# APPENDICES

## APPENDIX I PROPERTIES OF NEW COMPOUNDS

PYRETHROIDS

| | | |
|---|---|---|
| NRDC 161 | : | Procida; low solubility in paraffinic solvents but unlikely to be formulation problems as it can be used at low concentrations; mammalian toxicity high and similar to dieldrin, AO rats 25–63 mg/kg; available for field trials. |
| Permethrin (OMS-1821, | : | Various licensees; generally high solubility so unlikely to be formulation difficulties; low |

| | | |
|---|---|---|
| NRDC 143) | | mammalian toxicity, AO rats 1300 mg/kg; available for field trials. |

ORGANOPHOSPHORUS COMPOUNDS

| | | |
|---|---|---|
| Pirimetaphos (OMS-1504) | : | Sandoz; difficult to formulate as solution con- centrates; low mammalian toxicity AO rats 1500 mg/kg; available for field trials. |
| Azamethiphos (OMS-1825) | : | Ciba-Geigy; difficult to formulate as solution concentrates; low mammalian toxicity, AO rats 750–1400 mg/kg; available for field trials. |
| OMS-1283 (O-analogue of jodfenphos) | : | Ciba-Geigy; should be no formulation problems; moderate mammalian toxicity, AO rats 375 mg/kg; available for laboratory |

| | | |
|---|---|---|
| | | testing. |
| Fenthion (OMS-2) | : | Bayer; no formulation problems; AO rats 215 mg/kg; readily available. |
| chlorfenvinphos (OMS-1328) | : | Shell; formulation problems unlikely; high mammalian toxicity, AO rats 12–56 mg/kg; readily available. |
| Crotoxyphos (OMS-239) | : | Shell; formulation problems unlikely; moderate mammalian toxicity, AO rats 125 mg/kg; readily available. |
| Phosmet (OMS-232) | : | Stauffer; formulation problems unlikely; moderate mammalian toxicity, AO rats 230–300 mg/kg; readily available. |
| Dicrotophos | : | Shell; formulation problems unlikely; high mammalian toxicity, AO rats 16–20 mg/kg; readily available. |
| | | Chevron; would only be used as |

| | | |
|---|---|---|
| Naled (OMS-75) | : | technical material for ULV applications; very volatile; low mammalian toxicity, AO rats 430 mg/kg; readily available. |
| Tetrachlorvinphos (OMS-595) | : | Shell; difficult to formulate as solution concentrates; low mammalian toxicity, AO rats 2000 mg/kg; readily available. |
| Bromophos (OMS-658) | : | Cela-Merck; no formulation problems; low mammalian toxicity, AO rats 2000 mg/kg; readily available. |
| Jodfenphos (OMS-1211) | : | Ciba-Geigy; formulation problems unlikely; low mammalian toxicity, AO rats 2000 mg/kg; readily available. |

CARBAMATES

| | | |
|---|---|---|
| Propoxur (OMS-33) | : | Bayer; may be some difficulty in formulating as high concentration solutions; moderate mammalian toxicity, AO rats 35–120 mg/kg; readily available. |
| Bendiocarb (OMS-1394) | : | Fisons; difficult to formulate as concentrated solutions; moderate to high mammalian toxicity, AO rats 35–100 mg/kg; readily available. |

## APPENDIX II GROUND APPLICATIONS OF RESIDUAL INSECTICIDES

| | |
|---|---|
| Habitat | Riverine gallery forest |
| Main Species | G. palpalis, G. tachinoides |
| Location | Nigeria |
| Insecticides | Two suitable insecticides; dieldrin as reference hydraulic energy equipment; motorized knapsack |

mistblowers

| Costs | $ |
| --- | --- |
| 1 � entomologist 6 m/m | 14,000 |
| 1 � field officer 6 m/m | 4,500 |
| 12 � fly boys 72 m/m | 4,500 |
| Insecticides (2 candidates, 1 standard) | 1,000 |
| Supporting services (Land-Rovers, drivers, equipment) | 10,000 |
| Total | 34,000 |

A four-man spray team should cover about 2–3 km per day. Each experiment area will be approximately 5 km in length. A 1 km chemical or physical barrier will separate each experimental area. Nigeria is a suitable site since collaboration must be sought with operational ground spraying teams which have been there for many years.

Costs as at June 1975.

## APPENDIX III GROUND APPLICATIONS OF NON-RESIDUAL INSECTICIDES

| | |
|---|---|
| Habitat | Riverine |
| Main Species | G. palpalis, G. tachinoides |
| Location | Nigeria |
| Insecticides | Two suitable non-persistent insecticides formulated in oils or as ULV |
| Application Equipment | Motorized knapsack mistblowers (modified for ULV application), fogging machines, manual aerosol producers |

| Costs | $ |
|---|---|
| 1 � entomologist 1-� m/m | 4,000 |
| 1 � application expert 1-� m/m | 4,100 |
| Insecticides | 500 |
| Application equipment (machines & Accessories) | 1,000 |
| Supporting services (transport lab. facilities, etc.) | 5,000 |
| Local staff 9 m/m | 4,000 |
| Total | 18,600 |

Effectively a short-term exercise to evaluate the efficiency of single treatments of candidate insecticides. The need to collaborate with an operational tsetse fly control unit is vital and they would provide supervisors, spraymen, fly boys, etc. Approximately 2 km of riverine thicket will be sprayed per insecticide treatment.

## APPENDIX IV ROTARY WING AIRCRAFT APPLICATIONS OF RESIDUAL INSECTICIDES

| | |
|---|---|
| Habitat | Riverine |
| Main Species | G. palpalis, G. tachinoides |
| Location | OCP area (November-April, e.g. the dry season) |
| Insecticides | Two suitable insecticides, dieldrin as reference |
| Application Equipment | Bell 47 G4 or 206A fitted with rotary atomizers |
| Costs | $ |
| 1 � entomologist 4 m/m | 9,400 |
| 1 � application | |

| | |
|---|---|
| specialist, 1-� m/m | 4,000 |
| Insecticides | 3,600 |
| 1 � field officer 4 m/m | 3,000 |
| 12 � fly boys 48 m/m | 3,000 |
| Supporting services 13 DR/m | 11,050 |
| Helicopter 65 hours (@ $1,200 per hour) | 78,000 |
| Total | 112,050 |

The OCP area is suggested because of the availability of facilities, staff and equipment. Approximately 10 km of riverine habitat must be sprayed per treatment. Using 20 m swaths = 20 ha per treatment. 3 insecticides at 4 rates of application = 12 treatments = 240 ha at 1 kg/ha = 240 kg required at $10/kg = $2,400 + 50% allowance for possible spraying of both sides of the river = $3,600.

# APPENDIX V ROTARY WING AIRCRAFT APPLICATIONS OF NON-RESIDUAL INSECTICIDES

| | |
|---|---|
| Habitat | Riverine gallery forests |
| Main Species | G. palpalis, G. tachinoides |
| Location | West Africa |
| Insecticides | Endosulfan and one alternative non-persistent insecticide |
| Application Equipment | Bell 47G4 or 206 helicopter fitted with electrically powered rotary atomizers |
| Costs | $ |
| Entomologist 2 m/m | 5,200 |
| Application expert 1 m/m | 2,500 |
| 1 field officer 2 m/m | 1,500 |
| 12 fly boys 24 m/m | 1,500 |

| | |
|---|---|
| Supporting services 7 LR/m | 5,950 |
| Other costs | 2,000 |
| Insecticides | 500 |
| Helicopter (65 hours @ $1,200 per hour) | 78,000 |
| Total | 97,150 |

Endosulfan to be used in preliminary trials to establish viability of technique. Approximately 5 km of river to be treated in each trial. This technique is only to be considered in emergency situations because repeated applications by helicopter are economically prohibitive.

## APPENDIX VI MEDIUM FIXED WING AIRCRAFT APPLICATIONS OF NON-RESIDUAL INSECTICIDES

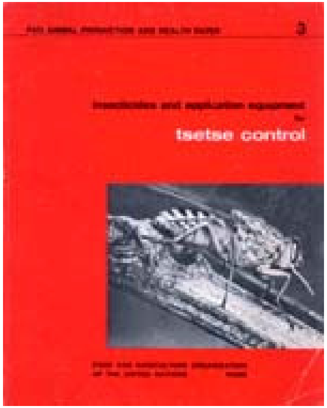
| | |
|---|---|
| Habitat | Savanna woodland |
| Main Species | G. m. morsitans |

| | |
|---|---|
| Location | Botswana (Okavango area) |
| Insecticides | Two suitable non-persistent insecticides, endosulfan as reference |
| Application equipment | Medium twin-engine fixed wing aircraft fitted with rotary atomizers |
| Costs | $ |
| 1 � entomologist 2-� m/m | 7,750 |
| 1 � application expert 1-� m/m | 5,650 |
| Insecticides | 7,000 |
| Supplies and services 40 IR/m | 3,400 |
| Equipment (lab facilities, etc.) | 3,000 |
| Entomological | |

| Assessments | |
|---|---|
| 1 field officer | 2,000 |
| 1 resistant field officer | 1,300 |
| 12 fly boys | 1,500 |
| Land-Rovers 6 LR/m | 5,100 |
| Aircraft (50 hours flying @ $500 per hour) | 25,000 |
| Total | 61,700 |

Each treatment block would be at least 4 km � 4 km = 16 km$^2$. Tsetse fly populations would be monitored pro- and post-treatment.

