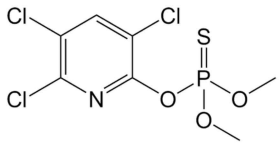

Figure 2. Chemical formula of chlorpyrifos methyl

ciatus in the chlorpyrifos methyl-IRS huts was 66.1% whereas in the DDT and lambdacyhalothrin-IRS huts it was only 14%". Therefore "chlorpyrifos methyl-IRS showed greater potential than DDT of lambdacyhalothrin-IRS for control of pyrethroid resistant *An. gambiae* M form and *Cx. quinquefasciatus* in areas of high *kdr* frequency" [11].

In terms of mortality the short residual activity of chlorpyrifos methyl on ITN is of great concern with a mortality rate decreasing from 100% to 9.7% within just one month while as IRS on cement it was observed "no loss of activity during the nine months of follow-up" compared to the fast decay of DDT and lambdacyhalothrin observed within the first month of spraying. A 9-month efficacy could be very valuable in many West and East African endemic countries with malaria transmission seasons lasting less than 8 months, and where IRS application of chlorpyrifos methyl each year could be adequate. In areas with developing pyrethroid resistance one might envisaged continued use of pyrethroid LLIN in combination with IRS, rotating the use of chlorfenapyr and CS long lasting chlorpyrifos methyl formulation.

2.2. New insecticides paints combining several insecticides and an insect growing regulator for IRS

Insecticide paints are new interesting paradigm for vector control with several advantages regarding classical IRS. It may provide future possibilities to combine several active ingredients in one product and therefore be used to help manage insecticide resistance. Paints can be produced in different colors to fit with people's choice. They may also be potentially implementable by households without the need for a specialized team to deliver the intervention, as is the case with IRS. This could improve community and household acceptance and uptake. Paints may also have the potential of being longer lasting than IRS. Insect growth regulator (IGR), a product usually used as larvicides, is also now being evaluated in Inesfly® 5A IGR™, a paint designed to target adult mosquitoes. Inesfly® 5A IGR™ is composed of two organophosphates (OPs), chlorpyriphos (1.5%), and diazinon (1.5%) and pyriproxyfen (0.063%) an IGR which was successfully used against *Triatoma infestans* [12]. The product is white vinyl paint with an aqueous base. Active ingredients reside within Ca CO3 + resin microcapsules. The formulation allows a gradual release of active ingredients, increasing its persistence.

In Benin the Inesfly® insecticide paint has been tested in laboratory [13] and in field [14] studies. In the laboratory study, the paint was tested against laboratory strains of the urban pest *Cx. quinquefasciatus* the susceptible (S-Lab) strain and the SR homozygote for the ace-1R resistant gene involved in the resistance to OPs and carbamates, with classical bioassay cones (tests on 30 min). Efficacy was measured not only in terms of induced mortality but also in terms of fecundity (number of eggs laid), fertility (% hatching) and larval development (%

pupation and % emergence). Insecticidal paints were tested at different time points: T0, 6 (= 6 months), 9 (= 9 months) and 12 months after application on four different surfaces: softwood, hard plastic (non-porous materials), ready-mixed cement and ready-mixed stucco (porous materials) at two doses, 1kg/6 m^2 (manufacturer's recommended dose to obtain surfaces completely white) and 1 kg/12 m^2. Female mosquitoes were given a blood meal 36 hours after standardized exposure to the painted surfaces. The study showed that the highest rates of mortality were obtained by both doses on susceptible as well as resistant strains even 12 months after treatment, on non-porous surfaces (softwood, plastic), whereas, on porous surfaces (cement, stucco) efficacy was much lower on resistant than on susceptible strain and it dropped to almost 0 at 6 and 12 months in both strains.

Thus long-term efficacy was an issue of porosity of materials rather than the pH of materials or the dose applied. It should be noted that 100% mortality was achieved on non-porous surface even against the OP resistant strain.

In terms of fecundity, fertility, and larval development, "a significant reduction in the number of eggs laid was shown at 0 and 9 months after treatment at either dose. A reduction in egg hatching was observed at T0, but not at T9. An increased mortality from the nymph to the adult stage was shown 9 months after treatment at the higher dose. No differences were found on the duration of the larval development. No IGR effect was observed 12 months after treatment". The percentage of emergence (i.e. adult emerging from pupa) dropped from 80% in control to #53% in samples from exposed females. Hence an adulticide could have impact not only on longevity of females exposed but also on their offspring which is a great advantage for mosquito population control.

