UNRELIABLE SUPPLY OF POTABLE WATER AND ELEVATED *AEDES AEGYPTI* LARVAL INDICES: A CAUSAL RELATIONSHIP?

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ABSTRACT. We investigated the hypothesis that a deficient supply of piped water was causing a high prevalence of water storage containers, which in turn, become important aquatic habitats of *Aedes aegypti* in a small town in Venezuela. The House (71.2%) and Breteau indices (229) were considerably elevated. Prevalent positive containers were: metal drums, small disposable containers (bottles, tins, etc.), tires, house plants (flowers in vases and plants in pots with earth) and tanks. Most people reported frequent interruptions in the supply of piped water and considered it to be unreliable. The frequency of interruptions in the supply of water was positively correlated with the House and Container indices, and with the number of positive containers, water-storage devices and positive water-storage devices per house. Even people who considered that they had an adequate supply of water kept numerous water storage containers. Most people (60%) said they would not stop storing water even in the event of the establishment of a reliable supply of piped water.

INTRODUCTION

Classic dengue fever has been an endemic disease in Venezuela, but recently dengue hemorrhagic fever (DHF) appeared in the country in epidemic form in 1989. The disease became endemic with a peak incidence from November to January. If the experience of Southeast Asia (Gubler 1989a) is repeated in Venezuela, major epidemics will occur initially every 4 to 5 years, and subsequently every 2 to 3 years.

Dengue and yellow fever are transmitted in urban Venezuela by the domestic mosquito *Aedes aegypti* (Linn.). Following the well-conducted, yellow fever vaccination program, official interest in controlling *Ae. aegypti* declined. The Venezuelan *Ae. aegypti* Control Program was practically dismantled after 1977, and the House Index (percentage of houses inspected found to be positive for *Ae. aegypti* larvae or pupae) increased from 0.2% (1977) to 32.8% (1989) at the national level (MSAS 1990, Llopis et al. 1979, Sánchez et al. 1979). Larval habitats in public grounds, such as flower pots in cemeteries, are also a major source of *Ae. aegypti* (Barrera et al. 1979, 1981, 1982). Given the high infestation levels with *Ae. aegypti* in Venezuela toward 1989, and the active circulation of dengue serotypes in the Caribbean (Armada-Gessa and Figueredo-González 1987, Gubler 1989b, Guzman et al. 1984, Knudsen 1983, Tonn et al. 1982), the spread of the disease into the country has been just a matter of time. Since virus transmission is likely to persist, and even to extend, vector control seems to be the only effective way to prevent eventual DHF epidemics.

Controlling urban vectors in the 1990s is made more difficult because much of the human population lives in rapidly expanding urban areas. Governments are unable to provide cities with adequate public services due to their rapid growth (Halstead 1988, Tonn 1988). Recent increases in solid waste production, coupled with inadequate refuse collection services, result in the accumulation of many small larval habitats of *Ae. aegypti* [e.g., tin cans, (Gubler 1989b, Winch et al. 1992)]. On the other hand, large larval habitats (e.g., drums, cisterns) seem to be common where water supply is unreliable or where traditional water storage habits persist (Knudsen 1983, Laird 1988, Nathan and Knudsen 1991).

During studies on the baseline ecology of urban *Ae. aegypti* in Venezuela, we observed the high prevalence of 208-liter metal drums as water storage devices in several towns and poor areas of large cities. The use of drums to store water seems to be generalized in several Caribbean countries where they become the most abundant aquatic habitats of *Ae. aegypti* (Chadee 1990, Knudsen 1983, Nathan and Giglioli 1982, Nathan and Knudsen 1991, Tidwell et al. 1990). The prevalence of drums as water storage devices has been linked to deficiencies in the supply of piped water and low income levels (Tidwell et al. 1990). Although we do not know to what extent metal drums are contributing to the high House Index in Venezuela, we decided to investigate the possible causal relationship between water supply and the high House Index observed in a small town with numerous metal drums. The basic hypothesis was that a deficient supply of piped water was causing the high prevalence of water storage containers, which in turn become prevalent aquatic habitats for *Ae. aegypti*.

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MATERIALS AND METHODS

The study was conducted in the coastal town of Puerto Píritu, Anzoátegui State, northeastern Venezuela. The town is surrounded by littoral herbaceous and xerophytic shrub vegetation, mangroves and the sea. There is a mean annual rain of 481 mm (April 1990–March 1991) with a rainy season from June to August. The town is composed of some 2,500–3,000 houses, with a few apartment buildings. The main economic activities of residents are fishing and tourism.

