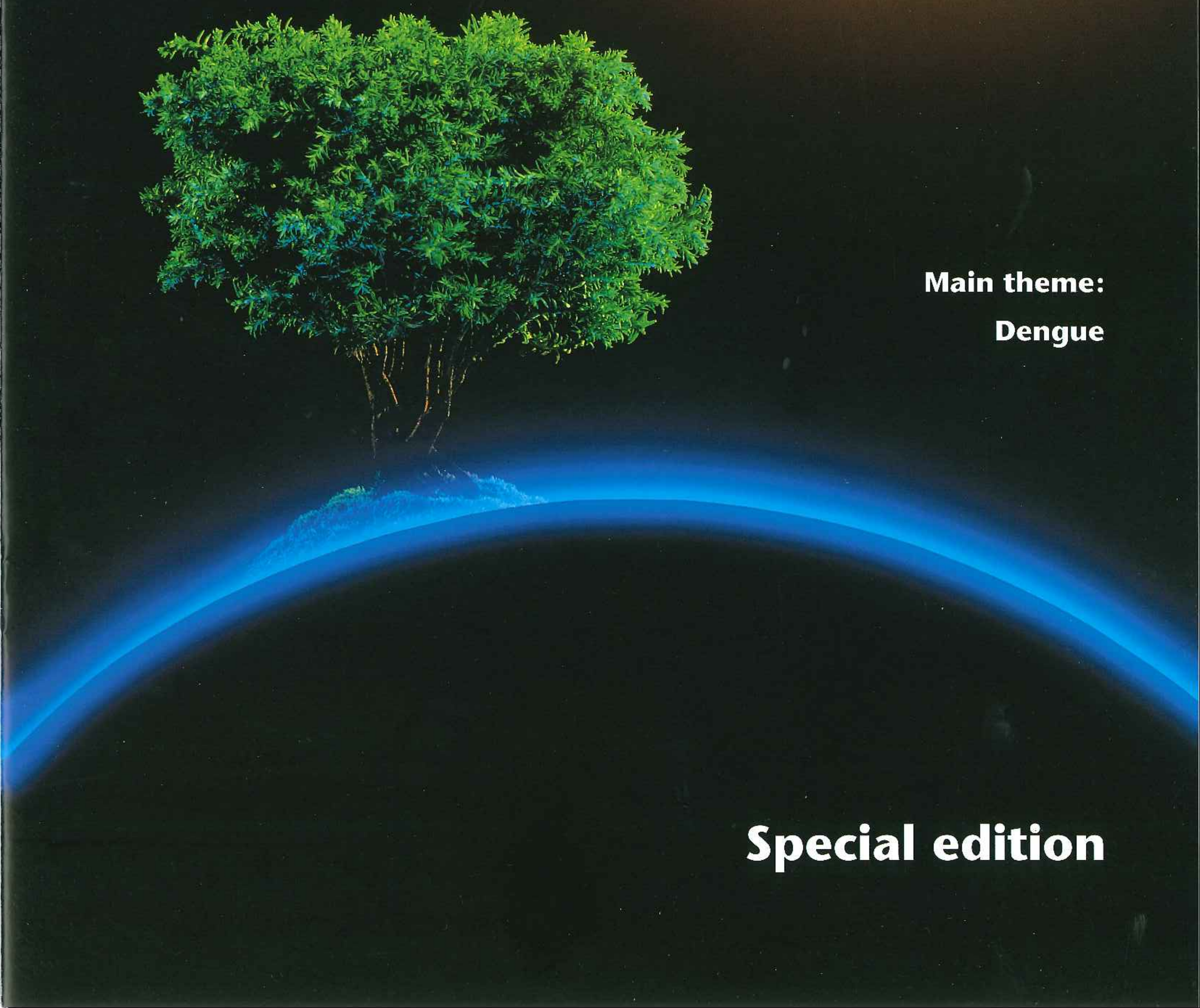
Public Health

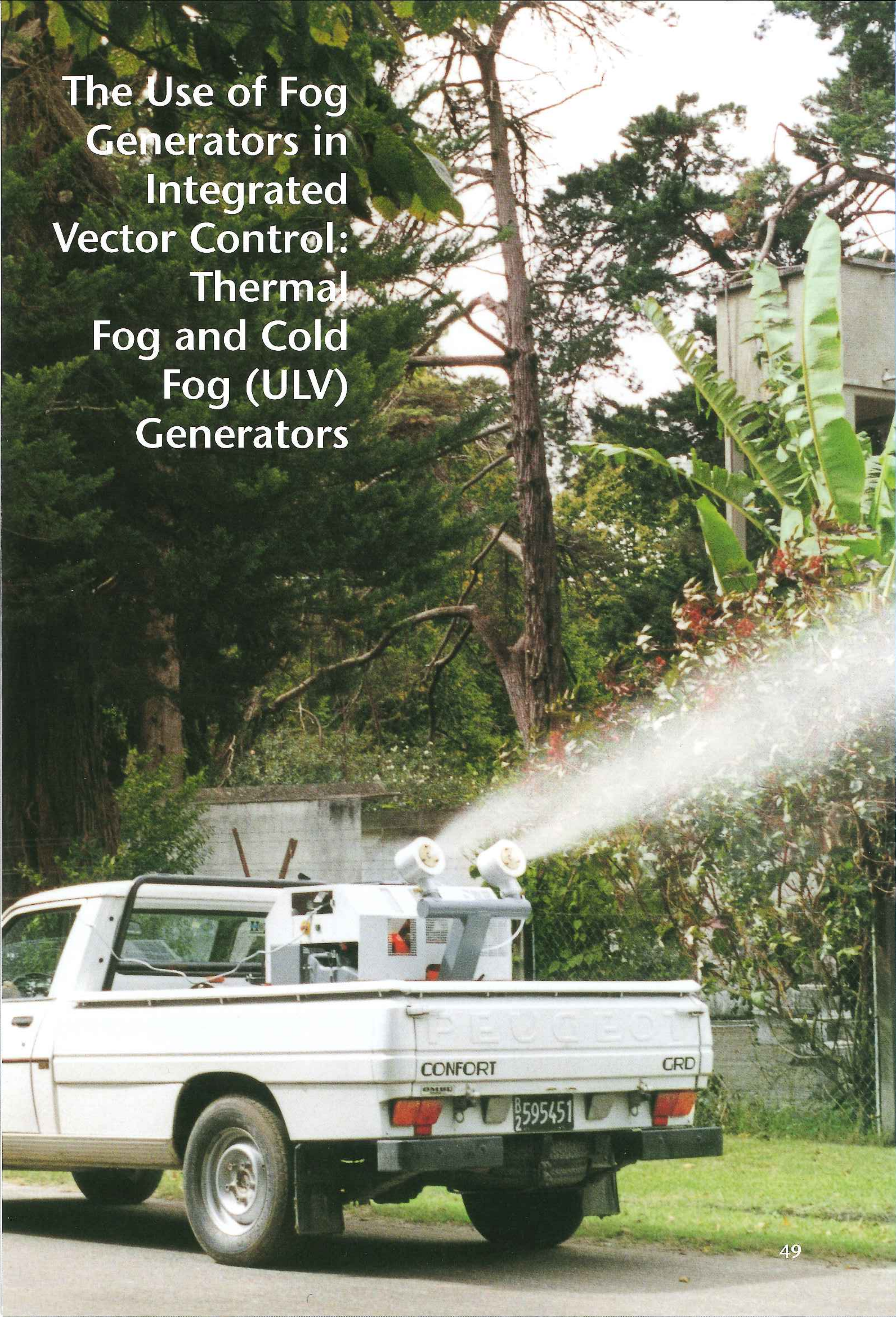
Bayer 1998 **14**



Main theme: Dengue

Special edition

The Use of Fog Generators in Integrated Vector Control: Thermal Fog and Cold Fog (ULV) Generators



The Use of Fog Generators in Integrated Vector Control: Thermal Fog and Cold Fog (ULV) Generators

By Bernd L. Dietrich

Principles, methods and techniques

The most important elements of efficient integrated vector control are:

- Research, field investigation, education;
- Chemical vector control
  - larvae
  - mosquitos by area and residual spraying
  - personal protection with impregnated mosquito nets;
- Environmental management and hygiene.

This report discusses the chemical control of mosquitos with the ULV (Ultra Low Volume) process using thermal and cold fog generators.