# FAO ANIMAL PRODUCTION AND HEALTH PAPER 3



# Insecticides and application equipment for tsetse control

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**authorities, or concerning the delimitation of its frontiers or boundaries.**

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**Rome 1977**


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# PART I. REVIEW OF INSECTICIDES AND APPLICATION

# EQUIPMENT FOR TSETSE CONTROL

## INSECTICIDES

## BACKGROUND

**When DDT became available in 1945, the East African Tsetse Research Organization soon showed in the laboratory that tarsal contact with a sprayed surface for a few seconds could be lethal to tsetse flies (105), but subsequent field trials with treated oxen as bait animals were not successful because they were unable to compete as tsetse hosts with the game animals and they had to be re-sprayed at too frequent intervals (8, 107). Meanwhile, also in 1945 in East Africa, the Colonial Insecticides Research Unit (the forerunner of the Tropical Pesticides Research Institute) showed that deposits of DDT and BHC on leaves were lethal to tsetse flies after a short contact, and demonstrated in field trials on islands in Lake Victoria that single ground applications to a very small proportion of the vegetation reduced fly counts by 50–80% for one-two weeks (95). Repeated applications to maintain a toxic deposit for longer**

**than a pupal period were necessary for a greater and more permanent reduction (108, 109). Dieldrin was first tested in 1955 (18) and soon replaced DDT in residual sprays on vegetation in Kenya (40). Residual treatments of vegetation from ground spraying equipment were begun in West Africa in 1953. Since these early operations until the present time, DDT and dieldrin have continued to be almost exclusively the insecticides used for residual treatments of vegetation in ground spray operations. The only real changes have been in techniques to improve effectiveness and reduce costs by reducing dosages and by more discriminative and selective applications (21, 26, 28, 48, 63, 64, 74, 75, 76, 89, 90, 110).**

**Applications of insecticides from aircraft for tsetse control have been made since 1947, and the first successful scheme was carried out with DDT and BHC in South Africa where air spray operations with both fixed-wing aircraft and helicopters were combined with other control measures over a period of years to eradicate G. pallidipes (101). A programme of research on aerial spraying for tsetse control began in 1948 (page 26) at the Tropical Pesticides Research Institute (TPRI) (13, 17, 19, 35, 49, 50, 51, 52, 53, 54, 55, 56, 68), and this has been the forerunner of air spraying**

**techniques employed in Zambia (page 29) and Botswana (page 26) today. DDT and BHC, the first insecticides used, were replaced by dieldrin and, more recently, by endosulfan at rates as low as 6g in 0.03 1/ha (61, 82). Since the late 1960's, techniques have been developed for the application of a residual insecticide to vegetation from a helicopter (91).**

## RESISTANCE

**Insecticides used in tsetse control operations on any scale from the ground and from the air have been limited to DDT, BHC, dieldrin and endosulfan. These are all organochlorine compounds. Where insecticides belonging to this class have been used to control other insect vectors and crop pests, resistance to them has frequently developed quite quickly and become a serious problem. Resistance to insecticides in tsetse flies has not been reported yet. Some tests in N. Nigeria in 1968 indicated that the susceptibility of a population of G. palpalis to DDT and dieldrin had remained fairly stable over a period of four years (86), but no systematic monitoring programme to detect resistance has been carried out in West or East Africa, and there is no reason to expect that it would not develop**

**sooner or later if populations are put under greater insecticidal pressure.**

## ENVIRONMENTAL EFFECTS

**Restrictions have been put on the use of organochlorine insecticides in some countries because of persistence in the environment and undesirable side effects on non-target organisms, and these compounds may become less readily available or acceptable for tsetse control. Destruction of birds and wildlife immediately after tsetse control operations with organochlorine insecticides has been recorded (41, 65, 67). There was a general decline in the prominence of certain insectivorous birds a year after a single application of dieldrin in Nigeria, but most of the species affected then recovered to pre-spray density (66), and monitoring in Uganda showed that the spray programmes were not leaving dangerous doses of dieldrin in the soil or vegetation. An ecological assessment after aerial applications of endosulfan in Zambia showed no lasting adverse effect on the insect fauna, and similar operations in Botswana have so far produced no adverse effects on people, cattle or fish. The various studies to date indicate that residual spraying of a single heavier dose of**

**insecticide to a selected and restricted part of the vegetation is more likely to have an impact on non-target organisms than is sequential aerial spraying.**

## Search for New Compounds

**A systematic search for insecticides that could replace the organochlorine compounds in tsetse control operations when necessary was begun at the TPRI, Arusha (9, 10, 12, 14, 15), and has continued at COPR as a part of the WHO Evaluation Programme (43, 46). Some of the candidate insecticides have also been tested recently at the Nigerian Institute for Trypanosomiasis Research (87).**

**In laboratory bioassays of the toxicity of organophosphorus compounds to tsetse by topical applications in solution, none is found to be appreciably more toxic than endosulfan and dieldrin and only a few are as effective. These include OMS-1825, OMS-1504, OMS-1283, fenthion, chlorfenvinphos, dicrotophos and crotoxyphos, while phosmet, naled, dichlorvos, tetrachlorvinphos, bromophos, jodfenphos and fenitrothion are**

**from two to four times less active. OMS-1825, OMS-1504, OMS-1283, tetrachlorvinphos, bromophos and jodfenphos have the advantage of low mammalian toxicity. Naled and dichlorvos are too volatile.**

**Propoxur and bendiocarb, the most active of the N-methyl carbamate tested, and two di-methyl carbamates, pyrolan and dimetilan, are similar to, or slightly less toxic than, endosulfan and dieldrin.**

**Tsetse are susceptible to natural pyrethrin (10) and to a number of synthetic pyrethroids, including resmethrin and its constituent isomers, bioresmethrin and cismethrin, permethrin (NRDC 143), NRDC 149, NRDC 156, and NRDC 161 (6). NRDC 161 is outstanding and is 100 times as effective as dieldrin to G. austeni. Resmethrin resembles natural pyrethrin in that it is unstable on exposure to light, but permethrin and NRCD 161 are light stable and involatile and at present have the greatest potential as residual insecticides for tsetse control, although some pyrethroids may be more suitable for sequential low rate applications than for single dose residual sprays because of their high toxicity to fish.**

## Susceptibility of Different Species

**Variation in susceptibility of different species to an insecticide is another important factor in field operations. As early as 1947, a 4-fold difference in susceptibility to DDT was found among 12 species and subspecies between the most susceptible G. pallidipes and the lease susceptible G. brevipalpis, G. longipennis and G. fuscopleuris (105). G. swynnertoni is more susceptible than G. morsitans but G. austeni, G. morsitans, G. palpalis and G. longipalpis appear to be similar in their tolerance to a number of compounds (43, 87), although few comparisons have been made by the same method under the same conditions.**

**The susceptibility within a species to an insecticide can vary according to sex and physiological condition, either because there is a real difference in the dose actually required to kill or because there is a difference in the dose reaching the flies, e.g. pick-up from a deposit by a fully-fed or a pregnant female may be greater than that by a teneral fly because the ventral surface of the abdomen, as well as the tarsi, makes contact with the treated surface.**

**Teneral flies of either sex and old fed males are generally equally susceptible to insecticides applied in solution by topical application (11, 43). All are more susceptible, however, than pregnant females to the organochlorine insecticides DDT, dieldrin and endosulfan (11, 43, 57), and 4- to 9-fold increases in tolerance in old females have to be taken into account in field operations with these insecticides.**

**Laboratory tests to date indicate only a small increase in tolerance in old pregnant females to natural pyrethrins and a synthetic pyrethroid resmethrin, and no increase in tolerance to the organophosphorus compounds fenthion, tetrachlorvinphos and bromophos, and the carbamate propoxur (11, 43, 87).**

## FIELD TRIALS

**Some of the compounds showing high toxicity to tsetse flies in laboratory tests and referred to above have already been subjected to limited field trials. In 1966, in northern Tanzania, three aerial applications at 3-week intervals of undiluted technical fenthion caused more than 90% reduction**

in tsetse populations in the four weeks after treatment, but no further trials have been reported (58).

In 1967, six aerial applications of 0.4% w/v solution of natural pyrethrins synergized with 2% piperonyl butoxide in power kerosene were made at 3-week intervals in Tanzania. Populations of G. pallidipes were reduced by 95% after three applications but subsequent applications did not significantly reduce fly numbers. It was considered that unfavourable meteorological conditions during these applications and full leaf cover were the main factors responsible for the lack of effect, and further work was recommended on the basis of the good results of the first applications (59). Subsequent aerial applications of natural pyrethrins at a higher concentration did not give high reductions of G. swynnertoni and G. pallidipes populations (97, 98), although two ground treatments reduced the population of G. swynnertoni by 98% (96). In aerial spray trials in Botswana in 1975, natural pyrethrins at 0.6 and 1.2 g/ha had no effect on the G. morsitans population. In the previous year in Botswana the same dosages of the synthetic pyrethroid bioresmethrin applied from the air in 2% and 4% solutions in diesoline were also too low and had little or no

**effect on the population of G. morsitans (71).**

**Earlier, applications were made from a helicopter in the Republic of Mali of cismethrin, bromophos, jodfenphos, fenitrothion and tetrachlorvinphos for aerosol contact of the flying adults in the gallery forest and of tetrachlorvinphos and methoxychlor for residual contact (24). Operational problems limited the scope of these trials, and additional tests with these materials could be valuable. The trials emphasized the need for further studies of the penetration of spray drops into the dense vegetation of gallery forests (60) and on the resting behaviour of tsetse flies, particularly at night.**

## FORMULATIONS

**Residual spraying techniques employ DDT and dieldrin as emulsions and suspensions. The concentrates from which these are prepared are those normally used for public health work, and the only example of a formulation specially made and used for tsetse control is the dieldrin 15T emulsion concentrate. This involves a modification of the surfactant part**

**of the standard dieldrin 180g/l e.c. which allows the preparation of relatively concentrated emulsions containing up to 5% active ingredient without inversion of the phases. Otherwise, formulations which meet the WHO specifications (Specifications for Pesticides used in Public Health, 1973) have been satisfactory.**

**Aerial spraying methods have used high volume rates of dieldrin emulsion (91), but aircraft normally distribute low or very low volumes of concentrated solutions of dieldrin, DDT or endosulfan with the intention of directly hitting the flies. The desired efficiency and economy are obtained by using insecticides which are very toxic to tsetse flies, the optimum range of droplet sizes and suitable choices of aircraft operation methods and meteorological conditions. An important factor controlling the droplet sizes in the aerosol as it reaches the standing vegetation or the ground is the volatility of the solvent used to dissolve the insecticide, and East African experience has shown that this should not be high, otherwise droplets become too small to reach the target efficiently. Kerosene with a boiling range of about 150 to 250�C produces less effective aerosols than diesel oil which has a wider range of around 200 to**

