MIDGE NUISANCE – A SWARM IN A POND

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ABSTRACT

Swarms of midges can cause a seasonal nuisance near wastewater treatment ponds in New Zealand and around the world. New Zealand midges (*Chironomus Zealandicus*) lay eggs in layers of sediment along pond edges, whereupon larvae hatch and undergo four stages of development, prior to emergence as adults two to seven weeks later (depending on water temperature). They are not identified as a disease vector and, thus, do not pose health risk. However, midges seek out cool, shaded areas such as the underside of leaves and sheltered buildings, they are attracted to outdoor lighting at night, and can form large mating swarms. As a result midges can cause significant nuisance to nearby residents and recreationalists.

This paper summarises the outcome of a comprehensive literature review into control of midges at wastewater treatment ponds. The purpose of this review was to better understand the range of factors which can affect the intensity of midge swarms around a wastewater treatment pond. Four key factors were identified as impacting on midge population and resulting nuisance; these are pond sludge thickness, pond BOD loading, total pond bank area, and nearby vegetation planting. Persistent midge nuisance can occur for prolonged periods, over consecutive years. In these instances, a programme for pest management has been reported to successfully control the nuisance. Such programmes target the eggs, larvae, and adults at different stages separately and use different mechanisms/pathways.

Within the New Zealand context, midges do not create a nuisance at all wastewater treatment ponds. Ponds operated in Motueka, Nelson and Blenheim are not known to generate midge related complaints from nearby residents. Conversely, residents in close proximity to the Christchurch and Mangere wastewater treatment plants regularly report complaints during the spring and summer months every year.

This paper establishes a history of midge control in wastewater treatment ponds both globally and within the New Zealand context. A summary of the current knowledge of midge control around the world is presented. A qualitative assessment is made on the benefits and shortcomings of a range of midge control methods and methodology for the development of a midge management programme is proposed.

KEYWORDS

Nuisance, Midges, Ponds

1 Introduction

Wastewater treatment ponds can provide an environment for midges to breed. The New Zealand midge, *Chironomus Zealandicus*, does not bite, but has a tendency to form large swarms which can create a significant nuisance to any residential populations located nearby. Midges will seek out the shade during daylight and will invade cool dark spaces, such as the south side of buildings or indoor areas. In the evenings midges will accumulate around exterior lights (NIWA, 2005). The transit of midges to these areas is often caused by wind, or through their attraction to lighting used by residential populations. Swarms of male midges will form around a female midge, causing a significant nuisance to anyone in the swarm's path

This comprehensive literature review examines the history of *Chironomus Zealandicus* midge control both in New Zealand and internationally, and compares a range of midge control methods. The benefits and shortcomings of various present day controls are assessed, and from this a model approach for midge control is proposed.

2 Background

The New Zealand midge's life cycle begins as eggs in a capsule, often floating on the water surface close to the edge of a wastewater oxidation or polishing pond. After 2-4 days the eggs sink to the bottom, hatch and begin the first of four larval instars (development stages) where they build tubes into the pond sediments to live in. After the fourth instar stage, the larvae leave the tubes and spend 24 to 48 hours pupating beneath the water. The pupae then rise to the surface and emerge as an adult midge.

The adult midges fly to the pond edge and seek out cool, shaded locations that are sheltered from the wind. Ideal locations are bushes and flax, but nearby buildings (such as homes and garages) are equally suitable. Midges swarm for mating with the male midges forming a dense cluster around the females. The swarms typically congregate at dawn and dusk and it has been concluded that they are triggered by changes in light (Watercare Services Ltd, 2016). After mating, the females move back to the pond where they immediately lay their eggs on the pond surface in a capsule. Adult midges to not feed, and have a short lifespan of three to five days.

In areas such as wastewater oxidation and polishing ponds midges have an advantage over other sediment and sub-layer organisms due to their resistance to pollutants, the ability of the larvae to inhabit low-oxygen environments and their ability to rapidly produce large numbers of offspring (Failla, Vasquez, Fujimoto, & Ram, 2015). Recent research into midge problems suggests that a comprehensive integrated pest management (IPM) programme is required for adequate control (EPA, 2016) (Watercare Services Ltd, 2016). The main principles of IPM focus on pest prevention and use pesticides only as needed, with the aim of achieving effective and environmentally sensitive control (EPA, 2016).

A key consideration of an IPM program is the risk of the development of resistance to individual insecticides. The Insecticide Resistance Action Committee (IRAC) have developed a comprehensive classification system for insecticides (IRAC, 2016). A classification table from Research by IRAC indicates that insecticide resistance can be minimised and delayed by varying the chemicals used.