Spraying methods, application quantity, droplet size

ULV is defined as the lowest amount of liquid per unit area (chemical formulation or active ingredient plus carrier substances) necessary to achieve efficient vector control.

The volume of spray liquid is directly related to the size of droplets which result from the different spraying methods. The relationship of volume (in liters per hectare) to droplet size is illustrated in Table 1.

Table 2 illustrates the cause of the great differentiation in application quantity. For specific droplet sizes (column 1), the theoretical volume of liquid is indicated which would be needed to cover every mm^2 of one hectare with at least one drop (column 2). Column 3 shows the number of droplets on each cm^2 when spraying one liter evenly over one hectare.

Table 2 clearly shows that through the output of very small droplets, the amount of spray liquid needed can be drastically reduced with no resulting disadvantages in coverage. In fact, distribution of small droplets is far more even and dense. Each droplet contains the same amount of active ingredient in percentage terms, since only the volume of carrier substances, and not the amount of active ingredient in the preparation, is altered. World Health Organization (WHO) studies also show that in fighting flying insects a 10-20 µm droplet size is most effective. A fog cloud consisting of droplets in this range provides the greatest possibility of contact with flying mosquitos.

Thermal foggers vs. ULV cold foggers

Both of these devices can be effective in mosquito control and both meet ULV standard: application quantity up to 5 liters/hectare with a corresponding droplet range of up to 50 µm. They differ in type of droplet preparation, which takes place pneumatically in a jet system or through rotation (spinning disc) for cold fog generators, and is thermo-pneumatic in thermal fog generators, whereby the preparation is injected into the hot exhaust flow of the device.

There is a major difference between the two systems, however. The capacity of the combustion chamber in portable thermal foggers ranges between 13-19 kW (approx. 17-25 HP), whereas the capacity of portable cold foggers is under 1.5 kW (approx. 2 HP). In devices which are mounted on motor vehicles, perform-

Spraying method (limits not exactly defined)	Application quantity liter/hectare	Droplet size (µm ø) Spectrum	-vmd*	Types of machinery
High Volume (HV)	>600	>400	450->700	Field sprayers, coarse sprayers
Medium Volume (MV)	200-600	200-400	250-350	Lever-operated knapsack and compression sprayers
Low Volume (LV)	50-200	50-200	75-150	Mist blowers (motorized)
Very Low Volume (VLV)	5-50	0-100	25-50	Mist blowers with ULV attachment
Ultra Low Volume (ULV)	<5	0-50	15-20	Fog and aerosol generators

* vmd = volume median diameter. Half of the spray volume consists of droplets smaller than the vmd; the other half contains larger droplets.

Table 1

Table 2

Droplet diameter (µm)	Spray liquid required (l/ha) for density of 1 droplet per mm² applied evenly to a flat surface	Number of droplets per cm² when spraying 1 l evenly over 1 ha
10	0.005	19,099
20	0.042	2,387
30	0.141	708
40	0.335	299
50	0.655	153
70	1.797	56
90	3.818	26
100	5.238	19
200	41.905	2.4
500	654.687	0.15

ance ranges between 35-45 kW (approx. 47-61 HP) for thermal foggers and between 6-13 kW (approx. 8-18 HP) for cold foggers. The output capacity and the ability to produce a correct spectrum of ULV droplets (< 50 µm) is directly dependent on the power output of a machine. Thus, the output of droplets ranging up to < 50 µm is some 3 liters/hour with portable cold foggers, about 30 liters/hour with portable thermal foggers, up to 25 liters/hour with vehicle-mounted cold foggers and up to some 75 liters/hour with vehicle-mounted thermal foggers.

In theory, due to the higher output capacity of thermal fog generators compared with that of cold fog generators, with thermal foggers an area could be treated much faster, or respectively a much greater area could be fogged in the same amount of time, using an identical concentration of active ingredient. In many cases, however, greater coverage will not be attainable since the speed of an operator or vehicle depends on personal performance (walking speed) and/or local terrain. In such cases there is a risk of exceeding the correct dosage if the total volume of the effective ingredient is administered to an area smaller than planned. This problem can be solved by adding a carrier ingredient such as diesel oil, kerosene, mineral or vegetable oil with similar viscosity to those chemical preparations which can be mixed with oil. This lowers the concentration of the active ingredient and allows for a slower operating speed. The same step can also be taken with cold foggers when concentrations in the chemical preparation are especially high.

