THE PREVENTION OF MOSQUITO BREEDING IN SEWAGE TREATMENT FACILITIES

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IN SEWAGE TREATMENT FACILITIES

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1.0 INTRODUCTION

Sewage treatment facilities can be major sources of pest and vector mosquitoes (Whelan, 1981, 1984, 1988). Nutrient rich sewage and sewage effluent has the capacity to produce enormous numbers of mosquitoes. As treatment facilities are usually relatively close to communities, these mosquitoes can cause large and continuous pest and potential public health problems.

The mosquito breeding associated with sewage treatment facilities is usually associated with their inadequate design, operation and maintenance, or faulty methods of effluent disposal or dispersal. Some of these problems can be rectified in the planning stages, while others need consideration in the operational phase. There is a need for increased awareness of the nature of the potential problems among designers, operators and regulators of sewage treatment facilities. This paper outlines the problems, and suggests design and operational practices that can reduce mosquito breeding.

2.0 MOSQUITO SPECIES ASSOCIATED WITH SEWAGE

Culex quinquefasciatus: 'The Brown House Mosquito'

This species usually breeds in organically polluted water near human communities. It is frequently found breeding in high numbers in unsealed septic tanks and primary sewage ponds, although it is sometimes found in organically overloaded secondary sewage ponds. This is a very significant pest species wherever favourable breeding sites exist. The females rarely travel more than 2 km from their breeding sites.

Culex annulirostris: 'The Common Banded Mosquito'

Culex annulirostris is one of the most common mosquitoes in Australia. The most prolific artificial breeding places are in secondary sewage treatment and evaporation ponds, and sewage pond effluent (Whelan 1984). The larvae are most frequently found in calm, sheltered areas where vegetation offers protection from disruptive wave action and aquatic predators. The females of this species can disperse up to 10 kilometres from the breeding site (Russell 1986), although the highest concentrations are usually found within 3 - 4 km of significant breeding sites.

Anopheles annulipes s.l.: 'The Common Australian Anopheline'

This species usually breeds in open, sunlit, temporary and permanent freshwater ground pools, streams or swamps. It is not found in septic tanks and is rarely found in sewage treatment ponds, but it can frequently be found in sites of disposal of sewage effluent, particularly where the effluent flows into shallow, grassed areas. The females can disperse up to 2 km from their breeding places.

3.0 MOSQUITO BREEDING AND SEPTIC TANKS

Mosquito breeding in septic tanks is entirely dependent on mosquito access into the tank, and is usually due to damaged or missing tank tops and inspection manholes or unscreened vents. *Culex quinquefasciatus* is the principal mosquito species found breeding in septic tanks. Septic tanks that overflow, or absorption trenches that are faulty or in water logged soil, can result in the pooling of untreated or partially treated sewage that can become prolific sources of *Cx. quinquefasciatus* or *Cx. annulirostris.*

In general, the close fitting inspection covers of fibreglass septic tanks are less likely to provide mosquito access than concrete prefabricated tanks. Concrete tanks with a flat concrete top slab invariably have a small space between the top slab and the tank walls that is sufficient to allow mosquito access. Inspection manholes or access points that are of faulty design or damaged can also allow mosquito entry.

Concrete tank tops and inspection manholes can be simply mosquito proofed by applying a sand and cement mixture or a silicone sealant to all joints. All vents to septic tanks including gully traps and breather vents should also be screened to prevent mosquito entry.

Mosquito breeding can be detected relatively easily by opening the inspection manhole and disturbing the interior of the tank with a stick. Any observed adult mosquito activity indicates that sealing of the tank is required. If septic tanks are correctly sealed there is no need for insecticide treatment.