**350�C, and the latter has been used as a diluting or primary solvent. Despite these results, the more recently developed and currently favoured endosulfan solutions (61, 82) are prepared by diluting a 35% emulsion concentrate to 20% with Shellsol AB. This solvent has a boiling range of 186 to 214�C, and a substantial proportion of the spray volume is presumed to be lost during the time it is airborne, especially as the solvent of the concentrate is even more volatile. However, at the time of this development work the formulation had to be chosen from those made for other applications. Also, volatility was necessary to allow suitable droplet sizes to be formed by evaporation of coarser sprays produced by the available equipment. Less volatile solvents are now being investigated (see following paragraph). Insecticides, which are themselves liquid, such as fenitrothion and malathion, do not require formulation for application at ultra-low-volume rates, have not been used against tsetse.**

**There has been little attempt during the last 20 years to improve formulations for the insecticide application in tsetse control. A good reason for this is the desire for economy. It is cheaper to employ concentrates which are already being used for the control of other pests**

**and to dilute these with locally available petroleum solvents than to transport specially prepared solutions over long distances. However, special formulations are being produced and the use of more involatile materials is being studied by some chemical companies. For example, trials with dieldrin and endosulfan in various solvents have been carried out in Nigeria and Botswana. The Nigerian tests involve selective residual spraying of dieldrin to vegetation by helicopter at 800 g/ha to approximately 10% of the total area. Bioassay of the residues are made with captured flies. In Botswana, five applications of endosulfan are sprayed at 6g/ha per treatment, the aim being to obtain direct contact of insecticide on the flies, either on the wing or in their resting sites and changes in the natural fly population are measured. Both investigations suggest that the less volatile solvents give the best results, although the reasons for the improvements are not clear because lower volatility influences both the persistence of insecticide in the residues and the particle size distribution of the spray. The solvents used are essentially non-volatile, e.g. vegetable oils (cotton seed oil, arachis oil or rapeseed oil), Genomoll (2-ethylhexylphthalate) and Dutrex 217 (an aromatic**

**product from petroleum). These have been compared with diesel oil which is partly volatile and Shellsol AB which is relatively very volatile. It is worth noting that although 'non-volatile' or 'low volatile' solutions are mentioned in reports, only part of the solvents they contain can correctly be given this description. Extremely low volatility means high viscosity and the solutions therefore contain other more volatile solvents to reduce viscosity to a sprayable level and, in some instances, to ensure that the active ingredient remains in solution during storage.**

## GROUND APPLICATION EQUIPMENT

### INTRODUCTION

**Anyone with access only to the published records of ground spraying against tsetse would have difficulty in discovering just how the insecticides are applied. This is being remedied to some extent by the publication of more information on pesticide application equipment, a good deal of which has relevance to tsetse control. COPR and the Overseas Spraying Machinery Centre (OSMC) in collaboration with other UK**

**scientific units through the Ministry of Overseas Development Natural Resources Advisors Coordinating Committee (ODM NRACC) Sub-Committee on Pesticide Application Overseas (80) help in the promotion and coordination of pesticide application research and development in relation to the demands of overseas countries. Assessment of spraying machinery is ongoing research at OSMC (79), and many of the tests carried out are based upon recommendations by WHO (30, 112).**

**Spraying equipment is used to disseminate pesticides as liquids in the form of aqueous suspensions, emulsions and solutions. It is not possible to list all the equipment in current use or which is available, but the apparatus mentioned below has been used in major control operations; e.g. aerosol dispensers are used at fly pickets, fogging machines, although employed in the early days, have now declined in use, whereas a variety of hydraulic energy and gaseous energy equipment is still in regular service.**

## HYDRAULIC ENERGY EQUIPMENT

### Spray Nozzles

**There are three basic pattern shapes produced by hydraulic energy nozzles; the falt fan, the solid cone and the hollow cone. The limitations of the fan pattern for tsetse work are reflected in the very few occasions on which it appears to have been used. In a campaign against G. palpalis (39), the Eclipse sprayer[1] was used, fitted with a lance that gave a fan-shaped spray for treating the leaves and stems of plants along paths. One difficulty which arises with these nozzles is that the width of the fan has to be orientated in order to cover the surface to be sprayed.**

[1] **Eclipse Sprayers Ltd., Rawlings Road, Smethwick, Warley, West Midlands B67 5AB, United Kingdom**

**Cone-shaped sprays are produced by nozzles which consist essentially of a swirl plate with angled slits or holes which produce a vortex in the flow of insecticide, causing it to issue from the orifice in the form of a solid or hollow cone of spray depending on the presence or absence of a central hole in the core. Whether the solid cone nozzle has ever been used in tsetse control is uncertain.**

**The hollow cone spray nozzle is in general use and either a constant or variable spray width can be produced. For the former, the actual dimensions are determined by the design of the swirl core, the size of the nozzle disc orifice and the operating pressure. The practical limitations of these nozzles is that when spraying tree trunks or individual branches, the position of the nozzle, in relation to the surface being sprayed, must be constantly adjusted to ensure that a swath of insecticide of the required width is obtained (27).**

**Accurate and, therefore, less wasteful application can be achieved by a skilled operator using a spray lance (sometimes referred to as "gun") emitting a cone of spray whose shape can be instantly adjusted to fit the width of the object being treated. This can be achieved by altering the length of the swirl chamber. The angular width of the cone at a given pressure is inversely proportional to the length of the chamber between the swirl block and orifice disc. Alternatively, wastage can be avoided by adjusting the distance between the nozzle and the target surface, but this may necessitate moving the nozzle more rapidly when close to the surface.**

## Spray Lances

**Two types of spray lances are in general use; one has a shut-off valve in the handle for controlling the flow of insecticide and produces a constant or variable cone depending upon the type of nozzle fitted.**

**With the other, the shape of the cone is adjusted from the handle by means of a control rod inside the lance.**

## Shut-Off Valve Models

**These consist of a trigger-operated, instantaneous shut-off valve which, with tube and nozzle, from the lance assembly. To produce a constant-shape cone, the nozzle assembly contains a swirl cone, an orifice disc and a screw-retaining cap. The shape of the cone produced for a given pressure is related to both the design of the swirl plate and the size of the orifice in the disc. Variable cone nozzles consist of a nozzle body attached to the end of the lance by means of an adaptor. Variations in the shape of the cone are produced by altering the length of the swirl chamber**

**between the core and the disc by screwing or unscrewing the cap. Leakage of insecticide down the lance from the nozzle is prevented by an 'O' ring immediately above the threaded portion of the body.**

**The CP 601 [2] spray gun has been used in some countries. This consists of a trigger-operated shut-off valve with a brass body, a plated steel trigger, a brass tube 58.5 cm in length with a 45� bend near the end and a single cone spray nozzle No. 520/P. The nozzle has a plastic swirl core, of which only one model is available, a stainless steel nozzle disc and a plastic nozzle cap. Six different orifice sizes are available, with diameters ranging from 0.79 to 2.38 mm, but in both Nigeria and Uganda disc No. 12 with a 1.19 mm orifice is fitted.**

**[2] Cooper Pegler Ltd. Burgess Hill, Sussex RH 15 9LA, United Kingdom**

**Also in this category is the Stoprex spray gun[3]. This has a thumb trigger in contrast to the models previously described, all of which have a four-finger trigger for operating the shut-off valve. The lance and constant-**

**shape cone nozzle assembly are, however, similar to those of the CP601, but the Rex Variable Nozzle[4] is of a different design. Variations in swirl chamber length are made by rotating a collar to which the same stainless steel orifice disc and plastic nozzle cap as those used for hollow cones are fitted.**

## Control rod models

**Spray guns of this type are intended for use in situations where frequent and often rapid changes in the width of the spray pattern are necessary, e.g. when treating the trunks of different trees and the underside of branches at varying distances from the operator. As with the variable cone nozzles described above, pattern shape is changed by altering the length of the swirl chamber. The disc is fixed but movement of the core is achieved by the control rod. The CP700 Spray Gun[5] is one example of this model which has been extensively used in Uganda but is no longer available.**

**A some what different mechanism for adjusting cone shape is found in the GunJet No. 12 and No. 14 spray lances[6] whose use in Botswana has been reported (3). The essential difference between these and the No. 700 is that changes in the swirl chamber are made by rotating the control rod. On rotating the handle the swirl chamber is progressively opened and spray is emitted, at first in the form of a short broad cone. As this movement is continued, the cone becomes progressively longer and narrower until a complete circle has been turned and the swirl chamber is fully open and the spray is emitted as a solid stream. The cone dimensions are related to operating pressure and orifice size and two types of fitting may be used for producing hollow cones. One is a stainless steel disc intended for the higher rates of application, while for the lower outputs the disc can be replaced by a ConeJet spray tip[7], of which ten sizes are available.**

[3] **Berthoud, 48 rue Victor Hugo, 69002 Belleville-sur-Sa�ne (Rh�ne) France**

**4 Berthoud, 48 rue Victor Hugo, 69002 Belleville-sur-Sa�ne (Rh�ne) France**

**5 Cooper Pegler Limited, Burgess Hill, Sussex, RH 15 9LA, United Kingdom**

**6 Spraying Systems Co., Schmale Road, Wheaton, Illinois 60187, U.S.A.**

**7 Spraying Systems Co., Schmale Road, Wheaton, Illinois 60187, U.S.A.**

**Another lance in which the spray cone is adjusted by means of a trigger-operated control rod has been used with a Platz vehicle-mounted sprayer in Zambia. The output of each lance is controlled by the manual operation of the trigger and can be varied between a very fine cone spray and a solid jet (37). The maximum output (from one lance) is about 4.1 per minute with a 2 mm disc orifice and 2.18 per minute with a 1.5 mm disc orifice. The maximum throw is about 15 m in still conditions.**

