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Short communication

Analysis and implications of aircraft disinsectants

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Abstract

Aircraft disinsection is required by various countries. In-flight spraying with a 2% phenothrin aerosol exposes passengers and crew directly. Residual spaying uses a permethrin emulsions in the absence of passengers and crew and results in dermal and oral exposures. Exposed passengers and crew often complain of, skin rashes, respiratory problems, tingling and numbness in fingertips and lips and burning eyes. A number of formulations were analyzed for their constituents using GLC-Mass. spec. Volatile organic compounds (VOCs) were found in all aerosol preparations including, ethyl benzene and xylene isomers along with phenothrin. Residual sprays contained, *cis*-, and *trans*-, permethrins, palmidrol, and occasionally naphthalene. Headspace analysis found methylene chloride and hexene derivatives but not the active ingredients. The known synergistic effects between organophosphates and pyrethrins, based on carboxyesterases inhibition, can be expected in the presence of Tricresylphosphates (TCPs), constituents found in jet engine oils and in some hydraulic fluids. During oil seal failure, the presence of TCP in the ventilation air could explain the increased sensitivity of some crew members and passengers to disinsectants.

Keywords: Aircraft disinsection; Aircraft air quality; Permethrin; Phenothrin; Tricresyl phosphates; Carboxyesterase inhibitors; Synergistic effects; Disinsectant composition

1. Introduction

Insect control in aircraft is referred to as disinsection (Naumann and McLachlan, 1999). Two publications (WHO, 1985, 1995) form the basis of current disinsection practices. The reasons given are: (1) threats to public health; (2) threats to agriculture; and (3) threats to the native ecosystem.

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The countries requiring disinsection on inbound flights using aerosolized sprays with passengers on board include Grenada, India, Kiribati, Madagascar, Trinidad, Tobago and Uruguay. Other countries requiring a residual treatment, or the application of an aerosolized spray while passengers are not on board, are Australia, New Zealand, Barbados, Fiji, Jamaica, and Panama (US Department of Transportation, 2001). Although the latter category requires spraying in the absence of passengers, this is often not the case. (Personnel communication with flight attendants.)

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In-flight spraying is applied by flight attendants using aerosolized canisters of a phenothrin formulation at 'blocks away' or 'top of descend'. The former refers to the time at which an aircraft is loaded, closed and ready to depart from the gate. The latter refers to that segment of a flight when the aircraft is ready to descend to its destination.

The required notification by the pilot (AQIS, 2001), refers to the application of ''….a non-toxic spray…'' at the top of descend stage of the flight, is generally not welcomed by the passengers because the option of informed consent has not been provided. Top of descend spraying requires 2% D-phenothrin as the active ingredient in the aerosolized formulation. Residual disinsection involves treatment of the aircraft surfaces with a water based solution of 2% permethrin in the absence of passengers (WHO, 1995) and is done by licensed operators. This certifies the aircraft for a period of 8 weeks but does require touch up spray of high use surfaces during this period (WHO, 1995).

Both permethrin and phenothrin are pyrethroids, originally extracted from the chrysanthemum plant (Ray and Forshaw, 2000; Huggins, 2000), but which are now produced synthetically.

Residual treatment of aircraft often exposes the public and crew unnecessarily because many aircraft are not dedicated to specific international routes.

Incident reports from the Los Angeles Airport, which were directly attributed to disinsection, indicate 78 reports between 1994–2000. The symptoms reported (AFA, 2000), included rash on face and neck, respiratory problems, burning eyes, tingling and numbness in lips and fingertips and two cases of chest pain, one of which requiring oxygen.

Because of incidents reported by flight crew members (AFA, 2000), and passengers (Woodyard, 2001) a number of disinsectant formulations were investigated for their composition products and their known toxic effects.

