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COST-EFFECTIVENESS ANALYSIS IN CHAGAS' DISEASE VECTOR'S CONTROL INTERVENTIONS

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After a large scale field trial performed in central Brazil envisaging the control of Chagas' disease vectors in an endemic area colonized by Triatoma infestans *and* T. sordida *the cost-effectiveness analysis for each insecticide/formulation was performed. It considered the operational costs and the prices of insecticides and formulations, related to the activity and persistence of each one. The end point was considered to be less than 90% of domicilliary units (houses + annexes) free of infestation. The results showed good cost-effectiveness for a slow-release emulsifiable suspension (SRES) based on PVA and containing malathion as active ingredient, as well as for the pyrethroids tested in this assay-cyfluthrin, cypermethrin, deltamethrin and permethrin.*

Key words: cost-effectiveness – vectors control – Chagas' disease – insecticides – slow-release formulations

In simple terms to make a cost-effectiveness analysis is to find the best way of achieving an objective by the comparison of effects with costs (Mills & Bradley, 1986). For Chagas' disease the objective can be stated in terms of reduction of number of cases (positive serology) among young children until a certain age born after the intervention (e.g. insecticide application). The end-point of the control programme can also be stated in entomological terms, e. g. the reduction of infestation by triatomines to a certain percentage of houses infested considering also, if possible, the reduction in the vector population in the houses still infested. Generally the epidemiological, rather than entomological, end-point is recommended, because the ultimate goal is the reduction of prevalence, incidence or severity of the disease transmitted by the vectors to the human population (Dias, 1987). However for Chagas' disease this is a hard difficult evaluation taking a long time to be representative of the situation of a given area (Schofield, 1985).

Cost-effectiveness have to be distinguished from cost benefit analysis. The latter is much more complex and broader, consisting in a process where one try to find out wether the benefits of a programme exceed its costs, placing values on health effects like improvements in productivity. The cost-effectiveness analysis is performed usually to answer two kinds of questions: a) which among various interventions will achieve a desired health objective for the lower cost? b) given a limited budget which intervention will result in the maximum achievement towards the health objective? (Klarman, 1982; Mills & Bradley, 1986).

To be complete a cost-effectiveness analysis in a Chagas' disease control programme should consider the cost of the various kinds of interventions possible, like application of insecticides, house construction or improvement, health education and blood transfusion care. Much better would be to consider the possibility of joining all these interventions in a unique programme, selecting inside the possible kinds of interventions which procedures would maximise the achievement of the health objective (Ault, 1986; Bos & Milles, 1986; Mitchell, 1986).

In the particular situation of Chagas' disease one could ask which insecticide, formulation and dose to be used, which materials and methods to use for house improvement or construction, how to motivate community participation, which kind of orientation about hygiene and maintenance of domestic animals

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should be given, etc. However it is very complicate to analyse and compare results when somebody deals with many kinds of interventions at a time, due to the difficulties of atributing a value to each kind of intervention in the whole situation.

Insecticide application proceed to be the favoured method of control of Chagas' disease transmission. This happens for many reasons, mainly due to the quick response obtained as a consequence of the great impact on the vector's population, to the relatively simple operation when compared with house construction or improvement and health education and, of course, due to an existing governmental structure already trained and directed to do that (Oliveira Filho, 1984; Piesman et al., 1985).

The present paper describes one of the first concrete attempts, to determine the cost-effectiveness of insecticide application against Chagas' disease vectors as a means of control of Chagas' disease transmission. It was based on a large scale field trial performed under strict supervision from the early beginning until the very end, 19 months after treatment of the houses and annexes (Oliveira Filho, 1988a) The economic and operational data was criteriously colected as well as the scientific results, although making great effort to simulate a real campaign done by governmental people involved in public health. In this field assay it was also compared the activity and persistence of conventional marketed formulations and a slow-release insecticide suspension developped in our laboratories (Oliveira Filho, 1988b).

