



Characterization of electrical properties of different chemical sprays for electrostatic spraying

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ABSTRACT

Application of chemicals application of chemical is an essential component of agriculture production system. Excessive use of these chemicals has led to search for a suitable chemical application method. Electrostatic spraying can be a viable option to eradicate the existing problem in chemical application. Electrical properties of spray liquid play an important role to impart charge to the spray droplet and its subsequent transportation to the intended target. Therefore it is necessary to characterize the spray liquid in terms of electrical properties for selected chemicals and their concentrations for electrostatic spraying. Hence, the present study was conducted to analyze the spray liquids in terms of their electrical properties using different chemicals. The implications of each electrical property with respect to spray chargeability, deposition on to the target, biological efficacy and suitability for electrostatic charging were established. The electrical conductivity varied from 0.50-0.526, 531-565 and 497-546 $\mu\text{S}/\text{cm}$ for distilled, ground and tap water, respectively at all selected levels of concentration and chemicals. For ground water and tap water, both the electrical conductivity was significantly higher than that of distilled water. Dielectric constant varied from 80.18–80.28, 80.26–80.42 and 80.597–80.66 for distilled, ground and tap water, respectively at all selected levels of concentration and chemicals. For ground water and tap water, the dielectric constant was higher than that of distilled water.

Key words: Dielectric constant, Electrical conductivity, Electrostatic spraying.

Application of chemical for plant protection is an important aspect in agricultural production system to improve crop production and productivity. Presently, the conventional methods of chemical spraying result in 95% wastage to the ground causing soil pollution. Off-target application and evaporation of spray droplets due to high temperature are also concern for plants, animals and environment. Therefore, there is need for modifications in existing methods of chemical application to enhance the deposition and efficacy of spray droplets into the target.

Electrostatic spraying system can be a potential option to overcome the above mentioned problems in chemical application. It is an emerging technology in Asia. The spraying method can provide better whole canopy coverage and biological efficacy compared to conventional methods (Hussain and Moser 1986). Hence, electrostatic spray charging method can offer a possible solution to the environmental concerns by improving on target application of spray droplets and reducing spray drift (Mishra *et al.*

2014, Zhou and He 2010).

The charging of spray droplets is mainly affected by electrical properties of spray liquids. The maximum possible charge attained by the spray droplets, its transportation to the target and biological effectiveness is a function of electrical properties of spray liquid (Maski *et al.* 2004, Maski and Durairaj 2010). Electrical conductivity and dielectric constant are the electrical properties of spray liquid which play important role in sustaining the charge on the droplet and carrying the charge imparted through various high voltage generating sources (Bailey 1988, Hislop *et al.* 1987).

The level of droplet charge imparted by the electrostatic induction process depends heavily upon the relative time rate of charge transfer to the droplet-formation zone as compared with the time required for droplet formation. The charge transfer time constant (τ) or charge relation is a function of the electrical conductivity. Researchers have recommended that the electrical conductivity below ($<10^{-4}$ m seimen m^{-1}) is suitable for induction charging of spray droplets (Law 1978). Hence, it is necessary to characterize the spray chemicals for electrostatic spraying for better charge transfer and canopy coverage to the target plant.

In Indian scenario, most of the farmers use water based spray liquid for agricultural application due to ease in preparation and economic viability. Therefore, a study on chargeability of spray liquid and its subsequent deposition on the target must consider the electrical properties of spray

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liquid to develop an electrostatic charging system (Kang *et al.* 2004, Allen *et al.* 1983, Lake and Merchant 1984). Hence, the present study was carried out to characterize the spray liquid in terms of its electrical properties with respect to source of liquid and chemical type used for preparing the chemical formulation.

The given theoretical and empirical equations were used to quantify the electrical properties of spray liquids.

Permittivity (ϵ): It is the measure of ability of a substance to store electrical energy in an induced electrical field.

$$\epsilon = D_F/E \quad (1)$$

Electrical conductivity (EC): Electrical conductivity is reciprocal of electrical resistivity is the measure of ability of a material to conduct electric current.

$$EC = 1/\rho \quad (2)$$

Dielectric Constant (K): It is the property of an electric insulating substance, and is defined as the ratio of capacitance of capacitor in dielectric media to the capacitance of the same substance when placed in vacuum. For a parallel plate capacitor the capacitance is given by

$$C = K \epsilon_0 A/D \quad (3)$$

When the capacitance of the capacitor is known the dielectric constant of the medium is calculated by substituting the value of capacitance in the above equation.