2. Methods

Unused aerosol canisters were obtained from flight attendants. Two canisters were identified as Callington Aircraft Cabin Spray Insecticide (2% phenothrin as the active ingredient), and Callington 1-Shot Aircraft Insecticide, Aerosol Insecticide for cargo holds (2% phenothrin and 2% permethrin as active ingredients) both manufactured by Callington Haven Pty Ltd, 2 Euston Street, Rydalmere, NSW. A third canister was identified as AIROSOL Aircraft Insecticide and was manufactured by Airosol Company, Inc. 525 North 11th St. Neodesha, KS 66757, Australia. This aerosol contained 2% phenothrin as the active ingredient and is meant to be sprayed on passengers and crew at least 30 min prior to landing.

Samples of water based residual disinsectant formulations included Pestgard and Pestgard 'low odor' (Manufactured by Gibson Chemical Industries, 350 Reserve Road, Cheltenham, VIC 3192, Australia) as well as Airez, and Airez 'low odor' (supplier not identified).

All samples were extracted using a non-polar solvent, toluene, as well as a polar solvent, ethanol/isopropanol mix (95/5). Head-space samples were collected for analysis by using a syringe and injecting 1 μl directly into the GC-mass spec. Another method exposed a Solid Phase Micro Extraction (SPME) fiber (Supelco) for 10 s to the air above the respective spray can samples. This fiber was directly introduced into the injector of the GC-mass spectrometer.

All samples were analyzed using GC/mass spec. The GLC was equipped with a Supelco PTE-5 column 30 m in length and 0.25 mm ID. The injector temperature started at 60 °C, was held for 1 min, followed by 180 °C/min increments up to 280 °C where it was maintained to the end of the run, 50-min. The column temperature started at 70 °C was held for 2 min followed by 15 °C/min increments up to 280 °C where it was maintained at that temperature to the end of the run.

The organic constituents were identified by mass spec using the National Institute of Standards and Technologies (NIST) library.

3. Results

The chromatographic traces of Callington 1-shot and Callington Aircraft Cabin Spray Insecticide are shown in Fig. 1.