This paper describes the common methods of control and the range of insecticides used.

3 Chemical Control Options

3.1 Overview

> *"Chemical control of midges in a habitat requires a specific strategy of avoiding frequent and indiscriminate use of a chemical and promoting rotational use of alternative effective materials where possible."*
>
> \- **Arshad Ali, Ph.D.**
> **Professor of Aquatic Entomology and Ecology**

Chemical control has been the most practiced midge control approach used internationally over the last 50 years (Ali, 1996). The two primary types of chemical control target the larvae (larvicide) and the adult (adulticide). Larvicides can be further categorised into insect growth regulators (IGRs), juvenile hormone analogues (JHAs), microbial pesticides and organophosphates. Adulticides are typically contact insecticides.

3.2 Larvicide

A larvicide specifically targets the larval life stage of an insect, and prevents larvae from achieving pupation. Midges spend the majority of their life in the larvae stage, spanning from two to seven weeks depending on the water temperature (NC State University, 2006). Thus larvicides provide the longest opportunity for insecticide treatment.

This literature review has found that larvicide chemical control of midges has been the main mainly used in the USA and Japan, however control studies have also been conducted in Europe, UK, France, Germany, Italy, Africa, New Zealand, and Australia (Ali, 1996). These studies have shown that the susceptibility of the chironomid family of midges (including the New Zealand midge, *Chironomus Zealandicus*) to individual chemical insecticides can vary greatly. A summary of common larvicides and their reported effectiveness is presented in Table 1.

Table 1: Larvicides Considered for Chironomid Midge Control

Larvicide	Mode of Action (Insecticide Group) ***See Appendix A***	Effectiveness	Comments	Sources
Methoprene	Juvenile Hormone Analogues (7)	Generally performs well or better than organophosphates and Bti	■ Successfully used currently at CWTP (around pond margins) and Mangere WTP ■ Perceived environmental safety ■ Rapidly degraded by UV light	■ (Watercare Services Ltd, 2016) ■ (AgResearch, 1999)
Pyriproxyfen	Juvenile Hormone Mimic (7)	Effective, found to provide better control than both methoprene and diflubenzuron (NIWA, 2005)	■ Same insecticide group and similar mode of action to methoprene ■ Wasn't approved for water related use in NZ in 2005 ■ A sand granule formulation applied to ponds in Florida has shown long term midge control	■ (IRAC, 2016) ■ (NIWA, 2005) ■ (Ali, 1996)
Diflubenzuron	Inhibitor of chitin	Found to perform	■ Slow release pellet or	■ (NIWA,

Larvicide	Mode of Action (Insecticide Group) ***See Appendix A***	Effectiveness	Comments	Sources
	biosynthesis (15)	more quickly and slightly more effectively than methoprene	granule form would be required ▪ Concern regarding possible effects on non-target organisms	2005)
Bacillus thuringiensis israelensis (Bti)	Microbial disruptors of insect midgut membranes (11)	Consistently found to be ineffective, attributed to dispersion and dilution of *Bti* in the water column	▪ Often not effective or requires very high rates of application to be so ▪ Rate of treatment required to be effective is at least 10X the established rate for mosquitoes ▪ Using a combination of Bti and methoprene has shown to provide control similar to that of methoprene alone	▪ (Duchet, Franquet, Lagadic, & Lagneua, 2015) ▪ (NIWA, 2005)
Bacillus sphaericus	Microbial disruptors of insect midgut membranes (11)	Does not appear to offer any potential for midge control	▪ Studies have confirmed ineffectiveness even at high application rates	▪ (Ali, 1996) ▪ (Ali, 1995)

This literature review has found that IGRs such as methoprene, pyriproxyfen, and diflubenzuron have proven effective for chironomid midge control as a result of their superior selectivity and environmental selectivity. The chemical methoprene appears to be the most established and the most widely used. It is available in a range of formulations, including sustained release pellets, boluses and briquettes. However literature has shown that methoprene has a short half-life in water (less than ten days) and is rapidly degraded by the naturally occurring ultraviolet rays in sunlight light (AgResearch, 1999). Another chemical, pyriproxyfen, acts as a juvenile hormone mimic with a similar mode of action to methoprene. This chemical has only recently been researched for chironomid midge control and results indicate it may prove to be more effective than methoprene. Pyriproxyfen is currently pending regulations for water related use.