In general, for vector control the total application quantity of chemical preparation and carrier ingredients is between 4 and 6 l/ha for thermal fog generators and between 0.5 and 2 l/ha for cold fog generators, with an identical dose of active ingredient. A greater quantity of spray liquid can be an advantage in fighting

Table 3

Thermal fog generators	Cold fog generators
Advantages	
shorter application time due to higher flow rate (liter/hour)	no traffic hazards because fog cloud is nearly invisible
dense, visible fog, therefore perfect observation of fog distribution and fog drift	little or no quantities of carrier substances
lower concentration of the active ingredient	therefore reduced volume of output (liter/hectare) (but not of active ingredient)
psychological effect on people (something is "happening")	little or no smell caused by carrier substances
people can escape direct contact with the fog cloud	lower noise level
Disadvantages	
cost of carrier substances	requires longer application time
strong smell of oily carrier substances	fog is hardly visible, therefore observation of fog distribution and fog drift is difficult
possible traffic hazards through dense fog	people cannot easily avoid the fog cloud
high noise level of the machines	lesser psychological effect (nothing can be seen)
operation requires some experience	higher concentration of active ingredient

flying insects (mosquitos) with thermal foggers since the cloud is more dense, i.e. three times as many aerosol droplets are produced and the probability of insect contact is greater. The individual droplets contain a lower concentration of active ingredient, but this has practically no impact on the effectiveness of eradication.

Both devices are mainly used for vector control treatment of areas and spaces. Distribution of the fog cloud initially occurs through the power of the device, and continues thereafter through the cloud's own kinetic energy and with airflow. This produces a relatively wide swath of vapor which allows quick, widespread treatment. An immediate "knock-out" effect is achieved with all insects coming into contact with the cloud, although the residual effectiveness of the chemical preparation is extremely low. For this reason, in area and space treatment, effective ingredients which work on a contact and inhalation basis are preferred to systemic preparations. A wider droplet spectrum can also be achieved (VLV/LV) with both devices by increasing output (liters/hour). This makes residual spraying possible with the appropriate chemical preparations.

Table 3 summarizes the advantages and disadvantages of thermal and cold fog generators.

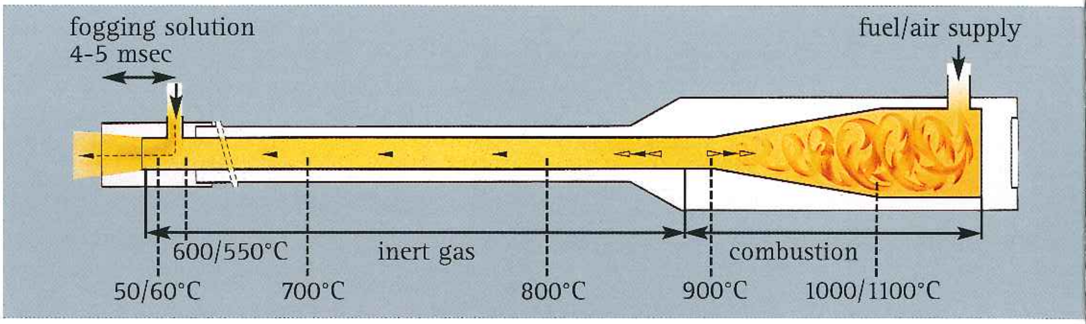


Figure 1 **Portable thermal fogger.**
(Photo MOTAN Swingtec GmbH)

Details on thermal foggers with regard to the operating temperature

It is often said that in thermal fogging, the temperature of the hot gas flow or the open flame destroys a portion of the active ingredient. This is not the case with high-quality devices which have been properly adjusted. Figure 1 shows a cross-section of a thermal fogger with its combustion stages and temperature ranges.

