Milestone Report C4

DRWH DESIGN AND INSECT BREEDING

prepared by

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1 Introduction

Task C of this contract, examination of the health implication of widespread use of DRWH, addresses two aspects namely:

i) concerns regarding water quality and possible direct implications due to contaminants
ii) insect breeding related to water storage and health implication arising out of it.

With regard to water quality, two reports have already been submitted. They are Reports C1, *'DRWH-Water Quality: A literature review'*, and C3, *'Water Quality in DRWH Systems'*.

With regard to insect breeding, Report C2, *'DRWH and Insect Vectors:A literature review'* has already been submitted. In it *Anopheles*, *Aedes* and *Culex* mosquito species were identified as the major carriers of diseases and their behaviour was summarised. Dr. Mittal from Malaria Research Institute, India, collaborated in this. The characteristics of the major mosquito species were examined at the different stages of their life. Based on these, a background paper was made for an email conference on "Health Issues related to Water Quality" which was held in October, 2000.

The current report C4 brings out further findings (up to January 2001) on DRWH design parameters for controlling insect breeding. Experimentation continues.

2 Parameters which control insect breeding

The following issues were raised for discussions in the email conference coordinated by I.I.T., Delhi on Water Quality and Health. A number of people from all over the world participated in the email conference responding to the same.

a. The mosquito is the major vector to be considered in the context of DRWH water storage, although entry of lizards, rats and other small animals also need attention.
b. Breeding parameters and behavioural patterns differ for different species of mosquitoes; design for mosquito control must take these into consideration.
c. Whatever the species of mosquitoes, denying access to water is universally effective in controlling breeding. So all openings in DRWH should be closed by suitable meshes, preventing the entry of not only adult mosquitoes, but if possible also that of eggs and larvae which may be washed off from the gutter. It is important not to allow water to stagnate in the gutter. If water in storage gets heated to 50^{o}C, the viability of egg and larvae are reduced.
d. In spite of preventive measures, mosquitoes may enter storage. What would be the appropriate measures to deter ovi position (egg laying) and larval growth? The outcome of the e-conference discussions are shown in appendix 1. It was seen that the web site http://www.ent.iastate.edu/mailinglist/mosquito-1 deals specifically with mosquitoes. The site is being scanned for information useful for DRWH.

Based on the above interactions and on experiments conducted by I.I.T. Delhi, the issues related to control of mosquito breeding in DRWH will be dealt with under the following heads:

- Barriers for preventing the approach of adult mosquitoes to water in DRWH (Sect. 3)
- Quality of water and other parameters which discourage or encourage ovi-position and larval growth (Sect. 4)
- Treatment of water in storage (Sect. 5)

3 Barriers for preventing approach of adult mosquitoes to water in DRWH tanks

Three types of barriers may be envisaged to prevent entry of mosquitoes:

i. Have repellents in the surrounding areas so that mosquitoes are deterred from entering DRWH sites. Burning of leaves, wood smoke and other repellents (e.g. mint, *Vitex negundo* & other essential oils) are deterrents. Further research is needed in this regard.
ii. Have traps with suitable attractant so that the mosquito reaching the site gets attracted and enters the trap (Use of CO_2 trap and other attractants, www.mosquitoes.com/biting/menacing2.htm,www.ent.iastate.edu/department/research/vandyk/hostseek.html). Availability of reagents and cost economics would however be an issue.
iii. Have physical barriers such as screens which will physically prevent entry of mosquito and larvae into the DRWH site.

3.1 Repellants and traps

Studies on the issues (i) & (ii) pertain to general measures for mosquito breeding and control. The I.I.T., Delhi team has some experience in this regard.

A large number of aquatic fauna (e.g. *Spirogyra* sp., *Hydrilla, Ipomea, Eichhornia* and *Pistia*) may support mosquito breeding. On the other hand Covell (1941, malaria control by anti mosquito measures. edn. 2, Thacker Spink and Co., Calcutta) in his book on anti malaria measures has grouped aquatic vegetation preventing mosquito breeding into three types.