3.3 Adulticide

An adulticide specifically targets the adult life stage of an insect and are usually contact insecticides that are toxic to insects upon direct contact. Adulticides usually have minimal residual activity. In the case of midges adulticides can rapidly reduce adult population, giving the perception of effectiveness. However, as adult chironomid midges have a short lifespan (three to five days) the opportunity for treatment for short and only a small portion of the total population is treated at any single treatment event.

Table 2 provides a summary of common adulticide chemicals used for Chironomid midge control including some shown to be potentially effective through research studies and small scale field trials.

Table 2: Adulticides Considered for Chironomid Midge Control

Insecticide	**Mode of Action (Insecticide Group)** ***See Appendix A***	**Effectiveness**	**Comments**	**Sources**
Malathion (Maldison)	Organophosphates (1) (Applied directly to water)	Fast acting and broad spectrum	▪ Traditionally used in NZ ▪ Used by both CWTP and Mangere in the past ▪ Desire for more specific insecticides with fewer adverse environmental affects has discouraged it's use	▪ (Watercare Services Ltd, 2016) ▪ (NIWA, 2005)
Temephos	Organophosphates (1) (Applied directly to water)	High level of effectiveness against a variety of midge species	▪ Toxic to a broad range of other aquatic organisms ▪ Repeated use can result in poor or lack of control	▪ (Techletter, 2013) ▪ (Ali, 1996)
Etofenprox	Sodium channel modulators (3)	Currently effective in its use at Mangere	▪ Currently being trialled at CWTP ▪ Sprayed onto vegetation at Mangere every 4 weeks, year round	▪ (Watercare Services Ltd, 2016)
Pyrethrin	Sodium channel modulators (3)	Effective in use with LED sprayers	▪ Initially used with LED sprayers at CWTP	
Bifenthrin	Sodium channel modulators (3)	Effective, however possibly only for a short time	▪ Was initially used as the contact insecticide at Mangere however was replaced by Etofenprox	▪ (Ali, 1996) ▪ (Watercare Services Ltd, 2016)
Spinosad	Nicotinic acetylcholine receptor (nAChR) allosteric modulators (spinosyns) (5)	Studies show it is effective for midge control	▪ Organic certified brands available (Entrust) ▪ Evaluated as a Reduced Risk product by the EPA ▪ Spray onto plants and surfaces	▪ (NIWA, 2005) ▪ (Lawler & Dritz, 2013)
Spinetoram	nAChR allosteric modulators (spinosyns) (5)	An analogue of spinosad	▪ EPA 2008 Presidential Green Chemistry Challenge Winner ▪ Typically applied to foliage as a spray	▪ (Dow AgroSciences, 2014)

Of the adulticides evaluated, Spinosad and Spinetoram show potential for effective chironomid midge control at wastewater oxidation ponds in New Zealand. However, these chemicals are relatively recent and require further investigation into their ecotoxicity before being widely employed. Etofenprox has been used at the Mangere WWTP as part of an IPM programme (Watercare Services Ltd, 2016), to control of *Chironomus Zealandicus*. Watercare reports that Etofenprox treatment has greatly reduced the number of midge related complaints from neighbouring residential populations. Organophosphates have provided successful chironomid midge control, however the broad spectrum nature of these chemicals results in other insects also being killed.

A significant factor to be considered with the use of contact insecticides is that they are usually applied to a surface, which provides the platform for direct contact with midges. Table 3 summarises the effectiveness of common surfaces found around wastewater oxidation ponds in New Zealand.

Table 3: Surfaces Suitable for Application of Contact Insecticides

Contact Insecticide Surface	Effectiveness	Comments	Sources
Grass edges around the pond	Likely less effective than other vegetation. Grass is exposed to direct sunlight and can be hot during the day. It also provides minimal shelter from the wind. Thus midges do not usually land on grass.	▪ Grass is quick to establish, usually taking only a few months over summer if the ground does not dry out.	▪ (Watercare Services Ltd, 2016)
Vegetation – trees, shrubs	Effective. Trees and shrubs provide cool areas shaded from sun and wind. Midges are reported to seek refuge in such vegetation while waiting to mate	▪ Trees and shrubs take time to grow and become established at sufficient size to provide refuge for significant numbers of midge.	▪ (Watercare Services Ltd, 2016)

The most common forms of application of contact insecticide is by spraying or fogging on to vegetation. This can be difficult in windy areas, as insecticide droplets can be blown away from the target area. Furthermore, the application of most contact insecticides requires an approved chemical handler, certified for the insecticide being used. Table 3 outlines the following surface options that were considered. Another limitation of spraying or fogging contact insecticide on to vegetation, most notably that not all vegetation is easily (or safely) reachable or treatable. Thus, it can be difficult to achieve complete insecticide coverage and midges can readily move to untreated areas (Techletter, 2013). Hence, contact adulticides are generally not effective when used in isolation and need to be used in conjunction with other approaches.

