

Effective residual life of bendiocarb insecticide on sprayed surfaces

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ABSTRACT

Effective residual life of insecticides on sprayed surfaces determines the number of spraying cycles required to cover malaria transmission season. However, residual efficacy of insecticides varies with spray surface type. This study assessed effective residual life of bendiocarb on cow dung plastered and mud plastered wall surface types of human dwellings against *An. arabiensis*. Wall cone bioassays were carried out following the WHO (World Health Organization) standard operating procedures. Percentage mortality was calculated according to WHO bioassay protocol and Poisson regression model was fitted to show the association of mosquito mortality with explanatory variables using SAS (SAS Institute Inc. 2016. SAS® 9.4 Language Reference: Concepts, Sixth Edition. Cary, NC: SAS Institute Inc.). Efficacy of bendiocarb against *An. arabiensis* was 100% for the first 35 days on both cow dung and mud wall surface types. However, its efficacy deteriorated earlier on non-plastered wall surfaces after 35 days. The relationship between mosquito mortality and explanatory variables was: Mortality = 3.637542 , Sprayed = $+ 0.282841$, Plastering = $- 0.0094612$ 35-Days after spray, $- 0.600159$ 65-Days after spray. Because coefficients for cone position were not significant, they were excluded from the regression equation. Generally, the effective residual life of bendiocarb on mud plastered wall surface was too short to cover malaria transmission season. Therefore, alternative insecticide with longer residual effective life is required in areas having more than two months of malaria transmission season.

Keywords: Bendiocarb; Ethiopia; Residual efficacy; Wall bioassay; Wall surface.

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INTRODUCTION

The history of indoor residual spraying (IRS) begun in 1960s and remains a powerful malaria vector control tool in Ethiopia where *Anopheles arabiensis* is the primary vector. DDT was the insecticide used for IRS in many malarious areas of

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the country until 2007 when it was replaced by deltamethrin due to the development and spread of DDT resistant vector. The country's IRS control program again replaced deltamethrin by bendiocarb 80% WP (wetttable powder) (carbamate group) in 2010 because deltamethrin resistant vectors emerged in different parts of the country (FDREMOH, 2012). The purpose of IRS with the recommended concentration of the insecticide of choice before the onset of malaria transmission is to shorten the life span of indoor resting vectors (Akogbéto *et al.*, 2011; FDREMOH, 2012). One round of IRS application has been implemented in most malarious areas of the country usually at the end of the main rainy season, while two rounds of IRS have been implemented in some areas especially at times of epidemics (FDREMOH, 2012) by considering the effective life of the insecticide used for IRS. Physical and chemical properties of sprayable surfaces of dwellings may impact the active residual life of the insecticide sprayed on it (Hadaway and Barlow, 1963; de Arias *et al.*, 2003; Arias *et al.*, 2004). Climate is also among other factors that influence the bio-efficacy of the insecticide sprayed indoors for vector control (Bordas *et al.*, 1953; Bami, 1961; Smith and Hocking, 1962). The residual efficacy of bendiocarb with the recommended concentration (80% WP) could last between 2 and 6 months depending on the nature of sprayable surfaces. Studies indicate that the effective life of bendiocarb 80% was not consistent across published reports (Mpofu *et al.*, 1991; Maharaj *et al.*, 2004; Etang *et al.*, 2011; Djènontin *et al.*, 2013). Studies on the impact of different wall substrates on the residual efficacy of insecticides used for IRS in Ethiopia are limited (Yemane Yeebiyo *et al.*, 2016). Besides, susceptibility of the same or different vector populations to insecticides could vary from region to region and/or from locality to locality (Sibanda *et al.*, 2011; Tangena *et al.*, 2013; Alemayehu Abate, 2018). Therefore, any malaria vector control program involving IRS operations should primarily confirm the susceptibility of the vector to the insecticide chosen for IRS and establish the effective residual life of the insecticide on common sprayed surface types of the structures under local ecological setups to determine spraying cycles. Thus, the effective residual life of bendiocarb 80% WP sprayed on common surface types of human dwellings against *An. arabiensis* was assessed in Andassa, Bahir Dar Zuria District, North west Ethiopia and reported.

MATERIALS AND METHODS

Study area description

The study was carried out in Andassa and its surrounding villages (11°30'14.6" N Latitude, and 037°29'27.8" E Longitude). Andassa is found at about 20 km southeast of Bahir Dar town, the capital of Amhara Regional State. Most of the residential houses in Andassa and its surrounding areas are constructed of wood

framework encrusted with mud and roofed by corrugated iron sheets. The walls are either cow dung surfaces plastered over a layer of mud or without cow dung plastering. Details of the study area are published elsewhere (Alemayehu Abate, 2018).