A sample of 365 houses was surveyed for larval habitats in August 1990. In addition, people were asked about their perceptions of the reliability of the supply of potable water. To obtain the sample we used a map from which we selected 53 out of 216 blocks in a semi-random, systematic way so that all localities in town were represented. The entomological survey for *Ae. aegypti* involved searching for every container that had water, then registering those that were positive and negative for larvae or pupae of the vector. Hand mirrors and flashlights were used to search for the immature mosquitoes.

The questionnaire asked the households their perception of the frequency of interruptions in water supply (interruptions of days, hours, seldom), the adequacy of water supply (adequate, somewhat adequate, inadequate), whether the water supply was the most important problem in the community (yes, no), whether they would get rid of their water storage containers (208-liter metal drums) once they had a reliable and continuous supply of piped water (yes, no), and the type of house (modern, traditional, "barrio," rural, "bahareque," "rancho," "quinta" and apartment). Modern houses are made out of concrete but they are not as well constructed as the "quintas," which are usually owned by people with the highest income. Traditional houses are usually the oldest in town and are occupied by people whose families had lived in the area for a long time. "Barrio" houses are not as well constructed as modern houses, more like rural houses, which are constructed with lighter materials as part of a program of the Department of Health. "Bahareque" houses are made out of raw materials such as clay mixed with plant material (canes), and together with the "ranchos" are owned by the poor. The ranchos are made out of wood, metal sheets and other inexpensive materials.

RESULTS

The results are based on 344 houses with complete entomological surveys and questionnaires. Out of the total, 245 houses had at least one positive container (House Index 71.2%). Positive houses had between 1 and 3 positive containers, but a few had between 10 and 18. We found 2,036 containers with water, of which 38.7% or 788 had larvae or pupae of *Ae. aegypti.* Such habitat abundance corresponds to a Breteau Index of 229 (positive containers per 100 houses).

Containers were classified into 5 classes: metal drums, tanks, house plants, discarded tires and small disposable containers (bottles, cans, plastic containers, etc.). The most abundant containers with water were small disposable containers, mostly bottles (Fig. 1; 1,004 containers labeled as other), followed by metal drums (687), tires (167), tanks (96) and house plants (82). Although the small disposable containers were the most abundant of all, only 22.4% were positive for *Ae. aegypti.* Metal drums were the most common aquatic habitats with 59.8% of them positive. Tires and house plants were also common habitats, with an infestation of 55.7 and 58.5%, respectively. Tanks were the least common larval habitats of *Ae. aegypti,* with only 11.5% of the tanks being positive for the vector.

There were 783 containers used for water storage, or 38.5% of all containers holding water. Positive water-storage deposits were 422, or 53.9% of all containers with *Ae. aegypti.* Metal drums were 87.7% of all water-storage containers in the sampled houses. The mean number of metal drums per house was 2.3 ± 1.6 (SD), and the mean number of positive ones per house was 1.2 ± 1.4. A few houses had up to 7 positive metal drums.

Interruptions in the supply of water seemed to be uncommon according to respondants in only 25.7% of the houses (Table 1). Those houses with interruptions of days showed the highest House Index, Container Index and number of positive containers per house (Table 1).

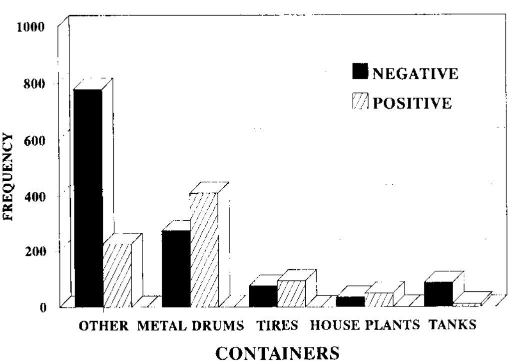

Fig. 1. Frequency distribution of containers observed with (positive) and without (negative) *Aedes aegypti* in the study area.

Table 1. Percentage of houses with a given level of water supply interruption and associated values of vector prevalence. Mean values are given with corresponding standard deviations

	Frequency of interruptions		
	Days	Hours	Seldom
% houses	41.5	32.7	25.7
House Index (%)	76.8	67.9	68.2
Container Index (%)	43.7	34.0	36.6
Positive containers per house	2.5 ± 1.3	2.2 ± 1.2	2.2 ± 1.2
Water storage containers per house	2.7 ± 1.9	2.1 ± 1.3	1.8 ± 1.2
Positive water storage containers	1.6 ± 1.6	1.0 ± 1.0	1.1 ± 1.1

However, the mean number of positive containers per house was not significantly different among the 3 classes of interruption in the service of water (ANOVA; $P > 0.05$). Even those houses with apparent, infrequent interruptions in the supply of water showed a high House Index (68.2%), Container Index (36.6%) and number of positive containers per house (2.2 ± 1.2).