3.4 Toxicology

Inherent with any chemical control method is the risk of harm to non-target species both directly and through secondary contact of residual chemicals in the food chain. This risk has particular relevance to the oxidation ponds in New Zealand which can be home to small mammals, birds, other insects, lizards, eels, etc.

The exact mechanism by which these chemicals can cause harm differs from chemical to chemical and can vary between formulations of the same chemical. Mammals, including humans, are more susceptible to harm through the inhalation of sprayed or fogged insecticides (adulticides) (Dow AgroSciences, 2014). Insecticides (larvicides) directly dosed into bodies of water, can pose a risk to non-target aquatic organisms such as eels (Lawler & Dritz, 2013). Commercial formulations come in a range of concentrations and may be mixed with other chemicals to alter the overall toxicology (AgResearch, 1999) (EPA, 2016).

4 Alternative Control Options

This literature review has found that the chemical control of Chironomid midges using larvicides and adulticides is the most widely used technique. However, other methods exist that can be used in conjunction with chemical controls in IPM program. These other controls can improve the overall success of the midge control programme. Table 4 outlines the control options identified in this literature review that differ from typical application of larvicides and adulticides.

Table 4: Alternative, Non-Chemical Options for the Control of Chironomid Midges

Type of Control	Mode of Action	Effectiveness	Comments	Sources
Invertebrate predators – planarian flatworm	Consumes aquatic stages of chironomids	May have potential for midge control in some habitats	▪ Other *Dugesia* species such as *tigrina* may have potential for control ▪ Study was done in experimental ponds through the University of California	▪ (Ali, 1996) ▪ (Arshad & Mulla, 1983)
Mosquito fish	Consumes aquatic stages of chironomids	Do not produce any significant midge reduction	▪ Limited evidence in literature around successful midge reduction using any type of fish ▪ May only be useful in small and closed habitats (<20 ha) ▪ Minimal effect noted when used at Mangere WTP	▪ (Ali, 1996) ▪ (Watercare Services Ltd, 2016)
Agnique Monomolecular Film	Reduces surface tension of water and prevents adult emergence	Largely ineffective when used at Mangere WTP	▪ Strong winds can push film to edges of water, leaving majority of the pond surface untreated	▪ (Watercare Services Ltd, 2016)
Light Boards	Boards sprayed with contact insecticide – midges attracted to the light	Didn't perform as intended at Mangere WTP	▪ Midges swarmed the boards and were then blown to neighbouring residential areas ▪ Barrier vegetation replaced the boards	▪ (Watercare Services Ltd, 2016)
LED lighting posts and spray	Midges attracted to light and insecticide routinely sprayed from light post	Effective yet are currently not adequately controlling numbers at CWTP	▪ Cost effective ▪ Dimmer lights could be used in more densely inhabited areas, and brighter lights in less densely inhabited areas in order to draw the midges away from populated localities ▪ Consider adding more lighting posts to increase effectiveness	▪ (Ali, 1996)

Type of Control	Mode of Action	Effectiveness	Comments	Sources
Barrier vegetation	Acts as a barrier to protect neighbouring populations as well as being a platform for contact insecticide spray	Effective at Mangere to discourage dispersal to residential areas	▪ Takes time to grow, so is a long term control effort ▪ Strategically planted vegetation is used at Mangere to attract midges to expose them to contact insecticide. This also discourages their dispersal off-site to neighbouring areas	▪ (Watercare Services Ltd, 2016)
Saltwater flushes	Maintain dominance of salt water intolerant form of midge	Frequent use proved ineffective	▪ When used frequently at Mangere WTP, the salt water tolerant form of midge began to dominate	▪ (Watercare Services Ltd, 2016)
Sun bakes	Reducing the amount of water in ponds to stress larvae	Used as an additional control rather than in isolation	▪ Carried out at Mangere as an additional control to cause short term reductions in midge numbers ▪ Dependant on the capacity of the ponds to have levels reduced	▪ (Watercare Services Ltd, 2016)
Mechanical dredging of sediment materials	Dredging and mixing of substrate materials on river beds	Studies shown it has been ineffective	▪ More research would be beneficial	▪ (Ali, 1995)
Electrocutor traps	Involve light to attract midges to an electrocuting grid	Often malfunction	▪ Often malfunction in situations where large swarms of adults are attracted to them and completely stick to and cover the electrocuting grid ▪ Most commonly used mechanical means of midge control	▪ (Ali, 1996)

A number of the above controls can be a beneficial addition to the chemical control of midges in an IPM program. The Mangere WWTP has found the strategic planting of barrier vegetation successful in discouraging dispersal of the midges off-site (Watercare Services Ltd, 2016). Supplementary to this, Watercare report that sun bakes and saltwater flushes cause short term reduction in larvae numbers at the Mangere WWTP. Electrocutor traps have been commonly used as a mechanical means of midge control internationally (Ali, 1996). These traps offer an entirely non-chemical alternative to insecticides, which is beneficial when considering insecticide resistance management.