MATERIALS AND METHODS

A detailed study was conducted to determine the effect of water quality and chemical formulation on electrical properties which affects the spraying quality of spray liquid for the design of electrostatic sprayer. For this study, five common water-soluble chemicals frequently used in the field with varying concentration were used with different water quality to estimate the electromechanical properties of spray liquids (Table 1).

To characterize the spray liquid for pesticide application using electrostatic charging method, it is necessary to determine the electrical properties of the spray liquid. The selected chemicals and the water source formulations were prepared at varied concentration and the properties of each sample were determined.

For the present study, the spray solutions were prepared with selected chemicals and concentrations were varied above and below the recommended concentration. The electrical conductivity meter of accuracy: conductivity $\pm 1\%$, temp $\pm 0.5^\circ\text{C}$, and measurement ranges: Conductivity (0 to 200 mS/cm, Temp -10 to 110°C) was selected for this experiment. The electrical conductivity of each formulation was recorded by using the EC meter. Reading was obtained in terms of $\mu\text{S/cm}$ in the digital display.

The dielectric constant of spray liquid plays an important role with regard to charge time in an induced electric field. The dielectric constant of spray liquids was measured by using a parallel plate apparatus similar to the capacitor. A

Table 1 Chemicals and different water types used to assess electromechanical properties

Chemical used	Pendimethalin
	Imidocloprid
	Metalaxyl
	Thiamethoxam
	Teidemoph
Water quality	Distilled water
	Tap water
	Ground water

parallel plate of aluminium plates 5.3 cm^2 was constructed with a separation of 2 cm to place the dielectric medium. The plates were separated using acrylic sheet to avoid any diffusion of charge through the surface (Maski *et al.* 2004). The parallel plate capacitor was connected in conjunction with capacitance meter to measure the capacitance of the dielectric medium (chemical formulations). The obtained values were substituted in equation 3 to calculate the dielectric constant of the medium. All the experiments were replicated thrice.

RESULTS AND DISCUSSION

The electrical properties; electrical conductivity and dielectric constant for selected chemicals and their respective concentrations were determined. The observed values were used to characterize spray liquid for electrostatic pesticide application for better efficacy and reduced spray drift.

Effect of water quality, selected chemicals and their concentration on electrical conductivity on spray liquid.

The observed results presented in Table 2 revealed that the electrical conductivity varied from 0.50-0.526, 531-565 and 497-546 $\mu\text{S/cm}$ for distilled, ground and tap water, respectively at all selected levels of concentration and chemicals. For ground water and tap water, the electrical conductivity was significantly higher than that of distilled water. Hence, the amount of electrostatic charge attained by the spray droplets of ground water and tap water will be more than the distilled water. Spray liquids having low ($<10.4 \text{ m seimen m}^{-1}$) electrical conductivities are not suitable for induction charging method. Hence, electrical conductivity of ground water and tap water samples lie within the satisfactory limit and were highly suitable for electrostatic induction charging method.

Since the electrical conductivity values of different water showed lot of variation, therefore electrical conductivity was plotted in logarithmic scale against the concentrations for each selected chemicals (Fig 1–5). The results clearly depict that the presence of soluble minerals in ground and tap water resulted in higher value of EC compared to distilled water. Since the soluble salt concentration was higher in ground and tap water for all concentrations of chemical, EC was higher in case of ground and tap water. The maximum value of EC (565 $\mu\text{S/cm}$) was obtained in case of thiamethoxam with ground water.

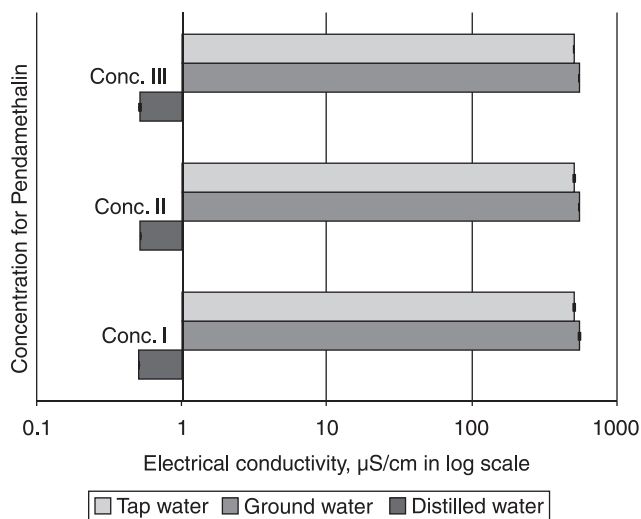


Fig 1 Variation in electrical conductivity of Pendamethalin in relation to concentration and water source.