Indoor residual application

Bendiocarb was sprayed at a rate of 400 mg/m² in October 5-11/2013 and 2014, and in both study groups in September 4-10/2015 based on the guidelines given on the pre-dosed sachets by the manufacturer. The spray men were recruited from the local community and were given hands on training on using WHO IRS modus operandi (WHO, 2013). The spray men were provided with protective gear (hand gloves, goggles and masks) and they sprayed the inside parts of the walls and roofs using manual pressure sprayer of the HUNDSON XPERT type. Over 90% of the structures (both human and animal shelters) were sprayed. The researcher with the support of field technical assistants supervised the quality of spraying.

Mosquito rearing

Pupae and larvae of *An. arabiensis* were collected from their breeding sites using larval sampling procedures and reared into adult in a field insectarium (WHO, 1975). Susceptibility of wild *An. arabiensis* to bendiocarb (0.1%) was confirmed following WHO susceptibility test procedures before using them for the cone test (WHO, 2013).

Wall cone bioassays

Wall bioassays (WHO, 2006) were carried out in four houses having mud-walls plastered with cow dung and dried before sprayed and in other four houses of same type without being plastered with cow dung. Cow dung plastering is a common practice by dwellers in these and other parts of the country to make the inside of mud wall surfaces smooth and fill out cracks. Sprayed houses were not re-plastered until the end of the study period. Non-sprayed wall surfaces of the same type with the sprayed ones (one house with mud walls plastered with cow dung and the other without plastering) were used for the control group. The bioassays were carried out after 5, 35 and 65 days of the spray. Ten sugar-fed two- to three-day old mosquitoes were introduced into cones firmly fixed near the bottom, in the middle and on top parts of wall surfaces. Mosquitoes were exposed for 30 minutes and transferred into labeled paper cups covered with untreated white netting. Knock down rate (kdr) was recorded 60 minutes after being transferred into paper cups, while mortality was recorded after holding them for 24 hours at a temperature of 26 ± 2 °C and 70-80% relative humidity (RH). They were provided with 15% sugar solution during the holding period.

Data analyses

Abbott's formula (1925) was used to correct control mortality when percent of control mortality was between 5% and 20%.

The effective residual life of bendiocarb 80% WP on mud walls plastered with cow dung and non-plastered mud walls was estimated based on its killing effect on susceptible female *An. arabiensis* exposed to these surface types. Efficacy was considered effective when percent mortalities in exposed mosquitoes were $\geq 80\%$. Mortality of *An. arabiensis* was calculated according to the WHO protocol (WHO, 2006). Poisson regression model was fitted to identify the variable that contributed to see the association of days after spray, wall plastering, insecticide spray and position of wall surfaces with mosquito mortality. The Poisson regression coefficients along with their 95% confidence interval and *p*-values were used to determine the strength, direction and significance of association.

Ethical clearance

Human or animal subjects were not involved in this study and therefore there was no need of any ethical approval and the work continued with verbal consent from heads of the households where wall bioassay tests were carried out.

RESULTS

Bendocarb effectively killed *An. arabiensis* mosquitoes (100%) for about one month on both types of wall surfaces (Figure 1). Its efficacy decreased on both surface types with time but the residual life of the insecticide deteriorated faster on non-plastered wall surfaces.

Wall plastering with cow dung, spray and time period had highly significant effect ($p \leq 0.001$, 95% CI) on mosquito mortality, while the impact of position was not significant ($p = 0.20$, 95% CI) (Table 1). Wall spraying [Coef = 3.637542; 95% CI (2.654363, 4.620721)] and wall plastering [Coef = 0.282841; 95% CI (0.1232043, 0.4424778)] had positive relationship with mosquito mortality, while the association between mosquito mortality and time lags was negative [Coef = -0.600159; 95% CI = -0.8157261, -0.3845919], i.e., as the time lags increased after spray, mosquito mortality decreased. However, there was no significant difference in mosquito mortality between day 5 and day 35 ($p = 0.917$, 95% CI = -0.3845919, 0.16757) after spray. The effect of wall spray was the strongest of all factors considered in this model followed by time lags and plastering.