With a correctly adjusted, quality device, fuel combustion should take place in the combustion chamber and the back section of the resonator tube, achieving nearly 100% combustion. Hot exhaust is the only thing remaining within the resonator tube itself, containing excellent exhaust values of 0.03% CO and 13-14% CO_2. The exhaust cools down to 600/550°C by the time it reaches the resonator area right in front of the opening for preparation injection. The preparation comes in contact with the hot exhaust flow. The pressure and temperature (thermo-pneumatic effect) convert the liquid into millions of tiny aerosol droplets. The high temperature of the exhaust is then absorbed by the droplets, cooling it down to 50°-60°C maximum. The droplets begin to evaporate, and the resulting latent heat drastically reduces the exhaust temperature. Through initial evaporation, each drop is surrounded by a gas shell which isolates the fluid and protects it from further evaporation. Although immeasurable, it is assumed that the temperature within the droplet is lower than the 50°-60°C measured at the injection opening. The time lag between injection of the preparation and fog output at the tube is a mere 4-5 milliseconds - not long enough for the active ingredient to be thermally destroyed or diminished. As soon as the fog leaves the device, it adapts to the surrounding temperature. In this regard, it may be of interest to note that in animal husbandry, thermal foggers have been successfully used to administer highly temperature-sensitive inhalation vaccines. A thermal loss of ingredient effectiveness cannot be ruled out, however, if the device is poorly adjusted and the flame reaches the injection opening or extends outside the device.

It is recommended that all thermal foggers which make use of combustible preparations be fitted with an automatic preparation shut-off device. Should the machine be incorrectly used or stop due to lack of fuel, the shut-off device prevents the pressure in the chemical tank from feeding the fluid into the extremely hot combustion chamber, where it could ignite (fire hazard!).

Application

As illustrated above, thermal and cold foggers produce droplets of comparable quality. The drops differ only slightly in weight, diameter, volume and breadth of droplet spectrum. From this we can deduce that physical properties are also identical as regards drifting, suspension and life span. Therefore, the following application tips apply equally to both methods.

Detailed studies have been published in the scientific literature which describe the behavior of aerosol droplets with regard to life span, suspension, falling speed, the effects of climatic factors, etc. Although these findings are significant, they are difficult, if not impossible, to follow and apply during spraying in the field, since the factors at work on site often cannot be clearly defined or undergo numerous changes during the course of an application. The following tips are intended to assist in the successful practical application of ULV methods.

Droplet life span

Water droplets with a diameter of 20 µm evaporate completely in 2.3 seconds at a temperature of 20°C and relative humidity of 80%, and as fast as 0.7 seconds at a temperature of 30°C and relative humidity of 50%. If the drops of ULV spray fluid were to behave in a similar way, the application would be completely

Thermal fog application.

ineffective. It is important to keep the aerosol droplets active as long as possible so that they can do their job. Most ULV preparations are oil-based or contain additives which greatly inhibit evaporation. Oily carrier substances increase this effect even further, thus preventing the evaporation of even the smallest aerosol droplets over a longer period of time.

For environmental reasons, water-based ULV preparations have also been made available over the last few years. These formulations also contain substances which prohibit rapid evaporation. Should water-based preparations be used which do not contain additives to prevent evaporation, it is imperative that such an ingredient be added to the water, which is in this case the carrier substance. These additives could include glycols or emulsifiable mineral oils, and should make up 5%-10% of the carrier substance.