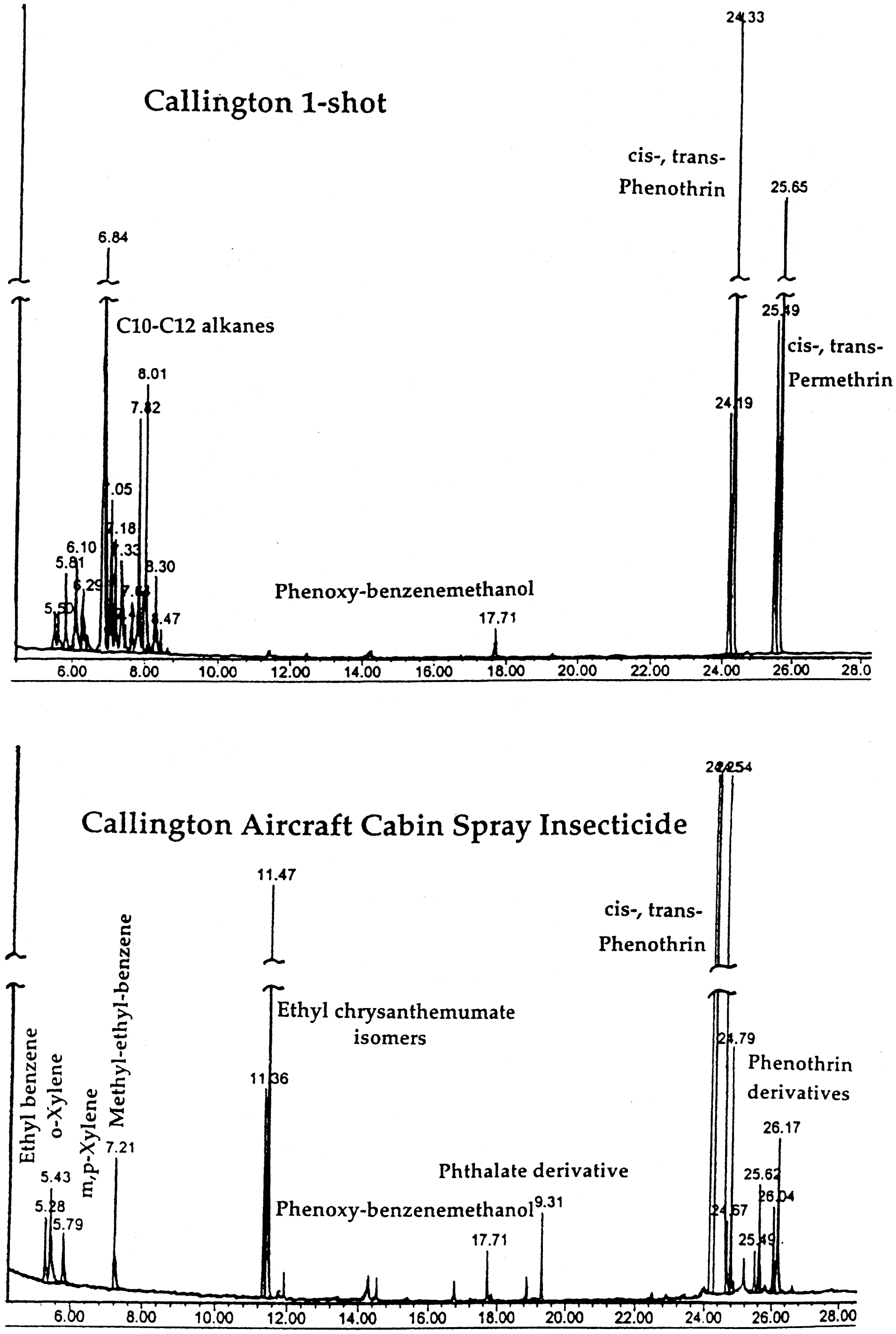

Fig. 1. Typical chromatographic traces of aircraft disinsectant formulations based on two aerosols showing the identification of their main constituents.

Compared to the alcohol extracts, toluene extracted more constituents and was more useful in identifying the composition of the various formulations. In general Callington 1-shot showed the presence of volatile organic compounds (VOCs) including hexene, cyclopentane, cyclohexane and octane derivatives along with the active ingredients. The VOCs made up roughly 4% of the total formulation. Similar chromatographic patterns were seen with toluene extracts from the Pestguard and Airez emulsions with the difference that they all contained palmidrol and Pestgard contained naphthalene in the original formulation but not in the 'low odor' variety. The chromatogram of the toluene extract from Callington Aircraft Cabin Spray Insecticide (Fig. 1) showed the presence of ethyl benzene and the three-xylene isomers. These VOCs made up 0.012% of the formulation. In addition, two ethyl chrysanthemumate isomers, 3-phenoxy benzaldehyde, an unidentified phthalate, the active ingredients *cis*- and *trans*-phenothrin, and three phenothrin related compounds were identified.

Airosol Aircraft Insecticide showed a similar composition to Callington Aircraft Cabin Spray Insecticide but with the non-active ingredients at much lower concentrations (0.007%).

Analysis of a 1-μl sample from the headspace of the various formulations did not appear to capture the same number of volatile agents as the SPME fiber which identified methylene chloride in Airez and hexene derivatives in Pestgard, Airez and Callington 1-shot. The head space chromatograms of the various formulations were generally identical to those obtained using the toluene extract except that the less volatile active ingredients, were absent.

4. Discussion

Historically, the 1985 WHO report on procedures for aircraft disinsection (WHO, 1985) recommended the use of DDT and the propellants, freon 11 and freon 12. Currently the only insecticides that are recommended by the WHO for disinsection are remethrin, bioremethrin, D-phenothrin, and permethrin (*cis*/*trans* ratio 25/75) (WHO, 1995).

The formulations which are used may include synthetic pyrethroids as well as certain organophosphates (Forum, 1999). Occasionally solvents are used in sprays to enhance the solubility of the active ingredients. This has been confirmed by our results.

The bulk of the formulations within the aerosol canisters are the propellants, which could not be trapped using the analytical procedures used. Based on the label descriptions these were identified as, 'hydrofluorocarbon and hydrochlorocarbon (HFA)'.