## HAND OPERATED MACHINES

**In contrast to the extensive use made of hand compression sprayers, few**

**organizations have adopted the lever-operated type, which is lighter but less robust. Unless a pressure regulating device is fitted, considerable variations in output rate can occur because of changes in lever operation, which is affected by operator fatigue. Operators have also found continuous pumping more tiring than the periodic pumping of compression sprayers and a further disadvantage is that they are unable to use both hands freely to gain access to difficult places or to steady long lances when spraying the undersides of high branches, one hand being required for pumping.**

## Pressure Retaining Compression Sprayers

**Extensive use has been made of these machines because they maintain pressure and, consequently, less effort is required to operate them than nonpressure retaining sprayers. The high operating pressure also reduces the tendency to blockages. This type of sprayer can be rapidly charged by means of a detachable pump and maintains air pressure after the spray has been discharged; further pressure loss is prevented by a floating ball valve.**

**Two types of Colibri[8] are still used in antitsetse operations, each using a different type of charge pump. The Leo-Colibri[9] has its own detachable hand pump, whereas the Favori-Colibri[10] machines are charged by means of a large manual or motorized pump which can charge several machines simultaneously. This can be time saving, especially where operators are working near tracks (29) or in close proximity to each other, e.g. when treating narrow zones of riverine forest (64).**

**The detachable pump is another favourable feature of Colibri equipment because it reduces the weight and, consequently, operator fatigue, a matter of some importance in highly selective operations where accuracy is essential. In Uganda, where the Leo-Colibri is still in service, each sprayer operator is accompanied by a porter carrying both a reserve supply of insecticide and a charge pump. In Nigeria, a group of sprayers is serviced by a single mobile manual Favori-Colibri hand pump. The Colibri has been used also in the Central African Republic (34).**

**8, 9, 10 Vermorel - Out of Production.**

## Non-pressure Retaining Sprayers

**Non-pressure retaining sprayers have been widely used, often in preference to pressure retaining sprayers. This has been due to their lower cost, the nonavailability of suitable pressure retaining models and the need to stock fewer spare parts.**

**Some of the first insecticide trials in Uganda (95), were carried out with a Kent[11] sprayer. In the past, this sprayer has seen brief service in East (38), West (29, 76) and Central Africa (32), but no reference has been found as to the model preferred. Three have been in production for many years with maximum working capacities of 4, 5, 9 and 13.6 1. The pump cylinder is of brass, tinned inside to prevent corrosion and is filled through a fairly small opening in the cylinder which can be closed with a plug.**

**Another non-pressure retaining machine is the Warley[12], which is very similar to the Kent. This, too, is filled through an opening but sealed with a cap. In Uganda it was replaced by the Leo-Colibri before large scale**

**spraying operations got under way, but its use in other countries is referred to by several authors (39, 78, 81). Like the Kent, there are three sizes of Warley sprayers of similar working capacities.**

**When the Leo-Colibri went out of production, a suitable pressure-retaining alternative could not be found. However, in both Uganda and Nigeria, the CP201[13] was then used, based on a Gloria[14] machine with the same number. As with all non-pressure retaining sprayers, the pump remains in the machine while spraying is in progress. Like the Kent and Warley it was filled through an opening in the top of the cylinder provided for this purpose and closed with a plug. In its commercially available form, the CP 201 was found to be much less comfortable to carry than the Leo-Colibri. Its extra weight was a factor with the low position of the upper sling swivel support band as near the top of the tank as its curvature allowed. The commercial life of this sprayer was, however, short, and by 1971 it had been replaced by the CP 148[15].**

[11] **Four Oaks Spraying Machine Co. Ltd., Four Oaks, Sutton Coldfield,**

**Warwicks, U.K.**

**12 Eclipse Sprayers Ltd., Rawlings Road, Smethwick, Warley, Worcs., U.K.**

**13 Cooper Pegler Limited, Burgess Hill, Sussex, RH15 9LA, England**

**14 Gloria-Merke POB 109, 4724 Waderisch-i-Westf., West Germany**

**The tank of the CP 148 is of stainless steel and the greater resistance to corrosion of this material may be an asset, although with proper care the corrosion of brass tanks is negligible. The tank (13.6 l capacity) provides greater tensile strength and the thinner sheet metal reduces its weight (7.4 kg). How well these thinner walls stand up to the falls which inevitably occur when treating vegetation on a rugged terrain remains to be seen. Unlike any of the machines referred to above, the CP 148 does not have a separate filling opening. Instead, the pump is removed and insecticide is poured in through that opening with the aid of the fairly large plastic funnel. This is firmly attached to the machine and is extended to surround and protect both the pressure gauge and the safety valve.**

**Other models with smaller tank capacities which have been used in African countries (33, 34) are the Muratori (10)[16], the Galeazzi (10 and 12 l)[17] and the Hudson x pert[17a] which also proved satisfactory.**

**[15] Cooper Pegler Limited, Burgess Hill, Sussex, RH 15 9LA, England**
**[16] Manufacturer unknown**
**[17] Firma Paolo Galeazzi S.p.A., Rome, Italy**
**[17a] H.D. Hudson Man. Co., 154 East Arie St., Chicago, Illinois, 60611 U.S.A.**

**A choice of either diaphragm pump or piston pump models, such as the Cosmos[18], is available and both have been utilized for spraying operations. There is one published record of the latter type (103), though these models have been used in Zambia. The Cosmos has a stainless steel 16 l capacity tank but the pump, which includes a paddle agitator, is of polyamid plastic.**

**In contrast to other lever-operated machines, the Kestrel[19] (21) has a pump fitted to the outside of the tank.**

**A very different machine is the CP 3[20] which is now in service in Zambia and Uganda having replaced the Polclair[21]. The polypropylene plastic body has a working capacity of 18 1 and mounted underneath it is a pump which is basically of the diaphragm type, but the upper diaphragm support has been so designed that it acts as a piston. The compression cylinder is not a separate component but is moulded in one piece with the pump body.**

**18 Berthoud, 69 Belleville-sur-Sa�ne (Rh�ne), France**

**19 E. Allman and Co. Ltd., Allman Patents Ltd., Birdham Rd., Chichester, Sussex P020 7BT, United Kingdom**

**20 Cooper Pegler Ltd., Burgess Hill, Sussex, RH 15 9LA, United Kingdom**

**21 Cooper Pegler Ltd., Burgess Hill, Sussex, RH 15 9LA, United Kingdom**

## Pressure Regulators

**Few authors refer to the working pressures used when spraying and the figures quoted are variable (73, 85). When the fitting of a constant pressure device is to be recommended (16), an on/off tap to the outlet valve is necessary so that faults in the machine can be rectified without loss of spray liquid. Pressure regulators were once used extensively in Nigeria but were later dispensed with because spray deposit was more effectively controlled visually by the operators. A simple alternative to the pressure control valve is the disc flow regulator which has been incorporated in some sprayers.**

## MOTORIZED MACHINES

**The use of a small motorized pump is referred to in an account of spraying operations along the Malawa river on the Uganda/Kenya border in 1956 (88). This type of pump was used from a dinghy and was capable of throwing a variable jet of spray to a distance of 8 m. It is believed that the 700 model spray guns were used in conjunction with the pump and, more recently, the banks of the same river were sprayed again from a boat. The insecticide was applied with similar guns but was supplied from a**

**different type of motorized sprayer. This sprayer consisted of a high pressure diaphragm pump powered via a reduction gear by a 4-stroke petrol engine. Two delivery hoses were attached and an adjustable regulating valve gave a range of pressures from 10 to 30 $kg/cm^2$.**

**In Zambia the use of powered pumps has been the standard practice since large scale eradication campaigns were implemented. The equipment employed was a Platz spray unit mounted on Unimog model 411 tractor. The unit consists of a 3-stage piston pump driven by a pto shaft. Insecticide was suppled from an 800 1 tank mounted on the vehicle and was delivered through two hoses at a constant pressure of 30 $kg/cm^2$ to a pair of lances. These were held by two operators sitting on swivel seats at the back of the loading platform, but in rough conditions they walk alongside the vehicle (2, 36, 37). This type of equipment is, in comparison to manual methods, relatively expensive and wasteful (81) and is likely to be replaced by knapsack sprayers.**

## GASEOUS ENERGY EQUIPMENT

## Motorized Knapsack Mistblowers

**These are used in most countries where tsetse control is practised. The model currently in use in Tanzania is the Motoblo Super 70[22] which closely resembles the Solo-Port 430[23]. Both are equipped with 70 cc 2-stroke engines and 10 1 insecticide tanks.**

**Motoblo sprayers have been used in Tanzania since the early 1960's (21). Both the 60 and 90 models were also in use in Nigeria at about the same time. The model 60 was preferred to the latter because it was lighter and easier to handle. Further spraying operations with these machines have been described (77, 99) but they have since been replaced by the CP 40[24], which is now out of production.**

**In spite of its smaller and somewhat unreliable engine, the CP 40 proved to be a reasonably effective machine. The plastic insecticide tank has a capacity of 10 1 and in Nigeria it proved effective for spraying persistent insecticides in swamp forest (66).**

A number of modifications were made to the CP 40, the most important being the replacement of the thin plastic air hose with a fabric-coated rubber hose, due to the plastic hose being very prone to perforation by thorns. This resulted in appreciable air loss and a consequent decline in the spray penetration.

Three KWH 77[25] machines were used in Uganda and they have been employed extensively elsewhere (67, 100). Motorized knapsack mistblowers have also been employed in Rhodesia (32, 90), but how long they have remained in service is not known.