- Thick growths on the surface actually preventing breeding, e.g. *Lemna, Azolla, Wolffia, Anacharis, Trapa* etc.
- Those which act as traps, e.g. *Utricularia* i.e. bladderworts, which are well known to entrap and digest insects including mosquito larvae
- Those which are actually poisonous e.g. *Chara*.

3.2 Barriers

However, specifically for DRWH design, issue (iii) on integrating barriers for denying entry to mosquitoes was taken up for study. The following questions were addressed:

(a) Can the adult mosquito be deterred from reaching water surface by depths or torturous paths (U bends)?
(b) What is the role of gutters?
(c) How effective are the screens in preventive entry of the mosquitoes.

Depth and path-related issues Literature review and discussions with experts in Malaria Research Centre indicated that mosquitoes can descend by at least 300 ft (in air) and also go through curvaceous paths.

"There are records of mosquitoes found in deep mines, particularly *Culicine* mosquitoes. They have been found at depths of over 1,000 m in the Kolar gold mines in Karnataka.

The following reports are available on different species:

- *Anopheles annularis* and *A. vagus* have been reported at depths of 300-600 ft.
- *A. culicifacies, A. nigerrimus, A. stephensi* and *A. subpictus* at depths of 300 ft.
- *Culex fatigans* was found breeding at 600 ft."

(Source: *The Anophelines of India*, ICMR, New Delhi, 1981 by T. Ramachandra Rao)

These data indicate that in DRWH, the mosquitoes can easily travel down to water through the down pipes.

Gutters It is well known that mosquito will breed even on 1 mm layer (minimal depth) of water. So if there is stagnation of water, breeding will occur. Thus, gutters form a very important breeding site. Infact, for houses it is even advocated that gutters may be avoided or painted with larvicidal components. (http://www.env.gov.sg/cop/dd/ cop4/hb-7.html).

However, in DRWH it is imperative to have gutters, nor can it be painted as above! Hence, at least the gutter design should allow for smooth flow of water and must be accessible to inspection. Dry leaves should not remain on it and hold water. Inspite of all these precautions if eggs are hatched and water is available they can reach larval stage. Hence it is important to study the effectiveness of screens for preventing entry of not only mosquitoes but also of eggs and larvae.

Screens There is sufficient evidence that screens are useful in preventing the entry of mosquitoes and larvae. However, reports were not available relating to the effectiveness of different mesh sizes with respect to not only adult mosquitoes but also larvae and eggs. The size of adult, larvae and eggs are reported in C2. In *Culex*, where egg come in rafts, the overall size is higher although the individual eggs are small. Besides the size of eggs, the stretchability of mesh and speed with which water flows pushing the screen, are factors which can affect the entry of larvae and eggs.

Under the project, experiments were undertaken on the efficiency of screens differing in mesh size, in preventing the entry of adults. Results of laboratory level experiments with different screens with varying hole sizes are shown in table 1. The screens, made of nylon or cloth net, were bought from the local market. Actual number of holes per inch square on each of these was determined by counting. It was noted that all the mesh sizes used prevented the entry of adult mosquitoes. Since adults are of size 0.5 cm or 0.2 inches in length and the hole size on the screens are in the range of 0.01 - 0.05 in square, the screens were effective in filtering out the adults.

Experiments on passage of mosquito larvae and eggs were also conducted and the results are shown in table 1. It is seen that I to III instar larvae of all the mosquitoes passed easily through the screens. Only the late third instar as well as fourth instar larvae were filtered out. This is because, by the time they moult into fourth instar, they are comparable or even bigger than the adult in size. Only muslin cloth with very small hole size (more than 500 holes per square inch) was able to prevent entry of larvae at all its stages of growth. As for the eggs, the eggs of *Aedes* and *Anopheles* pass easily through all meshes. Even muslin cloth does not prevent passage of *Anopheline* eggs. On the other hand *Culex* lays eggs in rafts which are bigger in size. The entry of eggs of this species is prevented by all meshes.