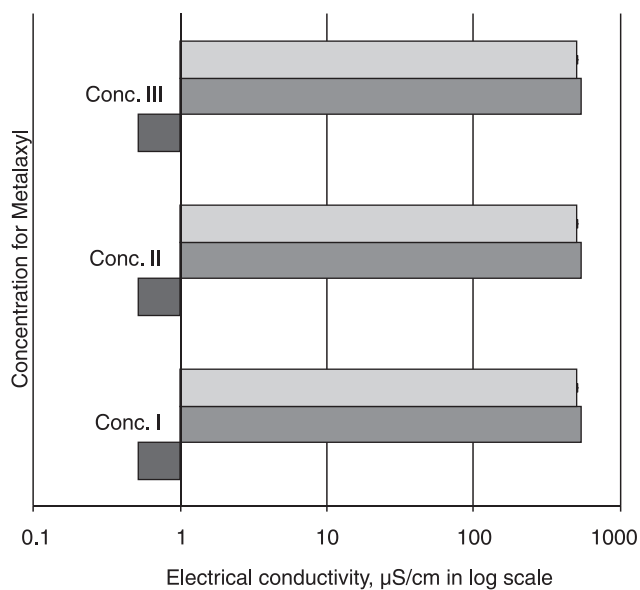


Fig 3 Variation in electrical conductivity of Metalaxyl in relation to concentration and water source.

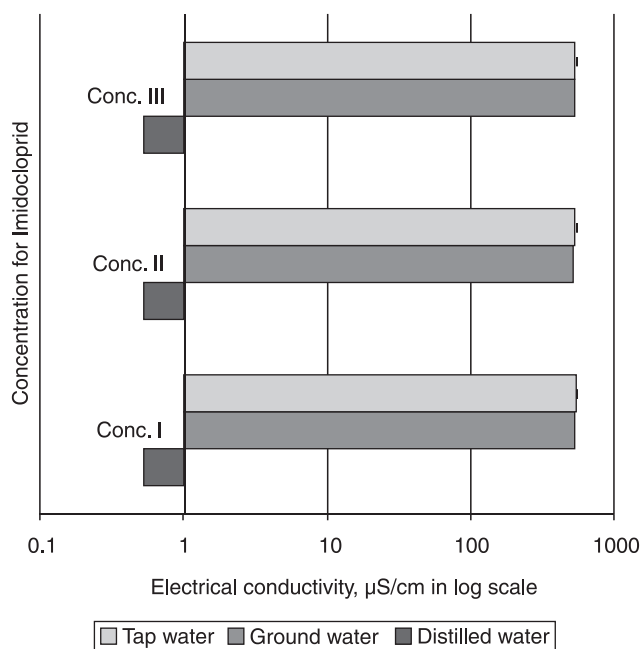


Fig 2 Variation in electrical conductivity of Imidocloprid in relation to concentration and water source.

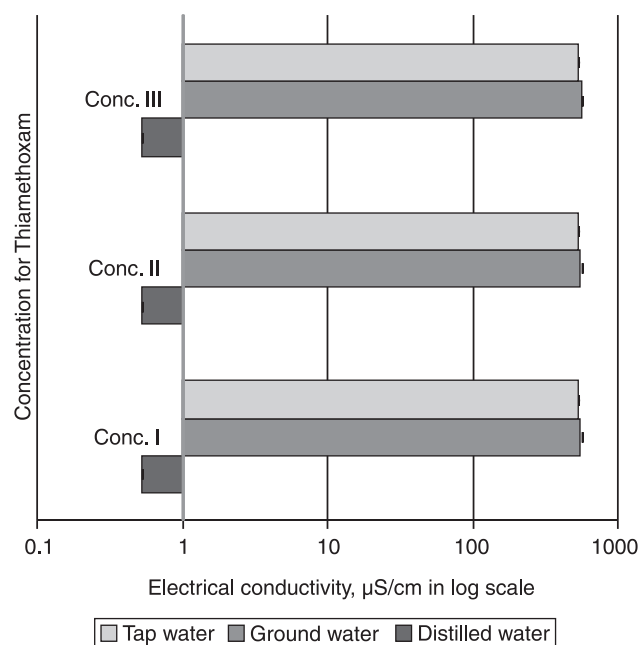


Fig 4 Variation in electrical conductivity of Thiamethoxam in relation to concentration and water source.