22 Kent Engineering and Foundry Ltd., Tovil, Maidstone, Kent, United Kingdom

23 Solo Kleinmotoren GMBH, 7034 Maichingen bei Stuttgart, Postfach 20, W. Germany

24 Cooper Pegler Ltd., Coopers Hill, Sussex, RH15 9LA, United Kingdom

25 KWH Wevelwind Holland BV, Wadeoijen-2720, Postbus 47,

**Bommelweg 63**

## CENTRIFUGAL ENERGY EQUIPMENT

**The only record of equipment of this type used in control operations (93) refers to the MEG[26]. Briefly, this consists of a large centrifugal fan powered by a 420 cc air-cooled, 4-stroke engine. At the exit of the fan housing there is an aerofoil section containing a propellor which, powered by the air flow, rotates a wire cage at speeds of up to 20,000 rpm. Insecticide is fed into this cage through a nozzle and is emitted as small droplets which are carried away in the air blast.**

**Another type, the ULVA[27], is a light weight portable rotary atomizer. Insecticide is gravity fed to a nozzle in the centre of an atomizer consisting of two stacked corrugated plastic discs with serrated edges. These are rotated at speeds of up to 9000 rpm by a small 7-watt electric motor powered by a 12-volt battery. Extensive use is being made of the ULVA in crop protection work in the tropics, and in Nigeria it has been**

**used to apply ULV formulations.**

**26 Micron Sprayers Limited - Out of production**

**27 Micron Sprayers Ltd., Three Mills, Bromyard, Herefordshire, United Kingdom**

## SMOKE GENERATORS

**Some small scale control operations were carried out with smoke generators against G. palpalis (G. fuscipes) in Uganda (20, 47), but accurate dispersal of smoke under varying weather conditions was difficult. Efforts have been made to overcome these problems but this technique has not been used extensively.**

## Thermal Foggers

**Field trials with the Todd Insecticidal Fog Applicator[28] (TIFA), and its use in the treatment of small pockets of tsetse have been reported (36,**

**47, 94). The Swingfog[29] has also been used (22, 23, 31, 62), and larger versions of this machine, such as the SNIOO[30], are available for vehicle mounting.**

## AEROSOL DISPENSERS

**A problem in any tsetse control operation is the prevention of reinfestation, and an essential aspect of protective measures is the deflying of traffic by pickets. Tsetse flies which are carried by pedestrians, cyclists and private cars can be caught with nets, but this method is impractical for dealing with numerous flies which can be carried by a single lorry. In Uganda, small hand-operated sprayers are issued to pickets, and both gaseous and hydraulic energy models have been tried. The former, which are invariably cheap, insubstantial and intended for household use, are uneconomic because of their short working life and inefficient because of the wide variation of droplet sizes produced.**

**Good quality hydraulic energy models, such as the 2180[31], are more**

**satisfactory. These are intended for indoor use but could be used in garage-type buildings erected at road pickets where lorries are treated.**

## SELECTION OF EQUIPMENT

**The diversity of types of spraying machines utilized in tsetse eradication work is largely attributable to the diversity of habitats occupied, not just by the genus as a whole, but by individual species. Ground spraying techniques have also been developed more or less independently in the countries where control is practised in a variety of ecological circumstances. Consequently, a variety of local factors have influenced the choice of equipment. The selection of machines is related to their spraying efficiency, cost, ease of handling, mechanical reliability, maintenance and availability of spares. Although tsetse control organizations carry out trials with different insecticides or formulations, there is rarely any mention of comparative trials of different spraying machines.**

[28] **Tifa Limited, Cook Lubbock House, Waterside, Maidstone, Kent,**

**United Kingdom**

29 **Jaydon Engineering Co. Ltd., Beacon House, 28 Worple Rd., London SW19 4EE**

30 **Jaydon Engineering Co. Ltd., Beacon House, 28 Worple Rd., London SW19 4EE**

31 **Ernest H. Hill Ltd., Beta Works, Fitzwilliam Street, Sheffield, United Kingdom**

**Similar savanna woodland habitats of G. morsitans have been treated with spray guns and pressure-retaining compression sprayers in Uganda and by motorized knapsack mistblowers in Tanzania. In Uganda, persistent insecticides have been successfully applied in tsetse resting sites with a 700 spray gun. When treating savanna woodland and forest communities where the undergrowth is not too dense to pass on foot, or where access could be provided with a minimum of path cutting, a compression sprayer (preferably a pressure-retaining type) adapted for use with a spray gun has proved to be most practical. A pressure control valve is fitted to ensure even emission, and this is suitable for spraying trunks up to 3.5 m**

**in height from a distance of 4 m. A much greater reach is often necessary when treating G. fuscipes infested vegetation from a boat. In such circumstances, a compression sprayer is inadequate, but a small portable, engine-driven, high-pressure diaphragm pump is used. With a motorized pump it is also possible to use an insecticide container with a much larger capacity than a compression sprayer, and this reduces refilling time to a minimum.**

**When dealing with thicketed or swamp forest habitats, access lanes are a costly item. Costs can be reduced by using suitable spray jets or motorized mistblowers which give better penetration in these situations.**

## AERIAL APPLICATION EQUIPMENT

## BACKGROUND

**The use of insecticides has for some time been the accepted and main method of controlling tsetse flies and this is likely to remain so in the foreseeable future. Residual treatments of persistent insecticides (e.g.**

**DDT and dieldrin) have been used both selectively and discriminatively by ground spraying methods. However, airspraying techniques have developed appreciably over the last few years, certainly to an extent where the use of aircraft to apply insecticides in antitsetse operations has progressed beyond the experimental stage. As far as the future is concerned, it seems likely that emphasis will be placed on the use of aircraft in many areas which are infested with flies, and it seems probable that any large scale control programmes will contain a significantly large serial input.**

**The principle reason for the choice of aircraft is the relative ease with which large scale operations can be carried out in comparison to spraying from the ground and also fewer trained staff required. Aircraft are able to apply spray to tsetse habitats which are inaccessible from the ground, and this either takes the form of placing the residual deposits in specific sites or by space spraying a wide area. Aerial applications of insecticides are likely to produce more general environmental contamination than ground spraying, except that much lower dosage rates are used, and therefore it is essential to incorporate ambient pesticide monitoring in any operational**

**airspraying programme (page 3).**

**Application techniques by fixed-wing aircraft and helicopters have now reached the stage of development such that suitable equipment is available to meet most tsetse control requirements. Many large scale programmes to control tsetse flies are now based on aerial application of insecticides and, although they often involve a high financial commitment, aerial spraying may be less expensive than ground spraying in terms of unit area covered, depending on the insecticide selected and the amount of ground per unit area. This is partly accounted for by the need for fewer personnel and less logistic support in aerial operations than ground spraying and this often simplifies the operational planning. However, there are often difficulties in executing airspray operations because of the necessity to service and repair sophisticated equipment in remote areas and to adhere strictly to a schedule of sequential applications.**

## THE DEVELOPMENT OF AIRSPRAYING TECHNIQUES

**Research on application of insecticides from aircraft for tsetse control has**

**progressed by two distinct and different methods. These methods are here referred to as “non-residual treatments” and “residual treatments”. Although the use of aircraft in agriculture had its beginnings more than 50 years ago (1), for tsetse control, non-residual airspray treatments have been in use for almost 30 years and residual airspraying about eight years.**

**Non-residual treatments rely on sequential applications of very small droplets of a relatively concentrated insecticide, dispersed widely in savanna woodlands areas with the objective of applying spray droplets which will come into contact with tsetse flies, either in flight or in their resting sites (45). This method has been used extensively in Eastern, Central and Southern Africa. Residual spraying treatments from aircraft have been developed as an extension to the traditional ground techniques and adapted to aerial spraying of persistent insecticides to specific targets where tsetse are known to rest. These have been particularly suited to tsetse control in riverine vegetation, ecotones and drainage lines in West African conditions, especially where the tsetse habitat is restricted during the dry season.**

## Non-Residual Spraying Techniques

**Aerial operations to control tsetse fly began shortly after the Second World War in South Africa, where Anson aircraft were fitted with extension tubes attached to their exhaust stubs. These devices were used to apply 5% solutions of DDT (102) to fly infested regions of Zululand. At about the same time in East Africa, work commenced on an experimental programme of aerial spraying to study methods of controlling tsetse fly (page 2). Work was carried out on an experimental basis and involved studies of insecticide formulations and spraying techniques with supporting physiochemical and biological assessments. Early experiments were carried out with war service aircraft fitted with crude devices, e.g. open pipes and thermal exhaust units which were used for the production of fine sprays and coarse aerosols (52, 53, 54).**

**Trials were ineffective in achieving control of fly but research continued throughout the years in improving application techniques, spray dispersal equipment and insecticide formulations. Eventually, improved fly control was achieved but only at high costs (56). The development of an improved**

**thermal exhaust device fitted to a Cessna 182 aircraft which was capable of producing good aerosol characteristics (70) was used to apply dieldrin and isobenzan (17) which gave very satisfactory control of tsetse flies at reduced cost. In 1964, endosulfan was introduced for the first time and this experiment was shown to reduce costs appreciably (51).**

**These experiments pioneered the use of aircraft for the control of tsetse flies by non-residual spray methods and laid down the foundation of techniques which have developed over the last few years in Central and Southern Africa. In 1967, an airspray experiment was carried out to control tsetse fly in SW Barotseland, and this subsequently led to the commencement of a large scale spraying operation which was carried out the following year and covered an area of 1600 km$^2$ (81). The techniques have been further refined in Botswana in 1973 where a twin-engine Piper Aztec aircraft fitted with a single Micronair unit has been used to control tsetse fly in the Okavango Delta (61, 71).**

## Residual Spraying Techniques

**Trials were carried out in Kenya (4, 72) using an experimental formulation of dieldrin applied by helicopter (Bell 470) and fixed-wing aircraft (Piper Pawnee 235) to control G. pallidipes. The insecticide was formulated as an invert emulsion and was applied from a Bi-Flon[32] device. Spraying by helicopter proved to be prohibitive because of the high operational cost, but trials were continued using a fixed-wing aircraft. The insecticide applied by this method was shown to penetrate the canopy and produce toxic deposits in the understorey thicket. A spraying technique was developed which consisted of applying a swath at intervals of 54 m across the thicket and this proved to be effective in controlling fly for at least eight months.**

