of the agitation system.

On the contrary, in the third tank examined, featured by the lack of the agitation system, the tracer concentration values registered at the intermediate and at the bottom tank level resulted very low, ranging between 20% and 40% of the reference concentration close to the tank bottom and ranging between 5% and 7% at the intermediate tank level (Fig. 16). Similar results were obtained for the tanks equipped with the agitation system when the latter was not activated (Fig. 13 and 15).

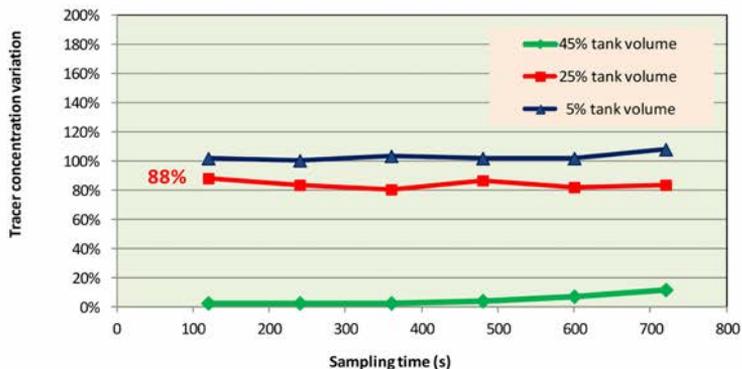


Fig. 12. Glass microspheres concentration in samples taken out of the 600 l tank when the agitation system was activated.

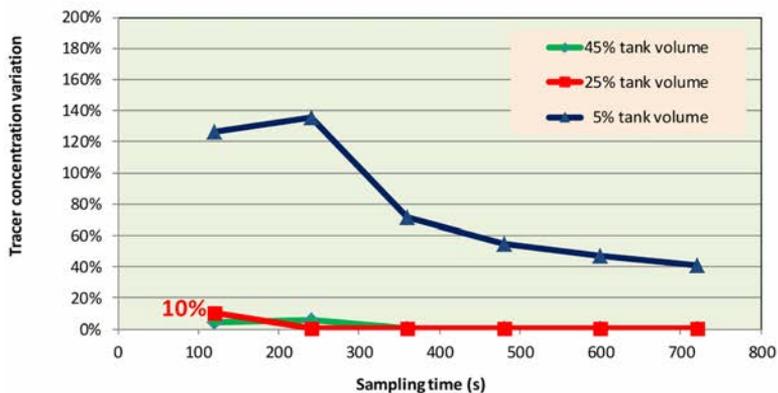


Fig. 13. Glass microspheres concentration in samples taken out of the 600 l tank when the agitation system was not activated.

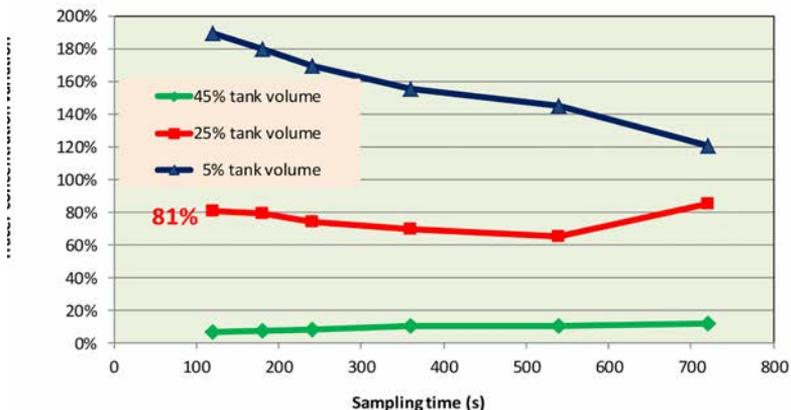


Fig. 14. Glass microspheres concentration in samples taken out of the 200 l tank when the agitation system was activated.

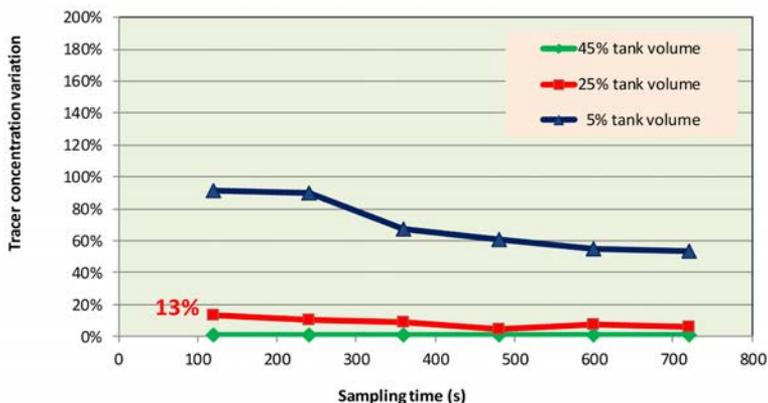


Fig. 15. Glass microspheres concentration in samples taken out of the 200 l tank when the agitation system was not activated.

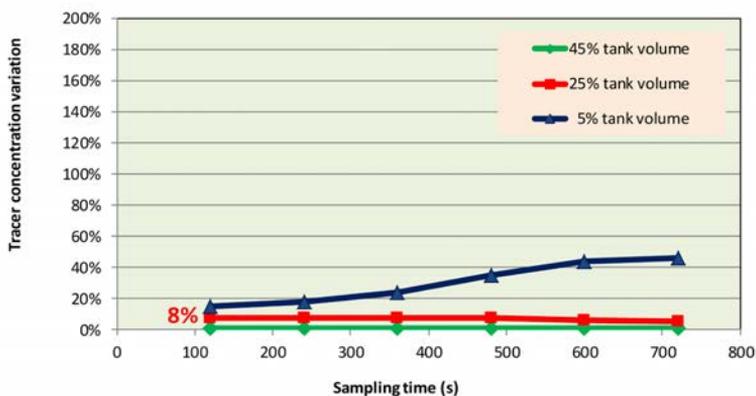


Fig. 16. Glass microspheres concentration in samples taken out of the 200 l lacking of any agitation system.

## Conclusions

First part of tests made pointed out that the use of sensors to assess the liquid turbulence in the sprayer tanks was not suitable to obtain reliable and accurate indications about the efficiency of the tank agitation systems. This method was therefore not further considered for the assessment of efficiency of tank agitation systems in sprayers in use.

In the second set of experiments, instead, it was individuated a tracer (glass microspheres) enabling to provide in short time some general but reliable indications about the efficiency of the sprayer tank agitation systems. This enabled to set up a first proposal of test methodology that shall be refined and consolidated after some further tests and evaluations.

Physical properties (quick sedimentation velocity, null abrasiveness, particle size not interfering with the action of the sprayer hydraulic circuit) revealed glass microspheres suitable to be used as tracer for assessing tank agitation system efficiency. Moreover, the possibility to reuse the material for several tests is useful to save money and to limit problems of tracer disposal after use.

Actually further tests are in course at DEIAFA – University of Torino in order to verify the use of glass microspheres on a wider sample of sprayer tanks, to compare the results obtained using this new tracer with the ones obtained for the same tank applying the ISO 5682-2 test method (based on use of copper oxychloride), that is normally applied for testing of new sprayers. Moreover it is intended to verify if using finer glass microspheres their sedimentation velocity is reduced, so that a higher tracer concentration could be registered also in the top part of the tank.

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