Dielectric constant

The observed results presented in Table 3 revealed that the dielectric constant varied from 80.18–80.28, 80.26–80.42 and 80.597–80.66 for distilled, ground and tap water respectively at all selected levels of concentration and chemicals. For ground water and tap water, the dielectric constant was higher than that of distilled water. Hence, the amount of electrostatic charge attained by the spray droplets of ground water and tap water will be more than the distilled water. Hence, dielectric constant of ground water and tap water samples lie within the satisfactory limit and were highly suitable for electrostatic induction charging method.

Effect of water quality, selected chemicals and their

concentration on dielectric constant of spray liquid.

The dielectric constant was plotted against the concentrations for each selected chemicals (Fig 6–10). The figures for all selected chemical and their concentrations showed the effect of water quality with different chemical formulation on dielectric constant. The dielectric constant was maximum in case of tap water. Since the tap water selected for study may contain mineral and ions which have property of holding charge for maximum duration. Therefore, dielectric constant for tap water was found to be maximum. All the above results clearly showed that the

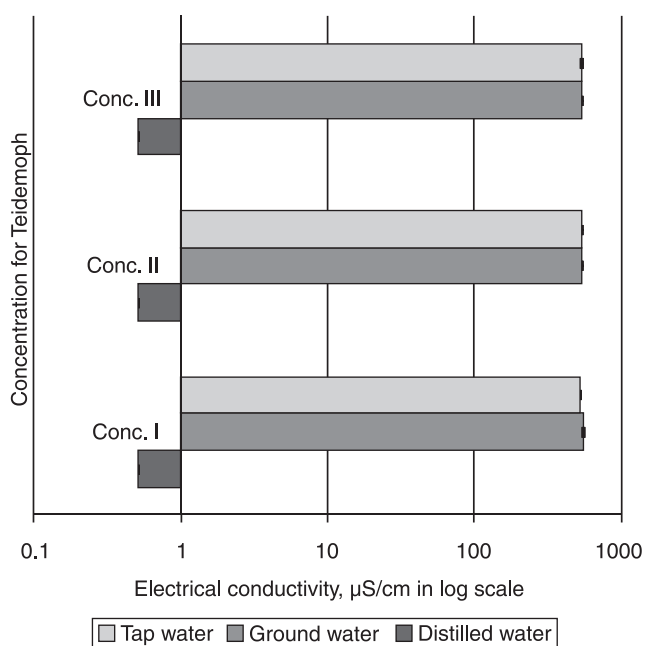


Fig 5 Variation in electrical conductivity of Teidemoph in relation to concentration and water source.

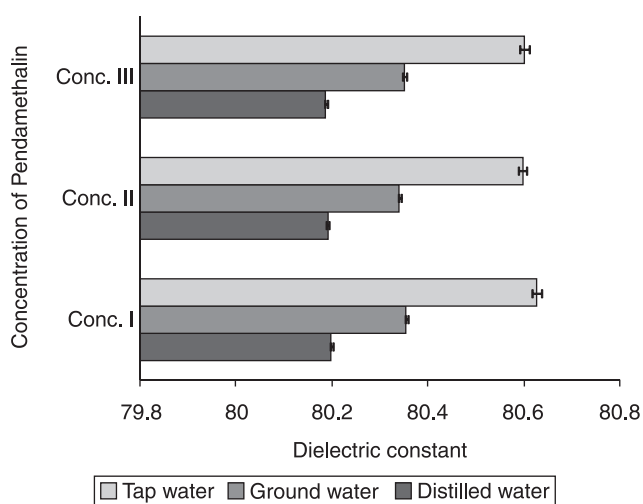


Fig 6 Variation in dielectric constant of Pendamethalin in relation to concentration and water source.

chemical formulation with varying concentrations does not have any significant effect on electrical properties of spray liquid. It may be due to the fact that the concentration used per litre water was minimal to effect the required properties. Whereas, the water quality and chemical use showed significant difference on electromechanical properties of spray liquid. The maximum value of dielectric constant (80.661) was obtained in case of Imidocloprid with tap water.