Field trials were conducted in area where the local population of *An. gambiae* is composed of the M molecular form with resistance to pyrethroids and DDT, *kdr* is present at a high frequency, but is susceptible to OPs and carbamates, the ace-1R mutation was absent. *Cx. quinquefasciatus* shows high resistance to DDT, pyrethroids and carbosulfan with high *kdr* frequency and elevated levels of esterases and GST activity but the ace-1R mutation was absent [9]. In these trials, experimental huts were treated with either 1 or 2 layers of insecticide paint at one dose (6 kg/m^2). Treatments were applied to either just walls, or to walls plus the ceiling. Unfed females of the lab-reared *An. gambiae* Kisumu strain (sensitive to all insecticides), were tested against local resistant wild strain *An. gambiae* and *Cx. quinquefasciatus*. The *An. gambiae* Kisumu strain mosquitoes were placed inside the huts at a distance of 1 m from two perpendicular walls, and left from 19:00 to 7:00 h [14]. The wild strains were tested using the standard WHO bioassay method.

Mortality of wild resistant *An. gambiae* was high with 83% even 9 months after treatment (2 paint layers on walls). Mortality of wild resistant *Cx. quinquefasciatus* was >50% even 9 months after treatment (2 paint layers on walls). No deterrent or excito-repellent effect was observed against *An. gambiae* nor *Cx. quinquefasciatus*. Mortality rates of exposed *An. gambiae* Kisumu strain in distance experiments in huts (1 m from two perpendicular walls; see above) with 2 layers were most striking, because even one year after treatment 100% of these sensitive mosquitoes were killed (Figure 3C).

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Classical cone bioassay showed that in huts with 2 layers "twelve months after treatment mortality rates were of 70-80% against *An. gambiae* and *Cx. quinquefasciatus*". Release of insecticide susceptible unfed *An. gambiae* specimens in huts treated but without net (untreated) showed that 2-13% of females took their blood meal while 72% were well blood fed in control huts. Mortality rates observed in distance experiments were most striking, (Figures 3A & 3B) and even one year after treatment 100% of exposed *An. gambiae* Kisumu strain specimens were killed in huts with 2 layers (Figure 3C).

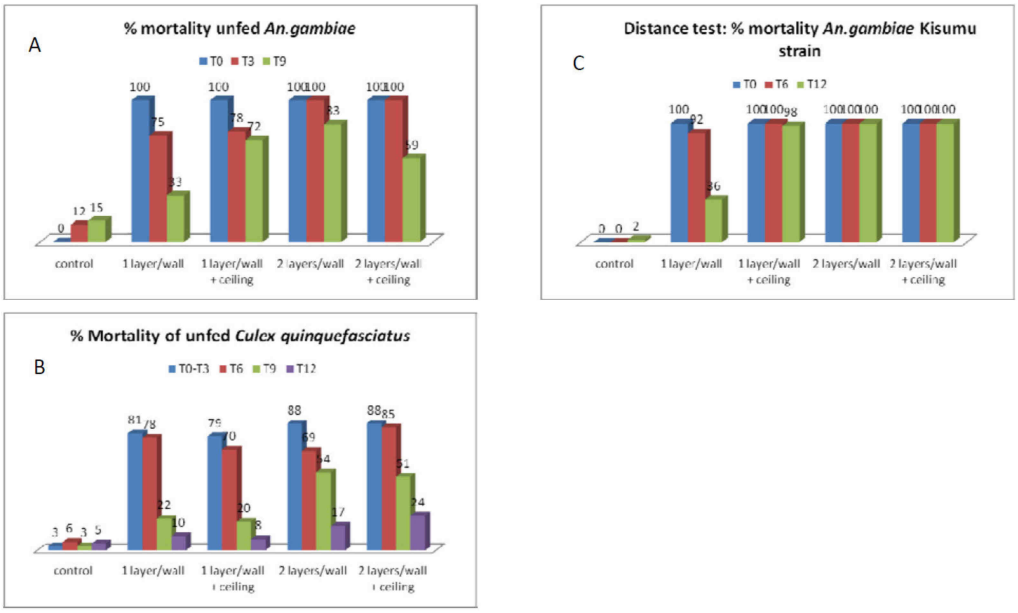

Figure 3. Mortality rates observed in distance experiments of exposed unfed *Anopheles gambiae* (A), unfed *Culex quinquefasciatus* (B), and *Anopheles gambiae* Kisumu strain (C) observed after 3 or 6 or 9 or 12 months after treatment (T3, T6, T9, T12 respectively).

These observations of "volume effect", "layer effect", "substrate effect", residual efficacy duration, and its efficacy against susceptible and resistant strains of the malaria vector *An. gambiae* and the nuisance insect *Culex quinquefasciatus*, are very encouraging. The paints ability to reduce mosquito fecundity and egg hatching opens up interesting new perspectives on malaria and mosquito control for urban settings where walls are commonly constructed with brick, concrete and plaster and provide suitable surfaces for paints, unlike classical mud made wall houses that characterize most rural communities. The paints ability to also reduce *Culex* mosquitoes is likely to increase community acceptance and maintenance of paint.

2.3. New mode of action families for IRS usage: Neonicotinoids

Neonicotinoid insecticides act on the central nervous system of insects by binding of agonist on postsynaptic nicotinic receptors [15]. Discovered in 1998, dinotefuran is a novel neonicoti-