Although the active ingredients, phenothrin and permethrin, are not found in the air above the liquids as a result of their low volatility, these agents are inhaled when they are aerosolized resulting in respiratory exposure. Once the aerosol has settled onto surfaces, the active ingredients are not likely to be found in the air at normal room temperature and at sea level. Dermal and oral exposure from contact with these surfaces can still occur and needs to be evaluated.

The preparations which are used when passengers and crew are present, Callington aircraft spray insecticide and Airosol, appeared to have lower levels of volatile organic compounds (VOCs). Although individually the presence of each compound in the air is likely to be relatively low, collectively these VOCs could pose a hazard when sprayed into a confined and unventilated space as required by Australian Quarantine Inspection Service (Naumann and McLachlan, 1999). The water based emulsions, Pestgard and Airez, also contained VOCs, which for Pestguard was in the range of 10–30% according to their Material Safety Data Sheet (MSDS).

Pyrethroid toxicity is generally related to two modes of exposure, systemic (i.e. via the oral and respiratory route) and dermal. Systemic effects are traced to direct excitation of the central nervous system resulting in tremor, hyper-excitability, chorea or seizures. As most symptoms are reversible within hours, there are generally no chronic effects in man or animals after single or repeated exposures (Ray and Forshaw, 2000; Leng et al., 2000; He et al., 1989).

After dermal exposure to pyrethroids approximately 1% enters the bloodstream, this compares to 36% for the oral route. Skin appears to bind pyrethroids and acts as a reservoir, resulting in local effects and symptoms which can last for several weeks in acute cases of pyrethroid poisoning (He et al., 1989). In general, dermal exposure leads to paresthesia, which develops within 0.5–5 h and can persist for 0.5–3 days. Areas on the body where the skin is thin are affected first, such as the mouth. The different susceptibilities between individuals is directly related to the wide variation of the presence of carboxyesterases in the skin (Leng et al., 2000). The average threshold dose for producing paresthesia is 0.2 mg/cm^2 in man (WHO, 1995).

Pyrethroids are destroyed by carboxyesterases which are highest in concentration in the liver followed by skin, muscle, kidney, brain and serum (Leng et al., 2000). Since organophosphate pesticides are also destroyed by carboxyesterases they compete for these enzymes with pyrethroids enhancing each others toxicity (Ray and Forshaw, 2000). A well known carboxyesterase inhibitor is triorthocresyl phosphate (TOCP) (Casida et al., 1983) along with tricresyl phosphates and (TCP) and triphennyl phosphates (TPP). These organophosphates are common ingredients found in jet engine oils and certain hydraulic fluids used in aircraft (van Netten and Leung, 2000, 2001; van Netten, 2000). Under special circumstances, such as an engine oil seal failure or hydraulic fluid leaking into the air intake of the Auxilliary power unit (APU) (Allied Signal, 1996; van Netten, 1998; The Seattle Times, 1998; Australian Parliamentary Inquiry, 2000), organophosphates can enter aircraft ventilation air. The potential exposure of flight crew and passengers to these synergists should be carefully evaluated and could form a possible basis for the increased susceptibility of some individuals to relatively low levels of pesticides. The enzyme, cholinesterase, is also inhibited by organophosphates, but is not important in pyrethroid metabolism (Leng et al., 2000).

It is known that aerosolized pesticides can trigger a 'non-specific' asthmatic response, i.e. broncho-constriction and respiratory symptoms (WHO, 1995). The synthetic pyrethroid sprays are not considered to be allergenic (WHO, 1995) and, until recently, there was no evidence that a non-asthmatic can become sensitized after exposure to aerosolized synthetic pyrethroid insecticides. One case describing such a response to tetramethrin has now been documented (Vandenplas et al., 2000).

It is interesting to note that some countries that justify their insistence on disinsection of incoming aircraft based on International Health Regulations are often reservoirs of vector borne disease such as India and Africa (Isaacson and Frean, 2001). These countries choose to ignore another International Health Regulation which requires countries to take measures to prevent the export of vectors of human diseases (Naumann and McLachlan, 1999).

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