Conclusion

Pesticide application is of paramount importance to prevent crops from pest and diseases. At the same instant, excessive use of these chemicals can be a threat to human, animals and the environment. Effective and on target application of these chemicals can reduce the above

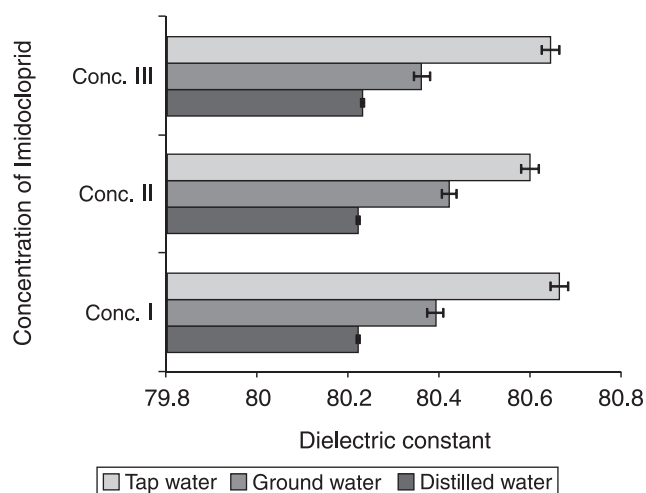


Fig 7 Variation in dielectric constant of Imidocloprid in relation to concentration and water source.

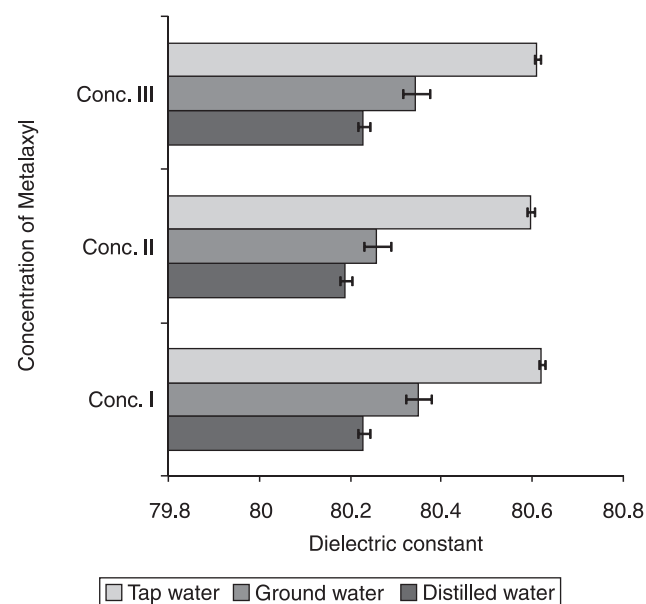


Fig 8 Variation in dielectric constant of Metalaxyl in relation to concentration and water source.

concerns. Electrostatic charging of these chemicals can solve the present existing problem of conventional chemical application methods. Assessment of electrical properties is utmost important for better design of the spray system. Therefore, the spray liquids of different concentration and chemicals were evaluated in terms of their electrical properties. The electrical conductivity and dielectric constant of tap water varied between 497-546 $\mu\text{S}/\text{cm}$ and 80.597 – 80.66, respectively and that of the ground water were 531–565 $\mu\text{S}/\text{cm}$ and 80.26–80.42, respectively. Electrical properties of spray liquid effected the chargeability, charge transfer capacity and deposition efficiency required for design of electrostatic sprayer. Hence, from the result it was concluded tap water and ground water of known electrical properties were found suitable for preparation of formulations intended for electrostatic spraying. It was observed that all the water soluble chemicals and their