Thus, while all the screens used were preventing entry of adult mosquitoes, there is enough chance of early instar larvae of various species being washed off into the storage tanks. Only muslin cloth is effective in this regard. However, it is to be seen whether muslin cloth when placed on the inlet, allows for the passage of water at a flow rate of 50 l per min. Designs have to be evaluated, in terms of the roof area, area of the inlet, as well as rate of rain fall at its peak. Also debris will collect with time on the screen and it has to be washed periodically. However, use of the cloth may be better than wire mesh made of iron or other metals. It may be used at the mouth of first flush device or at the junction between first flush device and storage. It could filter out mosquito, egg and larvae as well as dust particles. Further work may be done in optimisation.

4 Quality of water and other parameters which discourage or encourage ovi-position and larval growth

The effects of the following were studied:

a) Type of container
b) Quality of water in terms of oxygen availability and nutrient status

4.1 Effect of type of container

Common types of water container used in DRWH are made of ferrocement, plastic and clay. In a set of experiments, tap water (A), rainwater harvested from ferrocement tanks (B) and from syntex tanks (C) were withdrawn into clay pots and plastic tubs. To investigate the effect of both water type and cover type upon mosquito egg-laying, a set each of the containers was (i) left open, (ii) covered with clay lid, (iii) covered with iron mesh or (iv) covered by a plastic sheet. The results are presented in table 2. It was seen that in all cases when the containers were left open, mosquitoes entered and laid eggs. Wherever, there was a complete closure e.g. by a clay lid, which did not sag, there were no eggs/larvae. In the case of plastic cover held tight there was no ovi-position. However, where plastic cover was loosely held, small amounts of water accumulated where the cover sagged. This was sufficient for mosquito to lay eggs. An iron mesh under these circumstances did not encourage ovi-position. So the above experiments reiterate that water availability is the most important factor. Nature and shape of material used have no bearing on ovi position.

4.2 Effect of quality of water in terms of oxygen availability, nutrient status and temperature

Mittal et al. (Annual report, 1982, Malaria Research Centre, ICMR) have studied extensively the egg-laying of mosquitoes in water samples with different levels of salts and dissolved oxygen. The relevant data are reproduced from their report (Table 3). It is clear from this that the average dissolved oxygen requirement for *Culex* is 2.1 and for *Aedes* and *Anophele* is 6.2 and 6.6 ppm respectively. It has also been quoted by others that mosquito larvae can tolerate 4 ppm dissolved oxygen or less (www.mp.usbr.gov/geospat/olympiad/olyimage/larvae.html). Generally, rain water has sufficient dissolved oxygen at the time of harvest as well as storage. Hence oxygen levels are not likely to deter ovi-position in rain water. As for nutrients, for ovi-position high levels may not be needed initially.

However nutrient levels are a significant issue for larval growth. It is in fact known that *Anopheles* and *Aedes* prefer clean water while *Culex* can breed in water of higher BOD. To further study these issues, experiments were conducted on ovi-position and larval growth using rainwater samples as well as tap water and double distilled water for comparisons (Tables 4 & 5). Ovi-position in rain water and tap water was of a similar order whereas in freshly double-distilled water ovi-position was less. It was also seen that tap water, rainwater and double-distilled water supported larval growth up to third instar. In the case of double-distilled water and tap water there were no fourth instar larvae and in the rain water a few larvae could develop into fourth instar. However, in none of these cases there was emergence of adults, indicating that nutrient availability could be the limiting factor. When nutrient was added in the form of yeast and dog biscuits to tap water, out of 25 larvae, a good number (i.e. 14) emerged as adults whereas in the control (tap water) no larvae developed beyond third instar. In another set of experiments, rainwater and groundwater samples were compared. It was again seen that rainwater supported ovi-position (Table 6 & 7) and larval growth up to second instar, but larvae did not grow to adults.

Thus, although rain water supports ovi-position and larval growth, nutrient availability may be the limiting factor for adult emergence. Wherever a roof is under overhanging trees and gutter holds leaves and other materials which can provide nutrients, larval growth in rain water could be high enough for adult emergence. Also the growth of algae in storage may provide nutrients for mosquito breeding.