**In West Africa, DDT, dieldrin and BHC as emulsion concentrate formulations have been applied primarily to clear riverine vegetation of G. tachinoides (92). Two applications at three weekly intervals were made from a Bell Helicopter (47G-4A 280 HP) fitted with boom and nozzle equipment[3334]. These areas have remained fly free for over four years. In 1971, discriminative spraying of dieldrin to vegetation usually**

**sprayed from the ground was carried out in the Northern Guinea Savanna Zone (NGSZ) of Nigeria (91). The area sprayed consisted of riverine vegetation, Isoberlinia woodland and ecotones around hills and in the sub-plains (74). A 20% dieldrin EC was applied at the rate of 1.5 to 2.0 kg/ha and, with isolated exceptions where fly pockets were missed, these areas have remained fly free for over three years. During 1972 spraying trials in the NGSZ, a helicopter fitted with boom and nozzle equipment was successful in controlling G. morsitans for several months using ULV formulations at 0.5 kg/ha and 1.5 kg/ha of dieldrin and endosulfan, respectively. Subsequently, trials using eight Ulva[35] electrically operated rotary atomizers mounted on the boom of the helicopter indicated that tsetse fly was controlled and exterminated at 0.64 kg/ha and 0.8 kg/ha with ULV formulations of dieldrin and endosulfan respectively to about 10% of the infested area (25).**

**[32] Shell International Chemical Co. Ltd., London, England**
**[33] Sorenson Aircraft Co., Box 264, Worthington, Minnesota, U.S.A.**

34 Simplex Manufacturing Co., 5224 North-East 42nd Ave., Portland, Oregon U.S.A.

35 Micron Sprayers Ltd., Three Mills, Bromyard, Herefordshire, U.K.

## EQUIPMENT FOR NON-RESIDUAL INSECTICIDE TREATMENTS

### Open Pipe

The first trials carried out in East Africa employed an Avro-Anson XIX aircraft fitted with four spray tanks having a total capacity of about 800 l. Spray liquid was emitted under gravity from two wide pipes which extended about 35 cm below the fuselage of the aircraft. Emission rate could be adjusted by an Iris diaphragm which was situated at the end of each pipe. Adjustments were made by the pilot on the cockpit during the flight and spray atomization was achieved by the action of the slip stream which broke up the jet of liquid into spray droplets as it was emitted from the pipe. It was not surprising that the droplet spectrum from this rather crude device was fairly wide and the unit was subsequently discontinued.

## Thermal Exhaust

**One of the first devices to be used for the production of aerosol droplets was fitted to an Avro-Anson XIX aircraft (42). The coarse aerosol was produced by allowing the solution to flow into a modified exhaust system. The solution flowed through a narrow pipe 22 mm internal diameter and into the exhaust pipe at a distance of 50 cm from the centre line of the exhaust manifold. It then passed down along the exhaust tubes 10 cm in diameter, and was finally emitted vertically downwards into the slip stream about 30 cm below the trailing edge of the wing. The installation was based upon a design used for similar work against tsetse flies in South Africa.**

**In 1962, research was reopened to develop thermal exhaust units for aerosol production to enable studies to continue on aerial applications of insecticides for tsetse control. A device was developed for a Cessna 182, and this consisted of an Inconel tube 45.7 cm in length and 74.6 mm in diameter which was secured to the exhaust stub of the aircraft (70). The spray liquid was fed into the exhaust extension through a metering jet**

**located outside the exhaust system. Another device consisted of fitting extensions to twin exhaust pipes, the extensions being two slightly curved stainless steel pipes 5.1 cm in diameter and approximately 60 cm in length. A 340 l Sorensen spray tank was fitted below the fuselage of the aircraft and the system incorporated a 3-bladed, fan-driven Simplex centrifugal pump (2.54 cm). The flow of liquid was controlled by two diaphragm check valves[36], each fitted with a strainer and a D4 orifice disc. The liquid then flowed through two copper tubes 0.32 cm internal diameter to the outlet ports of the extension pipes. The point of entry into the extension was 20 cm below the manifold where the temperature was estimated to be 550�C. Thermal exhaust units are currently in use in Zambia with the parastatal organization, "Rural Air Services", which has three Beechcraft "Baron" twin-engine aircraft with Sorensen external tanks of 360 l capacity.**

**36 Spraying Systems Co., 3201 Randolph Street, Bellwood, Il 60104, U.S.A.**

## Rotary Atomizers (air driven)

**Micronair[37] has produced a number of rotary atomizers over the last few years and these atomizers have been used on a variety of aircraft in numerous pest control operations throughout the world. The physical characteristics of the spray emitted from the rotary atomizers are determined by the liquid throughput and the speed of rotation, but the droplet spectrum achieved is more uniform than hydraulic spray nozzles. The units are driven by a 6-bladed wind mill, whose blade angle and, therefore, speed of rotation can be adjusted between flights. Micronair equipment is used mainly for the ULV application of mists for the control of insects and diseases in crop protection and can be modified to produce aerosols in the range of 10–40 microns in diameter applied from small single-engine aircraft (69), provided that the insecticide solution is fairly volatile (page 8). The latest unit to be manufactured in this series is the AU3000 Micronair rotary atomizer, and this has recently undergone trials in Botswana fitted to twin-engine aircraft to control tsetse fly. This has a smaller diameter cage (12.7 cm) than previous models, and when fitted to**

**a Piper Aztec spraying at a speed of 260 km/h gave droplets of approximately 25–30µ vmd using insecticide solutions containing diesoline and Shellsol AB (71).**

**[37] Micronair (Aerial) Limited, Bembridge Fort, Sandown, Isle of Wight, U.K.**

## Hydraulic Spray Nozzles

**In Tanzania, A Beagle Husky D5/180 single-engine aircraft fitted with four nozzles has been used for tsetse control. The nozzles are located in each lift strut and wing tip and are fitted with D2/25 orifices and strainers. The total throughput is approximately 2.7 l/min, the reported droplet size 40–80µ and a swath width of 90 m is employed for a spraying speed of 175 km/h. A 20% formulation of endosulfan in oil is used at a nominal dosage rate of 12 l/km$^2$. In general, these airspray operations have proved satisfactory, but the very small pay load of the aircraft makes it difficult to treat large areas. Five applications are made at three weekly intervals.**

**The aircraft is not fitted with an automatic navigation aid and, therefore, ground marking is vital. Unsatisfactory marking has led to errors in several instances, and it is suggested that automatic navigational guidance systems would obviate many of these errors (page 36).**

**In recent years, other types of atomizing devices have been investigated (84), but at present, the rotary atomizer principle appears most suitable for non-residual insecticide application.**

## EQUIPMENT FOR RESIDUAL INSECTICIDAL TREATMENTS

### Bi-Flon Apparatus

**The Bi-Flon apparatus was designed specifically for the application of pesticides formulated as invert emulsions. Invert emulsions are produced when invert oils are mixed in water, the oil phase becomes continuous and the water phase dispersed. The greater ratio of water to oil, the more viscous the emulsion. The use of inverts was designed to develop drift-free spraying, but the equipment and the method proved to be too**

**complicated and the practice has now been discontinued. However, it is worthwhile mentioning some experiments which were carried out to control G. pallidipes and G. brevipalpis in the Lambwe Valley, Kenya because it may well have a bearing on future spray programmes using residual insecticide formulations. Trials with a Bell 47G helicopter proved to be very effective in producing appreciable reductions in fly numbers, but the technique was too expensive and investigations were not pursued further (72). Trials were continued with fixed-wing aircraft and efforts to cut the cost by reducing both insecticide and spraying time were successful. Studies were made to evaluate the effect of spraying at intervals of 54 m, and it was shown that at least 60% of the area would have to be sprayed to achieve any satisfactory degree of fly control (4).**

## Boom and Nozzle Equipment

**Residual spraying has been carried out in West Africa where helicopters have been in use to apply persistent deposits from the air in the Sudan savanna zone in Niger in 1969. An area mainly infested with G. tachinoides in dense riverine forest was sprayed twice with mixtures of**

**DDT, dieldrin and BHC in an emulsion concentrate using a Bell helicopter 47G-4A fitted with boom and nozzle equipment. In 1971, a trial covering 240 $km^2$ in the NGSZ in Nigeria was carried out with the same helicopter fitted with two spray tanks, each of 100 l capacity fixed to the right and left sides of the engine. A rotary pump which was belt driven from the engine was employed with 32 D3/25 nozzles at intervals of 50 cm. Applications were made at speeds of 32–40 km/h spraying to within 1–2 m of the canopy, and this gave an effective swath of about 20 m. In larger broken areas of Isoberlinia woodland, swaths were sprayed at intervals of 200 m. Only about 10% of the area was treated according to the discriminative ground spraying technique developed earlier for ground spraying (74). Dosage rates were reduced and techniques improved, and this was achieved by using fewer nozzles on the boom, thereby reducing the liquid throughput. In 1972, 12 of these nozzles were used to apply a ULV formulation of endosulfan in a vegetable oil. This ULV technique enabled helicopter applications to be made more efficiently in terms of insecticide used and in the overall cost of the operation.**

## Rotary Atomizers (electrically powered)

**During the period 1972–73, spraying techniques in Northern Nigeria were further refined by employing modified Ulva atomizers and eight units were fitted to a Bell 47G helicopter. Three were fitted on each side of the boom and two behind the engine. Each atomizer was driven by a 24-volt motor and rotated at a speed of 9000 rpm. Liquid was carried from the boom through a restrictor to the atomizers and a constant flow was achieved. The system allowed for multiple and single operation of the atomizers during the flight, and the spray techniques employed were similar to those used in earlier trials. The helicopter flew at 25–32 km/h over dense riverine vegetation and 40–47 km/h over open Isoberlinia woodland where spray swaths were made at intervals of 200 m.**

**In 1973, an investigation was carried out to study the penetration of spray droplets when applied from electrically operated rotary atomizers fitted to a helicopter to a forest habitat in Ivory Coast (60). A Bell 47G-4A HP was used for the trials and carried two tanks, each 100 l, fixed to right and left sides of the engine. The rotary pump, driven by a belt from the**