MATERIALS AND METHODS

The trial from where the data for cost-effectiveness analisys were collected, was performed in the municipality of Posse, State of Goiás, Brazil in an area localized between 46°00' to 46°50'W and 14°00 to 14°30'S. The spraying was done in May/June 1985 by SUCAM (Brazilian Ministry of Health) spraymen. For the statistical evaluation only infested houses were considered, although all the houses in each locality were treated with the same insecticide and formulation. Inside the municipality the operations were restricted to 60 localities (villages, farms, etc.) that were chosen on the grounds of having at least 20% of infested houses in relation to the existing ones.

The test involved 4860 houses (1837 positives) and 2370 annexes (230 positives) giving a total of 1912 domicile units (houses + annexes) positive per *T. infestans* (2336 insects) and *T. sordida* (535). From the total of 2871 triatomines captured, 2680 were examined for *T. cruzi* like trypanosomes and the mean infection was 7.3%.

The distribution of houses among the treatment groups considered mainly the wall type because different substracts act differently over the insecticides influencing in its persistence. In this way the proportion among houses with mud, plastered and wood walls along the groups was similar.

The houses were treated only once, without reapplication in cracks and crevices, considering the rate of application as 70 ml/m2, as determined by preliminary observations on the operational behaviour of the spraymen involved in this assay. The average real dose sprayed was determined by the amount of suspension or emulsion used in relation to the treated area, determined by direct measurement of a sample of 5-6 houses in each treatment group.

The insecticides, formulations and real doses (in g.a.i./m2 ± standard deviation) used in the trial, were as follows: HCH 30% WP = 0.8 ± 0.3; malathion 100% EC = 3.2 ± 1.2 and 2.2 ± 0.5; malathion 13.3% SRES (slow-release emulsifiable suspension) = 2.7 ± 1.1; malathion 9.4% SRES = 2.4 ± 1.0; chlorphoxim 50% WP = 1.2 ± 0.13; cypermethrin 25% EC = 0.126 ± 0.04; permethrin 50% EC =0.42 ± 0.13; deltamethrin 2.5% EC = 0.062 ± 0.24 and 0.33 ± 0.008; cyfluthrin 10% WP = 0.14 ± 0.07 and 0.05 ± 0.02. The SRES was developed in our laboratories and is a slow-release formulation designed to preserve the insecticide activity for much longer than conventional formulations like wettable powders (WP), emulsifiable concentrates (EC) or flowables (FW). The SRES is based on the organic polimer polyvinyl acetate (Oliveira Filho, 1984).

The readings consisted in the capture of insects inside houses and in the annexes, and they were done mostly by SUCAM well trained personell, after the spraying of a flushing-out agent (Pirisa L1E1) – with a small hand pump. The pre-treatment readings were always 100% infested houses because only those actually infested by nymphs were selected for this test.

The captures were limited to 10 triatomines indoors plus 10 outdoors.

To verify if the percentage of control obtained was really due to the persistence of the insectivide over the house walls, two series of biological assays were performed, at 6 and 13 months post-treatment. In the 6 months assay 10 5th instar laboratory reared *T. infestans* were put in contact during 72 hours, with treated adobe or mud walls, beneath transparent plexiglass cones (WHO cones for mosquito biossays), with a hole in the top. After this period the insecticides were taken out of the walls and transferred to test tubes containing clean filter papers and maintained for observation, without feeding, during 21 days. Two houses were tested for each treatment group. In the 13 months post-treatment assay only the groups that showed a reasonable activity in the 6 months assay were evaluated.

The basic data necessary for the determination of operational costs were collected during this field test that followed the normal procedures and staff organization used by SUCAM in the Chagas' disease vectors control compaigns performed in Brazil. All the insecticides and ingredients of formulations used were bought by the Ministry of Health in order to assure real market prices at the time these compounds were acquired, i.e., between 20/09/84 and 10/04/85. The prices were converted to US dolars by the official rate of the day of acquisition. The salaries, benefits and perdiem were informed by DIDOCH (Divisão de Doença de Chagas – SUCAM – Brasília) and were converted to US dolars in the same way, taking in account the workers income in the beginning of 1988.