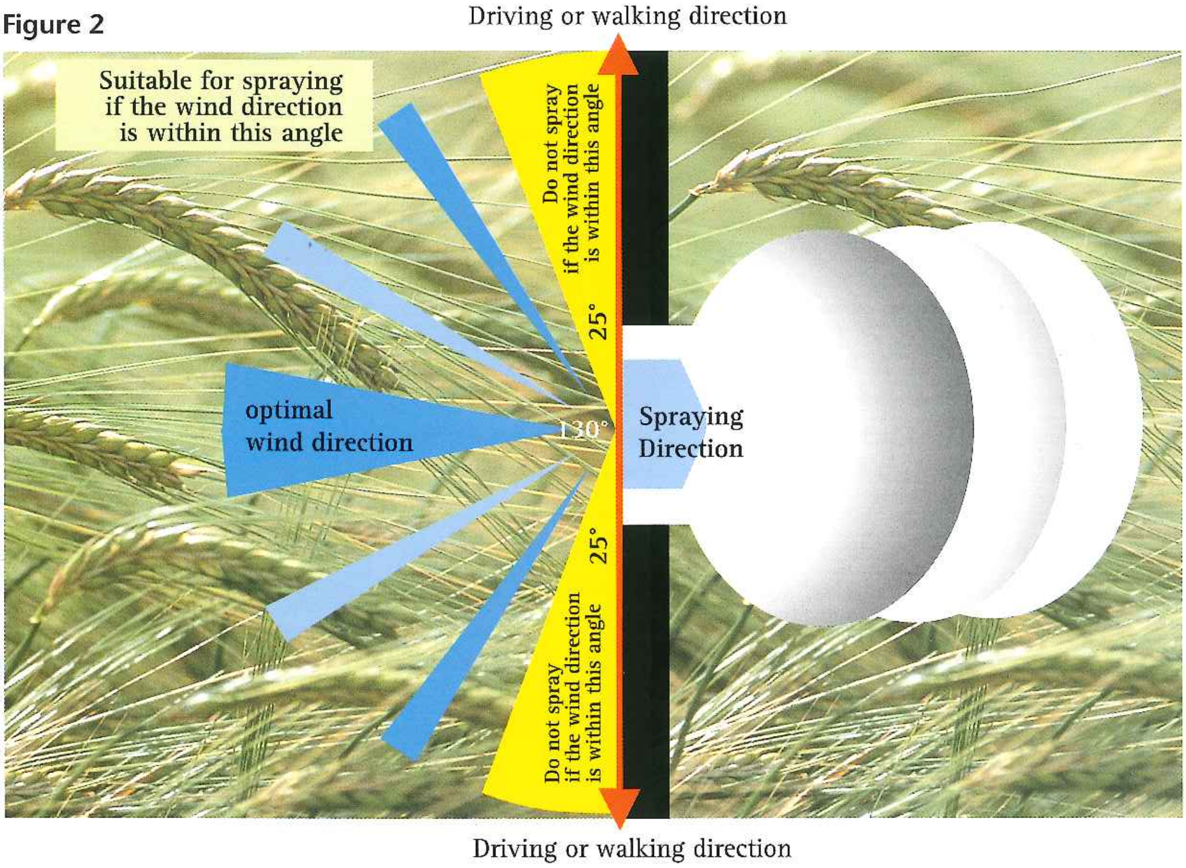
In applying water-based ULV preparations with thermal foggers, it is important to know that the droplet spectrum is far broader - droplets of over 100 µm are even produced which fall to the ground directly in front of the device and are therefore ineffective. There are special high-performance fogging tubes on the market which can produce a droplet spectrum with watery fog preparations that nearly matches that of an "oil fog."

Wind speed/swath width/wind direction

The strength of the wind is of great importance with regard to the distribution of the fog cloud.

Table 4 lists various wind forces and their corresponding wind speeds in keeping with the Beaufort scale. The observation of visible signs in the area contributes to the correct evaluation of wind conditions. Effective swath widths, which depend on wind speed, are also listed. Swath width is particularly crucial for calculating and adjusting the

Figure 2



output (liters/hour) of the device and walking or driving speed.

Windlessness or low wind speeds only allow for small swath widths of up to 50 m. At a wind force of 2 or 3 (up to 20 km/hour), greater swaths of 150 m and more are possible. Better saturation of vegetation and higher particle impact also result. This is especially desirable for the contact effect on flying pests in adult vector control.

The effective swath widths in Table 4 refer to application in an open area. The height and density of vegetation, buildings and other obstacles prevent the fog from spreading. The higher and more dense vegetation and other such obstacles become, the less effective the swath width becomes. In such cases, as a rule of thumb, a reduction of 50% of swath width can be assumed.

Wind direction is also significant since the application of concentrated chemicals must not occur against the wind, unnecessarily exposing operators to the fog. Figure 2 shows where the spray can be applied depending on wind direction.

Treatment procedure

Figure 3 illustrates typical area and space vector control treatment using ULV procedures.