**engine, supplied the spray system with liquid. The system consisted of eight electrically driven prototype Ulva atomizers which could be individually activated. These were attached at intervals of 0.5 m along a centre boom and two outer booms having a combined span of 10.5 m. The 24V/60W atomizer motors gave a nominal rotation speed of 9000 rpm unloaded. Spray droplet sizes depended on throughput and this could be altered by changing the size and number of the liquid feed nozzles.**

**Experiments have also been carried out to study the effectiveness of several ULV insecticides applied by helicopters to control G. palpalis gambiensis and G. tachinoides in the area of the WHO Onchocerciasis Control Programme in the Volta River Basin (24). The helicopter used was a Bell 47G-4A, 305 HP with a speed range of 32–80 km/h, and two rotary atomizers secured 6–8 m apart were used to apply ULV insecticide formulations. Two types were used: one type produced droplets between 20 and 30µ in diameter which were applied at a rate of 0.6 l/min; the other type, which had large apertures, produced droplets of 80–100µ diameter at 1.2 l/min. The helicopter flew at a constant height of about 2 m above the canopy, but it was necessary for it to make side turns to follow the**

**bends in the water course. The powerful air current propelled downwards and backwards by the rotor carried the insecticide, which assisted the penetration of spray into the vegetation at ground level. In order to avoid losses due to convection near the surface of the ground, ULV applications were conducted for about two hours after sunrise.**

## TYPES OF AIRCRAFT SUITABLE FOR ANTITSETSE OPERATIONS

**Small single-engine, fixed-wing aircraft are of limited use in tsetse control operations except possibly in the carrying out of experiments where relatively small areas need to be treated. In most instances, aircraft below 2500 kg maximum take-off weight would not have the range or weight carrying capability required for such programmes. It is probable that no single type of aircraft would be suitable for large scale tsetse control programmes and especially if a range of different tsetse habitats require treating. Large flat areas can be satisfactorily sprayed with medium and possibly large multiengine aircraft, while small mountainous areas, often found in Eastern Africa, are probably more suitably treated by light twin- or medium single-engine aircraft. Mountainous areas, areas difficult of**

**access and especially winding riverine habitats are treated more effectively by a light helicopter.**

**In general, the smaller types of fixed-wing aircraft used in tsetse control operations should have good pay load and range characteristics, be easy to control at low flying speeds and have good short take-off and landing (STOL) characteristics. In addition, they should allow the pilot good forward and downward visibility and be corrosion proof against the effects of insecticide chemicals. Tsetse control operations are often carried out in remote wooded areas where the opportunities for making a safe emergency landing (e.g. in the event of engine failure) are limited. For this reason, multiengine aircraft should be used whenever possible. Twin-engine aircraft should have a satisfactory single-engine performance at maximum take-off weight up to 2500 m density altitude.**

**With helicopters, important considerations are the forward and downward visibility for the pilot and the manoeuverability of the aircraft. The helicopter may be required to land in unprepared areas and a shielded tail rotor and high lift skids are valuable features. Any type of helicopter can**

**be used in tsetse control operations, although machines with a maximum takeoff weight in excess of 1500 kg will probably be prohibitively expensive to operate.**

**Despite rising prices which have recently affected all aspects of pest control throughout the world, airspraying costs for tsetse control have actually decreased since techniques were first developed. This is attributed to a number of things but, primarily, spraying equipment design, better insecticides and improved application techniques have all played a major role in reducing costs. Improvements in dispersal equipment have resulted in more efficient spray atomization which, as a consequence, has helped develop application techniques. Aircraft utilization has increased as a result of extending swath widths and high spraying speeds. Costs have also been reduced because of better pesticides which have been discovered and formulated as concentrates in aromatic oils containing higher percentages of active ingredients than was possible when field trials were initiated.**

**At periods of peak demand, the work output of aircraft can be extended**

**by the employment of additional pilots over a seven day working week or by fitting high powered lights in the nose and on the wings of the aircraft which makes it possible to fly at night. Typical work output data have been derived for various types of aircraft which are, or may be, used in tsetse control programmes (83).**

## NAVIGATION AIDS

**No ground markers are needed for helicopters in West Africa when treating tsetse in areas such as clearly visible drainage lines and vegetation interzones. However, traditional methods of swath marking for aerial spraying in tsetse control operations over large woodland areas have been in use for some time, e.g. smoke fires, flags, balloons, marker bands, signal flares or lights. The development of tsetse control techniques using fast aircraft, flying longer spray runs, wider swaths and night flying has made the development of more sophisticated navigational aids desirable. Several types of airborne guidance systems are under investigation:**

**One system is based on an airborne phase measuring device which measures the phase difference between the radio emissions from two or more ground stations (106). The equipment is essentially a refinement of the Decca Navigation aircraft guidance system and has the disadvantage that ground transmitting stations are required sited at accurately mapped locations. Although easily portable ground stations are now available, these may be difficult to site correctly in remote areas.**

**Another system consists of a sensor unit which measures the inertia changes induced by altitude and acceleration changes in the aircraft during flight. The inertial navigation systems (INS) are entirely self-contained within the aircraft and no ground stations are required (7). The main disadvantage of INS in vector control operations using light aircraft is the cost and weight of the equipment and the fact that the system is difficult to adjust to flying reciprocal tracks.**

**Medium and larger types of aircraft can be fitted with highly accurate electronic navigation equipment (e.g. Doppler, VLF), but ground markers are required to line up on approach and exit from large blocks, especially**

**when spray runs are many kilometres in length. In addition, these aircraft may be equipped with instruments to allow flying at night within close proximity to the woodland canopy. As weather conditions at night are often suitable for insecticide applications from aircraft, nocturnal tsetse control operations have been studied (61, 71).**

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# PART II FUTURE REQUIREMENTS FOR INSECTICIDES AND APPLICATION EQUIPMENT

## INSECTICIDES

**Candidate compounds for tsetse control from commercial companies, research institutes and other sources should continue to be assessed for**

**insecticidal activity in laboratory tests as a basis for selection for field evaluation. This selection should take into consideration not only toxicity to tsetse flies, but also existence of a suitable formulation, availability and cost, toxicology and possible effects on non-target organisms. Some of these factors are listed (Appendix I) for new compounds already regarded as possible replacement chemicals on the basis of toxicity to flies. The availabilities mentioned are of the order of 1g to 100g for laboratory testing, 1 kg to 100 kg for field trials, and in normal commercial quantities for those which are readily available and apply to the situation as far as it is known at the present time.**

**Highest priority should be given to field evaluation of the synthetic pyrethroids, NRDC 143 and NRDC 161, which are outstanding in their toxicity to tsetse flies and their persistence in spray residues and could be used in both aerial and ground sprays. NRDC 161 is the most potent insecticide known against many insects but also has a high mammalian toxicity with a site of action which differs from other pyrethroids. It is important therefore that further information should be obtained as soon as possible on hazards to other animals, although it should also be noted**

**that the very powerful insecticidal action means that it can be used at lower concentrations and dosages than the other candidates.**

**The organophosphorus compounds and carbamates listed have good to moderate toxicities to the flies as measured by topical application and can be divided into those which are likely to have a short term persistence only (for example, fenthion, naled, bromophos, propoxur) and those which could have a longer residual action (for example, azamethiphos, tetrachlorvinphos, jodfenphos, bendiocarb). Bromophos from the former group and tetrachlorvinphos from the latter have already been examined in field trials and found to be not very promising.**

**The susceptibility of different species and strains of tsetse to endosulfan and dieldrin and to representatives of other chemical classes that are likely to be used in field operations should be measured in different parts of Africa. This will provide guidance for variations in dosages required and also baseline data for a systematic monitoring programme for resistance. A simple standard method should be adopted; the most suitable is probably the WHO method for topical application (111), but**

field performance should also be studied by methods utilizing tarsal contact with weathered deposits on sprayed surfaces (e.g. bark) if persistence is to be investigated.

## RESIDUAL APPLICATIONS TO VEGETATION AT HIGH VOLUME RATES

Solutions are not usually employed because the solvent is expensive compared with water, but they were used in early trials in East Africa with DDT (95) or more recently in Nigeria with dieldrin (73). The cheaper solvents, such as kerosene, which can be used at high volumes, evaporate rapidly from deposits and do not influence persistence or activity of the insecticide by their presence. They can modify the initial distribution of insecticide by moving it into bark or leaves before they evaporate.

Emulsions or suspensions are much commoner systems for insecticide dispersal, and the two insecticides, DDT and dieldrin, are invariably used in these forms in the larger control schemes, for example in Nigeria, Uganda, Tanzania, Kenya and Zambia. Suspensions are prepared from

**water dispersible powders which contain insecticide and inert diluent particles and surfactants and give dry deposits since the water evaporates very rapidly. Biological potency depends upon the particle size distribution of the active ingredient, its physical state and the surface which has been treated (44). Finer particles are picked up more readily by resting insects, while the adhesive properties of surfactant residues reduce pick up on the less porous surfaces. Those powders which meet WHO specifications have about the optimum particle size distribution.**

**Since the insecticide is in solution in emulsion concentrates, or in the emulsions prepared from these, the physical forms of the deposit after solvent and water have evaporated will be controlled by the crystallization properties of the insecticide and, again, the sprayed surface since this crystallization occurs more readily on some surfaces than others (5).**

**The persistence of the deposits resulting from the use of powders or emulsions will be controlled by the physical properties of the active material (e.g. dieldrin is more volatile than DDT), by climatic variables**

and by the surface sprayed. Thus, water-dispersible powder deposits have been found more effective in hot drier areas than those from emulsions, but the reverse is true in cooler areas with higher rainfall (63, 76). The powder residues are more easily washed away by rain than those from emulsions. Another important factor is the intrinsic toxicity of a compound to the flies. For example, dieldrin is more potent than DDT and deposits can be reduced by a larger amount but still be more effective.