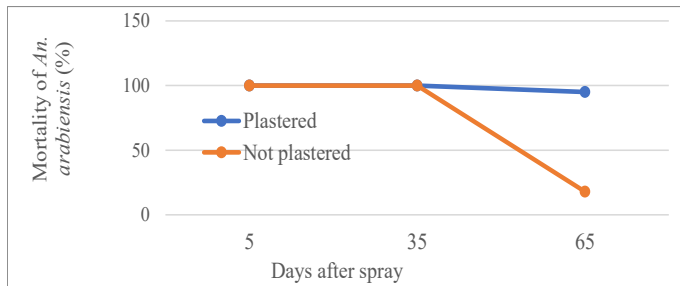


Figure 1. Estimated effective residual life of bendiocarb 80% WP sprayed (Blue) cow dung plastered surface and (Red) non-plastered mud wall surface based on percent mortality of bendiocarb susceptible female *An. arabiensis* against time.

Table 1. Effect of wall plastering on residual activities of bendiocarb 80% WP.

	Coef.	Std. Err	Z	P> z	[95% Conf. interval]	
Plastering	0.2828	0.0814	3.47	0.001	0.1232	0.4425
Spray	3.6375	0.5016	7.25	0.000	2.6544	4.6207
Days after spray						
35	-0.0095	0.0903	-0.01	0.917	-0.0186	0.1676
65	-0.6002	0.1100	-5.46	0.000	-0.8157	-0.3846
Position						
Middle	0.0195	0.0980	0.20	0.842	-0.1726	0.2117
High	-0.0197	0.0990	-0.20	0.843	-0.2137	0.1744

DISCUSSION

The residual efficacy of an insecticide chosen for IRS intervention for the control of malaria vectors is evaluated based on the criteria set by World Health Organization Pesticide Evaluation Scheme (WHOPES) (WHO, 2006). Based on this recommendation, efficacy of an insecticide sprayed indoors wall surfaces is considered effective if mosquito mortality is $\geq 80\%$ at 24 hours post exposure to sprayed surfaces for 30 minutes. In reference to WHOPES recommendation, the residual effective life of bendiocarb 80% WP was longer on cow dung plastered walls than on mud walls without plastering. Similar residual performance of this insecticide was reported from experimental hut trials in Ethiopia (Yemane Yeebiyo

et al., 2016). However, the results from experimental hut trials indicated that the residual effective life of bendiocarb on mud walls without plastering was >2 months, while the present study reported <2 months. The potential reason for the differences observed between the present and experimental trial might be attributed to differences in their experimental set ups, i.e., the present study used residential houses where real life activities of dwellers might influence persistence of the insecticide while these activities are absent in experimental houses. Furthermore, experimental hut trials were conducted in semi-arid area where humidity was reported to be low, while the present study was carried out in an area where humidity was expected to be high due to the available water sources and high temperature. Humidity is considered as an important factor to impact on the residual efficacy of an insecticide on sprayed surfaces (Maharaj *et al.*, 2004). This efficacy study also demonstrated that the residual effective life of bendiocarb was >2 months on plastered mud walls. This is in line with the results of other studies reported from different countries including Ethiopia (Etang *et al.*, 2011; Sibanda *et al.*, 2011; Djènontin *et al.*, 2013; Tangena *et al.*, 2013; Yemane Yeebiyo *et al.*, 2016). Although the residual life of the insecticide was not identical across these studies, the residual efficacy of bendiocarb was between 2 and 6 months, which is in line with WHOPES (WHO Pesticide Evaluation Scheme) recommendations. The differences observed in these reports might be due to different attributes associated with the natural conditions of each specific study sites.

Because the purpose of this study was to estimate the effective residual life of bendiocarb 80% WP on different surface types under natural conditions, it was conducted on two wall surface types only for the reason that the residential houses of the study site were having either of these surfaces types during the study period. Therefore, this study did not involve other wall surface types such as walls made of cemented blocks and painted walls that are common in semi-urban and urban areas in the country. The complete period of the residual efficacy of the insecticide was not established on plastered walls because it was not possible to monitor the residual efficacy of the insecticide beyond 65 days. Therefore, similar studies are recommended to better understand the impact of different wall surface types and other factors on the residual efficacy of this and alternative insecticides and establish the complete period of effective residual life of the insecticide(s) under natural conditions.

CONCLUSION

This study demonstrated mixed results. The effective residual efficacy of bendiocarb 80% WP on mud wall surfaces is too short to cover malaria transmission season in areas having >1 month transmission. Therefore, alternative insecticides should be considered for IRS in areas having >1 month malaria

transmission season and >20% houses with mud wall surfaces. On the other hand, the residual effective life of the insecticide was >2 months on cow dung plastered walls suggesting that bendiocarb would be the recommended insecticide for IRS in areas having cow dung plastered walls to cover at least 2-3 months of malaria transmission season. We hereby recommend that cow dung is available in rural communities in Ethiopia, so that community education to plaster their houses with cow dung would improve the effective residual life of bendiocarb.

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Conflict of interest

Authors do not have any conflict of interest.

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