For this example, we have assumed a wind force of 3 (speed of ca. 12.2-19.4 km/hour). This will produce a total swath width of some 130 m, whereby the effective swath width achieved is around 100 m and there is an overlap of 30 m. The overlap guarantees complete and even coverage of the target area. It is also practical to extend the actual treatment area beyond the target area to prevent a new on-

Table 4

Wind force	Description	Observations	Wind speed		Effective swath width / in m*		
			m/s	km/h	ULV	ULV-Plus	LV
Force 0	calm	smoke rises vertically	0.0 - 0.2	0.0 - 0.7	25 - 50	20 - 40	15 - 30
Force 1	light whiff	observable drift of smoke	0.3 - 1.5	1.1 - 5.4	35 - 70	25 - 50	20 - 40
Force 2	light breeze	rustle of leaves	1.6 - 3.3	5.8 - 11.9	50 - 100	35 - 70	25 - 50
Force 3	soft breeze	leaves and twigs are moving constantly	3.4 - 5.4	12.2 - 19.4	75 - 150	50 - 100	30 - 60
Force 4	moderate breeze	movement of small branches, whirl of dust and paper	5.5 - 7.9	19.8 - 28.4	Application possible with certain reservations**		

* Effective swath width = total swath width ./. overlap (approx. 30%)
** Application is only recommended under certain conditions at wind force 4, as the fog clouds swirl too strongly, reducing their effectiveness. Should application nevertheless take place under less than ideal conditions, a higher total application volume (more carrier substances with the same amount of active ingredient) must be used and walking or driving speed reduced to compensate for the lower concentration of the active ingredient.