Larval habitat composition (Fig. 2) did not seem to vary with the frequency of interruptions. The order of importance of positive containers per class of water interruption was the same. Positive containers are more numerous in those houses with frequent interruptions in the supply of water (Fig. 2). Even those houses reporting rare interruptions in the service of water showed a high number of positive containers (182), of which metal drums used for water storage were the most frequent (50%).

We would expect to find more water-storage containers per house as the perceived frequency of interruptions experienced by homeowners increased. This seemed to be the case (Table 1; ANOVA, $P < 0.05$), and the mean number of containers per house belonging to the class of interruptions of days was significantly higher than in the preceding classes, among which there was no significant difference [Scheffé "a posteriori" test; $P < 0.05$; (Neter and Wasserman 1974)]. The mean number of positive water-storage containers per house also differed among the classes of interruptions (Table 1; ANOVA, $P < 0.05$). Again, the mean number of water-storage containers per house with *Ae. aegypti* was higher in the class of houses with interruptions of days, while no significant difference was detected between the classes with a more regular supply of piped water (Scheffé; $P < 0.05$).

Household answers to the question about their perception of the adequacy of the supply of water (Table 2) revealed that only 24.1% considered it adequate. However, people's appreciation of the adequacy of water supply did not relate to any of the measures of vector prevalence (Table 2). There were no significant differences among the mean number of breeding places per house according to the adequacy of water supply (ANOVA, $P > 0.05$), nor were for the mean number of water-storage containers per house ($P > 0.05$) or the mean number of positive water-storage containers per house ($P > 0.05$). The order of importance of aquatic habitats per class of water supply adequacy was the same: drums, small disposable containers, tires, house plants and tanks. As with the frequency of interruptions, more people considered that they had an inadequate or somewhat inadequate supply of water (261 houses), and had most of the positive containers (76%). Also, even those houses in which respondants considered that they had an adequate supply of water had numerous water-storage containers with the vector (Table 2).

Most of the houses in the study site were modern (139), rural (64), "barrio" (51) and "bahareque" (34), with few "quintas" (16), "ranchos" (9) and apartments (4). Vector indices were lowest in apartments and quintas (Table 3). Most other types of housing presented high values of the indices. The composition of types of larval habitats per class of housing was quite similar (Fig. 3). Metal drums were the prevalent positive containers in most of the types of housing (Fig. 3).

Out of 323 answers to the question whether the household considered that water supply was the main problem of the community, only 105 (32.5%) said yes. The House Index was similar in each group of respondents (yes: 72.4%, no: 70.2%). The distribution of houses with given numbers of positive containers for water storage (0, 1, 2, 3, >3) in each class was not significantly different ($\chi^2 = 5.69$; d.f. = 4; $P > 0.05$). Therefore, even those households who considered that water supply was not the main problem of the community had a similar pattern of storing water.

The last question asked was whether the households would get rid of their metal drums as water storage containers if they had a reliable and continuous supply of piped water. A large portion (60%) of all households said they would not get rid of the metal drums. They also had more drums serving as larval habitats (247) than the fewer people (154) who would be willing to eliminate the drums. The mean number of metal drums per house among those who would not eliminate the drums (2.3 ± 1.7) was significantly higher than among those who would do so (1.9 ± 1.7; *t*-test, $P < 0.05$). The mean number of drums with the vector was also higher among

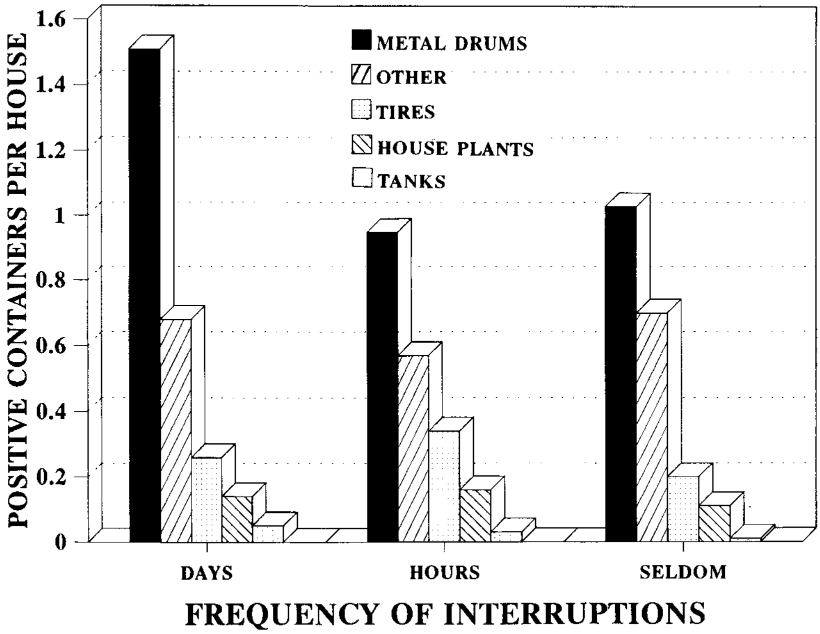

Fig. 2. Mean number of positive containers per class of water supply interruption.