4.0 MOSQUITO BREEDING AND PACKAGE SEWAGE SYSTEMS

Generally package sewage systems are relatively small facilities where the sewage treatment is carried out in tanks or chambers under an active process, rather than a large passive pond system. One of the finished products can be a variable volume of treated effluent that is usually disposed of by infiltration, sprinkler dispersal, evaporation or discharge to natural water bodies. Mosquito breeding does not usually occur within the treatment facilities, but inappropriate disposal of the effluent produced can cause pooling or ecological changes to receiving water, which results in breeding sites for *Cx. annulirostris* or *An. annulipes*. The precautions and remedies outlined below for sewage pond effluent disposal apply equally for package sewage systems.

5.0 MOSQUITO BREEDING AND SEWAGE TREATMENT PONDS

Sewage treatment in pond systems is one of the most common methods of sewage treatment in Australia. Usually the ponds are sited in a relatively low lying area where a gravity assisted sewerage system delivers untreated sewage. The sewage is treated in a series of ponds involving a passive or active primary pond, secondary aerobic ponds, and final evaporation or holding ponds for dispersal or disposal.

5.1 <u>Design Considerations</u>

5.1.1 Site Selection and Design

Disposal of Effluent

Appropriate planning for the final disposal is an important part of site selection. Disposal near the coast is relatively easy, but in inland areas can lead to major problems if appropriate techniques are not employed. These are discussed in section 5.2 of this paper.

Wind

Ideally ponds should be located in open windy areas away from steep hills or fringing tall or dense vegetation. Wind and the associated wave action plays an important part in preventing mosquito breeding by disrupting the larvae and pupae at the water surface. Wind action can also prevent the spread and hinder the growth of algae, aquatic floating ferns (*Azolla* sp.) and duck weed (*Lemna* sp.), or concentrate flotsam into discrete areas for ease of removal. These floating plants and flotsam should be regularly removed as they can shelter the larvae from both wave action and aquatic predators.

Drainage

The choice of a site should consider the necessity to drain the ponds for maintenance without thereby creating swamps or pools of stagnant water. Effluent release from the final pond is usually suitably arranged, but provision for emptying the intermediate ponds into suitable areas is often overlooked.

Site design should ensure that there is no disruption to normal site drainage pathways caused by any of the works. Diversionary drains around facilities that have seepage or dry season low flows should be constructed with concrete inverts and should discharge to suitable endpoints. The permeability of pond walls and groundwater seepage must also be considered and catered for.

Ponds or embankments constructed near tidal areas need to ensure existing tidal drainage patterns are maintained. If these are blocked, problems with salt water species of mosquitoes breeding in impounded water can be expected.

5.1.2 Access

Site design should allow for all weather access around the entire installation. Weed and tree growth maintenance, fire prevention, and erosion and siltation rectification in diversionary drains may require regular access. Seepage from ponds or diversion of site surface water can cause swampy conditions that require vehicle access for inspection and mosquito control.

5.1.3 Pond Dimensions

Pond Size

Sewage pond size is primarily determined by engineering parameters related to design flow rates, pollution loadings, and the required effluent quality. Frequently there is little consideration given to the effect of pond size on mosquito breeding. Adoption of oversized ponds, either from inaccurate predictions of sewage volume or a desire to provide for future capacity, can lead to the ponds becoming shallow, thickly vegetated swamps, capable of breeding large numbers of mosquitoes.

Consideration should be given to staging of pond construction, or the use of multiple ponds, although the use of smaller multiple ponds may inhibit wind and wave action. In most cases, it is the margins of the ponds which provide the mosquito breeding sites. Multiple small ponds can result in increased total margin length. Installing peninsular barriers to reduce short-circuiting sewage flow through a large pond can also markedly increase the margin length. Increased margins require more capital expense with edge treatments, and increased maintenance costs.

Pond Depth

Selection of pond depth is usually dictated by the function of the pond, ie. primary, secondary, or evaporation. Adequate allowance must be made for solids deposition, particularly in primary ponds, otherwise excessive deposits will lead to colonisation by vegetation and the creation of mosquito breeding sites.