4.3 Effect of temperature on larval growth

Water tanks may get heated up by solar radiation, so we should examine the effect of temperature upon larval development. The speed of larval growth is accelerated in warm water and lessened in cold water. Warmer temperatures also stimulate growth of aquatic plankton and provide more food to the larvae than cold water. However, the larvae can not survive extremely high temperature. The upper limits of temperature at which no larvae can survive is called "thermal death point" (TDP). For example, for *Anopheles minimus,* the TDP is 41^{o}C and for *Anopheles vagus*, it is 44^{o}C. At 52^{o}C all larvae die immediately. This is the limit of biological tolerance of high temperature (*The Anophelines of India*, ICMR, New Delhi, 1981 by T. Ramachandra Rao).

5 Treatment of water in storage

WHO guidelines on use of chemicals for preventing mosquito breeding are presented in table 8 & 9. However, most of these are not suitable for use in DRWH, i.e. with respect to potable water. Only Abate (temephos) has been recommended by WHO as a larvicide for potable water also and the dose for application is given in the table. This requires further discussions.

It has been shown that kerosene, in small amounts sufficient to cover entire surface area of water kills larvae, by blocking oxygen. (www.nt.gov.au/nths/publich/entomology/programs/dissure/dengueph.html). Some experiments were done at the laboratory level at I.I.T., Delhi on the effect of kerosene oil addition. The results are presented in table 10. While kerosene is effective as larvicide, the kerosene oil locally available in developing countries may not be suitable for adding to drinking water.

6 Conclusions

- Stored water in DRWH can be a potential breeding site for *Aedes* and *Anopheles*. The amount of oxygen, light as well as nutrients in rain water are sufficient for ovi position and larval growth. However nutrient availability may be the limiting factor for adult emergence. In experiments with rainwater from roofs *no* larvae achieved adulthood and it seems that only where organic content is significant (or perhaps where light levels permit algal growth) will successful breeding occur.
- First-flush devices and the use of a screen between the first-flush system and storage could be tried as a barrier for preventing entry of adult mosquitoes. However the finest practical (peak-flow-permitting) screens are too coarse to hold back the eggs of *Aedes* and *Anopheles* or the first instar larvae of any mosquito species. To do that Nylon mesh or muslin cloth with 500 holes or more per square inch would be needed.
- There are several surface or whole-fluid agents that can be (and are) used to safely kill mosquito larvae or prevent ovi-position in water tanks. However none is simple to apply automatically nor, once applied, will last for many months.

7 Plan for further action

Some of the experiments initiated will be continued. The findings will be discussed in the dissemination workshop scheduled from April 18th-20th, 2001. Based on these discussions, additional experiments may be undertaken up to June, 2001. The literature review will also be continued. Information already presented in C1, C2, C3 and C4 will then be integrated with additional data obtained, in the final report to be submitted in July 2001.

TABLES

Table 1: Passage of mosquito eggs and larvae through different nylon/cloth screens

Mesh sample label	Mesh size (No. of holes/inch^2		*Culex quinfasciatus* (raft)	*Aedes ageypti*	*Anopheles stephensi*
A	**Muslin mesh cloth (more than 500)**	Egg	x	x	√
		I	x	x	10% can pass
		II	x	x	x
		III	x	x	x
		IV	x	x	x
B	**364**	Egg	x	√	√
		I	√	√	√
		II	√	√	√
		III early Late	√ x	-	√ x
		IV	x	-	x
C	**360**	Egg	x	√	√
		I	√	√	√
		II	√	√	√
		III early Late	√ x	-	√ x
		IV	x	-	x
D	**351**	Egg	x	√	√
		I	√	√	√
		II	√	√	√
		III early Late	√ x	-	√ x
		IV	x	-	x
E	**324**	Egg	x	√	√
		I	√	√	√
		II	√	√	√
		III early Late	√ x	-	√ x
		IV	x	-	x
F	**136**	Egg	x	√	√
		I	√	√	√
		II	√	√	√
		III early Late	√ √	-	√ x
		IV	√	75% passed	x
G	**130**	Egg	x	√	√
		I	√	√	√
		II	√	√	√
		III early Late	√ √	-	√ x
		IV	√	30% passed	x

Note: √ is passes through and x does not pass

Table 2: Ovi-position of the mosquitoes in rain water in different containers (clay and plastic) and use of screens (clay cover, iron mesh and plastic sheet)