RESULTS

The percentages of control, i.e., the percentages of domiciliary units (houses + annexes) without infestation in each reading performed at 3, 6, 9, 12, 15 and 19 months after a single spraying on the 11 groups of treatment considered, are shown in Table I. For the purposes of the work described here, dealing only with insecticide intervention, the end-point was established as the achievement and maintenance of at least 90% of houses bug-free for the maximum time interval up to 19 months post-treatment. The limitation to 19 months is a practical assumption due to the precariousness of construction and materials employed in the majority of huts built in the rural endemic areas and also due to modifications and aggregation of new constructed rooms to the treated houses, resulting almost worthless the remaining insecticide effect after this rather long period.

Three groups of treatment – malathion 100% EC at 2.2g a.i./m2, chlorphoxim 50% WP at 1.2g a.i./m2 and deltamethrin 2.5% EC at 33 mg a.i./m2 were discarded after the 15 months post-treatment reading due to the low level of control achieved at that time. The comparison of the results obtained in the groups treated with malathion shows that the one which received the SRES gave consistently higher control than the corresponding groups treated with comparable doses of the emulsifiable concentrate. The remaining groups, treated with synthetic pyrethroids, showed good level of control at least until the 15 months reading.

The biological assay results on the house walls, performed 6 months post-treatment, using 5th instar nymphs of *T. infestans* showed that only the groups of houses treated with malathion slow-release emulsifiable suspension at 2.7g a.i./m2 were still able to kill 100% of the nymphs. In the sequence came cyfluthrin where 55 and 45% mortality were observed, respectively for the dose of 140 and 50 mg a.i./m2, followed by malathion in the lower dose (Table II). In the 13 months post-treatment assay the group treated with malathion SRES at 2.7g a.i./m2 was tested using both 5th and 1st instar nymphs. For the other groups only 1st instar, more susceptible to insecticides than the 5th, were used. These groups were malathion SRES at 2.4g and cyfluthrin 10% at 140 and 50mg a.i./m2. Again the results showed that the only group with presence of insecticide enough to kill all the nymphs (after 7 days) was the SRES at 2.7g, however active at this time only against 1st instar nymphs. These two biological assays summarized in Table II confirm the long-lasting properties of this formulation.

For the cost-effectiveness analisys of the insecticide treatments, the parameters considered to determine the operational costs were the cost of staff and transport of personell during the field operations.

TABLE I

Percentage domiciliary units (houses + annexes) without infestation after a single treatment with the mentioned insecticides, formulations and doses.

Insecticide and formulation	Dose sprayed (g a.i./m^2)	Houses in the sample	% of domiciliary units without infestation						
			Months pre-treatment	months post-treatment					
			1	3	6	9	12	15	19
BHC 30% WP	0.8 ± 0.3	64	0	62[a]	57	62	56	63	–
malathion SRES 13.3%	2.7 ± 1.1	74	0	96	94	96	97	90	81[a]
malathion 100%EC	2.2 ± 0.5	58	0	73[a]	74	70	73	76	–
malathion 100%EC	3.2 ± 1.2	55	0	94	86[a]	85	76	78	68
chlorphoxim 50%WP	1.2 ± 0.3	68	0	80	90	83[a]	68	79	–
cyfluthrin 10%WP	0.14 ± 0.07	67	0	98	98	98	98	96	95[a]
cyfluthrin 10%WP	0.05 ± 0.02	60	0	100	98	91	98	96	98[a]
cypermethrin 25%WP	0.126 ± 0.04	59	0	88	94	96	94	92	83[a]
deltamethrin 2.5%EC	0.033 ± 0.02	59	0	93	81[a]	84	85	80	–
deltamethrin 2.5%EC	0.062 ± 0.02	67	0	87	90	97	93	95	87[a]
permethrin 50%EC	0.42 ± 0.13	59	0	89	93	96	94	89[a]	94