Profiling the pond base, with the deepest side at the pond entry, can help, particularly if there is a seasonal variation in sewage input. For evaporation ponds, particularly those with earth sides or which may be continually full, a depth of 2 m or more is recommended to prevent the intrusive growth of semi aquatic reeds such as *Eleocharis* sp. and *Typha* sp.

5.1.4 Construction Details

Vertical Concrete Margins

Vertical concrete margins have proven to be the most satisfactory means of controlling mosquito breeding by promoting wave action, and maintaining margins free of vegetation and debris.

Concrete walls can be precast for remote locations or constructed *in situ*, and are cost effective in the long term. The walls should be deep enough to allow for a wide variation in water level and should have a horizontal or slightly sloping bench at the base above the bottom level of the pond, to discourage establishment of vegetation and reduce silt accumulation immediately adjacent to the pond wall. Sealed verges around the top of the banks are desirable to facilitate maintenance and to prevent the erosion of soil into the pond. Walled ponds may still have problems, particularly in primary ponds, with floatables and wind blown debris in the corners, and silt accumulation near sewage entry points. Truncated or rounded corners and multiple or variable entry points can help to reduce these problems.

Unlined earth banks

Sewage ponds with unlined earth banks have the greatest capacity for mosquito breeding, particularly those with gentle slopes where marginal vegetation can establish. They are accordingly not recommended, except as temporary or emergency measures. The banks should be constructed using impervious materials such as compacted clay. If neglected, unlined earth banks can become either eroded, or overgrown with grass, shrubs and trees. Corrective measures can then be a major undertaking.

Other Linings

Various systems have been used to line earth banks as a temporary measure to reduce growth of vegetation, but they have not been entirely satisfactory.

Stone pitching of the margins is not satisfactory as it does not offer sufficient deterrent to vegetation growth, and mechanical maintenance is difficult. Overlapping cement or iron sheets have been used, but have problems with damage and stability, resulting in subsequent weed growth. Various types of bituminous or plastic sheeting have also been tried, and have shown promise as short to medium term solutions. Problems encountered include inadequate anchoring, weed growth, ultraviolet deterioration, and human interference. The more modern ultraviolet resistant heavy duty plastics, anchored with earth mounds back from the rim of the ponds, have been more successful.

Sloping concrete margins have been tried in a number of locations. While better than unlined ponds they have the drawback that wave action is damped by the slope. Dust and organic matter can also build up and enable vegetation to establish. It is important that the margins have a slight rim and sealed verges to prevent erosion and subsequent accumulation of soil and vegetation at the water margin.

5.1.5 Maintenance

Before commissioning sewage pond systems, a general survey of the whole site should be conducted to ensure that mosquito breeding sites have not been created inadvertently by borrow pits formed during pond construction, pools of water resulting from site drainage works or pooling caused by road access. Any problems should be rectified before the ponds are commissioned, so that they do not become a routine maintenance problem.

Pond maintenance is a vital part of pond management. The highest levels of maintenance will be required for earth lined primary ponds and final or evaporation ponds with low and seasonally variable effluent flow rates. Some form of maintenance will be required even for ponds with vertical concrete margins and sealed verges. Even those ponds of good design in favourable locations, with ideal effluent characteristics, must have adequate provision for people and resources to carry out a regular and defined maintenance program.

Aspects of maintenance frequently overlooked are the regular control and removal of vegetation on the margins or the pond verges, the regular removal of floatables, algal mats or aquatic plants from the pond margins, and the repair of cracks and other failures that can allow increased soil moisture levels on the banks and subsequent vegetation growth.

For some ponds, a program of water level management may be adopted which alternately floods and strands marginal vegetation or floatables. The form of maintenance will depend heavily on the pond design, effluent parameters, and staff experience.

Regular and adequate maintenance to prevent mosquito breeding is not common in many sewage treatment facilities. If there is any anticipation that proper maintenance will not be carried out regularly, a maintenance-free design should be chosen.