Container type	Open/covered	Presence/absence of larvae
A. Laboratory tap water		
Clay pot	Open	√
	Clay lid	x
	Plastic (tightly covered)	x
Plastic	Open	√
	Iron mesh	x
	Plastic cover (sagging)	√ (on top of cover, not inside tub)
B. Ferrocement tank 1 (rain water) tinned roof		
Clay pot	Open	√
	Clay lid	x
	Plastic (tightly covered)	x
Plastic	Open	√
	Iron mesh	x
	Plastic cover (sagging)	√ (on top of cover, not inside tub)
Ferrocement tank 2 (rain water) cement roof		
Clay pot	Open	√
	Clay lid	x
	Plastic (tightly covered)	x
Plastic	Open	√
	Iron mesh	x
	Plastic cover (sagging)	√ (on top of cover, not inside tub)
C. Syntex tank 1 (rain water) Plastic roof		
Clay pot	Open	√
	Clay lid	x
	Plastic (tightly covered)	x
Plastic	Open	√
	Iron mesh	x
	Plastic cover	√ (on top of cover, not inside tub)
Syntex tank 2 (rain water) Asbestos roof		
Clay pot	Open	√
	Clay lid	x
	Plastic (tightly covered)	x
Plastic	Open	√
	Iron mesh	x
	Plastic cover (sagging)	√ (on top of cover, not inside tub)

Note: √ is larvae present, x is no larvae

Table 3: Chemical analysis of waters supporting breeding of different species of mosquitoes

Mosquito		pH	Hardness	Sodium	Chloride	Potassium	Bromide	Nitrates	Nitrites	Free ammonia	Dissolved oxygen
Anopheles	Range	7.97-9.525	73.5-1030	60-2500	25-1760	7.8-175	0.27-8.22	3.8-13.3	1.4-43.8	1.2-6.6	4-10.6
	Average	(8.6)	(295.4)	(766)	(606.8)	(63.9)	(3.13)	(8.2)	(8.52)	(2.81)	(6.66)
Culex	Range	7.63-8.7	115.256	28-490	23.5-545	10-109	0.26-5.03	4.2-8.2	1.57-8.2	0.7-21.5	0.6-5.1
	Average	(8.1)	(188)	(256)	(236)	(35)	(1.79)	(5.4)	(3.8)	(6.99)	(2.1)
Aedes	Range	8.1-8.5	82.5-130	17-150	22.5-52	4.25-5.3	0.15-0.8	3.9-7.3	0.7-3.44	0.22-0.7	4.7-7.4
	Average	(8.26)	(102)	(52)	(36.3)	(4.75)	(0.4)	(5.3)	(1.94)	(0.45)	(6.2)
Mixed (*Anopheles* + *Culex*	Range	7.9-10.8	61.3-355	45-910	65.7-961	7.3-67.8	0.76-4.73	3.01-10	0.7-27.50	1.1-16.8	1.0-10.2
	Average	(8.9)	(177)	(446)	(446.5)	(23.0)	(2.36)	(6.55)	(5.7)	(4.301)	(5.25)

Table 4: Effect of water quality on ovi-position

Water type	***Anopheles culicifacies***	***Aedes agepyti***
Rain water	+++++	+++++
Tap water	++++	+++++
Double distilled water	+	++

Note: Female mosquitoes were blood fed and were placed inside a mosquito cage containing different water samples for ovi position (16.2.2001)

Table 5: Effect of water quality on growth of *Anopheles stephensi* first instar larvae

Date	**Double distilled water**						**Tap water**						**Tap water + food (yeast powder + dog biscuits)**						**Rain water**					
	I	**II**	**III**	**IV**	**P**	**A**	**I**	**II**	**III**	**IV**	**P**	**A**	**I**	**II**	**III**	**IV**	**P**	**A**	**I**	**II**	**III**	**IV**	**P**	**A**
07.02.2001	23	2					20	5					22	3					20	5				
08.02.2001	13	11																						
09.02.2001	5	18					7	16					2	21	2				9	16				
10.02.2001							9	9	5															
12.02.2001		20						18	5					2	2	21				13	8			
13.02.2001		10	8					17	6					1	2	21	2			8	13			
15.02.2001		1	17					3	4						2	17	5	2		4	13			
16.02.2001		1	17					3	4						2	10	8	4		2	11			
19.02.2001		3	3					3	3						1	8	2	13	2	8				
20.02.2001		1	5					3	3						1	7	1	14	1	9				
22.02.2001		5						1	3							7				2	5	2		