5 Monitoring

A key aspect of an IPM program is ongoing evaluation of its effectiveness through monitoring of the midge population numbers. This provides information on the effectiveness of the overall programme and can highlight when changes need to be made. Table 5 summarises the monitoring options identified in this literature review.

Table 5: Monitoring Options for Midge Outbreak Numbers

Monitoring Option	Effectiveness	Comments	Sources
Number of public complaints	Effective in use at Mangere WWTP	▪ Reduction in public complaints is the primary objective of midge control	▪ (Watercare Services Ltd, 2016)
Yellow sticky traps	Convenient and reliable method	▪ Sticky StripsTM (Olsen Products) were placed 1m from the water line ▪ No need to come into contact with sewage water ▪ Cost effective	▪ (Broza, Gahanma, Halpern, & Inbar, 2003) ▪ (Olson Products Inc., 2016)
Larval counts	Not significantly correlated with other methods	▪ Sampling of mud cores	▪ (Broza, Gahanma, Halpern, & Inbar, 2003)
Egg-mass counts	Inaccurate for larger populations	▪ Styrofoam boards used as artificial oviposition sites for female midges ▪ Can detect major trends in population dynamics	▪ (Broza, Gahanma, Halpern, & Inbar, 2003)
Adult emergence traps	Not effective for large scale operation	▪ A standard fly trap modified by cutting open the bottom of the trap, and hung to be partially submerged in water	▪ (Broza, Gahanma, Halpern, & Inbar, 2003)

As the primary objective of midge control is to reduce the negative and nuisance effects on the neighbouring residential populations. Thus the number of public complaints is the most relevant means of monitoring the midge nuisance, but may not reflect the midge population. It is important to note that midge population outbreaks tend to occur in the summer months, so complaint numbers should be compared for corresponding months rather simply averaged throughout a year.

Yellow sticky traps show promise as a tool to assist with decision making and assessment of control practices (Broza, Gahanma, Halpern, & Inbar, 2003). This method does not require the sampler to contact with sewage water (in comparison with larval and egg-mass counts, as well as adult emergence traps) which is desirable. Although yellow sticky traps appear to be the easiest and most appropriate monitoring method in larger scales, the accuracy may be effected by the wind strength and direction (Broza, Gahanma, Halpern, & Inbar, 2003).

6 Conclusion

Chironomid midges have a history of proliferating around wastewater oxidation ponds, causing nuisance problems to residential areas in New Zealand and around the world.

This literature review has concluded that there is no one, steadfast solution to midge control. There are many options for midge control. However for successful and long-lasting controls an IPM programme is recommended, where multiple methods are used in a planned programme over several years. The susceptibility of Chironomid midges to specific insecticide chemicals can vary greatly between species and midge populations can develop resistance to specific insecticides.

This literature review has found that larvicides are generally used as the primary method for midge control. These chemicals prevent pupation of the larvae and reduce the resulting adult numbers. For larvae that progress to the adult stage, secondary control uses a contact insecticide (adulticide) sprayed on vegetation. Synchronising the application of adulticides with the emergence period of the adults, combined with applying the contact insecticide in the location where the adults congregate, provides the greatest likelihood of contact with the adult midges.

To mitigate the risk of the development of chemical resistance, IPMs make use of sequencing or rotations of insecticide chemicals with different chemical action (IRAC, 2016). An example IPM programme is described below:

- Application of a larvicide IGR such as methoprene in the summer months
- Spray vegetation and/or areas around the pond with an adulticide such as Etofenprox
- It is important that the larvicide and adulticide used should be from a different insecticide group, so that both larvae and adults are not exposed to products with the same mode of action, thus minimising the development of resistance
- Installing LED light traps with adulticide sprays to attract midges away from residential areas for treatment.
- Planting vegetation close for contact insecticide spraying
- Specific chemicals should be alternated if monitoring shows the midge population is developing resistance
- Installation of yellow sticky traps for sampling and monitoring of midge population

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