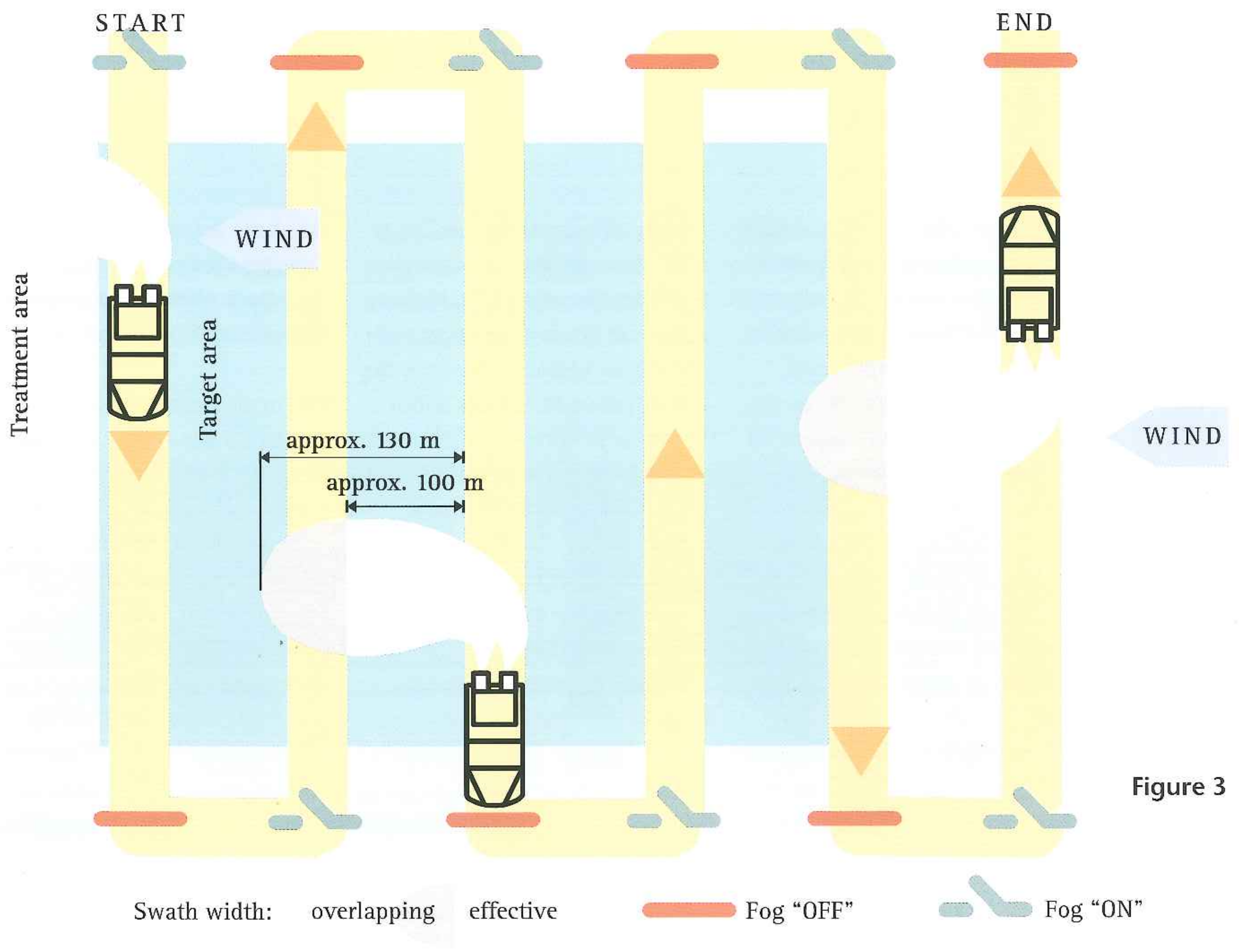


Figure 3

set of vectors from untreated areas as long as possible. The treatment area should be far larger than the target area when treating residential areas in particular.

It is imperative to switch off the fogging function every time the vehicle stops. This is also true for the route travelled from one fogging area to the next.

Determining the adjustable output of the device and the driving or walking speed

Calculating the output rate
The device's flow rate in liters/hour is determined by the following parameters:

- Speed of the vehicle or walking speed with portable devices (km/hour = 1,000 m/hour).
- Effective swath width according to Table 4 (in meters).
- Quantity of the chemical preparation as per manufacturer information (liters/hectare = liters/10,000 m² including any carrier substances).

Determining driving or walking speed
The driving speed can be calculated as follows:

- Effective swath width according to Table 4 (in meters).
- Quantity of the chemical preparation according to manufacturer instructions per hectare (in liters including any carrier substances).
- Area (in m²).
- Output rate (in liters/hour).

Formula for calculating output rate:

Speed (meters/hour)	X	Swath Width (meters)	X	Quantity (liters/hectare)	=	Output amount to be adjusted on the device (liters/hour)

For example:

Driving speed: 10 km/hour = 10,000 m/hour	X	Effective swath width: 50 m	X	Dosage: 0.5 liters/hectare = 0.5 liters/ 10,000 m²		

$$\frac{10{,}000\ \text{m} \times 50\ \text{m} \times 0.5\ \text{l}}{\text{h} \times 10{,}000\ \text{m}^2} = \frac{50 \times 0.5\ \text{l}}{\text{h}} = 25\ \text{liters/hour}$$

Formula for calculating driving speed:

$$\frac{\text{Area (m}^2\text{)}}{\text{Quantity per ha (l)}} \ \frac{\times}{\times}\ \frac{\text{Output Quantity (l/h)}}{\text{Swath Width (m)}} = \text{Driving Speed (meters/hour)}$$

For example:

$$\frac{\text{Area: } 10{,}000\ \text{m}^2}{\text{Quantity per ha: } 0.5\ \text{liters}} \ \frac{\times}{\times}\ \frac{\text{Output quantity: } 25\ \text{liters/hour}}{\text{Effective swath width: } 50\ \text{meters}}$$

$$\frac{10{,}000\ \text{m}^2 \times 25\ \text{l}}{0.5\ \text{l} \times 50\ \text{m} \times \text{h}} = \frac{250{,}000\ \text{m}}{25\ \text{h}} = 10{,}000\ \text{m/h} = 10\ \text{km/h}$$

Time of application

If at all possible, application via ULV methods should not take place at midday when the sun is at its strongest. Early morning and late afternoon hours are preferable.

As we have learned from the above application criteria, the ideal ULV application requires careful evaluation of swath width and correct calculation and adjustment of the fog generator's output. Great precision and consistency in driving or walking speed is also a prerequisite for achieving an application which is as even as possible. This could be quite difficult in rough terrain or heavy traffic. State-of-the-art cold foggers solve this problem and make it possible to adjust output of the chemical preparation according to speed. This can be achieved by measuring speed at the vehicle axle or tachometer. The very latest devices use a radar controller for a speed-synchronized chemical output (mode of output now liters/km instead of liters/hour) to avoid having to make adjustments to the vehicle. With these devices, it is also possible to program the spray application, locking it so as to prevent any alterations by the operator.

Bernd L. Dietrich, who was a background in business administration and economics, is the executive shareholder of MOTAN Swingtec GmbH, based in Isny, Germany.

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