A pre-treatment reading was done 1 month before spraying and the post-treatment readings were performed at around 3 months intervals until 19 months. The percentages marked with *a* correspond to the months of persistence considered to make the calculations of cost-effectiveness. This field assay started in June, 1985 and was performed in Posse, Goiás, Brazil. EC = emulsifiable concentrate; WP = wettable powder; SRES = slow-release emulsifiable suspension.

A – Basic operational cost

A.1 – Cost of staff

A.1.1 – Field Team
(full time)
3 guards
1 chief guard
1 driver

Income/worker
salary US$ 96.00
benefits US$ 40.30
perdiem US$ 11.85 x 20
total US$ 373.40

Cost/team
US$ 373.40 x 5 = US$ 1,867.00

A.1.2 – Cost of Supervision & technical services team (25% of time)
1 inspector
1 driver
1 technician
(2 for surveillance)

Cost/team
US$ 373.40 x 3 x 25 = 280.00 or
(373.40 with 2 technicians)

A.2 – Transport

A.2.1 – Fuel for 100 Km/day (3 Km/liter at approx. US$ 0,5/liter).
20 days/month (1.25 vehicles)
US$ 416.00/month

TABLE II

Mean percentage of mortality of *Triatoma infestans* nymphs (5^{th} instar for 6 months assay and 1^{st} instar for the 13 months assay) at 0 an 3 days after a period of 72 hours in contact with the treated adobe or mud walls.

Insecticide and formulation	Doses (g a.i./m^2)	% of mortality (Days after 72 hours contact with treated walls) 0 days		3 days	
		6mo.	13mo.	6mo.	13mo.
BHC 30%WP	0.8	7.0	–	14.5	–
Malathion SRES 13.3%	2.7	100.0	90.0	100.0	95.0
malathion 100%EC	2.2	0.0	–	11.5	–
Chlorphoxim 50%WP	1.2	10.0	–	10.0	–
Cyfluthrin 10%WP	0.05	45.5	15.0	56.5	45.5
cyfluthrin 10%WP	0.14	55.0	0.0	55.0	0.0
Cypermethrin 25%WP	0.126	0.0	–	5.0	–
Deltamethrin 2.5%EC	0.033	5.0	–	10.0	–
deltamethrin 2.5%EC	0.062	0.0	–	0.0	–
Permethrin 50%EC	0.42	15.0	–	15.0	–
Control	–	0.0	0.0	0.0	0.0

Ten insects were used per house. Two houses were tested per treatment group.

A.2.2 – Manintenance and devaluation of the vehicles corresponding to 100% of A.2.1 – US$ 416.00/month

Taking that data in account it was possible to calculate the operational costs for each house treated, regarding the various activities performed during the campaigns, accordingly to SUCAM's methodology, i.e., mapping, surveillance, spraying, post-treatment evaluation and selective treatments:

B – Operational cost/house

B.1 – Mapping

8 houses/man/day during 20 days/month = 480 houses/month

field team salaries	1,867.00
supervision & technical	280.00
transport	832.00
	2,979.00

B.2 – Surveillance

6 houses/man/day = 360 houses/month

field team salaries	1,867.00
supervision & technical	373.00
transport	832.00

3,072.00/360 = US$ 8.5/house

B.3 – Spraying

4 house/man/day = 240 houses/month

field team salaries	1,867.00
supervision & technical	280.00
transport	832.00

2,979.00/240 = US$ 12.8/house

TABLE III

Cost of the insecticide used for the treatment of a house with 250 m^2 of mean treated area, acordingly to the mean dose sprayed and the concentration of the insecticide formulation.