I - IV: instar larvae P: Pupae A: Adults

Note: 25 first instar larvae were placed in 200 ml water samples in a plastic bowl and the larval growth was observed as a function of time. Experiment was initiated on 5.2.2001

Table 6: Effect of water quality on ovi-position

Water type	*Anopheles culicifacies*
Rain water	+++
Water pumped with motor (Micromodel)	+++
Hand pumped water (Micromodel)	++

Note: Female mosquitoes were blood fed and were placed inside a mosquito cage containing different water samples for ovi position (16.2.2001)

Table 7: Effect of water quality on growth of *Anopheles stephensi* first instar larvae

Date	Rain water		Tap water		Water pumped with motor		Hand pumped water	
	I	II	I	II	I	II	I	II
19.02.2001	23	1	17	-	25	-	23	-
20.02.2001	3	20	16	-	20	-	-	-
22.02.2001	1	21	10	3	11	1	-	-
23.02.2001	1	21	7	6	10	1	-	-

Note: 25 first instar larvae were placed in 200 ml water samples in a plastic bowl and the larval growth was observed as a function of time. Experiment was initiated on 16.2.2001

Table 8: Insecticides suitable for interior treatment against mosquito vectors

Insecticide	Chemical type[a]	Dosage of a.i.[b] (g/m^2)	Duration of effective action (months)	Insecticide action	Toxicity: [c]oral LD_{50} of a.i. for rats (mg/kg of body weight)
Alphacypermethrin	PY	0.02 - 0.03	4 - 6	Contact	79
Bendiocarb	C	0.1 - 0.4	2 - 6	Contact & airborne	55
Carbusulfan	C	1 - 2	2 - 3	Contact & airborne	250
Chlorpyrifosmethyl	OP	0.33 - 1	2 - 3	Contact	> 3,000
Cyfluthrin	PY	0.02 - 0.05	3 - 6	Contact	250
Cypermethrin	PY	0.5	4 or more	Contact	250
DDT	OC	1 - 2	6 or more	Contact	113
Deltamethrin	PY	0.01 - 0.025	2 - 3	Contact	135
Etofenprox	PY	0.1 - 0.3	3 -6 or more	Contact	> 10,000
Fenitrothion	OP	2	3 - 6	Contact & airborne	503
Lambdacyhalothrin	PY	0.02 - 0.03	3 - 6	Contact	56
Malathion	OP	2	2 - 3	Contact	2,100
Permethrin	PY	0.5	2 - 3	Contact	500
Pirimiphosmethyl	OP	1 - 2	2 - 3 or more	Contact & airborne	2,018
Propoxur	C	1 - 2	3 - 6	Contact & airborne	95

[a] C = carbamate; OC = organochlorine; OP = organophosphate; PY = synthetic pyrethroid

[b] a.i. = active ingredient [c] Toxicity and hazard are not necessarily equivalent

Source: Chemical methods for the control of vectors and pests and public health importance, edited by D.C. Chavasse and H.H. Yap, WHO, Division of Control of Tropical Diseases, WHO Pesticide Evaluation Scheme (WHO/CTD/WHOPES/97.2), pp. 25.