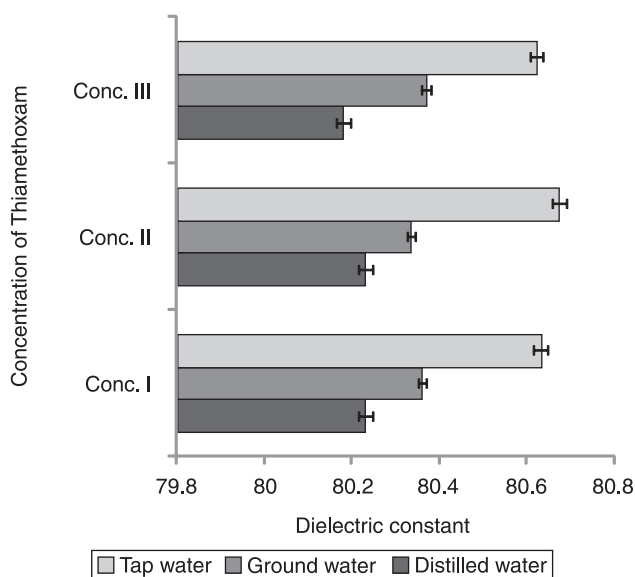


Fig 9 Variation in dielectric constant of Thiamethoxam in relation to concentration and water source.

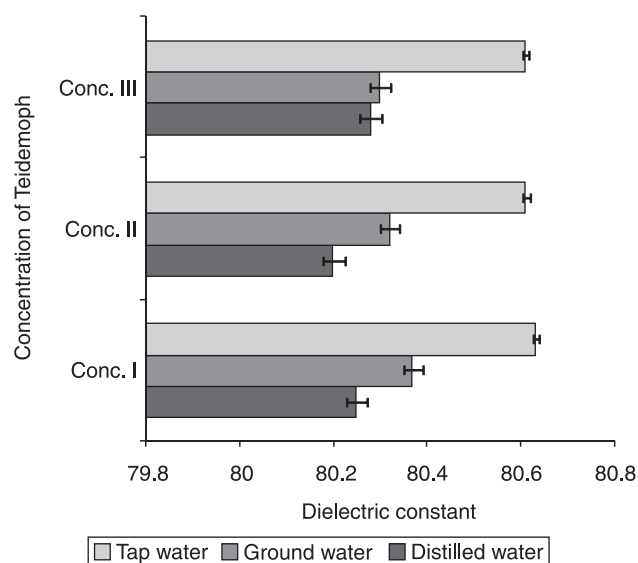


Fig 10 Variation in dielectric constant of Teidemoph in relation to concentration and water source.

Table 2 Measure delectrical conductivity ($\mu\text{S}/\text{cm}$) of water sample with selected chemicals and formulations

Water quality	Pendimethalin	Imidocloprid	Metalaxyl	Thiamethoxam	Teidemoph
<i>Concentration I</i>					
Distilled water	0.5	0.52	0.519	0.518	0.516
Ground water	546	538	546	563	549
Tap water	500	546	502	542	532
<i>Concentration II</i>					
Distilled water	0.512	0.525	0.515	0.515	0.514
Ground water	542	531	540	560	545
Tap water	502	542	502	540	537
<i>Concentration III</i>					
Distilled water	0.509	0.526	0.518	0.517	0.512
Ground water	541	534	543	565	541
Tap water	497	544	501	542	534

Concentration II: Recommended concentration for selected chemical in terms of percentage of active ingredient. Concentration I & Concentration III: 1.25 & 0.75 of recommended concentration for selected chemicals.

Table 3 Measured dielectric constant of water sample with selected chemicals and formulations

Water quality	Pendimethalin	Imidocloprid	Metalaxyl	Thiamethoxam	Teidemoph
<i>Concentration I</i>					
Distilled water	80.2	80.22	80.23	80.23	80.25
Ground water	80.356	80.39	80.35	80.36	80.37
Tap water	80.627	80.661	80.621	80.631	80.632
<i>Concentration II</i>					
Distilled water	80.192	80.221	80.19	80.23	80.2
Ground water	80.342	80.42	80.26	80.335	80.32
Tap water	80.598	80.598	80.597	80.672	80.611
<i>Concentration III</i>					
Distilled water	80.188	80.23	80.231	80.18	80.28
Ground water	80.351	80.36	80.346	80.37	80.3
Tap water	80.601	80.643	80.611	80.621	80.61

Concentration II: Recommended concentration for selected chemical in terms of percentage of active ingredient. Concentration I & Concentration III: 1.25 & 0.75 of recommended concentration for selected chemicals.

concentrations can be used as spray liquid for electrostatic charging of spray liquid.

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