5.2 <u>Effluent Disposal Or Dispersal</u>

5.2.1 Problems

Many sewage treatment facilities give insufficient consideration to the disposal of treated effluent. It has been assumed that effluent after 'adequate treatment' is no longer a problem, and can therefore be left to run down the nearest flow line. In fact, this effluent often forms flooded, overgrown, stagnant pools that create very productive mosquito breeding grounds.

In some situations effluent has been directed into sand dunes or sandy situations in the belief that infiltration would provide a satisfactory disposal method. This is totally inadequate because the high organic loads of the effluent and resultant algae invariably seal against infiltration and result in extensive pooling of effluent.

Even after tertiary treatment in evaporation ponds, the resulting 'treated' effluent still retains a great capacity to breed mosquitoes. It still has relatively high nutrient levels that lead to high algal and vegetative growth, and can disrupt freshwater ecology including that of the fish predators on mosquito larvae. Even high quality tertiary treated effluent with low nutrient levels may be sufficient to cause pooling, ecological change, and mosquito breeding, if not disposed of adequately.

5.2.2 Large Evaporation Ponds

Evaporation ponds either of intentional or 'ad hoc' design have commonly been used as an effluent disposal method. Large evaporation ponds are rarely filled to capacity for the entire year, and in many instances are just bunded areas that store effluent against escape to other areas. Because of their large area, the variable inflow, and seasonal variations, large evaporation ponds can become shallow, flooded, swamps with dense weed and reed vegetation. Evaporation ponds that dry up and are then seasonally inundated by rain or effluent release can become breeding grounds for floodwater mosquitoes.

The aspects to be considered in designing large ponds to reduce mosquito breeding, include:

- initial and regular removal of all emergent vegetation within the evaporation area,
- levelling of the floor of the evaporation area,
- division of the evaporation area into a number of smaller areas,
- constructing a sloping floor to concentrate the water in a 'sink' area at the effluent entry point;
- concrete lining of the 'sink' area on the floor of the evaporation area and concrete lining of embankments.

However, incorporating some of these aspects into the design can be prohibitively expensive. The alternatives are to have a regular maintenance program, which could be more expensive in the longer term, or to choose a more suitable method of effluent disposal.

5.2.3 Small Evaporation Ponds

The use of a series of small concrete lined evaporation ponds can be a very effective method of effluent disposal. The best designs incorporate a series of relatively small ponds that can progressively fill by gravity overflow. Such a system may be expensive to construct, particularly if the evaporation area required is relatively large. However, the method has the advantage of being relatively maintenance free and can cope with variations in effluent volume.

5.2.4 Disposal to the Sea

Disposal direct to the sea or to a daily flushed tidal area is one of the most suitable methods for effluent disposal. It is important that the disposal outlet is to the open sea or a large creek or river with considerable tidal movement. Disposal at the lower end of a relatively long, narrow or tortuous tidal creek can result in effluent build up in the creek, which can be pushed by incoming tides higher up the creek line and overflow or pool in areas where mosquito breeding sites can develop.

Disposal onto large flat, inadequately flushed, tidal areas can create breeding sites not only for freshwater species of mosquitoes, but also for salt and brackish water species.

5.2.5 Disposal to Rivers

The suitability of discharge to rivers depends upon the volume of flow in the river, the seasonal variability of flow, and the downstream effects of the disposal. When the flow in the rivers or creeks is small or subject to wide seasonal variation, this method can result in eutrophication or ecological and vegetation changes which lead to mosquito breeding.

5.2.6 Disposal to Land

Sprinkler dispersal

This method has been relatively successful in areas where there have been particular problems with other disposal methods. It is most successful onto areas with well developed stands of trees that are on soils of good permeability. In these situations the final effluent can be automatically and periodically dispersed via a system of overhead sprinkler heads. Fire damage in natural vegetation can be rectified by the construction of an underground pipe system with steel uprights and metal sprinklers. Sprinkler irrigation can also be undertaken using small volume undertree micro sprinklers in plantation settings. However weed maintenance can be a problem with smaller systems and is generally only suited to plantations or organised irrigation areas where regular maintenance is practical or cost effective.