Table 9: Insecticides suitable as larvicides for mosquito control[a]

Insecticide	Chemical type[a]	Dosage of a.i.[b] (g/m^2)	Formulation[d]	Duration of effective action (weeks)	Toxicity: [c]oral LD_{50} of a.i. for rats (mg/kg of body weight)
B. thurigiensis H-14	MI	[f]	AQ,GR	1 - 2	> 30,000
B. sphaericus	MI	F	GR	1 - 2	> 5,000
Chlorpyrifos	OP	11 - 25	EC, GR, WP	3 - 17	135
Chlorpyrifosmethyl	OP	30 - 100	EC, WP	2 - 12	> 3,000
Deltamethrin	PY	2.5 - 10[g]	EC	1 - 3	135
Diflubenzuron	IGR	25 - 100	GR	2 - 6	> 4,640
Etofenprox	PY	20 - 50	EC, oil	5 - 10	> 10,000
Fenitrothion	OP	100 - 1,000	EC, GR	1 - 3	503
Fenthion	OP	22 - 112	EC, GR	2 - 4	586
Fuel oil	-	[h]	Soln	1 - 2	Negligible
Malathion	OP	224 - 1,000	EC, GR	1 - 2	2,100
Methoprene	IGR	100 - 1,000	Slow release suspension	2 - 6	34,600
Permethrin	PY	5 - 10	EC	5 - 10	500
Phoxim	OP	100	EC	1 - 6	1,975
Pirimphosmethyl	OP	50 - 500	EC	1 - 11	2,018
Pyriproxyfen	IGR	5 - 10	EC, GR	4 - 12	> 5,000
Temephos	OP	56 - 112	EC, GR	2 - 4	8,600
Triflumuron	IGR	40 - 120	EC, WP	2 - 12	> 5,000

[a] Pyrethroids are not normally recommended for use as larvicides because they have a broad spectrum impact on non-target arthropods and their high potency may readily potentiate larval selection for pyrethroid resistance
[b] IGR = insect growth regulator, MI = microbial insecticide; OP = organophosphate; PY = synthetic pyrethroid
[c] a.i. = active ingredient
[d] AQ = aqueous; EC = emulsifiable concentrate; GR = granules; soln = solution; WP = wettable powder
[e] Toxicity and hazard are not necessarily equivalent
[f] Dosage according to the formulation used
[g] The lowest levels are recommended for fish bearing waters
[h] Apply at 142-190 l/ha or 19-47 l/ha if a spreading agent is added

Source: Chemical methods for the control of vectors and pests and public health importance, edited by D.C. Chavasse and H.H. Yap, WHO, Division of Control of Tropical Diseases, WHO Pesticide Evaluation Scheme (WHO/CTD/WHOPES/97.2), pp. 27.

Table 10: Effect of kerosene oil on the growth of *Aedes agepyti* IIIrd instar lavae

Dated	Parameters	Rain water	Distilled water
10.09.99	Close lid	All alive (100%)	1 dead (90%)
	Kerosene oil (2 drops)	All dead	All dead
13.09.99	Close lid	5 alive (50%)	3 alive (30%)
	Kerosene oil (2 drops)	All dead	All dead
15.09.99	Close lid	3 alive (30%)	All dead (0%)
	Kerosene oil (2 drops)	All dead	All dead
23.09.99	Close lid	All dead (0%)	All dead (0%)
	Kerosene oil (2 drops)	All dead	All dead

Closed lid: means control water in tightly closed BOD bottles

Note: 10 larvae were placed in 150 ml of rain water and distilled water in BOD bottles and the effect was observed

APPENDIX

Summary of email conference discussions prepared by Padma Vasudevan, I.I.T., Delhi

Mosquito Breeding

It must be noted that firstly availability of mosquito in the vicinity is an important pre-requisite for mosquito breeding. Also only mosquitoes which are carriers vectors of various diseases are a health hazard; otherwise mosquito bite would only be an irritant and not a major risk. Flight range of different species of mosquito (refer report C-2) is of the order of 50 m to 3 km.

John Gould and others have referred to reports available on the presence of mosquito, in DRWH, prevention and control of its breeding (see references). In the e-conference the Indian/ Srilankan partners reiterated that mosquito breeding is a potential threat to health issues if not already one. Arya Bandhu observed that mosquitoes enter the tank even when they are reasonably secure. He invited factual evidence of egg and larvae getting washed off and entering the tanks through filter systems. Innovative methods are needed to free the water tanks from mosquito especially for poor households who do not have proper guttering and sufficient labour to attend to first flush systems. Based on discussions with Malaria Research Centre, India (see report C-2 under the EU project), it is noted that eggs and larvae could be small enough to pass through screens. Further research is in progress in examining whether they could be retained by nets of appropriate mesh size and filters. Terry Thomas has summarised the 5 strategies to reduce the mosquito breeding and control.