Insecticide and formulation	Brand name (manufacturer)	Mean dose sprayed (mg/m^2)	Price/kg or 1 of formulation (US$)		Price/house treated (US$)	
			1985	1988	1985	1988
Cyfluthrin 10%WP	Baythroid-H (Bayer)	50	47.4	105.0	6.00	13.12
		140	47.4	105.0	16.50	36.75
Chlorphoxim 50%WP	Baythion-C (Bayer)	1200	13.4	b	8.00	–
Cypermethrin 25%EC	Cymperator (ICI)	126	35.5	86.0	4.50	6.80
Permethrin 50%EC	Ambush (ICI)	420	44.5	53.0	9.25	11.13
Deltamethrin 2,5%EC	K-Othrine (Quimio)	33	16.0	72.0	5.20	23.76
		62	16.0	72.0	10.00	44.64
Malathion 100%EC	Cythion 100E (Cyanamid)	2200	10.6	15.0	5.75	8.25
		3200	10.6	15.0	8.50	12.00
Malathion SRES (7.9%[a])	– (NPPN)	2700	2.0	2.2	17.10	18.80
BHC 30%WP	BHC (various)	800	4.0	4.0	2.70	2.70

The prices were furnished by SUCAM, that bought the products in the period between 20/09/84 and 10/04/85 and transformed in US$ by the official rate. Due to many recent alterations, the insecticide prices and the price/house treated are also shown for 1988.
[a] The final concentration over dry weight is 13.3%.
[b] Out of market.

B.4 – Post-treatment evaluation + selective treatment (x% of the houses).
Cost of surveillance + x% of the cost of spraying + x% of the cost of insecticide/house

To calculate the mean cost of the insecticide sprayed in each house, for each treatment group, the following formula and parameters were considered:

C – Cost of insecticide/house

cost insecticide/house =

$$= \frac{\text{dose x treated area x price of form.}}{\text{concentration x 10}}$$

dose: g a.i./m^2
treated area: the average was 250 m^2 for the domiciliary units
price: in US$/Kg or liter of formulation
concentration: of the formulation before dilution

Ex: BHC dose: 0.8g
area: 250 m^2
price: US$ 4.00
conc.: 30%

$$\text{cost} = \frac{0.8 \times 250 \times 4.0}{30 \times 10} =$$

= US$ 2.7/house

Finally the formula for the total cost for each house to be maintained free of infestation during a one year period could be developed.

TABLE IV

Cost per house, per year of infestation prevented, after a single treatment with the mentioned insecticides, doses and formulations with the prices obtained in 1985 and 1988.

Insecticide and formulation	Brand name (manufacturer)	Mean dose sprayed (mg/m^2)	Months of protection	Cost/house/year protection (US$)	
				1985	1988
Cyfluthrin 10%WP	Baythroid-H (Bayer)	50 140	19 19	21.2 27.8	25.65 40.58
Chlorphoxim 50%WP	Baythion-C (Bayer)	1200	9	31.7	b
Cypermethrin 25%EC	Cymperator (ICI)	126	19	20.2	21.70
Permethrin 50%EC	Ambush (ICI)	420	15	29.4	30.90
Deltamethrin 2,5%EC	K-Othrine (Quimio)	33 62	6 19	44.4 23.7	66.34 45.56
Malathion 100%EC	Cythion 100E (Cyanamid)	2200 3200	3 6	73.8 47.5	78.30 51.47
Malathion SRES (7.9%[a])	– (NPPN)	2700	19	28.2	29.24
BHC 30%WP	BHC (various)	800	3	73.4	73.40

The calculations were made by the formula:

$$\text{cost/house/year} = \frac{MA + SU + SP + IN + (SU + x\%SP + x\%IN)\ n}{MO} \ X\ 12$$

where MA, SU, SP and IN represent respectivelly the cost/house of mapping, pre-treatment surveillance, spraying operation and cost of insecticide. MO represent the number of months with 90% or more domiciliary units (houses + annexes) without triatomine infestation. x = the percentage of house to be treated in the selective treatment n = the number of selective treatments necessary to maintain > 90% control at least for one year (see text).