Ideally, sites should be relatively flat but have adequate drainage to cope with rainy periods. Feeder lines to spray heads should be laid out along contours, rather than at right angles, so that effluent pressures are equal and effluent will be retained in the lines after spraying rather than permitting continued flow to the lowest spray head. This will avoid creating semi permanent pools of effluent at the base of one sprinkler head.

The area required will depend upon the volume of effluent to be disposed, and the long term absorption capacity of the soil and the vegetation. Precautions are required to ensure that effluent contaminated run off after rain episodes cannot pool in nearby depressions, flow lines or creeks.

Sprinkler dispersal can be used for tree and pasture growing or landscape watering, but the National Health and Medical Research Council Guidelines for the Reuse of Waste Water must be adhered to (NH&MRC, 1979). This can include fencing, adequate signs and chlorination. Tertiary chlorination can provide a high quality effluent for drip irrigation and recreational area watering but may need filtration.

If tertiary treated chlorinated effluent is held in open temporary storage ponds, the ponds should be constructed as for secondary sewage treatment or evaporation ponds. Algal and other microscopic growth will still occur and lead to marginal vegetation growth and ideal conditions for mosquito breeding. Reuse of tertiary treated effluent for landscape watering may require freshwater flushing of the distribution pipes immediately after effluent dispersal to prevent odour problems resulting from anaerobic action on the retained effluent in the pipes.

Sprinkler disposal using high volume spray units has been successfully used in some areas, but potential problems include regularly moving the spray units, and overwatering leading to pooling and rising water tables.

Dripper dispersal

Disposal by dripper systems requires a high standard of effluent, usually with a tertiary chlorine treatment, to prevent dripper blockage by algae. Dripper systems can be used for both small or large scale disposal, but is usually only suitable for plantation situations where the vegetation growth at each dripper site can be practically and economically maintained. Drippers held off the ground can reduce root blockages of the drippers. Generally dripper systems are only suitable for the dispersal of small volumes of effluent per unit area or periodic release, and are prohibitively expensive because of their high maintenance requirement.

Small Furrow Irrigation

This method is useful for relatively small volumes of effluent on sandy soil in low rainfall areas. A feeder channel is used to deliver effluent to a ploughed area of small furrows that slope gently away from the feeder channel. Disposal is by infiltration into the sandy soil. When infiltration becomes less efficient, the flow is directed to an adjacent ploughed area, and the original area is allowed to dry out and is reploughed.

This system requires a considerable amount of attention and maintenance, but has a low capital cost.

Channel Infiltration

In this system, permanent infiltration channels are constructed and effluent flow is directed down a number of groups of channels which are alternatively spelled and maintained. The method can be used on less porous soils than is possible for furrow irrigation. If this method is used for the irrigation of tree or bush crops, intensive monitoring of water tables and salinity levels is required to ensure viability of the crop in the long term. Problems with larger scale use have included, high capital cost with infrastructure, high labour input, regular weed and erosion control in the channels, rising soil salinity, and elevated water tables.

Flood Bay Irrigation

The degree of land preparation for flood bay irrigation is usually considerable, as a system of correctly graded flood bays is necessary to allow for efficient flooding and to prevent pooling in or at the end of the flood bays. The bays are periodically or alternatively flooded by a distribution feeder channel and the effluent is allowed to evaporate or infiltrate in the bays over a period of 3 - 4 days. This method has been used successfully to grow irrigated pasture and tree crops.

Problems with flood bay irrigation arise during rainy periods, when extended flooding of the bays with nutrient enriched water can result in mosquito breeding. Small flood bay systems are suited for relatively small effluent volumes, arid areas where surface evaporation is high, or in situations with good soil infiltration. Some of the problems with flood irrigation systems can be reduced by using an automatic siphon and a multi discharge distribution channel to release effluent periodically and evenly over the flood bay. Generally flood systems require at least two separate bays so maintenance and spelling can be carried out.