1. <u>Sealing</u>

   Terry Thomas felt that it is not easy to properly seal household tanks and maintain the seal. However, Brian Skinner felt that tight cover can be produced for ferrocement tanks. Paper or polythene could be used for this. He suggested that initially casting a slight upstand on the roof around the edge of the access hole, to give a raised flat rim (say 50 mm wide), and then casting a flat overlapping cover (e.g. thin concrete or ferrocement slab) on this upstand will produce a good tight closing access cover. One could of course also use mud or very weak cement mortar under the cover to play safe. Perhaps other alternative could be a gap filler made from a continuous piece of string laid on the upstand.

According to Arya Bandhu old cycle tube seals have provided good protection against mosquito entry. It basically seals the tank to cover interface. These are individual household practices and thus are not widely practiced. In his opinion a light weight galvanised cover over the entire mouth with proper fit on the upstand part would be most appropriate.

2. Screening

Unless the inlet of a storage tank has a mosquito screen, obviously they can enter and leave via the inlet pipe.Having a proper mosquito screen which will not permit entry of mosquito seems to be a very important step. Use of suitable mosquito nets of appropriate mesh size needs to be considered.

An inclined mosquito screen, set into a small chamber (200 mm x 200 mm in plan) position on the roof of the tank directly under the discharge from the down pipe and over hole over the roof would be useful. One side of the chamber, on the low side of the mesh, should be opened so that the debris screened out of the water are washed off the mesh. There should also be a split cover over the chamber, around the pipe to prevent the light entering the pipe through the mesh covered hole into the roof.

3. Surface Barrier

Use of kerosene and plastic balls have been mentioned as surface barrier. Infact Malaria Research Centre, India (see C-2 report) have also recommended the use of expanded polystyrene beads (EPS). Brian Skinner has described an idea successfully used to control mosquitoes in septic tanks and wet pit latrines by floating a 20 mm layer of particles of polystyrene on the surface.

According to Allan D. Weatherall, in Australia, mosquito larvae are being eradicated from domestic water storage tank by using couple of drops of kerosene which forms a thin film and floats on the water surface. However these methods may not be entirely be satisfactorily for DRWH tanks meant for storing drinking water.

4. Use of chemicals

Vince Whitehead sent useful information which can be found at: http://www.ent. iastate.edu/mailinglist/mosquito-1/. The WHO website http://www.who.int/ctd/whopes/progress.htm showed under the heading of the first table 'products under evaluation by WHOPES (Sept., 2000)' that Methoprene or temephos are used as a mosquito larvicide. One comment from Argentina mentioned use of ABATE as a larvicide not toxic at the concentration used for water tanks. During a visit to household in Cambodia, Vince Whitehead came across 1 cu. m tank that having about 6 small packets laid, equally spaced out on the bottom of the tank. The house owner explained to him that these were to kill mosquito larvae. The contents of the packets presumably dissolved into the tank over a period of time. Indian participants suggested the use of herbs. <u>Indepth research on toxicity is needed before suggesting chemicals as larvicides in drinking water</u>.

5. <u>Biological Control</u>

   Dragon fly/fish and other methods of biological control including use of *Bascillus thurigenesis* Bti had been summarised by Padma Vasudevan in report C-2, page 14. Brian Skinner pointed out that if it is not feasible to totally screened the tank from mosquito then they can be controlled in the tank by using dragon fly larvae which consumes mosquito larvae. However, the consumers may not relish the idea of such creatures in the tanks and presumably they need a continual supply of dragon fly larvae for control.

   Shiela Carmen has described use of fish in ferrocement water storage tanks in the St. Vincent Grenadines. The water from these tanks had been used for drinking and cooking and users are of the opinion that this method reports no ill effects, though the quality of water has not been tested.

   A participant indicated that WHO has recommended use of BTi in the storage tanks for potable water. This is a very promising area.