[a] The final concentration over dry weight is 13.3%.

[b] Out of market.

D – Total cost/house/year protection

$$\text{cost/house/year} = \frac{MA + SU + SP + IN + (SU + x\%SP + x\%IN)\ n}{MO} \times 12$$

where:

MA = mapping = 6.2 (US$/house)
SU = surveillance = 8.5 (US$/house)
SP = spraying = 12.8 (US$/house)
IN = cost of insecticide/house
x = percentage of houses to be treated in the selective treatments, taken from the data obtained, considering the first result above 90% of domiciliary units uninfested. When the initial results showed a tendency of increase in the percentage of control surpassing in the next readings 90% of control it was chosen the reading in which was registered the first decrease under 90%.
n = number of selective treatments necessary to maintain > of = 90% control at least for one year. For practical reasons, the minimum time lapse between

treatments was considered to be 3 months and the maximum 18 months (19 for the Posse assay).

MO = months with > or = 90% control estimated to be obtained with the operations considered in the formula for this particular product.

Ex: BHC

$$\text{cost/house/year} = \frac{0.2 + 3.5 + 12.8 + 2.7 + (8.5 + 0.38 \times 12.8 + 0.38 \times 2.7) \times 3}{12} \times 12 = \text{US\\$ } 73.4$$

Table III shows the prices of the insecticides converted to US dolars when SUCAM bought all the products for the trial (1985). It shows also the cost of the amount of insecticide used in the treatment of houses with the mean treated area of 250 m^2. These data were used to calculate the cost/house/year of infestation prevented. However, as some of the prices suffered a hudge variation, even dealing in US$, the table also shows the prices seen in the market in April 1988 (offered to SUCAM).

Table IV shows the cost/house/year protection, taking in account the cost of each operation, already estimated in previous items, and the insecticide necessary to maintain the houses bug free for at least a year accordingly to the number of selective treatments and percentage of house to be treated in each one. The number of months of protection (end point = 90%) were taken from Table I.

DISCUSSION

The cost-effectiveness analysis of insecticide treatments in the Posse field assay, considering the prices of 1984/85, showed that cypermethrin (0.126 g a.i./m^2), cyfluthrin (0.05 g a.i./m^2), deltamethrin (0.062 g a.1./m^2) malathion SRES (2.7 g a.i./m^2) and permethrin (0.42 g a.i./m^2) represented the most cost/efficient products with the cost/house/year varying from US$ 20.2 to 29.4 and giving from 15 to 19 months of protection. Considering the 1988 prices, the order of increasing costs would be cypermethrin, cyfluthrin, malathion SRES and permethrin, varying from US$ 21.7 to 30.9/house/year protection. The cost of deltamethrin would be much higher now (US$ 45.56/house). Accordingly to SUCAM pump charges used recently the cost/house/year of the treatment with cyfluthrin (10% WP, 125 g/10 liter) would be US$ 32.1 and with cypermethrin (40% WP, 80 g/10 liter) would be US$ 31.5. Considering these facts the most cost/effective treatment would be with malathion SRES at 2.7 g a.i./m^2. Of course in a massive campaign other factors should also be taken into consideration when choosing the appropriate formulation, like acceptance of the product by the human population, disponibility in the market, ease of operation, difficulties of transport of formulations by the field teams, necessity of special devices for spraying, etc.

Even being partial results, because only a group of insecticides were studied, the data presented here will be a helpfull contribution to those who are in charge of decision making about Chagas' disease vectors campaigns. Furthermore the methology of acquiring and analysing data for determination of cost-effectiveness on insecticide application to control triatomines may represent a unique tool, till the moment, to those interested in making sound decisions about chemical control.

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