Background

Over the last two decades, Aedes aegypti mosquito control in many countries has relied on household visits by centrally-run vector programmes to eliminate immature vector forms by placing the organophosphate larvicide temephos in clean household water containers. In some places, ultra-low volume pesticide spraying complements temephos placement to control the adult mosquito. In a strategy laid out 20 years ago and followed since then to intensify the “war against Aedes aegypti” [1], temephos placement in household water stores was “the fundamental operation of the attack phase” of the programme. The World Health Organization promotes integrated vector management [2] and there are reports of successful experiences of community involvement [3–6], yet community participation in dengue control is mostly still secondary to chemical-based control strategies run by centralized vector control programmes.

The Nicaraguan government has made substantial efforts to control the Aedes aegypti vector of dengue virus and to mitigate the impact of dengue epidemics. As in nearly all other countries in tropical and subtropical regions of the world, however, the Aedes aegypti mosquito that carries dengue and other arboviruses of medical relevance, continues to gain ground. After two decades of temephos use in the country, a recent paediatric cohort study in Nicaragua found an incidence rate of 16.1 cases and 90.2 dengue virus infections per 1000 person-years in children aged 2–14 years of age [7]. Complicating the public health picture are multiple viral strains, the increasing severity of clinical cases, and the increasing costs incurred by governments and communities due to dengue infection.

The well-documented temephos resistance [8–15] combined with recent explosive epidemics of zika and chikungunya across Latin America suggest the vector is out of control, fuelling concern about reliance on temephos in dengue prevention. This has spurred a search for sustainable alternatives to pesticide-based vector control, through biological approaches [16, 17], community self-management [3, 4] or evidence-based communication strategies [5].

A (2004–2008) pilot study in Managua, Nicaragua, in coordination with the Centro Nacional de Diagnóstico y Referencia (CNDR) of the Nicaraguan Ministry of Health, CIET International, the University of California at Berkeley, and the Sustainable Sciences Institute, established the feasibility and acceptability of a pesticide free approach [18, 19]. The intervention engaged communi-

Inspections and analysis of specimens

Twelve-person field teams conducted the household interviews and entomological inspections. Entomological inspections used the standard protocols of the national programme for inspecting, collecting, transporting, identifying, counting and classifying immature Aedes aegypti specimens. Inspectors checked every water container using the appropriate instruments (net, pipette, bowl, magnifying glass, flashlight) to find larvae or pupae. They classified containers as: barrels or large tanks, buckets, washtubs, flowerpot plates, flowerpots, tyres, containers for non-storage use (bowls, water fountains, etc.), and items that had no clear household use (calaches). The government entomologists verified and classified the collected specimens of larvae and pupae. A container was considered positive when it contained one or more immature forms of Aedes aegypti in any stage, confirmed by the government entomologists. A household was considered positive when it had one or more positive containers.

Exposure to temephos

At six measurement points, the temephos exposure indicator came from the observation of temephos in inspected water containers. This served for the principal analysis. In a supplementary analysis at four measurement points (2006, 2007, 2012 and 2013), exposure to temephos came from two variables: i) temephos identified at the time of the entomological inspection in at least one container in the household (yes/no), and ii) the report in the household questionnaire of the last temephos application within 30 days of the interview (data binomialised at 30 days). We excluded from the analysis households unable to respond about the timing of the temephos application visits – 10 in 2006 (<1%), 15 in 2007 (<1%), 361 in 2012 (9%) and 403 in 2013 (10%).

Entomological indicators

We derived three entomological indicators of the presence of immature forms of the Aedes aegypti mosquito: The number of larvae- or pupae-positive households per 100 inspected households (Household Index), the households where pupae were found (Households Positive for Pupaes.an exposure indicator of temephos found upon inspection and reported to have been applied within the last 30 days. This was possible in four of the six surveys. Additional file 1: Table S1 shows the association between the presence of at least one larvae or pupae positive container in the household and temephos exposure; none of the four GLMM models showed a significant negative association between temephos exposure and household positivity for larvae or pupae. Additional file 1: Table S2 and S3 show associations between temephos exposure and pupae-positive households and pupae per person; again, none of the GLMM models at the four time points showed a significant negative association between temephos presence and the entomological outcome.

In households reporting temephos application in the last 30 days, entomological inspectors observed the

application [2] is a challenge for any health authority: a study in two cities in Nicaragua showed that in order to control pupae effectively temephos needs to be applied at least every 30 days [23]. Across the surveys reported here, on average about two of every three households reported that they had received a temephos application visit in the previous 30 days.

Use of domestic water containers

In the four surveys in which we asked about the timing of the temephos visits, entomological inspections found the larvicide in only 24–37% of households that reported temephos had been distributed to them during the previous month. Official norms require larvicide to be placed in all containers used for storing water [24]. Both washtubs and tanks are targeted for temephos but people are more likely to empty washtubs needed for washing or laundry. This is borne out by the finding of temephos in fewer washtubs (15%) than tanks (42%). The alternative uses of temephos-treated washtubs, beyond storing water, reduce pesticide persistence and therefore the value of the temephos strategy [25]. Frequent topping up of storage tanks also reduces temephos effectiveness [26].

“false sense of security”

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