All the candidates for replacement insecticides in tsetse control are available, or could be made available, as water-dispersible powders and emulsion concentrates. A few, such as pirimetaphos, azamethiphos, tetrachlorvinphos and bendiocarb, have a low solubility in the common solvents used to prepare emulsion concentrates, but this could be improved with known co-solvents. Conversely, their low solubilities mean that they usually make good water-dispersible powders.

## AERIAL APPLICATION AT ULTRA-LOW VOLUME RATES

This usually requires that the formulation should be a solution of high

**concentration, say 10% upwards, since it is important that a lethal dose is present in one or very few droplets. Although this criterion applies to most insecticides it is possible that with exceptionally toxic compounds, such as NRDC 161, the concentration can be reduced to something of the order of 1%. For these solutions the vital component is the solvent or, more often, solvents. Their properties control the initial atomization, the reduction in droplet size during passage to the target and the efficiency with which the insecticide passes into the insect, either from droplets on the cuticle or from droplets on surfaces on which the insect rests. They can also influence the persistence of insecticides in spray deposits when they are of low volatility themselves.**

**A discussion of all these interactions between insecticide, solvent, insect and surface would be too long for this report. Briefly, however, the best solvent system probably consists of a non-volatile component such as a vegetable oil, plasticizing ester or Dutrex-type petroleum extract combined with a volatile solvent which may be lost during application but ensures that the physical properties of the blend are appropriate for the atomization process. The non-volatile solvent is a less efficient carrier for**

**insecticide**

# PART III RESEARCH TO IMPROVE THE TECHNOLOGY OF TSETSE CONTROL

**to the design and execution of substantial antitsetse activities.**

## SPECIFIC CONSIDERATION

**The natural limits of the tsetse population to be attacked should be determined before control operations are initiated. Surveys should be undertaken with care to determine population limits and maximum dispersal capabilities at the most favourable seasons of the year. Low**

**density populations require the development of new sampling techniques (page 52).**

**Restricted application of residual insecticide requires prior knowledge of those plant communities with which a large proportion of the tsetse population is associated, especially at unfavourable seasons of the year ("discriminative" phase). Resting sites utilized by the flies throughout the day and night in these plant communities should be determined ("selective" phase). Resting sites can be confined to a small proportion of the overall habitat, and very restricted use of insecticide is possible under such circumstances, especially when applied by ground spray teams applying the principles of "discrimination" and "selection". Findings from one area are not necessarily applicable elsewhere within the range of a species and such studies are necessary wherever control operations are to be undertaken.**

**Less detailed knowledge of the ecology of the species to be attacked is necessary when blanket applications of non-residual insecticide are to be employed. In order to determine the optimum number and interval**

**between application it is, however, necessary to know the duration of the pupal period throughout the time when spraying is to be conducted; particular attention should be paid to the coolest breeding sites where the period will be most prolonged. It is the maximum period and not the mean which is most significant. For the same reason, it is also necessary to determine the length of time between the emergence of a female fly and the production of its first lava throughout the spray period, particularly at the shortest period.**

**At the conclusion of control operations, detailed surveys are again required to determine whether or not eradication has been achieved. The detection of tsetse flies at very low population densities is difficult and inefficient and the development of appropriate methods is perhaps the most pressing need in studies of Glossina ecology. Now efficient devices for sampling tsetse populations have been developed (104); the possibility of adapting these to detect low density populations requires urgent investigation.**

## ENVIRONMENTAL EFFECTS

**If land is to be opened up for the purpose of providing food resources, then it must be recognized that the agricultural activities themselves which will ensue will bring about a far greater environmental change than initial applications of insecticides for tsetse control. Furthermore, the agricultural changes will require greater amounts of more persistent insecticides for crop protection than will be used in public health. Accordingly, planners of such large programmes should approach the problem of environmental modification from a realistic viewpoint. Governments which seek the long-term objective of increased agricultural yield cannot at the same time criticize too severely the short-term use of insecticides for vector control.**

**The alternatives to the use of insecticides for tsetse control are the direct killing of game and habitat clearance. The environmental effects of these operations are probably greater than the use of the insecticides. Although genetic control of <u>Glossina</u> is a distinct feasibility, a great deal of work will have to be done to determine its operational value. Despite recent publications on the possibilities of biological control of <u>Glossina</u>, it is considered to have a remote feasibility.**

**For tsetse control certain areas of wooded savannah, riverine forests and forests proper, including the ecotones between such systems, will be treated. The first step would be to map or classify the major ecosystems that will be covered by treatment and, based upon existing literature, to provide a preliminary listing and structure of the major animal groups in each. From this, a series of indicator organisms can be derived and their availability and relative abundance in each of those main ecosystems approximated and checked by spot surveys. Once spraying operations have been decided upon and the toxicity of the insecticide (s) selected determined for major groups, i.e. mammalian, avian, fish, etc., a sampling procedure for the indicator species population levels can be established. There are numerous adequate procedures for determining vertebrate population levels depending on availability of manpower and the precision desired. Other major groups to be sampled would be non-target forest insects, as well as soil organisms, especially Annalida and arthropods.**

**Physical measurements to determine the distribution and quantity of insecticides applied by aerial spraying in sample habitats should also be made. Initially, this should be done in a wooded area at a canopy level, at**

**intermediate tree level, on ground vegetation and, ultimately, in the soil. Again, details can be determined for each of the habitat types.**

## FUTURE RESEARCH REQUIREMENTS

**Recent progress in the use of fixed-and rotary-wing aircraft and ground equipment for insecticide applications needs to be exploited in a wider variety of situations and new insecticide formulations require field evaluation. Thus, field studies to evaluate new techniques and chemicals should be extended to situations where treatments have been difficult or impossible in the past, as in certain riverine, moist savanna and forest zones. In some situations where control has been successful alternative methods are desirable as, for example, when economic or environmental aspects must be taken into account.**

## LABORATORY EVALUATION OF NEW INSECTICIDES AND FORMULATIONS

**CORP is engaged in a continuing programme for the laboratory testing**

**and evaluation of candidate insecticides for toxicity to tsetse flies in collaboration with WHO. Comparative toxicities of compounds supplied by industry, research institutes, universities and other sources are determined by a standard method of topical application of solutions to teneral G. austeni obtained from pupae*. The results are published from time to time (43) and indicate the most promising insecticides for space sprays. Other properties, such as volatility, solubility and stability are also measured to indicate suitability of compounds for residual activity.**

**A research programme on formulations of insecticides for residual activity on vegetation is also currently in progress. A spray tower has been constructed for the simulation of ULV conditions; that is, the application of concentrated solutions of 10% or more active ingredient at low volume rates and controlled droplet size. Observations are made on the physical state of deposits on leaves and of the persistence of the active ingredient on leaves. The persistence and availability of the active ingredient is measured by bioassay and chemically by GLC analysis.**

*** Supplied by Ministry of Overseas Development and University of**

**Bristol, Tsetse Research Laboratory, Dept. of Veterinary Medicine, Langford House, Langford, Bristol, ES18 7DV, U.K.**

## FIELD STUDIES OF NEW INSECTICIDES AND TECHNIQUES

### Ground Applications of Residual Insecticides

**Persistent chlorinated hydrocarbon insecticides, e.g. DDT, dieldrin and BHC are in current use for tsetse fly control. Insecticides are applied selectively to the known resting sites of flies, e.g. the trunks of trees and the undersides of certain branches or to leaves in the canopy and are effective when applied to riverine and savanna vegetation using ground spraying machines. Insecticides which are environmentally more acceptable and less toxic to cattle and humans would be evaluated for use by this method. Trials with these insecticides should include dieldrin as a reference treatment. Details of proposed trials are shown in Appendix II.**

### Ground Applications of Non-Residual Insecticides

**Hand carried equipment for applying aerosols for tsetse fly control has been used in various parts of Africa, but the method has never been developed to any extent. Equipment applying DDT as fogs has been tried but there is a need to evaluate alternative less persistent insecticides applied as ULV or as dilute formulations suitable for fogging. These methods are unlikely to lead to permanent eradication, but there are requirements to reduce fly numbers rapidly in emergency sleeping sickness situations, in areas of human habitation or of tourist interest. It would be necessary to study sequential applications of insecticide if long-term control was required. Applications of insecticide from boats would have to be considered for access to difficult riverine areas. Details are given in Appendix III.**

## ROTARY WING AIRCRAFT APPLICATIONS OF RESIDUAL INSECTICIDES

**Persistent chlorinated hydrocarbon insecticides, e.g. DDT, dieldrin and endosulfan have recently been shown to control tsetse flies effectively in West Africa by discriminative treatments of aerial sprays applied by**

**helicopter to forest islands, drainage lines, ecotones and stretches of river where the vegetation is suitable. Since aerial applications are necessarily more diffuse than hand spraying, it is vital to evaluate alternative insecticides which are environmentally safer and less toxic to man and cattle. It is also important to examine closely the economics of this method and the possibility of using different formulations for greater efficiency. Details are given in Appendix IV.**

## ROTARY WING AIRCRAFT APPLICATIONS OF NON-RESIDUAL INSECTICIDES

**The control of tsetse flies along large stretches of rivers where ground access is difficult has always presented problems. Fixed-wing aircraft do not have the manoeuverability to follow the course of the riverine vegetation and residual spraying from the air causes greater environmental side effects. There is, therefore, a need to devise a non-residual spraying technique using environmentally safer insecticides for the rapid reduction of fly, especially in areas where sleeping sickness is epidemic. Details are given in Appendix V.**

# MEDIUM FIXED WING AIRCRAFT APPLICATIONS OF NON-RESIDUAL INSECTICIDES

**The technique of applying aerosols from fixed-wing aircraft for tsetse fly control has been well tried and has been shown to be effective with a variety of insecticides in field experiments and in large airspray operations but requires additional development work. Endosulfan is currently used at rates of 6–14 g/ha per treatment. There may be situations where this insecticide is a hazard, e.g. around rivers or lakes, and it would be worthwhile assessing alternative insecticides. Details are given in Appendix VI.**

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