Table 2. Percentage of houses with different perceived levels of water supply adequacy and associated values of vector prevalence. Mean values are given with corresponding standard deviations.

	Perceived adequacy of the supply of water		
	Adequate	Somewhat adequate	Inadequate
% houses	24.1	29.4	46.5
House Index (%)	79.5	68.3	69.4
Container Index (%)	42.9	35.7	39.0
Positive containers per house	2.4 ± 1.1	2.3 ± 1.3	2.2 ± 1.2
Water storage containers per house	2.3 ± 1.5	2.2 ± 1.5	2.3 ± 1.7
Positive water storage containers	1.4 ± 1.2	1.2 ± 1.3	1.2 ± 1.5

Table 3. Larval indices for each class of housing in the study area (number of positive containers in parentheses)

Housing	Container Index (%)	Water storage containers (%)	House Index (%)
Modern	36.5 (276)	49.1 (140)	69.1
Rural	44.8 (170)	49.4 (84)	78.1
Barrio	50.7 (141)	69.3 (88)	78.4
Bahareque	44.7 (143)	64.7 (79)	82.4
Traditional	25.0 (48)	56.5 (26)	68.0
Rancho	38.3 (23)	51.8 (14)	88.9
Quinta	6.5 (6)	13.7 (4)	18.7
Apartment	15.4 (2)	0.0 (0)	50.0

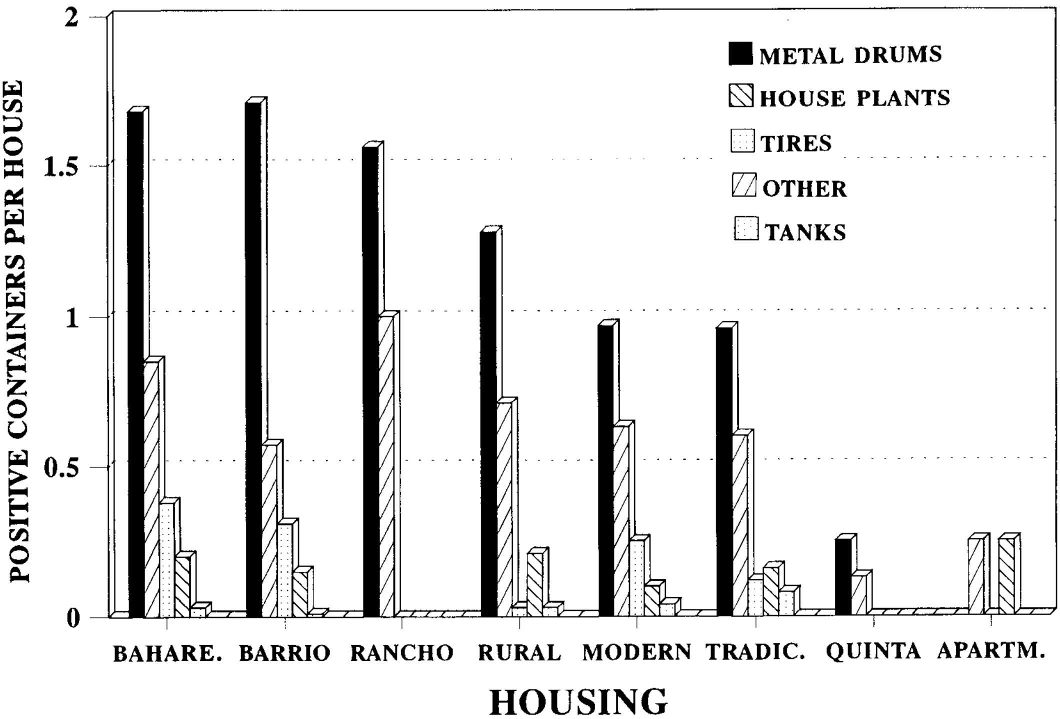

Fig. 3. Mean number of positive containers per type of housing in the study area.

those who would not eliminate the drums (1.4 ± 1.5) than among those who would eliminate them (1.1 ± 1.3; t-test, $P < 0.05$).