5.3 Biological Control

Biological control, though not generally efficient or applicable to primary ponds, can be a very efficient means of controlling mosquito larvae in secondary and evaporation ponds.

The major biological control agents are fish, aquatic beetles and aquatic bugs. Fish can control mosquito larval numbers directly by eating the larvae, or indirectly by reducing algae which provide protection from other predators or wave action. Fish are usually only suitable for the higher oxygenated waters. Several native species have shown promise including the rainbow fish, *Melanotaenia* sp. Wildlife regulations must be observed when considering using fish as biological control agents.

Marginal vegetation such as couch grass and reeds should be eliminated or kept to a minimum, so that fish can have physical access to the mosquito larvae. Actively growing reeds with upright stems may not restrict access. However, when these reed species die or lodge over, they prevent physical access for the fish and enable mosquito breeding.

Aquatic beetle larvae (Carabidae) and aquatic bugs (Belostomatidae) can be very efficient mosquito larvae predators in secondary and evaporation ponds. The aquatic bugs are able to live in higher organic water than the aquatic beetle larvae, and can be present in enormous numbers. Again, physical impedance by thick vegetation at the margins will reduce the effectiveness of these predators. Vegetation problem areas should be eliminated by physical removal or weedicide application. Insect predators can achieve almost total control of mosquito larvae in sewage ponds of suitable water quality, and steep or vegetation free margins.

5.4 Chemical Control

The aim of chemical control of mosquito larvae should be to apply the minimum amount of insecticide to prevent the production of adult mosquitoes. Chemical control should not be used as a long term strategy in sewage treatment areas, in order to avoid insecticide resistance and unwanted effects on non-target organisms. Weedicide application to mosquito breeding sites often provides more efficient short to medium term control and can greatly reduce insecticide requirements. However, it may be necessary to apply insecticides during the initial operational period or when proper maintenance has not been carried out. The insecticides of choice to control mosquito larvae in sewage ponds and effluents are temephos or *Bacillus thuringiensis* var. *israelensis* (Bti). Correct rates for temephos must be strictly adhered to, as overdosing can kill fish and other aquatic insects.

5.5 Mosquito Sampling

Regular inspections should be carried out in sewage ponds and their effluents to determine whether mosquito larvae are present and to determine the necessity for weed or chemical control. Chemical control with temephos or Bti may be necessary at weekly or longer intervals. The presence of pupae indicates that control should have been conducted at shorter intervals. If only first and second instar larvae are present, then either biological control is quite efficient, or the mosquitoes have just started to breed in that area, and continued monitoring is necessary.

Mosquito larval or pupal samples can be collected by dipping into sheltered vegetated zones with a soup ladle. Any larvae collected should be stored in small vials with 70 % alcohol or methylated spirits, together with information on collection locality, site, date and collector.

Adult specimens that have been collected as they bite or harbour can be killed by freezing and packed loosely in tissue paper in a small box, together with all the details of collection. Larval, pupal and adult specimens should be sent to an entomologist for identification or verification.

Chironomid midge pupae or adults are often in very high numbers near sewage treatment facilities and are frequently mistaken for mosquitoes. Their presence has often resulted in control programs being instituted where none was necessary.

6.0 CONCLUDING REMARKS

In the past, the design of sewage treatment and effluent disposal facilities was usually dictated solely by engineering and microbiological principles. Little attention was paid to the possibility of breeding mosquito populations close to habitations, and the resulting potential pest and public health problems. Appreciation of this potential risk, followed by the application of simple design principles and adequate maintenance can reduce these problems. Biological control can often be used to supplement good design features. Chemical control can be used under certain situations but should be reserved as a short term remedy until permanent solutions or maintenance measures can be implemented.

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