DISCUSSION

Aedes aegypti was undergoing preadult development in a large portion of the houses surveyed (71.2%). A substantial proportion of all positive containers were metal drums used for water storage (52.2%). Metal drums were the predominant devices for water storage (87.7%), and 59.8% had larvae or pupae of *Ae. aegypti*. On the other hand, tanks seemed to be a safer way of storing water, since only 11.5% had immature stages of *Ae. aegypti*.

Most people were not satisfied with the water supply because of frequent interruptions. Perceptions of the reliability of water supply correlated well with the House Index, Container Index and the number of metal drums per house inspected. Even those households who perceived that interruptions in the supply of piped water were infrequent kept between one and 2 metal drums per house, of which one was positive for *Ae. aegypti*. Similarly, households who reported having an adequate supply of water presented indices and numbers of containers similar to those reporting a somewhat adequate or bad supply of water. The question, then, would be why households who perceived that they had an adequate supply of water kept a similar number of water reservoirs to those who considered that the water supply was bad. Related to the question was the divided opinion concerning whether the water supply was the main problem of the community (67.5% said no). The key to an understanding why people who apparently had a "good" supply of water still kept numerous water reservoirs may be in the answers to the question of whether households would get rid of the metal drums (as water storage containers) if they had a reliable and continuous supply of water. Again, opinions were divided, but most people (60%) said they would not.

Although we can only pose hypotheses to try to explain the apparent paradox, before writing this report the community experienced a lack of piped water for 21 consecutive days, throughout Christmas holidays (from December 25, 1991 to January 14, 1992). The hypothesis we propose to explain the persistence of water reservoirs among people who considered having a reasonably adequate supply of water is precaution. Even in the residential areas with the highest quality of housing and services of large cities in Venezuela, houses or apartment buildings usually have their own water storage tanks. A common occurrence in marginal areas of large cities and small towns is the use of metal drums as water-storage devices. So it seems that even if each dwelling had a "reasonably" adequate supply of water, precaution would still encourage the storage of water, the method depending on the economic status of the family (cement tanks, metal drums, etc.). This situation is discouraging because it implies that, unless water supply is really efficient and of a nationwide coverage, water storage containers will continue to be the main aquatic habitats of *Ae. aegypti*. Unfortunately, the provision of a reliable supply of water to every home in Venezuela may take a long time. However, the potential for new DHF epidemics in Venezuela in the near future means that we cannot afford to wait.

From the aspect of controlling *Ae. aegypti*, metal drums in the locality are a major problem because of their generalized use. Most houses in the locality have access to tap water; however, on many occasions we have observed that the water coming out of the pipes is highly turbid, so the residents cannot use it right away, but until after the sediment precipitates and the water turns transparent. Also, most of the metal drums in the locality have an inner layer of cement, so they last longer. The layer of cement makes them more difficult to be cleaned regularly by the residents because of the added mass and fragility.

There are 2 alternatives for controlling *Ae. aegypti* in domestic water reservoirs: one involving safer ways of storing water (mosquito-proof containers, devices to impede *Ae. aegypti* colonization); and the other, using control agents to kill the immature in open reservoirs (insecticides, biological control, cleaning). Whichever measures are undertaken, they would seem to require community participation and much public health education. Most people do not understand why the "saltones" (larvae of *Ae. aegypti*) are now a major public health hazard when they have been in the drums ever since they are able to remember. Long-term results of education would likely be obtained if knowledge and motivation concerning the proper management of the larval habitats of *Ae. aegypti* start with preschool children and are continued throughout elementary school. Community participation is important because of the domestic nature of the aquatic habitats of the vector. It is difficult to obtain access to inspect *Ae. aegypti* in water reservoirs inside homes, and even more difficult is to obtain permission to continuously manipulate their water reservoirs through direct control measures (e.g., temephos application).

Positive containers found in the study area could be conveniently classified for control purposes as: disposable (tires, cans, bottles, etc.), house plants and water reservoirs (metal drums, tanks). Each class merits its own control methodology. Fortunately, the relative uniformity in aquatic habitat composition among housing types in Pto. Píritu simplifies control operations, because there is no need for stratification. As with the management of water reservoirs, disposable containers and house plants may require community participation and public health education. Finally, we propose the establishment of nationwide programs to motivate and help people building domestic, *Ae. aegypti*-proof tanks that could replace the apparently cheapest way of storing water available to the low-income population, the metal drums. In the long run, only the establishment of an efficient service of piped water to all houses in the country would be the main way to eliminate water storage containers and *Ae. aegypti*.

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